PRIMARY SCIENCE SUBJECT LEADERS CREATING COMMUNITIES OF PRACTICE: STORIES OF PROFESSIONAL DEVELOPMENT

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Abstract

A policy epidemic of marketisation and accountability in education (Ball, 2003) has led to a narrowing of the curriculum in English primary schools, and the importance of science has declined (Spielman, 2020). In addition, the identities of teachers have been adversely affected (Ball, 2017). The abolition of the science Standard Attainment Test (SAT) in 2009 was key in the deprioritisation of science. In 2010 the Primary Science Quality Mark (PSQM) was introduced nationally with the aims of raising the profile of science and improving the quality of primary science teaching and learning. In this programme, schools' science subject leaders embark on a year-long programme of evaluation, action planning, implementation and reflection, based on the PSQM framework. Four half days of PSQM training, and on-line support, are provided by a PSQM hub leader. At the end of the year evidence is submitted for review and an award is made. The result depends, not on outcomes measurable through tests or examinations, but on a review of the evidence of participation and reflection.

English primary school teachers usually teach most, if not all, subjects to their classes. Each curriculum area typically has a subject leader responsible for the monitoring and development of her or his subject throughout the school. While this offers a model for distributed leadership it imposes an additional burden on hard-working class teachers. Despite this, over 3500 science subject leaders have led their schools to gain a PSQM.

Evaluations of the PSQM programme suggest it is successful in supporting the development of leadership and improving the profile and quality of science teaching and learning. This research sets out to examine the ways science subject leaders and science teaching and learning changed over the course of the PSQM year and to understand the processes involved in these developments.

The research is based on a study of eight science subject leaders who narrated their experiences throughout the PSQM year. Using narrative methods, I collected their stories using both minimally-structured interviews and rivers of experience; an arts-based method. These data were analysed in comparison with Lave and Wenger (1991) and Wenger's (1998) conceptualisations of situated learning, communities of practice, legitimate peripheral participation and identity.

Science subject leaders developed science teaching and learning within their unique school settings, in addition to raising the profile of science. Each operated as a master within her own school community and, either developed a science community of practice where none existed before, or, if a science community of practice existed, she was able to strengthen it. They were able to do this because participating in the PSQM enabled border crossings between their own schools' communities of practice and the broad primary science community of practice. The values and understandings of the broad primary science community of practice became apparent in the discourses of the participants. The discourses influenced practice in their schools which developed as a result of the engagement of the school communities in science events and activities.

In addition, the identities of the participants changed over the course of the PSQM year with engagement and reification playing important roles. By the end of the year, they identified themselves, and were identified by others, as effective science subject leaders. In addition, some perceived themselves as better leaders and better teachers, not just of science. Where their roles as science subject leaders conflicted with other identities, for example, some perceived themselves as not 'sciency' people, while others'

inexperience led to hesitation about leading more experienced colleagues, they were able to reconcile these conflicts.

Acknowledgements

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Without the generous funding of the Primary Science Teaching Trust (PSTT) I would never have been able to embark on this journey. I thank them whole-heartedly and can only apologise to them for taking so long to complete my submission.

Thanks also to Jane Turner who has been so generous in providing so many opportunities and opening so many doors for me. I think my research proves you really have released tigers! I have been very fortunate to have been adopted as a member of the PSQM family, and through that, stumbled across a very special community of practice; the one supporting the teaching and learning of primary science. The whole PSQM family and members of this community of practice have been so kind and supportive throughout. Thank you all.

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List of abbreviations and their meanings

AfL	Assessment for Learning
ARE	Age related expectations
ASE	Association for Science Education – A registered charity supporting all those involved in science education
BBC	British Broadcasting Corporation
CAQDAS	Computer Assisted Qualitative Data Analysis Software
CIEC	Centre for Industry Education Collaboration
CPD	Continuing Professional Development (sometimes also called Continuous Professional Development)
EAL	English as an additional language
EHCP	Education, Health and Care Plan. Replacement for the discontinued Statement of Educational Need
EYFS	Early Years Foundation Stage
FSM	Free School Meals – the percentage of children entitled to FSM is used as a measure of deprivation
GERM	Global Educational Reform Movement (Sahlberg, 2016)
HLTA	Higher Level Teaching Assistant
IoP	Institute of Physics
ITAF	Interim Teacher Assessment Framework – Framework against which teachers should make judgements about whether children have achieved age related expectations at the ends of key stages 1 and 2
LEA	Local Education Authority
NC	National Curriculum
NCC	National Curriculum Council
NPQML	National Professional Qualification for Middle Leaders
NQT	Newly Qualified Teacher
OECD	Organisation for Economic Cooperation and Development
Ofsted	Office for Standards in Education
PCK	Pedagogic Content Knowledge
PD	Professional Development

PHSE	Personal, Health and Social Education
PISA	Program for International Attainment – Tests used to compare education systems internationally.
PPA	Preparation, planning and assessment
PSQM	Primary Science Quality Mark
PSTT	Primary Science Teaching Trust
PTA	Parent Teacher Association - a group of parents and teachers who generally organise fund raising and social events
RQT	Recently Qualified Teacher (the year after being an NQT)
RS	Royal Society
RSB	Royal Society of Biology
RSC	Royal Society of Chemistry
SA	Science Ambassadors
SAT	Standard Attainment Test
SCORE	Science Community Representing Education
SDP/SIP	School Development Plan or School Improvement Plan – A strategic plan for school improvement
SEERIH	Science and Engineering Education Research and Innovation Hub, (University of Manchester).
SEND	Special Educational Needs and Disabilities
SES	Socio-economic status
SIP	School Improvement Plan
SLT	Senior Leadership Team - The team responsible for the day to day management of a school
SRE	Sex and Relationships Education
STA	Standards and Testing Agency
STEM	Science, Technology, Engineering and Mathematics
STEM Learning	Provider of education and careers support in science, technology, engineering and mathematics (STEM).
TAPS	Teacher Assessment in Primary Science. A project based at Bath Spa University and funded by the PSTT, aiming to develop support for a valid, reliable and manageable system of science assessment which will have a positive impact on children's learning.
TALIS	Teaching and Learning International Survey

Chapter 1. Introduction

> *You can disempower somebody but you cannot empower them. They will really begin to change, take initiatives, take risks, provide real feedback, learn from mistakes and accept responsibility for what they are doing when they feel sufficiently confident to do so and are provided with a clear framework. (Binney and Williams, 1997:69)*

1.1 Rationale for the research

I begin my submission with a small part of my own story to explain my motivation for pursuing this research.

I first became a Primary Science Quality Mark (PSQM) hub leader in 2012, running a hub for ten science subject leaders, supporting them on their journeys to gain a quality mark. The PSQM is described in detail in section 2.5 (see page 37). At the time I was a part-time teacher and science subject leader in my own school, also working towards PSQM gold. Therefore, I was performing dual roles as hub leader and science subject leader. During that first year I was fascinated to see the growing empowerment of science subject leaders as they initiated a wide range of activities to improve science teaching and learning. The changes they were able to forge in science education in their schools were impressive and over the years that fascination grew, as did my wonder at the positive impact on science teaching and learning that the science subject leaders were able to facilitate.

Two years after my first experience as a hub leader, I was confronted with a situation I had not expected nor experienced before. I will call the subject of this anecdote Ruth, although that is not her real name. She turned up to the first PSQM training session and, when I asked everyone to introduce themselves, she was very clear that she did not want to be there. Previously she had been subject leader for history, a subject she enjoyed and was confident teaching, until her head teacher had told her that she would now be leading science. I was told, in no uncertain terms, that she did not want to lead science but wanted to return to leading history. She was further incensed because she had been told she would be leading the school to gain a PSQM. Her body language further demonstrated her negative approach to being there.

I remember a sense of discombobulation at her attitude, but I cannot recall my response. I continued with the training and supported her as best I could for the remainder of the year, although I was perhaps a little wary of her. She attended all the PSQM training sessions and additional primary science training that was funded by the local authority. By the end of the year her attitude was transformed. She had become a confident science teacher and subject leader, and was thrilled with the silver PSQM she achieved despite the fact she had originally thought she would aim for the bronze PSQM. A few years later she reminded the school's new head teacher that the PSQM had expired, was due for renewal, and worked enthusiastically to renew the award. Subsequently she changed schools and became science subject leader in her new school, once again embarking on a PSQM. I could not wish for a better advocate for the PSQM.

Although I was delighted by the transformation in Ruth's attitude, her developing science teaching and leadership, and hugely impressed by the way science teaching and learning had improved in her school, I was unclear as to the cause of this change, and interested in the part played by the PSQM. When the opportunity arose for a funded PhD to research the PSQM this was my chance to gain a deeper understanding. While I appreciate this story focuses on the positive outcomes of the PSQM, I recognise that the programme is not infallible and the experiences of some of my participants, as discussed later, attest to some of the aspects that might be improved.

The story above describes my personal fascination with the perceived outcome of participation in the PSQM programme being to raise the profile of science within a primary school and improve the quality of science teaching and learning.

To gain the understanding I sought, I refined my thinking to create four research questions.

1. What happens to the identities of the science subject leaders during the PSQM year?
2. What changes do the science subject leaders establish within their schools?
3. What are the processes involved in these changes?
4. What are the affordances and constraints encountered in these processes by the science subject leaders?

1.2 Structure of the submission

Chapter two describes the context in which my research is set. A brief history of the English education system leads to a description of the current position with the focus of education being on measurable outcomes and accountability. The chapter then goes on to narrow the focus and consider primary science education more specifically. It also looks at the evolution of the role of science subject leaders; how the role developed and what might be expected of someone currently fulfilling the role. Finally the chapter considers the Primary Science Quality Mark (PSQM), briefly discussing how it developed, and, the way the framework supports science subject leaders to initiate activities to improve the profile and quality of science teaching and learning in their own schools, and sometimes beyond.

White et al. (2016) note the potential of the PSQM for the professional development of science subject leaders and a McKinsey report (Barber & Mourshed, 2007) argued that continuing professional development (CPD) is more effective than increased funding or reform initiatives. So, at a time when funding for schools is reducing and teachers have been subjected to on-going reform initiatives, a professional development programme like the PSQM, has the potential to improve science instructional practices. Therefore, Chapter three starts with a review of the literature about professional development and learning, defining the terms I will use.[1] Through this discussion the importance of informal or situated learning will become clear, as will the extent to which this is underrepresented in the literature about professional development. Situated learning describes the learning of science subject leaders taking part in the PSQM, because the direct instruction and formal learning related to the teaching and learning of primary science is limited.

The next section of chapter three explores situated learning, the work of Lave and Wenger (1991), and subsequent relevant publications, to explain more about situated learning, legitimate peripheral participation and communities of practice. Wenger (1998) claims that learning in communities of practice is in the form of identity, so the chapter continues with a review of the literature about identity and my conceptualisation of identity. Finally, chapter three will consider the discourses of the broad primary science community of practice, because as science subject leaders adopt these discourses their membership

[1] Throughout the submission, for clarity, any key definitions I use will be contained within a box.

of new communities of practices emerges, as does their developing identity. One of the discourses is around science investigations. In England this process is referred to as science enquiry, however, elsewhere the term science inquiry is used. Throughout I will use the term science enquiry.

Chapter four will consider methodology, situating my research within a constructivist framework and applying an interpretivist approach to the knowledge gained from participants. These decisions had implications for the research methods I used to answer my questions and led me to consider narrative approaches. In turn these influenced decisions regarding research instruments. The chosen instruments included interviews, rivers of experience, notebooks and documents. Next, I describe the process of data collection, the ways I immersed myself in my data to ensure my familiarity with it, and final choice of a method of analysis. I also acknowledge my position as an insider (Unluer, 2012) with respect to the research. The chapter concludes with consideration of ethical issues that also influenced the approach to the research, including the sampling and recruitment methods I chose.

Chapter five explains the findings from my data analysis with reference to the literature discussed in chapter three. This chapter is structured around the work of Lave and Wenger (1991) on situated learning and Wenger (1998) on communities of practice. The data I gathered from my participants will be compared to their work.

Conclusions are reached and my research questions are answered in Chapter six. In this chapter I will also consider the implications of my findings for other audiences, in addition to identifying further research questions that arose.

Chapter 2. Context

2.1 Introduction

At the time they[2] participated in my research, the science subject leaders were all employed as primary school teachers in England. Therefore, this chapter starts with brief history of the English state education system leading to a description of the national context in which they were working. Next, I discuss different conceptions of science and how these relate to the primary science curriculum and assessment requirements.

The role of science subject leader in a primary school will be described and conceptions of teacher leadership will be explored. The potential benefits of distributed leadership will be discussed, then the focus will narrow to consider specifically science subject leadership. The background on how the position arose, the responsibilities, and the factors impacting on the effectiveness of science subject leaders will be considered.

2.2 English education system

The PSQM is a primary science development programme and award for primary schools in the UK and beyond (PSQM, n.d.). All my data will be collected from science subject leaders in state funded schools in England, so the context I will consider is education in English primary schools. Where information directly related to this sector is unavailable, the wider UK will be considered.

Views of the current state of the English education system are contested, with the Conservative Party Manifesto (2017:49) stating, "We are proud of our reforms to education, which are giving children a better start in life than they could have expected a decade ago … There are now more than 1.8 million more children in schools rated good or outstanding than in 2010." While school reforms may aim to improve the quality of education and pupil achievement, the desired results have not always been achieved (Day & Smethem, 2009). The education system in England has been the subject of comprehensive and continuous political interventions causing, "negative effects upon teachers' motivation, morale, well-being and effectiveness" (Day & Smethem, 2009:143).

The School Teachers' Review Body (2019) concluded recruitment and retention had continued to worsen over several years. Further, based on international comparisons, schools in the UK do not fare well. The average class size in the UK is 27 compared to an Organisation for Economic Cooperation and Development (OECD) average of 21. The ratio of pupils to teachers in the UK is 18 to one compared to the OECD average of 15 to one. Teachers' pay in the UK decreased in real terms between 2010 and 2014, whereas it increased in most OECD countries; and, the UK has the youngest and least experienced workforce of all developed countries (OECD, 2017). The implications extend beyond teachers to children,

[2] Nearly all participants who provided data for my research were female, and the majority of science subject leaders are female (Leonardi et al., 2017). Therefore, where science subject leaders or participants are referred to in the singular, I will use the feminine pronoun.

especially those with more deprived backgrounds, who have also been adversely affected (O'Neill & Adams, 2012).

I will start this history with James Callaghan's 1976 seminal Ruskin College speech on education which introduced the idea of efficiency in education. He argued education should prepare pupils for the world of work and to play a constructive role in society. The discourse around the preparation of economically productive citizens has continued and strengthened since this time (Ball, 2017).

The Education Reform Act (1980), for the first time, allowed parents some choice in their child's education, and was part of an emerging narrative around market-led growth and individual choice. This was introduced at the same time as cuts in public expenditure and the liberalisation of labour markets (Ball, 2017). With the introduction of the Education Reform Act (1988), the trend for increasing parental choice continued, along with more far-reaching changes to the education system. The 1988 Education Act established the national curriculum (NC) and national testing in English, mathematics and science for 7, 11, 14 and 16 year olds, known as standard attainment tests (SATs). Budgets were devolved from Local Education Authorities (LEAs) directly to schools, and governors and head teachers became subject to increased responsibility (Ball, 2017). A quasi-market in primary education had arrived and testing at the ends of key stages one and two was a fundamental part.

During the late '80s and early '90s educational reform continued with the adoption of a progressively private sector model where LEAs were further disempowered. Teachers became more closely scrutinised and during the '90s teacher standards were introduced, against which teachers' performances were reviewed (Ball, 2017).

The Parents' Charter (Department of Education and Science, 1991) provided parents with the right to information about schools' performances, and league tables of test and examination results were published. The imperative to improve performance in relation to other local schools increased as per capita funding led schools to compete to recruit pupils (Ball, 2017). However, Ball (2013) notes, while schools vied for pupils, they were simultaneously expected to cooperate and share good practice.

In 1992 the creation of the Office for Standards in Education (Ofsted) gave rise to an additional way schools could be measured. This was followed by the Education Act (1993) allowing schools to opt out of LEA control and be funded directly by the Department for Education and Science (DfES). The Act also introduced measures to intervene in failing schools.

New Labour won the 1997 general election with Tony Blair's stated priorities being 'Education, education, education' and the focus on parental choice and market forces continued. Private companies were, for the first time, allowed to sponsor or provide state education through the introduction of academy schools. Academies were permitted to appoint unqualified teachers, could create their own curricula, and, implement their own pay and conditions for teachers (Ball, 2013).

For teachers within LEA schools, pay improved but became linked to performance. Targets for literacy and numeracy were introduced along with support for teachers to spread good practice through provision of coaching and training materials. SATs results for 11 year olds improved, yet plateaued after 2002 (Fullan, 2009), but the interventions were criticised for their narrow focus on English and mathematics (Hargreaves & Shirley, 2012).

The reforms created what Ball (2008:150) described as a "highly prescriptive system of accountability, performance indicators, inspections, league tables and achievement targets", but he questioned whether these, "indicators represent valid, worthwhile or meaningful outputs." Connell and Connell (1985) argued the outcomes of education are difficult to measure, yet the drive to quantify and drive up the measured outputs of primary education continued (Ball, 2017).

In 2007/08 teachers received over 6000 pages of government documents (Henry, 2008). "Teacher stress and alienation are at an all-time high, judging from the increase in work-related illness, and the number of teachers wanting to leave the profession" (Fullan, 2007:115). However, it was not just England that was subject to what Levin (1998) described as an international 'policy epidemic' as the import and export of education policies expanded, promoting the themes of markets, management and performativity across the globe.

In 2009 the abolition of the science SAT was announced. This move away from high stakes testing towards a system of teacher assessment was welcomed by the Science Community Representing Education (SCORE, 2009), because it allowed teachers to cover the wider science curriculum rather than focusing predominantly on teaching pupils to pass tests. However, the importance of science declined (Alexander, 2010) and teacher assessment of science suggested pupils performed worse than previous test measurements had indicated (The Royal Society, 2010). Possible explanations include the reduction in the importance and coverage of science compared to English and mathematics, or teachers' measures of pupil performance represented a more, or less, accurate picture of performance.

After a two-year pilot the PSQM was introduced in 2010 and appears to have played a positive role in raising the profile of science in those schools that participated in the programme (Ofsted, 2011). Further information about the introduction and development of the PSQM programme is provided on page 37.

In 2010 a coalition government of Conservatives and Liberal Democrats retained many of the New Labour education policies but introduced their own reforms based on a return to old fashioned values; for example, increased emphasis on spelling, grammar and times tables. Pressure on school performance increased further when Ofsted announced, in 2012, that the 'satisfactory' category was no longer good enough and would be replaced by 'requires improvement'. With the outcome of Ofsted judgements partially based on the outcomes of high-stakes testing, yet more pressure on the outcomes of English and mathematics SATs tests was applied (Stevenson & Wood, 2014). 2012 also saw the introduction of performance related pay with teachers becoming responsible for pupils' progress despite a review by the OECD (2012) revealing that although countries with higher paid teachers tended to have better outcomes for students, there was no clear link between performance relate pay and pupil performance.

The pressure on primary teachers continued to intensify when, in 2014, the Coalition government introduced a new national curriculum with children expected to accelerate their learning in mathematics, focus more on spelling and grammar, learn to write computer code and learn scientific facts (Richardson, 2014). In 2016, 47% of pupils failed to attain the expected standard in reading, writing and mathematics tests (DfE, 2017). The method of assessing pupil progress through the use of levels, that had been used to measure the progress of pupils under the previous national curriculum, was abolished with schools now able to decide how to track pupil progress using their own systems (Pratt, 2016).

By February 2016 the number of academy schools had increased rapidly to 2400 out of 16,766 primary schools with an ambition for all primary schools to become academies by 2020 (Cook, 2016). However, a parliamentary report (House of Commons Education Committee, 2015:4) stated, "Academisation is not always successful nor is it the only proven alternative for a failing school."

2.2.1 The outcomes of educational reforms

The reforms described above have resulted in the education system that provides the context for my research. This is described below as it has a bearing on the experiences of my participants.

Ball (2003) discusses how a policy epidemic has spread internationally and Sahlberg (2016) has discussed this convergence of education policy, referring to it as the Global Educational Reform Movement (GERM). He claims it is characterised by:

- increased competition between schools
- standardization of teaching and learning
- an increased focus on reading literacy, mathematics, and science. Although in the case of the UK the focus in primary schools is on mathematics and English because of SATs tests.
- borrowing of change models from the corporate world
- adoption of *test-based accountability policies*
  (Sahlberg, 2016:133-136)

However, Hargreaves and Shirley (2012:8) consider two additional factors:

- the use of data to drive decisions and discussions about student learning and achievement; and
- the spread of digital technology into everyday life of classrooms and schools

Under the guise of greater freedoms in education, schools are constrained by the way funding is linked to performance, as pupils and their parents choose which school to attend.

As Stevenson and Wood (2014:53) state, "In the new educational market failure has become a very real phenomena". The way this has impacted teachers concerns Ball (2003:215), "The novelty of this epidemic of reform is that it does not simply change what people as educators, scholars and researchers do, it changes who they are." He thereby suggests their identities are affected.

Biesta (2010) argues the measurement culture has created a misplaced confidence in the power of tests to provide meaningful information. He describes how the government decides what will be measured, probably based on what is easy to measure, and teachers aim to gain the best test results for their pupils. Stevenson and Wood (2014) argue a testing regime narrows the curriculum while wider learning is neglected because it is less easy to measure. Pratt (2016:897) discusses the way assessment data have become measures of the overall standard of education and the way SAT scores have become synonymous with the word data, "to ensure that only that which has been enumerated counts". Thus, adopting a learning as acquisition metaphor (Sfard, 1998).

The accountability regime, school inspections, pressure on teachers to ensure pupils achieve targeted examination results, and education policies that lack coordination, are piled on top of long working hours affecting the retention of teachers in the profession (See & Gorard, 2020). The excessive workload is causing teachers to leave the profession (CooperGibson Research, 2018) causing concern at policy level as the teacher shortage continues to worsen (Allen et al., 2020). Despite government initiatives over the last five years there has been no reduction in teacher workload (Allen et al., 2020) and teachers in England are working longer hours than teachers in the other countries included in the most recent Teaching and Learning International Survey (TALIS) (Jerrim & Sims, 2019).

One further outcome of educational reforms has been a developing leadership crisis, with more head teachers retiring and others in senior leadership roles reluctant to take on increased responsibilities (Harris, 2008). Howson (2016:3) stated, "Rarely… has there been as much concern over finding the next generation of school leaders as there is now." Existing head teachers form an aging cohort, many of whom are expecting to retire shortly. A DfES (2007) report showed heads were struggling to cope, spending an increasing proportion of their time managing day to day events, leaving little time for leading and increasingly removing them from classroom practice.

Ball (2017:163) questions whether the, "highly prescriptive systems of accountability – performance indicators, inspections, league tables and achievement targets", are actually measuring the economic benefits which forms part of the narrative necessitating these changes. Throughout the 40 years discussed above politicians have talked about the need to promote social mobility, yet their policies are often at odds with this aspiration. The inequalities remain and are greater than ever (Ball, 2017).

The ASPIRES research (Archer et al., 2013b) showed inequalities are prevalent in the uptake of science subjects once pupils have the option to choose which subjects they continue to study. While primary pupils are enjoying their science experiences and see the value of science, few aspire to be scientists in the future and this view is unlikely to change through secondary school. Figure 1 shows the striking difference between the few pupils who aspire to become scientists, compared to the numbers who otherwise have positive views of science. Archer et al. (2013b) found that although children generally have high aspirations, they are unlikely to include science as a potential career choice. They concluded families had narrow views of where studying science might lead and so in many cases saw it as irrelevant. Most pupils considered science was for 'brainy' people which many found off-putting, and inequalities persist.

As a result of the research of Archer et al. (2013b) the concept of science capital was created that, "refers to science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g. knowing someone who works in a science-related job)" (Archer et al., 2013b:3). They discovered girls were less likely than boys to aspire to science-related careers, but ethnicity and socio-economic factors were also influential. They identified the students least likely to have STEM aspirations as being in the lowest set for science, white, female, with low cultural capital, and with no friends or family in science related careers.

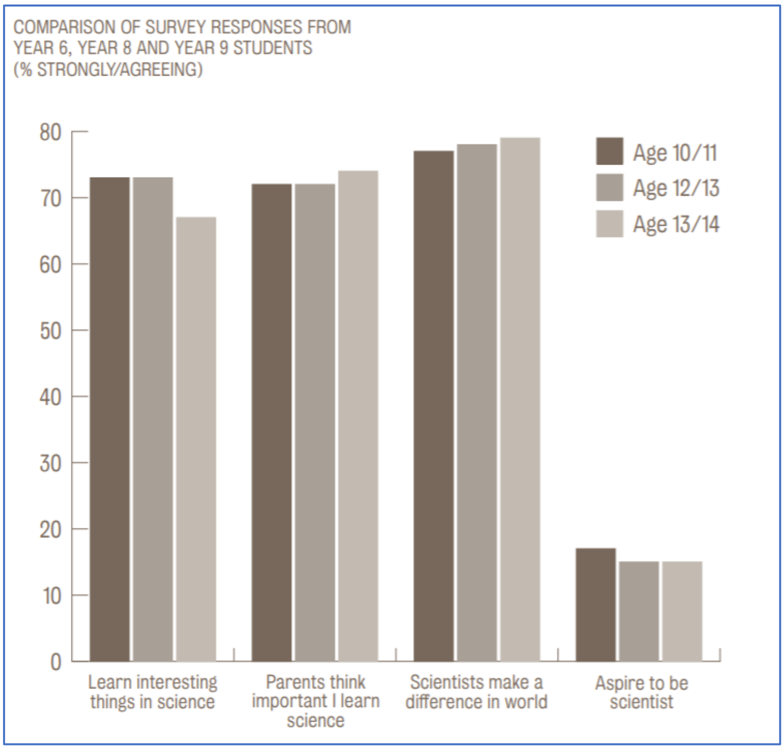


Figure 1 - Comparison of survey responses from year 6, year 8 and year 9 students. (Archer et al. 2013b:2)

Ofsted (2019b) recognised the narrowing of the primary curriculum resulting from the focus on the high stakes testing of English and mathematics. Consequently, a new school inspection framework (Ofsted, 2019c) has been introduced with a focus on a broad and balanced curriculum. However, my data were collected before this recent change to the context.

Sadly, Stevenson and Wood (2014) believe it unlikely that the developments instigated by GERM will be halted or reversed. However, Hargreaves and Shirley (2012) see a way forward. Having studied the highest performing states and schools internationally, they reject notions of market driven education policy and conclude effective education systems are based on several key principles grouped into purpose, professionalism and coherence.

Hargreaves and Shirley (2012) consider the purpose of an education system should be inspired by a vision and driven for the public good with the support of the community and financed prudently but with enough funding to meet the aims of equity and quality. The system should also allow schools to set and implement their own development agenda and provide the capacity to work within local networks for the good of the local community.

Regarding professionalism, the very best teachers should be recruited and retained and take collective responsibility for their own professional development as well as the progress of their students. Learning should be in depth as opposed to superficial teaching focused on students passing tests. Any use of technology should be focused on teaching and learning (Hargreaves and Shirley, 2012).

Hargreaves and Shirley (2012) further contend that an education system should be coherent. Educators should learn from good practice in other education systems rather than competing to be top of international tables and use tests in ways that do not distort the curriculum. Communication should be paramount as should understanding differences rather than working towards a standardised system. Finland is presented by Hargreaves et al. (2007) as a country meeting the criterion of coherence, consistently performing at or near the top of Program for International Attainment (PISA) tests. They do not use standard tests across the country and provide an environment where teachers' professional judgements are trusted, teachers are supported and encouraged to be creative.

2.2.2 Conclusion

More than 20 years ago Whitty (1997) suggested the aspiration that marketisation would lead to school improvement was unlikely ever to become a reality. Following a whole raft of policy initiatives over the last 40 years, it seems he was probably right. The suggestions of Hargreaves and Shirley (2012) have not been implemented, nor does there appear any prospect they will be in the foreseeable future.

As Apple (2004:15) contends, "This contradictory discourse of competition, markets, and choice on the one hand, and accountability, performance objectives, standards, national testing and national curriculum on the other hand, have created such a din that it is hard to hear anything else." It has highlighted to me the importance of hearing my participants' voices above this din.

Having considered the English primary education system, I will now narrow the focus to primary science education.

2.3 Primary science education in England

This section starts with a brief consideration of how science might be defined and how this relates to science in primary schools. The structure, content and statutory assessment of the primary science curriculum in England will then be explained. Hattie (2017) concluded teacher efficacy was the most influential factor in improving pupil attainment, so the way primary science in England is taught will also be discussed, as will science subject leadership.

2.3.1 The English primary science curriculum

Reiss (2004) notes the failure of philosophers and historians of science to define a unique scientific method capable of distinguishing science from other disciplines. He suggests science should be understood to mean: "That which is recognized as such by the scientific community" Reiss (2004:11). Osborne (2011) also argues the concept of a single scientific method is a myth, failing to acknowledge the diversity of approaches used in practice. He notes the distinction between 'doing science' whereby a scientist aims to create new knowledge and 'learning science' where students are taught a body of knowledge specified in the curriculum. He argues 'doing' and 'learning' science should have more in common. In conclusion, Reiss (2004) argues school science, at present, does not account for the many and diverse understandings of the methods of science and suggests this negatively impacts students' attitudes.

In the report, Beyond 2000, Millar and Osborne (1998) argued science should be presented as explanatory stories and Harlen (2010), along with other international experts, developed this idea creating the Principles and Big ideas of science education. This document argues that through development of the 'big ideas' of science, students will be better able to understand the world around them and make informed decisions about the way science may impact their lives. In my experience, the extent to which the national curriculum in England is presented to learners as explanatory stories is limited and this is not a concept with which teachers are familiar. The English primary science curriculum will now be explained in more depth.

The national curriculum (NC) programmes of study for England (Department for Education, 2013) include science as a core subject alongside English and mathematics, with other subjects designated foundation subjects. However, high stakes testing of English and mathematics at the end of key stage two narrows the curriculum (House of Commons Education Committee, 2017) with the teaching of English and mathematics typically prioritised ahead of science. A Wellcome report (Leonardi et al., 2017) found on average, in the UK, science is taught in primary schools for one hour and 42 minutes each week. Teachers in England who are male, are confident teaching science, and those who have completed or are working towards the PSQM, tend to teach science for longer. There is currently no advice from government on the number of hours for which each of the core and foundation subjects should be taught.

The programmes of study are divided into key stages. Key stage one covers the objectives for children in years one and two (ages five to seven) and key stage two covers the objectives for children in years three to six (ages seven to eleven). At age eleven children move on to key stage three then four, both generally taught in secondary schools and thus beyond the scope of this study. The NC specifies the topics that should be taught to each year group, for example, plants; animals, including humans; everyday materials; and seasonal changes within year one. In addition, for each key stage the programmes of study set out the requirement for children to study the nature, processes and methods of science, referred to as working scientifically. This should be embedded within the teaching and learning of the science subject knowledge.

The NC in England is statutory for state schools, except for academies and free schools that are exempt under the terms of the Academies Act (2010). However, teacher assessments in English, mathematics and science at the ends of key stages one and two, based on the programmes of study, are statutory for all state schools including academies and free schools. Thus, the opportunity for them to deviate from the curriculum followed by other state schools is constrained. Discussion of the primary science curriculum would be incomplete without mention of the Early Years Foundation Stage (EYFS). Most primary schools accept children prior to statutory schooling commencing in year one and have a duty to follow the EYFS Framework (Department for Education, 2017) which follows an integrated approach to learning and specifies development in the three prime areas of:

- communication and language
- physical development
- personal, social and emotional development

These three prime areas are to be strengthened and applied in four specific areas, which are:

- literacy
- mathematics
- understanding the world
- expressive arts and design

Learning related to science typically fits within understanding the world. Pupil learning in the EYFS is assessed in relation to seventeen early learning goals.

Millar and Osborne (1998) concluded the science curriculum of the time, presented science as a value-free, objective and detached subject, and stated a case for increased prominence for teaching science as understanding; science as a human endeavour; the tentative nature of science; and reality as the ultimate test of theories. Although the curriculum arguably allows opportunities to include these suggestions, based on many years classroom experience, primary science in England still does little to promote these conceptions of science.

2.3.2 Statutory assessment in primary science

At the end of key stages one and two teachers are required to assess and report whether pupils have achieved the expected standards, known as Age Related Expectations (AREs). The Standards and Testing Agency (STA, 2016a, STA, 2016b) provides exemplars of work to help inform teachers' judgements. In addition, there is a biennial science test for a national sample of key stage two pupils that monitors performance across England. In 2018 approximately 9500 pupils from 1900 schools each sat tests in biology, physics and chemistry (Standards and Testing Agency, 2019). The results of teacher assessment and the science sample tests are shown in Table 1.

	Percentage of pupils achieving at least the expected standard in science based on teacher assessment		**Percentage of pupils achieving at least the expected standard in the science sample test**
	Key Stage 1	**Key Stage 2**	**Key Stage 2**
2016	82%	81%	22.3%
2017	83%	82%	Tests are biennial. No tests in 2017.
2018	82%	83%	21.1%

Table 1 Primary pupils achieving the expected standard in science, based on data from Department for Education (2019b), Department for Education (2019a), (Spielman, 2020) and Standards and Testing Agency (2019)

Ofsted's current Chief Inspector (Spielman, 2020) noted the disparity between the science sample test results and teacher assessment data. She confirmed science is being squeezed out of the primary curriculum as schools focus on English and mathematics in their desire to perform well in SATs.

The diminished focus on science is reinforced by the results of research from Leonardi et al. (2017:25) who discovered, while 57% of heads, deputies and acting heads thought science was very important in their schools, the perceptions of those in other roles (mainly classroom teachers) differed with only 25% of them considering science was very important. As part of the same research teachers, including senior leaders, were asked how important English, mathematics and science are to the school leadership;

- 83% think English is 'very important' and 11% 'important'
- 84% think maths is 'very important' and 11% 'important'
- 30% think science is 'very important' and 50% 'important'

(Leonardi et al., 2017:3)

Ofsted inspection reports also reflect the lower status of science compared to the other core subjects with 47.8% of primary school Ofsted reports mentioning science compared to 99% that referred to mathematics. Where science was mentioned, in many of the reports, it was in respect of its contribution to writing skills (Wellcome, 2017b).

2.3.3 Teachers of primary science

Teachers play an essential role in enabling pupils to acquire the skills and knowledge set out in the curriculum. Research by Wellcome (Leonardi et al., 2017:35) found science is mostly taught by the class teacher in 90% of primary schools in England, in 5% of schools science is taught by a science teacher, and in 6% an approach somewhere between the two is used, with small schools more likely to have a designated science teacher.

The Royal Society (2014) claims the quality of science education in the UK is suffering because only 5% of primary teachers have been awarded a degree in science. However, Jarvis and Cavendish (1994) found many teachers with higher science qualifications tried to teach more difficult concepts and use more complex vocabulary before the learners were ready, thus leading to negative perceptions of the subject. Kirkham (1987) discovered 78.5% of subject leaders had developed their subject knowledge through taking an interest in the subject or by attending CPD events. Therefore, I contend primary subject leaders should be less concerned about their science qualifications and recognise subject specific CPD, and, taking an interest in science in the world around them, might enable them to acquire sufficient subject knowledge and pedagogical content knowledge (Shulman, 1986) to improve the teaching of primary science.

Hargreaves (1995:9) further extends the understanding of the skills, knowledge and attitudes required for effective teaching claiming, "while policy rhetoric stresses knowledge and technique as central to good teaching, I draw attention to the importance of purpose, passion and desire." He goes on to highlight, "the central place of moral, political, and emotional issues in the field" (Hargreaves, 1995:9).

A survey by Murphy et al. (2007) found most teachers believed the greatest factor holding back primary science teaching, was lack of ability and confidence to teach science. However, their research showed confidence was now rated as third below English and mathematics, suggesting an improvement since Harlen (1997) conducted a similar study when science rated 8th out of 11 subjects in terms of teacher confidence. A Wellcome report (Leonardi et al., 2017:30) suggests the situation may have improved further with the majority of teachers now agreeing or strongly agreeing they are confident teaching, assessing and answering children's questions in science (see Figure 2). However, the way Murphy et al. asked about teachers generally, and Leonardi et al. asked the participants specifically about their own practice, might be one reason accounting for the different results.

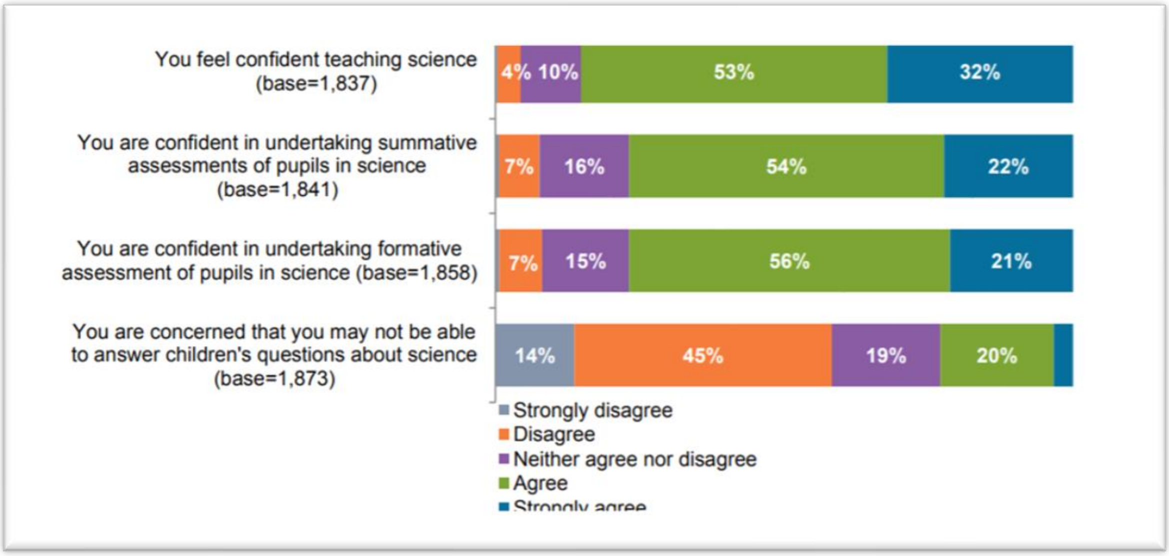


Figure 2 - Extent of agreement about confidence teaching science (Leonardi et al., 2017:30)

Any lack of teacher confidence to teach science may have an impact on the quality and quantity of science teaching. Harlen and Holroyd (1997) suggest those teachers who are less confident employ a range of avoidance strategies including: teaching the absolute minimum while focusing on the areas where they have the greatest confidence; reducing the amount of discussion and practical work; relying on materials gathered from books or elsewhere; and focusing on the outcomes in preference to the conceptual understanding.

Alexander et al. (1992) sparked debate over whether the subject knowledge of teachers was sufficiently strong in all curriculum areas, particularly with older primary children, and suggested subject specialists might be considered. However, O'Neill (1996) claimed this suggestion was overly focused on the delivery of the NC and paid insufficient attention to curriculum development. The Royal Society (2014) found the role of science specialist became a reality in few schools because of the lack of primary trained science specialists, so in most schools, science is taught by a class teacher.

Wellcome (2017a), in collaboration with other organisations working to improve the provision of primary science education, has set out the expertise they consider a teacher of primary science should have in terms of subject knowledge and pedagogical content knowledge (see Figure 3).

Subject knowledge
A teacher of primary science should have secure understanding of the scientific concepts within the primary science curriculum, with a focus on the age range they are teaching. They should understand how the content they are teaching fits into the progression from early years in to secondary education (ages 11-14). They should recognise areas where their knowledge is less secure and use appropriate sources to address these before teaching.

A teacher should use correct age-appropriate scientific vocabulary and expect pupils to do the same. They should understand and model the different methodologies for science enquiry, including appropriate methods for recording and presenting different types of data.

Pedagogical content knowledge
A teacher of primary science should have good knowledge of a range of teaching methods suitable for the science curriculum for all their pupils, including addressing gender stereotyping. Their knowledge should include enquiry-based teaching and learning methods, practical activities, out-of-classroom learning, independent and group work, problem solving, and digital technologies. They should have good understanding of both formative and summative assessment practices, and use outcomes to ensure their pupils make good progress.

Figure 3 - Primary science teacher expertise (Wellcome, 2017a:3)

These attributes will inform my understanding of the discourses of the primary science community of practice in section 3.5 (see page 61).

2.4 Science subject leaders

Having considered those who teach primary science in England, the role of science subject leader will now be explored. The participants in my research were all designated science subject leaders within their schools, in addition to being teachers of science and many other subjects. Subject leadership is a form of teacher leadership, that might also be referred to as distributed leadership (Spillane & Zoltners Sherer, 2004). Teacher and distributed leadership will therefore be discussed, as will the more specific role of subject leader, including science subject leader, within English primary schools. The history of the role will be examined along with the functions, skills and attitudes required to fulfil the role. Those undertaking these duties typically also have responsibility for a class of children and delivery of most, if not all, of the subjects in the primary curriculum. Being a class teacher is a demanding job and adding the complex role of subject leader increases the pressure on primary teachers (Bell, 1992).

2.4.1 Teacher leadership

Fullan (2006:31) states a, "culture of distributive leadership that grooms new leaders for the next phase must be established", as a potential solution to the leadership crisis referred to above (see page 23). A report (DfES, 2007) concluded distributed leadership would support the development of such future school leaders. Hammersley-Fletcher (2004) and Harris (2009) also highlight the benefits of developing collaborative or distributed leadership, with Spillane and Zoltners Sherer (2004) connecting distributed leadership with improvements in teaching and learning for some subjects in US elementary schools.

Harris (2008) states there is much confusion around the concept of distributed leadership with many contradictory definitions suggested, however associations with informal leadership are common factors. Spillane and Zoltners Sherer (2004), suggest distributed leadership is, "constituted through the interaction of leaders, teachers, and the situation as they influence instructional practice". Gronn (2000:266) envisages distributed leadership as an, "emergent property of a group or a network of interacting individuals." Thus, distributed leadership is a process involving the whole community rather than associated with influential individuals and their followers. It also shifts leadership closer to teaching and learning and fits with the concept of situated learning which is explored further below (see page 50).

Given the criticisms of distributed leadership, I will use the term teacher leadership, defined as resulting from interactions and sharing the six dimensions below.

- Shared decision making
- Collaboration
- Active participation
- Professional learning
- Leadership as activism (Muijs & Harris, 2006:964)
- Authority which is important because without it teacher leaders may be left vulnerable. (Timperley, 2005)

Gronn (2016), originally an advocate for distributed leadership, has become increasingly sceptical and he now argues leadership is configured rather than distributed. This allows room for both collectivism and individualism to operate simultaneously. He suggests distributed leadership only captures a part of this picture, hence its limited usefulness. However, the concept of teacher leadership as defined above is sufficiently accurate and detailed for my purposes.

2.4.2 History of subject leadership

Having considered teacher leadership more generally, I will now explore the emergence of the role of subject leader. Historically the responsibilities of primary school teachers revolved around teaching their classes and management responsibility of schools fell to head teachers, until Plowden (1967) suggested a formal role for teachers to lead curriculum areas. Initially the term 'consultant' was used to refer to this role. Several years later Her Majesty's Inspectorate of Schools (Department of Education and Science, 1978) linked the role to impact on teaching and learning and suggested the title 'curriculum coordinator'. Further names for the role were suggested including, 'curriculum post holder' (Campbell, 1985) and 'specialist' (Morrison, 1986). Bell and Ritchie (1999) note the lack of agreement on the name for the role but focus on the terms leader and coordinator. They perceive the role of coordinator as responsive and passive, while portraying the role of subject leader as more proactive. Since the term subject leader is used by the PSQM I will use this term. However, when referring to the work of other authors, I will employ the term or terms they use.

The report, Science 5-16 – A Statement of Policy (Department of Education and Science, 1985) noted around 55% of schools had a subject coordinator for science, and grants were made available to Local Education Authorities (LEAs) to train primary science coordinators. The report recommended each school should have one or more teachers with the knowledge and skills to drive improvements in science teaching and learning.

In 1987, a role leading a curriculum area became part of a primary teacher's contractual duties. The School Teachers Pay and Conditions Order (1987) set out the requirement for teachers to adopt responsibility for a curriculum area without any extra remuneration. Shortly after the 1988 Education Reform Act, a Framework for the National Curriculum (National Curriculum Council, 1989) defined responsibilities for curriculum leadership. Around the same time ASE (1988) recommended all schools, except small schools, should have a teacher responsible for the co-ordination of science.

Given the contractual requirement to lead a curriculum area, Edwards (1993) discovered teachers had been delegated increased responsibility and either became a member of the schools' Senior Leadership Team (SLT) or took responsibility for a curriculum area. Initially teachers were enthusiastic about their new responsibilities but over time frustrations began to surface (Menter, 1997). Teachers, "reported significant increases in the amount of time they had to spend on work and nearly all saw the extent of such increases as unmanageable and unreasonable" (Campbell & Neill, 1994:71).

Another new name for the role arose when Ofsted (1994) coined the term 'subject manager', clarifying each subject manager should take account of the whole school perspective, based on the strategic views of the governors and head teacher. They also set out their expectations for incumbents of the role.

In my experience the title subject leader currently seems to have replaced curriculum coordinator in most primary schools, perhaps as a result of the Teacher Training Agency (1998) who published National Standards for Subject Leadership. At this time there was a proposal to introduce a National Professional Standard for Subject Leaders, however this never transpired, and Lawler (2002) speculates that the sheer number of primary subject leaders and the associated cost were strong disincentives to pursue the project.

Ofsted (2013a) published guidance on self-evaluation for science subject leaders, but this was withdrawn in March 2017 as it was more than three years old and may no longer reflect policy. Although there is currently no guidance from government on the role of science subject leader, the role is filled in most primary schools. A survey of a representative sample of primary teachers and senior leaders found only 5% of respondents said they worked in a school without a science subject leader (Wellcome, 2016).

The next section explores the skills, knowledge and attributes which might be required for the role of science subject leader.

2.4.3 Functions and characteristics of subject leaders

Hammersley-Fletcher (2004) considers subject leadership a complex role and a variety of authors over the years have tried to define the role and the associated responsibilities.

Guidance from the National Curriculum Council (1989), defined some responsibilities of the role which included:

- creating schemes of work;
- working with colleagues and other local schools;
- arranging training;
- having up to date knowledge of their subject;
- purchasing and organising resources

Based on the work of Bell (1992), Bentley and Watts (1994), The National Standards for Subject Leaders (1998), Hammersley-Fletcher and Brundrett (2005), Hammersley-Fletcher (2004) and the ASE (2017), I have drawn together the knowledge, key activities and qualities that they believe are important for subject leadership and these are included in the model in Figure 4. In this model I have linked them to the schools' pupils and the colleagues of the science subject leaders.

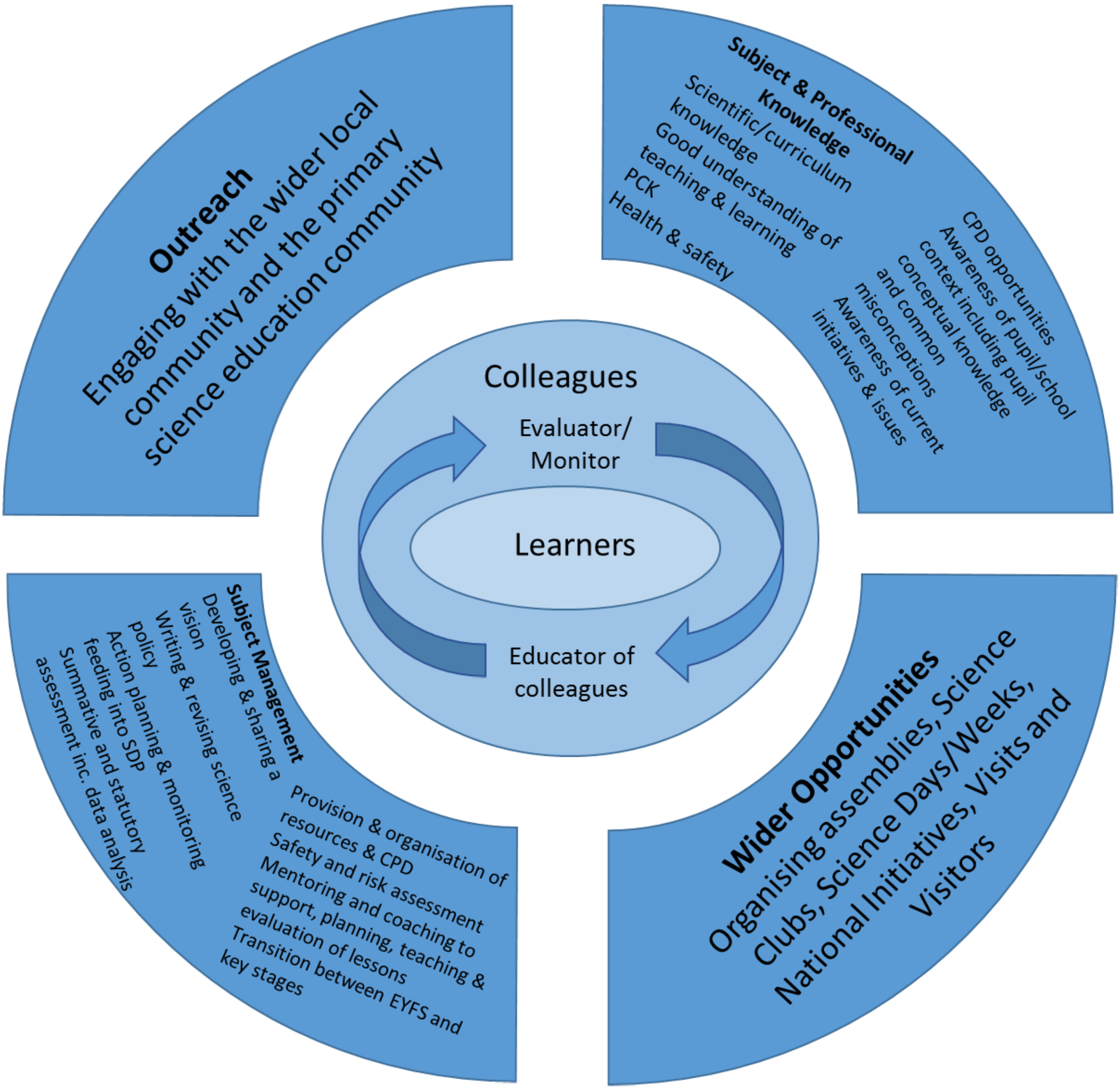


Figure 4 - Summary of the knowledge and responsibilities of the primary science subject leader

The model puts learners at the centre of the role surrounded by colleagues who will have direct impact on children's learning. The central circle features a cycle of monitoring and addressing areas of development for colleagues and self through CPD. In summary, the literature suggests effective subject leadership entails numerous responsibilities alongside substantial knowledge. This leadership role is supposed to be carried out, in addition to the incumbents' other roles in school, predominantly that of class teacher.

A recent view of the role of subject leader is published by Wellcome (2017a) (see Figure 5).

Primary Science Subject Leaders

A Primary Science Subject Leader is the person in school who has responsibility for ensuring that the science element of a broad and balanced curriculum is delivered effectively so that children make good progress in their understanding of science and develop the scientific skills they need to prepare them for the next phase of their education. Across the UK different titles may be used to describe this role, and science may not be referred to as a discrete subject but as a component of the curriculum. There is no requirement for a primary science subject leader to have qualifications above national statutory requirements for teaching. They should recognise the links and opportunities for learning between science and closely associated subjects such as maths, design and technology, and computer science.

Subject leadership
A Primary Science Subject Leader should value science, understanding the importance and relevance of science in our lives, and recognising that teaching and learning science develops skills and ideas that can be either specific to science or can be applied across the curriculum.

They should:

- keep up to date with broad developments in science and science education, and consider how to share these with colleagues, and pupils when appropriate

Subject knowledge
A Primary Science Subject Leader should have a deep understanding of the scientific concepts within the primary science curriculum, supported by an understanding of progression into the next phase of education. They should identify any gaps in their knowledge or weaker areas of understanding of the scientific methods, and address these through appropriate sources, including high quality CPD.

They should understand the different methodologies for science enquiry and when to use them, including appropriate methods for recording and presenting different types of data. They should be confident in the use of scientific vocabulary related to the curriculum and able to explain these terms to colleagues.

Pedagogical content knowledge
A Primary Science Subject Leader should have secure knowledge of, and be able to apply and model, an appropriate range of methods suitable for teaching across all phases in their school. Their knowledge should include enquiry-based teaching and learning methods, practical activities, out-of-classroom learning, independent and group work, problem solving, and digital technologies. They should have secure understanding of both formative and summative assessment practices for primary science, and evaluate outcomes to monitor the impact of science teaching and learning on pupils.

Figure 5 - Primary science subject leader expertise (Wellcome, 2017a:2)

Many of the skills, attitudes and knowledge required in the Wellcome description of necessary expertise are also included in my model. However, neither addresses the issue raise by O'Neill.

> The role of subject coordinator as someone able to provide support, guidance and reassurance for the work of colleagues has remained a seductive model of effective primary school curriculum management without any clear idea where the role of classroom teacher begins and that of coordinator ends. (O'Neill, 1996:25)

2.4.4 Contexts in which subject leaders operate

Hammersley-Fletcher and Brundrett (2005:74) take the view that in order to become effective leaders, teachers need to be taken out of their comfort zone. "It was clear that in order to have active involvement in distributed leadership schools need some method in place to force staff 'out of their nest'. This results in, as one subject leader put it '. . . being allowed to fly. . .'" Conversely, Muijs and Harris (2006) suggest a supportive culture, along with shared professional practice, coordinated improvement efforts, innovative CPD, collective creativity, and recognition, enable the development of teacher leaders. Context may therefore be influential, and Busher et al. (2007:406) contend that too little attention is paid, "to the institutional, social and political context in which they operate". Therefore, the contexts in which the science subject leaders operate will be discussed below.

Hammersley-Fletcher and Brundrett (2005) concluded there were too many demands on the time of a class teacher who was also attempting to fulfil a subject leadership role. Teachers were aware of a contradiction: while the role of the subject leader was to improve standards, that very role took them away from their classroom teaching thus having the opposite effect. Teachers were left with the dilemma of being the best class teacher they could, or, devoting time to effective subject leadership (Lunn & Bishop, 2002).

Muijs and Harris (2006) also noted the capacity of teachers to take on additional work might be a barrier to teacher leadership. A survey by Wellcome found, "51% of science subject leaders get specific release time to lead science in addition to planning their own lessons. One-third take 10 hours (or less) a year, one-third take 11-20 hours and one-third take more than 21 hours" (Leonardi et al., 2017:3).

Head teachers determine how much release time science subject leaders have available and through this they influence the effectiveness, or otherwise, of science subject leaders. Hammersley-Fletcher and Brundrett (2005:73) state, "subject leaders recognise the extent to which they are given responsibility relies on the attributes and philosophies of the head". Tensions between subject leaders' desire for power and head teachers being prepared to relinquish it, were identified by Hammersley-Fletcher and Kirkham (2007). Harris (2009) argues a shift in power is needed to ensure leadership becomes distributed and resources similarly need to be distributed. Moreover, lack of communication by head teachers may constrain teacher leadership (Muijs & Harris, 2006). Other staff in school are also influential, with perceptions of the role and its incumbent by the other class teachers, the head teacher, and the subject leaders themselves, having an impact on their effectiveness (Bell, 1992).

Other contextual factors that may mitigate against effective subject leadership were confidence, time and money (Hammersley-Fletcher and Brundrett, 2005). Although some science subject leaders may have previous experience leading other curriculum areas, Spillane (2005) discovered different primary subject areas require different leadership and he saw teaching and leading as situated within each subject. Therefore, previous experience of leading another subject area may be insufficient to develop an effective science subject leader.

A further tension exists, as noted by the Hammersley-Fletcher and Kirkham (2007), in the way centrally imposed initiatives may impede the ability of subject leaders to implement their own agendas. Central government initiatives and the mechanisms for accountability, especially in schools designated by Ofsted as requiring improvement, and were also noted as barriers to teacher leadership (Muijs & Harris, 2006). In a survey, teachers and subject leaders were asked about the barriers to teaching and leading science and what would help overcome the barriers. The four most frequent responses to each category are shown in the Table 2.

What, if any, barriers do you experience when teaching or leading science?	**What, if anything, would help when teaching or leading science?**
Lack of budget and resources (35%)	More resources/funding (36%)
Lack of time and curricular importance (22%)	A need for CPD or other support (22%)
Lack of subject knowledge (11%)	More time/curricular standing (11%)
Issues relating to setting up space or access to resources (10%)	The need for more model activities/exemplar materials (9%)

Table 2 Barriers and enablers when teaching and leading science (Wellcome, 2016)

This survey supports the view that a lack of time, resources, subject knowledge and access to CPD act as constraints to effective science subject leadership.

Hammersley-Fletcher (2004) summed up issues hindering subject leaders. These included a lack of leadership training, power relationships, government initiatives, multiple roles in small schools, and the ethos of the school, where the head teacher had a strong impact. In contrast to the constraints discussed above, Muijs and Harris (2006) found the most successful initiatives occurred when teachers took an active approach to a project.

2.4.5 Perceptions of the role

Lack of confidence to teach science has previously been discussed, but Hammersley-Fletcher and Brundrett (2005) state that a lack of confidence in scientific knowledge is also a concern to some science subject leaders. Without an academic background in science many subject leaders do not believe they have the science knowledge to teach, let alone lead, science (Bentley & Watts, 1994).

Based on interviews with subject leaders, Hammersley-Fletcher (2002) established subject leaders' behaviour was sometimes at odds with their perceptions of an effective subject leader. For example, while they thought improving learning experiences and implementing change were important parts of their roles, they were more focused on maintaining resources and putting policies and schemes of work in place. Bell (1992) confirmed co-ordinators were focusing on, for example, organising resources and writing policies, and they required training to develop their management role and improve their subject understanding. While head teachers and subject leaders viewed the involvement of all staff in collaborative discussions regarding leadership as beneficial, Ofsted suggested subject leaders had a narrow view of their role (Hammersley-Fletcher, 2002).

Some subject leaders were also uncomfortable with some of their responsibilities (Hammersley-Fletcher, 2002). For example, they felt awkward about observing lessons and were very conscious of the need to be sensitive to the feelings of colleague. A reluctance to identify with the title of subject leader affected some because they felt it created an uncomfortable illusion of expertise.

Having considered the role of science subject leader I will now explain the development of the PSQM and the way it is designed to support science subject leaders.

2.5 The Primary Science Quality Mark

Here I will briefly explain the history of the Primary Science Quality Mark (PSQM) and the way it has been described in evaluations. A semi-structured interview with the founder and director of PSQM took place at the University of Hertfordshire on Tuesday 2nd May 2017 and the information below is based on that shared at the interview, on my knowledge of the programme since 2012, when I first became a hub leader, and, on documents that have reported on the PSQM. I will go on to explain the structure of the programme and how it operates.

The programme was piloted in 2008 and 2009 based on three aims:

- to raise the profile of science in primary schools

- to provide schools with a framework and professional support for developing science leadership, teaching and learning
- to celebrate excellence in primary science

The evaluation of the pilot (Ponchaud, 2008:10) stated, "Overall the pilot has succeeded in developing reliable procedures for the award of a Quality Mark which have the potential to encourage further development of science in participating schools". Recommendations informed developments for the next round of the pilot study. Following a second pilot and further development of the process, the programme was rolled out nationally.

Round one began in March 2010. However, there was demand for a cohort starting in September, corresponding with the academic year, and from then on two rounds commenced each year. Over the years the PSQM has continued to recruit schools and the number completing PSQM in each round is shown in Chart 1 below.

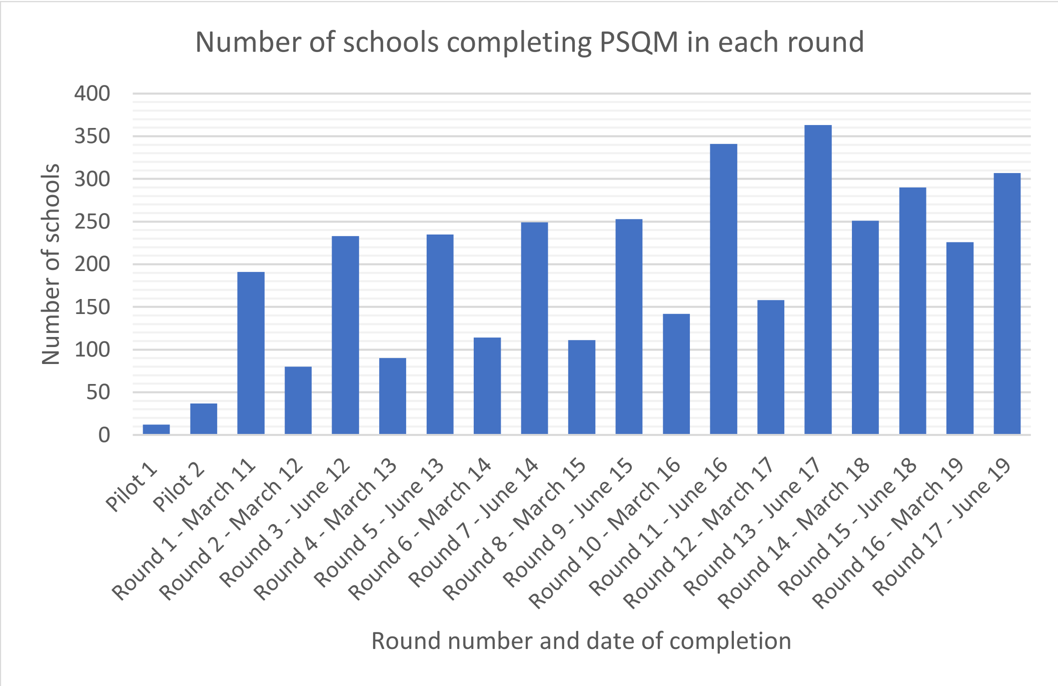


Chart 1 - Number of schools completing PSQM in each round.

The evaluation of the rollout (Ponchaud, 2011) identified several keys to the success of the PSQM including evidence-based criteria, the promotion of a development and improvement cycle, an emphasis on training, committed hub leaders, and, moderation working with primary science experts. He praised the effectiveness of the processes, including the quality assurance procedures and suggested expansion of this evidence-based model would be desirable.

Further validation was provided by the report, Successful Science (Ofsted, 2011:49), which noted schools, in aiming to achieve the PSQM, made key improvements, including an increase in practical science and more visits, visitors and links with outside organisations. These improvements were identified by pupils, teachers, governors and parents.

The report highlighted the effect of English and mathematics being at the centre of school improvement initiatives and the consequent loss of profile for science. Maintaining Curiosity (Ofsted, 2013b) noted the same effect and suggested taking part in the PSQM was a successful way to raise the profile of science. The same Ofsted report identified the capacity of the PSQM to evaluate and improve science provision and connect science subject leaders with those in other schools. Their comments regarding the PSQM were reported by The Royal Society (2014) and the Confederation of British Industry (2015).

In their evaluation of the PSQM from 2013 to 2015, White et al. (2016) found that the PSQM raised the profile of both science and the science subject leaders. The framework was important in allowing the science subject leaders to develop teaching, learning and their own leadership skills. The report also suggested that the PSQM might provide a model for developing leaders of other curriculum areas.

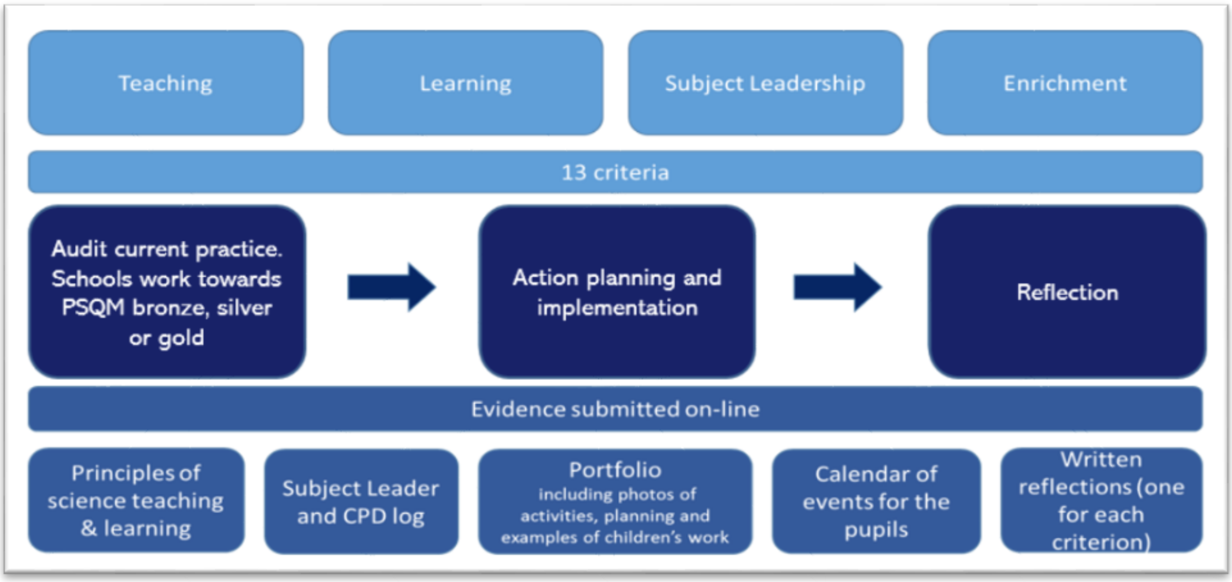


Figure 6 - The PSQM year

At the time I collected my data, the PSQM operated as shown in Figure 6. The year started with the science subject leaders evaluating their schools' provision for science teaching and learning against the PSQM framework of 13 criteria. They decided whether their current provision met the descriptors for the bronze, silver, gold quality mark, or were not yet reaching the bronze level. The criteria were divided into four groups: Teaching, learning, subject leadership and enrichment. Having completed the evaluation, the science subject leaders decided whether they wished to work towards a bronze, silver or gold quality mark and wrote an action plan for the year to allow them to meet the criteria descriptors for their chosen quality mark.

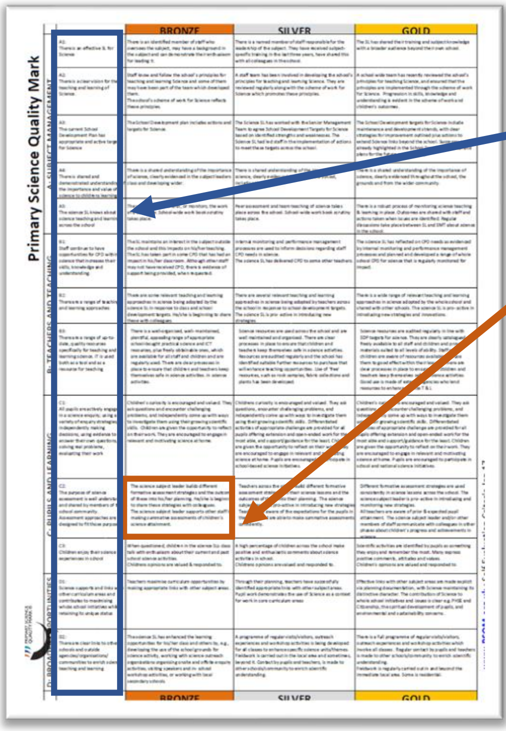
Throughout the year they implemented their action plans, working with colleagues and other members of the school community, and sometimes others outside the school community, to develop science teaching and learning. They logged their activities in the subject leader and CPD log, and recorded activities for pupils in a calendar of events. At the end of the year they wrote a reflection for each of the 13 criteria in the PSQM framework, to evidence their achievement of the bronze, silver or gold descriptors. They also produced a portfolio of other evidence to support their written reflections.

The framework developed over time and the full framework, listing the 13 criteria, each with a descriptor at bronze, silver and gold level is shown in appendix A. This was the framework in place at the time my data were collected. To clarify the meanings of the terms framework, criteria and descriptor please see Figure 7.

I use the term framework to refer to the whole document in Figure 7 and appendix A.

The criteria were presented in four groups:

- Subject Management (five criteria)
- Teachers and Teaching (three criteria)
- Pupils and Learning (three criteria)
- Wider Opportunities (two criteria)



Each criterion has three descriptors, one each for bronze, silver and gold.

The criteria are the 13 statements in the second column of the table.

The descriptors refer to the statements in each of the boxes below the bronze, silver and gold bars at the top of the page. For example, the descriptor in the bronze box to the left is for criterion L2 at the bronze level.

A larger, legible version of this framework can be found in appendix A.

Figure 7 - The PSQM framework, criteria and descriptors

The following core documents form the evidence schools were expected to submit at the end of the year. For clarity, all future mentions of core documents will use a bold font. Where I use the wording of the criteria or the descriptors this will be denoted using italicised text.

- The **Principles of science teaching and learning**. The PSQM pilot study found the school's science policy provided minimal useful information, so was replaced by the **principles**. A collaborative approach involving all staff and possibly other members of the wider school community was required, leading to a statement, in simple terms, (several bullet points) of what good science teaching and learning entails. Presentation as a single A4 sheet was encouraged. An example of a principles document produced by one of my participant's school is included in appendix B (see page 202).

- The **Action Plan** stated the required actions to move the school from the position identified during the self-evaluation to the standard required by the quality mark they were aiming for. It stated what actions were planned to meet the criteria descriptors at the chosen bronze, silver or gold level. An example of the action plan produced by one of my participants is included in appendix C, (see page 203).

- The **Continuing Professional Development (CPD) Log** recorded any science CPD attended by staff shortly before, or during, the year. Both formal (courses) and informal (a meeting with a colleague after school to assist with planning) CPD should be recorded. There was an expectation that the subject leader facilitated some CPD for colleagues. The impact of any CPD needed to be stated on this document. An example of a CPD log is included in appendix D, (see page 213).

- The **Calendar of Events** recorded science enrichment activities involving pupils. For example, it might include science assemblies, science clubs, visits to museums and other science related places of interest, visitors, like STEM ambassadors, and any science days or science weeks. The impact of such events needed to be stated. An example of a calendar of events from one of my participants is included in appendix E, (see page 215).

- The **Subject Leader Log** included science activities and meetings not included in the logs above. For example, any pupil voice and monitoring activities as well as meetings with members of the senior leadership team. Once again, the impact of these activities should be noted. An example of a subject leader log produced by one of my participants is included in appendix F, (see page 217).

- The **Portfolio,** usually collated as power point presentation of approximately 20 slides including examples of pupils' work, examples of planning, and photographs, presented as evidence they had reached the required standard for their selected level. An example of the 20 portfolio slides produced by one of my participants is included in appendix G, (see page 222).

- **Reflections,** of no more than 300 words, were written about each criterion to justify how the school had achieved the descriptor at the chosen level. The **portfolio** and other core documents were referred to in these **reflections** as providing supporting evidence. An example of the reflections written by one of my participants is included in appendix H, (see page 232).

The schools' science subject leaders were provided with training by PSQM hub leaders who worked with a group of local schools. Hub leaders provided four half days (or equivalent) face-to-face training and this was supplemented by on-going on-line support using the website. After submission the evidence was reviewed by a PSQM hub leader from a different area and in most cases a quality mark was awarded. Any evidence that the reviewer believed did not meet the right standard was referred for a second review. The possible outcomes were; the first reviewer's opinion was overturned, and an award made at the level originally applied for, a lower award was made, or the school was given time to submit additional evidence.

Each PSQM award was valid for three years after which the school has the option to reaccredit and the science subject leader would be required to repeat the entire process and submit evidence in the same way as a school completing the PSQM for the first time. [3]

2.6 Chapter Summary

This chapter has considered the history of the English education system and the changes wrought as the marketisation of education has spread internationally. The pressure on teachers has been noted. The dichotomy between the working hard to fulfil complex roles as classroom teachers, or using their time to carry out responsibilities as subject leaders, has not been resolved by policy makers.

The focus of the chapter then narrowed to consider primary science education, including science in the national curriculum for England and statutory science assessment. Teachers of primary science are usually generalist teachers without an in depth understanding of science and this causes many to lack confidence, although with the right support, they should be equally confident to teach science as any other subject.

Science subject leaders rarely have a background in science but nevertheless are expected to take on a complex role as detailed in Figure 4 (see page 34). The context in which they operate includes the English education system, however within this, each science subject leader has her own set of skills, knowledge, attributes and prior learning, and each school also has its own unique set of circumstances which impinge on or support the science subject leader's ability to perform her role.

[3] Subsequent to conducting my research further developments to the PSQM programme have been implemented. From September 2017 three new quality marks replaced the old system of bronze, silver and gold. school staff working to increase children's Science Capital*, and other changes to increase the imperative for reflective writing improving the focus on impact. This involved changes to documentation, marketing materials and retraining of PSQM hub leaders.
*Science Capital is a concept that can help us understand why some young people participate in post-16 science and others do not. In particular, it helps shed some light on why particular social groups remain underrepresented and why many young people do not see science as 'for me'.
https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/stem-participation-social-justice-research

Chapter 3. Literature review

3.1 Introduction

The PSQM marketing literature (n.d.) describes PSQM as, "A CPD supported school-led initiative which will make a difference to the quality and profile of science in your school." Because of this claim to be a CPD programme I will explore the literature about professional development. First, I will define the terms that will be used, then explore the characteristic of, and contexts for, effective continuing professional development (CPD). Criticism of the research in this area suggests incidental and informal learning are underrepresented, so due consideration will be given to these forms of situated learning.

The chapter then discusses the theory of situated learning (Lave and Wenger, 1991; Wenger, 1998), as it presents tools for analysis of legitimate peripheral participation, situated learning and communities of practice. The main themes of Lave and Wenger's work will be examined with a view to using these to analyse the stories of science subject leaders as they worked towards a PSQM. Criticisms of their work will be considered, as some of the perceived weaknesses are relevant in endeavouring to understand the schools' developing primary science communities of practice and the changing identities of the science subject leaders.

Wenger (1998:9) contends, "our *conception* of learning … needs urgent attention", and describes, learning as, "a process of becoming" (Wenger, 1998:215). This process of becoming through participation leads to developing identity. "To know in practice is to have a certain identity" (Wenger, 1998:220). Thus, this chapter continues with an exploration of the literature relating to identity and considers the extent to which this corresponds with Wenger's understanding of identity.

Bearing in mind the PSQM's claim to develop the profile and quality of science in primary schools, the final part of this chapter will consider current views of the expertise required by primary science teachers (Wellcome, 2017a). Research on the facets that may lead to effective pupil learning will be considered. However, there will be recognition that reducing effective primary science education to a series of components, risks losing sight of the combined effects.

3.2 Professional Development

3.2.1 Professional development - introduction

UNESCO (2014:98) emphasises the importance of government support for teachers, including the provision of continuing opportunities for professional learning, and draws attention to the link between high quality teaching and effective learning. However, the process of teacher learning and development aimed at raising the quality of teaching and learning is a complex process (Avalos, 2011, Timperley et al., 2008). Not all professional development opportunities result in improved pupil outcomes (Guskey, 2003). One reason is that teachers find it difficult to replace their existing practices with new ones because the process of 'unlearning' involves risk and may be stressful (Eraut, 2002b). Neuroscience research supports the view that changing practice is difficult because, as behaviours are repeated, they become less susceptible to change (Seger & Spiering, 2011).

Although Kennedy (2014:689) argues the professional development literature is, "partial in its coverage, is fragmented and under theorised", the literature will be considered, and terms defined. Effective professional development frequently refers to that which improves pupils' scores in tests and examinations, but I will also consider other ways in which effectiveness might be judged.

The Department for Education (2012) requires head teachers to ensure professional development opportunities are available to teachers in their schools. However, a report from the National Audit Office (NAO, 2017) stated there are no regulations governing the entitlement of teachers to professional development opportunities. The average time devoted to CPD in England is four days each year compared to an international average of 10.5 days (NAO, 2017). A survey by the National Union for Education (2018) found 45% of primary teachers thought their access to professional development had been reduced over the last five years, with those who had been teaching for at least five years most likely to be adversely affected. The survey also found 61% of teachers considered the professional development opportunities in which they had participated matched the requirements of the school rather than their individual needs, with only 12% able to select their own development experiences.

Focusing now on professional development opportunities for primary science subject leaders: research commissioned by Wellcome (Leonardi et al., 2017) discovered, during the previous 12 months, 52% of science subject leaders in the UK had been supported to develop science in their school by undertaking externally facilitated CPD of at least one day. In larger schools there was a greater likelihood the science subject leader attended external CPD. Only 9% of teachers who were not subject leaders reported attendance at externally facilitated CPD, however, 23% had received training from the school's science subject leader.

3.2.2 Terminology

Above I have used the abbreviation CPD, however, other terms are used for activities intended to promote teacher learning, and the outcomes of these activities. These include professional development, professional learning, continuing professional learning, professional growth, and professional learning and development. Furthermore, Coffield (2000:3) suggests the terms related to professional development, are subject to "conceptual vagueness".

Evans (2019) remarks on the proliferation of professional development literature failing to define terms, and, even when terms are defined, the definitions are frequently inconsistent. For example, O'Brien and Jones (2014) note the term INSET, which was used to describe in-service training, and was generally regarded as an opportunity to provide teachers with updates. This has now fallen out of favour. The term continuous professional development (CPD) became used by many professions. In some instances, the continuous is replaced with the word continuing to indicate potential breaks between development episodes. More recently the continuous or continuing are omitted, thus becoming professional development (PD). However, the term professional learning is now used by "more forward-looking education systems" (O'Brien & Jones, 2014:684). They also draw a distinction between professional development and professional learning noting, "a significant difference between the systematic career progression associated with professional development and the broader, more critically reflective and less performative approach to professional learning" (O'Brien & Jones, 2014:684).

In contrast, Boylan and Demack (2018:340) use professional development to refer, "to the activity or experience that teachers engage in". However, this lacks any focus on the purpose of the activity or experience. They separate this from professional learning which they regard as, "the outcome of professional development." This distinction between events and outcomes is helpful so, extending Boylan and Demack's definition by incorporating a phrase from Cordingley et al. (2015:3),

I define a professional development experience as the activities, processes or events likely to impact positively on teachers' practices.

Having discussed events and activities, I now consider the outcomes of these professional development experiences. Guskey (1986) believes changes in classroom practice come first and lead, over time, to changes in teachers' beliefs and attitudes; they do not happen simultaneously. Fraser et al. (2007:156-157) similarly consider professional learning as a process rather than a single event defining it as, "the process that, whether intuitive or deliberate, individual or social, results in specific changes in the professional knowledge, skills, attitudes, beliefs or actions of teacher". They use the term teacher professional development to refer to, "broader changes which may take place over a longer period of time resulting in qualitative shifts in aspects of teachers' professionalism" (Fraser et al. 2007:157).

I will use the definition proposed by Boylan and Demack (2018:340); professional learning is, "the outcome of professional development."

This simpler definition of professional learning, including changes in practice, attitudes and beliefs, is appropriate for framing the discussion of professional learning in the context of PSQM. This definition also recognises that while a professional development experience might impact positively on teachers' practices, attitudes and beliefs, this may not always be the case. This is a comprehensive yet straightforward definition of professional learning that I will adopt because it encompasses the whole process described by Guskey (1986) and Fraser et al. (2007). Formal, informal, intended, unintended and situated learning are all included in this definition.

Boylan and Demack (2018) suggest the focus on what is measurable may restrict future developments in professional learning. Therefore, a broad range of outcomes should be considered when evaluating professional development experiences, rather than the only outcome being improvement in pupil attainment as measured by tests and exams (Fraser et al., 2007). Opfer and Pedder (2010b) suggest this expanded range of outcomes might include enhancing teachers' career prospects, and, improving recruitment and retention.

3.2.3 Characteristics of effective professional development experiences

Professional development programmes are frequently ineffective (Guskey, 2002), and Clarke and Hollingsworth (2002:948) note the "failure of one-shot professional development approaches". Opfer and Pedder (2010b:428) suggest the reason for this ineffectiveness is because, "teachers spend the majority of their time in workshops and seminars that do not have many of the forms and features associated with positive impacts." Additionally, they report, in some circumstances, professional development experiences still fail to change teachers' practices, despite displaying attributes suggesting they should be effective (Opfer & Pedder, 2011). This is possibly associated with the difficulties observed in achieving changes in teachers' behaviour, as discussed earlier.

Guskey (2003) claims the factors that lead to effective professional development are multiple and complex, and the nature of the real world is such that defined changes in practice will not necessarily lead to intended outcomes. However, a meta-review, based on publications since 2000, showed "evidence of impact on learner outcomes" (Cordingley et al., 2015:3). It considered which features are most likely to lead to positive pupil outcomes as measured by tests, neglecting the broader range of outcomes suggested by Opfer and Pedder (2010b). This provides an indication of the widespread influence of GERM (Sahlberg, 2016), leading to a narrow understanding of effectiveness.

The factors leading to this narrow view of effective professional development experiences (Cordingley et al. 2015) are listed below and where other authors make related comments, these are included.

1) A strong focus on pupil outcomes and aligned to teacher need. Opfer and Pedder (2010a) also argue professional development experiences should be directly transferable to the school setting.
2) Professional development experiences lasting for at least two terms were more effective than shorter term interventions. Avalos (2011) agrees longer term programmes have a greater impact than briefer experiences. However, Fletcher-Wood and Sims (2018) consider it is repeated practice, especially when supported by coaching, which has impact. This idea of repeated practice chimes with the neuroscience research (Seger & Spiering, 2011) indicating that repeated patterns of behaviour are harder to change.
3) The programme creates a rhythm with regular support and follow-up activities. Teachers should also understand the reasoning behind the strategy and apply this to develop their classroom practices.
4) A recognition of teachers' prior understanding and opportunities for them to surface their beliefs and engage in peer learning and support. This forms part of the wider focus on collaboration. Cordingley et al. (2005:4) considered collaboration involved, "specific plans to encourage and enable shared learning and support between at least two teacher colleagues on a sustained basis". The report found the impact of collaborative activities on teachers' practices, attitudes and beliefs and pupil attainment was greater than individually oriented activities. This focus on teacher attitudes and beliefs indicates a focus on a broader range of outcomes. Evans (2019) agrees collaborative, interactive learning is more effective than formal classroom didactic teaching. However, Timperley et al. (2008) note a collegiate community alone, may be insufficient to change pupil outcomes because, in the absence of challenge, current practices may be reinforced.
5) Teachers' involvement in selecting their own professional development activities was shown to be less influential than other factors. So, whether participants were volunteers or conscripts made less difference than a shared sense of purpose. However, Clarke and Hollingsworth (2002:948)

believe teachers should have the opportunity to exert agency and become, "active learners shaping their professional growth through reflective participation." The critical role of reflection in enhancing informal learning is also highlighted by Marsick and Watkins (2015).

6) Pedagogy and subject knowledge are both important, and development of pedagogic skills should be underpinned by improving subject content knowledge.
7) Outside expertise was influential in improving pupil outcomes. Opfer and Pedder (2010b) suggest professional development experiences should be facilitated by people with expertise, perhaps providing the challenge which Timperley et al. (2008) promote.

3.2.4 Contexts for professional development

Contexts in which teachers work are influential in determining the effectiveness of professional development experiences. For example, Kuijpers et al. (2010) consider professional development experiences will be more effective when embedded in whole school initiatives than when a teacher participates in training in isolation. Therefore, the school's senior leaders have a role to play, yet, too few schools specify the desired outcomes of professional development experiences along with appropriate measures of success (Ofsted, 2006).

Cordingley (2008) claims school leaders have four key roles to play in creating a context to support effective CPD. Once again, the narrow view of effective CPD is considered.

1) Developing a vision, including persuading teachers to consider alternative views of pedagogy and curriculum.
2) Managing and organising, including providing the funding and time for teachers to take part, in addition to identifying appropriate forms of CPD, although as discussed earlier, the perception is that both time and funds have reduced over recent years.
3) Modelling professional learning and promoting an ethos where teachers are challenged to monitor the effectiveness of their teaching and consider future development needs.
4) Leading colleagues to develop either curriculum or pedagogy. However, there was scant evidence the cascade model of professional development was effective. Some teachers were reluctant to assume the role of 'expert' and advise others, while others lacked the necessary skills and experience.

The agency of teachers is also dependent on context. For example, Fraser et al. (2007:116) link the school ethos with the individual agency of teachers stating a socio-cultural understanding of professional development, "relies upon the assumption of individual teacher autonomy within an environment characterised by collaborative, collective decision making." The agency of individuals participating in professional development experiences is also influential because it, "shapes engagement with work practices and what is learnt" (Billett, 2002:63).

It is important to note, although certain behaviours and contexts may result in professional development experiences leading to improving pupil attainment, there are always exceptions in both directions (Brown et al., 2014). Opfer and Pedder (2011:376) suggest one reason why many professional development initiatives are ineffective is because of the use of, "simplistic conceptualizations of teacher professional learning that fail to consider how learning is embedded in professional lives and working conditions." So, although a combination of the important 'ingredients', is indicative of a successful outcome, there is no guarantee.

3.2.5 Informal or situated learning

Webster-Wright (2009:713) is critical of much of the literature in the field of professional development because it is based on an "objectivist epistemology that views knowledge as a transferable object". In addition, she criticises professional development research because it fails to take a holistic approach in studying situated learning experiences. Hence, school leaders should broaden their conceptions of professional development experiences, recognising the wide range of contexts in which they might occur and aiming for the multidimensional approach to professional learning advocated by Evans (2014). For these reasons I consider it important to employ a broad understanding of knowledge and consider learning that occurs both in the workplace and beyond.

Hodkinson and Hodkinson (2005) argue there should be a greater connection between the considerable volume of literature on both teacher professional development and workplace learning because teachers learn during their everyday classroom experiences. Eraut (2004) also notes the lack of connection and considers most people understand learning as happening in formal educational scenarios with work being a separate endeavour and workplace learning not recognised as such. He believes workplaces are not typically structured to support learning, yet identified four main workplace activities which resulted in learning:

1. Participation in group activities;
2. Working alongside others;
3. Tackling challenging tasks; and
4. Working with clients. (Eraut, 2004:271)

Eraut (2004) concluded informal learning was neglected, and the processes and outcomes of learning were oversimplified. Evans (2019) agrees more attention should be devoted to informal learning and Coffield (2000) concluded formal learning should no longer be regarded as more important. Therefore, workplace learning will be attended to in my research and afforded its rightful importance.

Hoekstra et al. (2007:2) define informal learning as, "learning in and from engagement in work activities, thus learning that is not explicitly organised by external actors". They discuss how some authors consider informal and formal learning processes as distinct while others believe the process to be the same but occurring in different contexts. Hoekstra et al. (2007:2) define learning as, "being consciously or unconsciously involved in internal and observable activities that lead to a change in behaviour or cognition". My definition of professional learning (see page 45) similarly includes a wide range of outcomes.

The lack of convenient measures of informal learning, compared to participation and pass rates used to measure more formal learning leads to resistance in prioritising informal learning (Fevre et al., 2000). For example, in their review of the design features of effective professional development, Van Driel and Berry (2012) intentionally exclude informal and incidental learning because these forms of learning are difficult, if not impossible, to measure based on student attainment. The PSQM does not focus on pupil outcomes as measured by tests or examinations, but the framework broadly aligns with practices that are likely to lead to pupil learning in science.

Billett (2002) suggests the word 'informal' is not appropriate to describe learning which occurs outside formal situations. He finds this description "negative and unhelpful" (Billett, 2002:56), because it suggests learning outside of educational institutions is inferior. He suggests "workplaces and educational institutions merely represent different instances of social practices in which learning occurs through participation" (Billett, 2002:56) and learning occurs through participatory practices, whether they be in a workplace environment or a more formal educational institution. Accepting that 'informal' describes what learning is not, and it might be regarded as inferior, I will use the term situated learning (Lave and Wenger, 1991) to describe this socially constructed practice.

"As with any learning environment, the contributions of workplaces have strengths and weaknesses" (Billett, 2002:65). One weakness being teachers rarely apply or seek theory when they learn informally (Webster-Wright, 2009; Hoekstra et al., 2007). Hoekstra et al. (2007) discovered teachers learn in the workplace even when systems have not been put in place to support such learning. However, learning may be restricted because even when teachers are committed to their own professional learning, their inability to see themselves as learners may mean they do not recognise and act on opportunities to learn. As a result, they suggest teachers should make greater efforts to link theory with their classroom practice.

Hoekstra et al. (2009) established five conditions for workplace learning, although acknowledged there may be others. These were:

1) Teacher autonomy
2) Teacher collaboration
3) Reflective dialogue
4) Receiving feedback
5) Experience of shared norms and responsibilities within the school.
(Hoekstra et al. 2009:280)

I shall therefore consider my data in the light of these conditions as indicative of the potential for workplace learning.

Webster-Wright (2009) claims that workplace learning is increasingly regarded as an effective form of CPD. Instead of the term workplace learning, Lave and Wenger (1991:35) propose legitimate peripheral participation, "as a descriptor of engagement in a social practice that entails learning", in which "members move towards more intensive participation and become more empowered" (Lave & Wenger, 1991:36). For Lave and Wenger the word legitimacy relates to the way members belong to a community of practice and this, along with identities and perspectives, are dynamic and evolve over time. For them learning is situated and, "the social relations of apprentices within a community change through their direct involvement with activities; in the process apprentices' understanding and knowledge skills develop" (Lave & Wenger, 1991:93). This is in contrast to a conventional view of learning that is, "viewed as a process through which the learner internalises knowledge whether 'discovered', 'transmitted' from others, or 'experienced in interaction' with others" (Lave & Wenger, 1991:47).

3.3 Situated Learning, Legitimate Peripheral Participation and Communities of Practice

The theory of situated learning (Lave & Wenger, 1991) created a paradigm shift (Kuhn, 2012) in views of learning. Previously behaviourist and cognitivist concepts of learning predominated, but, Lave and Wenger (1991) linked social participation to a theory of learning, which resonates with ways learning happens (Barton & Tusting, 2005). Their theory proposed three concepts:

1. **Situated learning** is Lave and Wenger's "umbrella concept of learning" (Hughes, 2007:31).
2. **Legitmate peripheral participation** is proposed by Lave and Wenger (1991:35) as, "a descriptor of engagement in social practice entailing learning as an integral constituent." They clarify that it provides a way to understand learning and is not, "an educational form, much less a pedagogical strategy or teaching technique" (Lave & Wenger, 1991:40).
3. **A community of practice** is, "a largely intuitive notion", (Lave & Wenger, 1991:42) but they offer more detail stating,

   > The term community does not imply co-presence, a well-defined identifiable group or socially visible boundaries. It does imply participation in an activity system about which participants share understandings concerning what they are doing and what that means for their communities and their lives.
   > (Lave & Wenger, 1991:42)

   They go on to describe it as, "a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice" (Lave & Wenger, 1991:98). Communities of practice are ubiquitous, but, remain unnoticed until we refocus our attention to observe the informal structures arising from engagement in practice, and the resulting situated learning (Wenger, 2009). Etienne Wenger in Farnsworth et al. (2016:6) clarifies his interpretation of a community of practice as, "a social process of negotiating competence in a domain over time", rather than primarily a group of people.

   In stating that a community of practice is primarily a social process and not a group of people, a contradiction arises with his previous work (Wenger, 2009:1) where he defined communities of practice as, "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly." He includes both intended and unintended learning in this definition. A similar definition was also used by Wenger et al. (2002).

I will define a community of practice to be a group of people who share the three characteristics required by Wenger.

1. The Domain

Wenger (2009:1) suggests members of a community of practice have shared interests and a "shared competence …[that] distinguishes members from other people."

2. The Community

"Members engage in joint activities and discussions, help each other, and share information. They build relationships that enable them to learn from each other." (Wenger, 2009:1).

3. The Practice

"Members of a community of practice are practitioners. They develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems." (Wenger, 2009:1-2)

In each of the three areas above Wenger refers to members. This focus on members appears to contradict his view that a community of practice is not primarily a group of people. My understanding of a community of practice aligns with an understanding that it is a group of people, but they must also share Wenger's three attributes, described above, in order to distinguish them from other ways of interpreting the term community.

3.3.1 Learning as Legitimate Peripheral Participation

"Learning viewed as situated activity has as its central defining characteristic a process that we call *legitimate peripheral participation*" (Lave & Wenger, 1991:29), which concerns the, "process by which newcomers become part of a community of practice." They further propose legitimate peripheral participation leads to learning through engagement in social practice. Although the process is not fully understood, they consider it happens over time and involves newcomers becoming part of the community of practice. They therefore studied the legitimate peripheral participation of apprentices in different historical and cultural contexts to better understand the social nature of learning. They argue learning is understood as relating to the practice of the community and is not directly linked to specific learning outcomes.

Themes related to legitimate peripheral participation occur in their work. These include, masters and mastery, access, talk and language, engaging in practice, and, change within the community of practice. These will be explored below.

The first theme related to legitimate peripheral participation concerns mastery and resources for learning. Traditional views of apprenticeships regard the relations between masters and apprentices as key resources for learning. However, Lave and Wenger (1991) assert the nature of these relationships vary across contexts and direct instruction is less important than conferring legitimacy. Contrary to what might be assumed, "Mastery resides not in the master but in the organisation" (Lave & Wenger, 1991:94) and communities of practice can be analysed through studying the location of mastery. Rather than arising through direct instruction they contend knowledge spreads effectively among apprentices and refer to a space of, "benign community neglect", in which they learn with and from other apprentices (Lave & Wenger, 1991:93). Masters are thus decentered, changing the focus from teaching to learning.

Communities of practice can also be analysed in relation to issues of access. "The key to legitimate peripherality is access by all newcomers to the community of practice and all that membership entails" (Lave & Wenger, 1991:110). One way learners are granted legitimacy is through acceptance by masters and the opportunity to engage with them. Apprentices then begin to form a view of, "a field of mature practice" (Lave & Wenger, 1991:110) to which they aspire. Learners also require access to other facets of practice including technology, information and artefacts, and, should access be denied, a barrier to legitimate peripheral participation is created.

The themes of talk and language also occur in discussion of legitimate peripheral participation. The use of language is an essential way to share knowledge during direct instruction. However, this may afford or constrain learners' access to a community of practice. Lave and Wenger (1991) draw a distinction between talking as an outsider to the community and talking within it. They consider, "for newcomers then the purpose is not to learn from talk as a substitute for legitimate peripheral participation; it is to learn *to* talk as a key to legitimate peripheral participation" (Lave & Wenger, 1991:109). "Linguistic practice", thus becomes a "form of learning, but does not imply that newcomers learn the actual practice the language is supposed to be about." (Lave & Wenger, 1991:108).

Important themes in primary science education are explored in section 3.5 (see page 61). The extent to which participants in this study engage in discussions involving these will be indicative of their learning within the broad primary science community of practice. However, evidence of engagement in appropriate practices, rather than just using the language of the community is an important consideration.

The use of language is also important in the stories supporting the learning of apprentices. "These stories, then, are packages of situated knowledge" (Jordan, 1989:935). In the example of Alcoholics Anonymous, Lave and Wenger contend the telling of one's own story not only denotes membership but also develops individual identity. Thus, the participants' stories and the language they use will support their developing identity.

Lave and Wenger also distinguish between learning and teaching curricula. A traditional view of curriculum is what Lave and Wenger would term a teaching curriculum; intended to equip learners with relevant skills and knowledge. The learning curriculum, however, "is a field of learning resources *viewed from the perspective of learners*." (Lave & Wenger, 1991:97). Through engagement in practice a learning curriculum arises, and learning is described as, "an improvised practice" (Lave and Wenger, 1991:93). Thus, a learning curriculum can be considered situated, and apprentices' knowledge and skills develop as a result of their engagement with activities relevant to their community of practice. Yet, Lave and Wenger (1991:111) claim, "a deeper sense of the value of participation to the community and the learner lies in becoming part of the community."

As a contrast, direct instruction focuses on individuals and changes in their cognitive processes, that are often measured through tests and examinations. In this situation, "the identity of learners becomes the explicit object of change," and the results of examinations and tests become more important than the value of increasing participation (Lave & Wenger, 1991:112). There is typically a lack of testing and formal examinations in the communities of practices described by Lave and Wenger (1991) and the focus is primarily on increasing engagement in practice.

Another theme in the work of Lave and Wenger (1991) relates to the way change occurs in communities of practice. They believe conflict between newcomers and masters is inevitable yet may be resolved because of their mutual needs. Such tensions lead to the evolution of the community as newcomers learn and move towards full participation. The inexperience of newcomers may be helpful in bringing new ideas and instigating reflective practices. It is through these changes that the gradual development of a community of practice happens but Lave and Wenger do not suggest how new communities of practice are formed. This is one of the criticisms of their work, and others will now be explored.

3.3.2 Critiques of Situated Learning

While the literature around the concept of situated learning has continued to expand since Lave and Wenger's book in 1991, some has been critical. Some researchers have applied the concepts in situations beyond those intended by Lave and Wenger which has led to the meaning of the concept becoming unclear (Gee, 2005). Boylan (2010:62) states learning as participation has been applied in three ways: as a "conceptual tool for understanding learning"; "a model of the social formations and forms in which learning takes place"; and "an advocated way to organise learning." Lave and Wenger intended their theory to be used only in the first of these three ways and this is the way in which I shall apply it.

Overlapping critiques of the work of Lave and Wenger (1991) and Wenger (1998) are summarised below.

The first criticism concerns the adequacy of the concept of learning as participation. Lave and Wenger (1991:47) argue intentional instruction does not directly lead to learning and, "learning as internalisation is too easily construed as an unproblematic process of absorbing the given as a matter of transmission and assimilation." However, according to Hodkinson and Hodkinson (2004) and Hager (2005) situated learning theory overstates the importance of legitimate peripheral participation in learning and is dismissive of the role of teaching (Fuller et al., 2005). Hager (2005) also disputes the concept that participation provides a general explanation for all learning.

Hughes et al. (2007) question whether learning as participation and learning as acquisition are mutually exclusive, or if the two are complementary. They question the difference between absorption and acquisition based on the statement by Lave and Wenger (1991:98) that learners are, "both absorbing and being absorbed in the culture of practice." Hager (2005) argues acquisition and participation views of learning coexist because, through participation, learners increasingly assume the characteristics of more established members. He regards these as the products of learning occurring alongside changing identity. I will therefore consider learning occurring as a result of both acquisition and participation.

Hodkinson and Hodkinson (2004) regard most of the literature concerning communities of practice as including the inherent assumption engagement in pratice leads to desirable learning and, in contrast, draw attention to the fact that communities of practice can spread poor and unethical practices. They conclude that while the focus is on learning through engagement, insufficent attention is paid to the quality of the learning, therefore the quality of the participants' learning will be considered by comparing their discourses to the discourses of the broad primry science community of practice .

While Wenger (1998) highlights the importance of learning through participation, he fails to acknowledge the prior learning and dispositions of individuals that Fuller et al. (2005) regard as important. However, Wenger (1998) contends that it is not possible to isolate communities of practice and their members from their wider context and their existing practices, thus acknowledging their existing knowledge and beliefs, negating the criticism of Fuller et al. (2005).

3.3.2.1 Criticisms relating to definition of communities of practice

A further criticism relates to the breadth of Lave and Wenger understanding of communities of practice. Hodkinson and Hodkinson (2004) argue Lave and Wenger refer to two versions of communities of practice. A broad version of a community of practice, "is a set of relations among persons, activity, and the world, over time and in relation with other tangential and overlapping communities of practice" (Lave & Wenger, 1991:98). Yet the examples which Lave and Wenger (1991) include involve groups of workers sharing a common location, aims, activities and work practices. Hodkinson and Hodkinson (2004) consider this a narrower version of communities of practice. Fuller (2007) claims the narrower version is nested within the broader definition like a Russian doll.

Hodkinson and Hodkinson (2004:14) suggest renaming the broader conception as "situated learning or learning as social participation", would help distinguish it from the narrower form which they continue to refer to as communities of practice. They also contend a third, narrower still, level of workplace learning should be considered, that being the level of the individual. However, individuals will be considered through examination of the identities and the broader definition is appropriate for my analysis.

Fuller (2007) provides a further criticism stating that Lave and Wenger fail to adequately explain how communities of practice may be transformed or how new ones are created (Hughes et al., 2007). Edwards (2005) too is critical of the theory of situated learning because it does not account for the way new knowledge arises but instead focuses on the continuation of existing communities of practice. However, Wenger et al. (2002:23) infer it is possible to create a new community of practice when they state, "Designing them is more a matter of shepherding their evolution than creating them from scratch." However, they claim existing networks are important in supporting their creation.

Fuller et al. (2005) argue legitimate peripheral participation is insufficient to understand all workplace learning because it focuses soley on the learning of apprentices. Boylan (2010) describes Lave and Wenger's full and legitimate peripheral participation as binary concepts and is critical of the way the on-going learning of full participants is neglected. However, this binary conception can be rejected because Lave and Wenger (1991) suggest a community of practice provides examples in the form of masters and apprentices at various stages of their development. They account for the possibility of learning occuring for all participants when they state, "peripherality suggests that there are multiple, varied, more- and less-engaged and -inclusive ways of being located in fields of participation" (Lave & Wenger, 1991:35-36). Wenger (1998) expands on the number of possible trajectories allowing for the possibility of a range of ways of participating in practice and these are now explained.

3.3.2.2 Criticisms relating to trajectories

The initial work of Lave and Wenger (1991) considered only the learning of newcomers; those on an inbound trajectory and neglected other members of the community. However, research by Fuller et al. (2005) found experienced workers continued to learn.

Wenger (1998) considered four additional trajectories allowing for the possibility others might also learn.

1. Peripheral trajectories are unlikely to lead to full participation yet are sufficiently significant to influence identity.
2. Insider trajectories relate to those who are already full members yet continue to learn.
3. Boundary trajectories apply when members of overlapping communities of practice cross boundaries creating constellations of practice.
4. Outbound trajectories lead members away from a community of practice. (Wenger, 1998:154)

The theory of situated learning, however, remains focused on the learning of newcomers because, Wenger failed to adapt other respects of the original theory to account for the learning of others (Hodkinson & Hodkinson, 2004).

A further criticism concerns Lave and Wenger's failure to take account of learning occurring in other contexts (Østerlund, 1996). Yet, the concept of boundary crossings allows for the transfer of knowledge between different communities of practice. Fuller and Unwin (2004) noted the advantages for apprentices who participated across a range of contexts rather than at a single site, thus indicating that crossing boundaries facilitates learning.

Wenger (1998:103) maintained, "Communities of practice cannot be considered in isolation from the rest of the world or understood independently of other practices". Members relate to the world outside their community and in doing so cross boundaries. Fuller (2007) claims 'boundaries' in the context of communities of practice are ill-defined but, in earlier work, Fuller et al. (2005:63) noted they were, "necessarily imprecise." Taking account of the broader contexts, Wenger (1998:127) describes communities of practice as enabling midlevel analysis, but he also proposes analysis of larger configurations, known as "constellations of practices." Within constellations, border crossings have an important role to play. I will therefore consider both the mid-level and larger configurations in my analysis.

Asymmetries of power are also not considered in the work of Lave and Wenger. Hughes et al. (2007:173) argue issues of, "conflict, collaboration, resistance and control", are underrepresented in the work of Lave and Wenger, and they highlight the potential for struggles in relation to power and access. Gee (2005) concurs; the term community has connotations of harmony and agreement. Yet, Eraut (2002a) contends these qualities rarely exists in modern industries where mergers and takeovers act as catalysts for transformations. While such events used to be rare in education, the forced academisation of underperforming schools and federations of schools may now provide some of the catalysts suggested by Eraut (2002).

The final criticism of the work of Lave and Wenger concerns the way the group is the unit of analysis at the expense of individual identity, which is not fully developed and ignores other influences on the learner (Fuller, 2007). Hodkinson and Hodkinson (2004) argue Wenger (1998) neglects individuals, despite his interest in identity, and individuals deserve greater prominence.

While accepting the work of Lave and Wenger has limitations, their conceptualisations of identity, situated learning, legitimate peripheral participation and communities of practice, are useful tools in my research as a way of, "exploring and understanding learning contexts" (Barton & Tusting, 2005:195). They suggest we should consider anew the original work of Lave and Wenger as a lens through which to consider learning and, in a similar way to Fuller et al. (2005) I find the focus on learning through participatory practices in the workplace provides a good fit with my data. Thus, it was through the lens of the work of Lave and Wenger that I analysed the engagement of my participants, their membership of communities of practice, their learning and the impact on their identities.

3.4 Conceptualising Identity

This section explores the most common features in the rapidly growing, yet diverse, field of research into identity, including teacher identity. The concepts of identity and self are frequently linked in the literature so will be discussed, along with the way they become evident through stories. Given the many interpretations of the term identity, I will explain how I have conceptualised and bounded identity with reference to the work of Wenger (1998) and others.

One of the greatest challenges in any study of identity is providing a clear definition (Beijaard et al., 2004). With many differing views of identity, the concepts feel elusive (Rodgers & Scott, 2008) and Luria (1976) suggests a continuous reinvention of identity is untenable because patterned behaviour is an essential part of being human. Akkerman and Meijer (2011) question the usefulness of a concept which is multiple and changing across both time and context, yet, note the rapid expansion of the literature about teacher identity.

A review of the literature on identity by Akkerman and Meijer (2011) identified three threads common to many definitions: a discontinuity of identity; the social or relational nature of identity; and a multiplicity of identities. While Akkerman and Meijer (2011) used the term discontinuous, Beijaard et al. (2004), in their systematic analysis of studies of teacher professional identity, found many studies preferred to use the term dynamic. Avraamidou (2014) supports this view when she describes identity as a process rather than a product.

Identity as social or relational is considered by Beijaard et al. (2004) who include context as a factor leading to discontinuous identities, but Rodgers and Scott (2008) add more detail referring to a combination of historical, cultural, political and social contexts as important influences on identity. Fitzgerald (1993) and Coldron and Smith (1999) take a more radical view, considering identity as dependent on context alone. This could account for identity being dynamic or discontinuous as context changes and infers multiple identities.

A multiplicity of identities arises as a result of different contexts and relationships (Beijaard et al., 2004), leading me to conclude that teachers' identities consist of multiple identities. For example, the concept of a multiplicity of identities is employed by Gee (2001) who divides identity into four interrelated perspectives: Nature perspective (N-identity), Institutional perspective (I-identity), Discursive identity (D-identity), and Affinity perspective (A-identity).

Having considered the discontinuous, multiple, and social and relational nature of identity it is important to include discussion related to the self in the context of identity. Nias et al. (1994) draw on the work of Mead (1934) and Ball (1972, cited in Nias et al. 1989) to develop the concept of a relatively 'substantial' self (I) which she distinguishs from the 'situational' self (me) that is context dependant. However the concept of 'self' is contested. MacLure (1993:313), focussing on the ways teachers described themselves and how they used identity during discussions, rejected the idea of a core or substantial self, preferring instead the idea of "identity as a set of discursive practices". She perceived identity more as a process than an entity; a view supported by Leach and Moon (2008) who argue identity is a process developed in discourse with others rather than a sense of self. In line with the year-long PSQM process impacting on the professional learning of my participants, and the recording of their experience as a story, I conceptualise identity as a process.

3.4.1 Identity through stories

Rodgers and Scott (2008) state identity can be interpreted through stories. They intertwine stories with notions of identity; changing across time, contexts, and in dialogue with others. They suggest identity, "is both interpreted and constructed through the stories that one tells oneself and that others tell. These stories change over time, across contexts, and depend on relationships" (Rodgers & Scott, 2008:737). Thus, I needed to hear the stories of my participants over the course of the year, during which they influenced their contexts and the nature of their professional relationships changed.

Clandinin and Huber (2005:44) consider a teacher's identity as, "a unique embodiment of his/her stories to live by, stories shaped by the landscapes past and present in which s/he lives and works". Their definition relates to the work of Bruner (2004:93), who suggested, "the most natural and earliest way in which we organize our experience and our knowledge is in terms of the narrative form". Wenger et al., 2002:137) conclude that, "The best way to assess the value of a community of practice, therefore, is by collecting stories." Thus, the changing identities of my participants and the value of their communities of practice will become evident through their stories.

3.4.2 Conceptualisations of identity

There are many conceptualisations of identity and one particular example, linked to the development of primary science teachers, is evident in the work of Danielsson and Warwick (2014). They choose the conceptualise identity as a, "question of how personal histories impact on an individual's willingness to engage with particular Discourses" (Danielsson & Warwick, 2014:107). They refer to Gee's (2005:7) 'big D' Discourses, "when 'little d' discourses (language-in-use) is melded integrally with non-language 'stuff' to enact specific identities and activities." While this approach initially seems applicable to my research, because they focus on primary teachers using teaching approaches to enhance pupils' scientific literacy, my research takes a broader view of participants' identities as science subject leaders and teachers of primary science and does not seek to define the Big D discourses at the outset.

An alternative conceptualisation of identity that might also have relevance to my research is presented by Komives et al. (2006), who developed a stage based model of leadership identity through the application of grounded theory which they termed Leadership Identity Development (LID). However, I find their contention that the model is stage-based, necesitating the completing of one stage before beginning the next, contradicts their view that their model is at the same time complex and cyclical as stages are repeated. The six stages are Awareness, Exploration/Engagement, Leader Identified, Leadership differentiated, Generativity and Integration/Synthesis. This model also fails to reflect the view that identity is discontinuous, social or relational in nature and multiple identities can exist (Akkerman & Meijer, 2011).

Their research was based on thirteen students at a United States university who were nominated because they demonstrated relational leadership. In contrast, my participants will be selected without any reference to their leadership abilities. Thus the model may not be applicable in them, and so when combined with the perceived contradiction discussed above, I therefore explored other conceptualisations of identity.

I agree with Taylor's (2017) sociocultural approach that identity is a constant process of construction and co-construction. While I accept identities are multiple and interrelated, (Gee, 2001) to answer research question one, about the identities of my participants, and ensure the study is manageable, I need a focused conceptualisation of identity. Rather than trying to mitigate the messiness of identity, Carlone (2012) recommends it is more effective to place boundaries around the concept. Given the multiplicity of identities assumed by individuals, it is not possible to form a comprehensive picture of my participants' identities. Instead I will create boundaries and focus on certain aspects of their identities. I will examine the identities of my participants in respect of their membership of their schools' science community of practice and the broad primary science community of practice. On occasions, this my be extended as they cross boundaries within constellations of practice (Wenger, 1998). Their identities will also be bounded in time as I listen to the story of each participant over the course of her PSQM year.

Carlone (2012:9) suggests that for those who wish to study identity, "How will I know it when I see it?" is a useful question to establish which conceptualisation of identity might be relevant. Having established that I will be capturing their narratives and that identity can be interpreted through stories (Rodgers & Scott, 2008), I therefore need to be clear how I will find evidence of changing identity in their stories. Throughout their stories I expect to find evidence of at least the first four of Wenger's five characterisation of identity. The five are: identity as negotiated experience; identity as community membership; identity as learning trajectory; identity as multimembership; and, identity as a relation between the global and the local.

3.4.3 Wenger's interpretation of identity

Wenger (1998) believes that through membership of communities of practice newcomers are able to negotiate their identities. A combination of participation and reification leads to five characterisations of identity. These will now be explored in more detail.

First, I will consider identity as negotiated experience. Wenger indicates identity is an on-going process of negotiation which involves both participation and reification.

> Identity in practice is defined socially not merely because it is reified in a social discourse of the self and social categories, but also because it is produced as a lived experience of participation in

> specific communities. What narratives, categories, roles, and positions come to mean as an experience of participation is something that must be worked out in practice. (Wenger, 1998:151)

Through speaking to my participants over the course of the year I hope to observe how they negotiate their roles as science subject leaders and their positions with respect to other members of the school communities.

The second of Wenger's characterisations of identity is as community membership. For Wenger (1998) it is not just labels, like job titles, that indicate community membership. More fundamental are displays of competence and knowing how to engage with other members of the community and it is through these that identity is developed. Full members will be familiar with the community, its domain and practices, and be reified by both themselves and others as competent. I will therefore seek examples of displays of competence and evidence of familiarity with the domain and practices of the broad primary science community of practice. Reification by others will also be of interest.

Wenger also characterised identity as a learning trajectory. "Our identity is something we constantly renegotiate during the course of our lives … The term trajectory suggests not a path that can be foreseen and charted but a continuous motion." (Wenger, 1998:154). This corresponds to the dynamic nature of identity (Beijaard et al., 2004, Avraamidou, 2014).

While the original work of Lave and Wenger focused on a single inbound trajectory, later Wenger (1998) suggested there are five trajectories: inbound, peripheral, insider, boundary and outbound. These have been described above. (See page 55.) The trajectories of my participants will be considered with respect to the communities of practice relevant to this study.

The fourth of Wenger's characterisation of identity is as a nexus of multimembership. Identity entails experience of membership of numerous communities of practice while reconciling ways to maintain one's identity whilst crossing boundaries. This process of boundary crossing may make us aware of different perspectives and assume a range of different roles (Wenger, 1998). Wenger (1998:160) uses the term "reconciliation" to "describe the process of identity formation." Where conflict arises due to simultaneous membership of more than one community of practice, reconciliation may be achieved, but not in all situations. This too will have an impact on identity.

Wenger's fifth and final characterisation of identity is as a relation between the local and the global. Although they may have no bearing on the work of the community of practice, members may share outside interests. In sharing those interests, other practices develop within the community. For example, this might involve discussion of television programmes or sporting events. In this way the community is linked to the broader context. This becomes part of the community members' shared repertoire and supports the building of relationships (Wenger, 1998).

3.4.4 Modes of belonging

In addition to the five characterisations of identity, Wenger (1998:173) claims that, "to make sense of the processes of identity formation it is useful to consider three complementary 'modes of belonging', each requires the 'work of belonging'" (Wenger, 1998:184). These modes are engagement, imagination and alignment and each will be described.

Wenger (1998) notes how through mutual engagement, communities of practice develop, and thus the two are closely associated. He also draws attention to the boundedness of engagement both in terms of time and place. Members of the community require access to sustain engagement in activities, interactions and production of shareable artefacts in order to carry out the work of engagement. My research will therefore examine the engagement and interactions of my participants and note any shareable artefacts they create.

Wenger's (1998:176) conceptualisation of imagination, "refers to a process of expanding our self by transcending our time and space and creating new images of the world and ourselves." He highlights, "the creative process of producing new 'images' and of generating new relations through time and space that become constitutive of the self" (Wenger, 1998:177).

To carry out the work of imagination Wenger suggests members require, the ability to consider the work of the community from other perspectives, and initially as outsiders, newcomers may bring such new perspectives. "It needs the willingness, freedom, energy, and time to expose ourselves to the exotic, move around, try new identities, and explore new relations … to accept non-participation as an adventure and to suspend judgement" (Wenger, 1998:185). Wenger et al. (2002) believe that part of the short-term value of a community of practice is that it enhances individuals' confidence to take these types of risks. Further, reification is required, because without it, "there may not be enough material to play with, to bounce off from, and to shake free from time and space." (Wenger, 1998:186). Thus, the feedback from others is important and will be considered as and when it is reported by my participants.

Alignment is entirely separate from imagination (Wenger, 1998) yet an important part of belonging to a community of practice. Through alignment, members coordinate "their energies, actions and practices", (Wenger, 1998:179) to become part of a community. As practices align it becomes possible to, "amplify our power and our sense of the possible." Wenger (1998) also notes alignment, without a degree of scepticism, might lead to abuse and thus be detrimental to identity. Alignment requires coordinated action and defined forms of participation. It further requires members to cross boundaries to gain the broader discourses of, and reification from the wider constellations of practice (Wenger, 1998).

3.4.5 Summary – identity

In conclusion, the five characterisations of identity and three modes of belonging considered by Wenger (1998) offer a conceptualisation corresponding to the common threads of discontinuity, contextually determined and multiple identities (Akkerman and Meijer, 2011). The element of discontinuity or dynamism is evident because identity is considered a process rather than a product. It changes over time. Identity as understood by Wenger (1998) is contextually determined. For example, it is dependent on the community the participants engage with. The identity of the science subject leaders will be different when they are teaching children compared with when meeting senior leaders or governors. This leads to the conception of identities as multiple, changing over time and with context.

This understanding of identity also enables links to be made with the earlier section on situated learning, legitimate peripheral participation and communities of practice (see page 50). I will therefore discuss the evolving identity of my participants with respect to these five characterisations of identity and three modes of belonging.

3.5 The discourses of the broad primary science community of practice

3.5.1 Introduction

In this section I wish to establish the discourses of the broad primary science community of practice. Having established these, it will then be possible to consider the extent of the legitimate peripheral participation of the science subject leaders as they adopt the discourses of the broad primary science community of practice. Through use of these discourses the science subject leaders may display their competence and engage in discussion with other members of the community. Their identity may develop alongside their increasing security in employing these discourses.

The teaching and learning of science are complex (Harlen, 2017:v). Furthermore, while the aims of science education are subject to on-going debate, and measures of success are contested, (Osborne and Dillon, 2010), it remains difficult to determine definitive discourses of the broad primary science community of practice. Also, on-going research and discussions continue to influence pedagogy and curriculum.

However, I need to establish the discourses of the broad primary science community of practice against which to compare the developing discourses of my participants. Representatives of the following organisations collaborated to define the expertise required by a primary science teacher:

- Association for Science Education (ASE)
- Campaign for Science and Engineering (CaSE)
- Institution of Engineering and Technology
- Institute of Physics
- Primary Science Quality Mark
- Royal Society
- Royal Society of Biology
- Royal Society of Chemistry
- Wellcome
  (Wellcome, 2017a)

Given the expertise and influence of these organisations I will consider their definition indicative of the discourses of the broad primary science community of practice. The extent to which other research supports the views of this group will be discussed and research indicating approaches to primary science education that have not been included in this definition will also be explored.

The Wellcome (2017a) definition describes the expertise required to teach primary science (see Figure 3, page 30). In summary, teachers should:

- Have a secure understanding of the primary science curriculum and, where necessary, address areas of insecure understanding
- Use age-appropriate scientific vocabulary and expect the same from pupils
- Pedagogic Content Knowledge
  - Understand and model a range of appropriate methodologies for science enquiry, and, recording and presentation strategies
  - Have a good knowledge of appropriate pedagogies including:

        - Practical work
        - Learning beyond the classroom
        - Independent and group work
        - Problem solving
        - Digital technologies
    - Counter gender stereotypes
    - Understand formative and summative assessment strategies

Each of these areas will be considered in order, with reference to the literature and the relevant PSQM criteria, where appropriate. The PSQM was represented on the committee working on the Wellcome definition, so it is to be expected that there will be similarities between the Wellcome definition and the PSQM criteria.

3.5.2 Secure curriculum understanding

Wellcome (2017a) contend primary teachers need a secure understanding of the subject matter they teach. The scientific knowledge and confidence of primary teachers to teach science has already been discussed along with the way CPD can support development needs in this area (see page 28). The primary science curriculum in England has also been described (see page 25), however, Wiliam (2011) recognises learning will not follow the curriculum precisely. He asserts that curriculum operates at different levels. The first is the intended curriculum; in England the national curriculum. The next level is the implemented curriculum, influenced by the schemes of work and learning resources that teachers use. The final level is the achieved curriculum relying on the way teachers mediate the NC or the implemented curriculum. Both the implemented and achieved curricula will be influenced by whether schools present subjects separately or using cross-curricular themes or topics.

Curriculum is included in the PSQM criterion requiring planning to link science to other areas of the curriculum. Hayes (2010) suggests there are many understandings of cross-curricular learning and, Kelly (2013:3) acknowledges the range of terms used, including project work, themes, topic work or integrated learning. Therefore, to draw firm conclusions about the effectiveness this approach is fraught with difficulty. Nevertheless, some authors favour a cross-curricular approach, for example, Harlen (2006), and Boyle and Bragg (2008), while a contrary view is presented by Jarvis (2009), and Venville et al. (2002) who suggest it leads to lower pupil attainment.

Alexander et al. (1992) claimed both single subject teaching and cross-curricular approaches were desirable and could be improved. "We see a need both for more sharply-focused and rigorously-planned topic work and for an increase in single subject teaching" (Alexander et al., 1992: para 3.4). Hence, both subject specific and cross-curricular teaching have advantages and drawbacks, and Rose (2009) and Alexander (2010) agree subject teaching should be combined with opportunities for pupils to apply their learning in cross-curricular contexts. This understanding differs from the relevant PSQM criterion which refers solely to a cross-curricular approach.

While the Wellcome definition (2017a:3) advocates teachers should, "have a secure knowledge of the curriculum", they do not make it clear if this includes an understanding of the advantages and drawbacks of cross-curricular teaching. The PSQM criteria do little or nothing to encourage science subject leaders to reflect more widely on curriculum. For example, considering the Principles and Big ideas of science (Harlen, 2010). Also science subject leaders might consider whether their achieved curriculum presents science to their pupils as a value-free, objective and detached subject, and if they need to do more to teach science as understanding; as a human endeavour; the tentative nature of science; and reality as the ultimate test of theories (Millar & Osborne, 1998).

3.5.3 Vocabulary and talk for learning

Wellcome (2017a) advocate the use of age-appropriate vocabulary by teachers and express an expectation that children will do the same. While discussion supports the development of scientific vocabulary, surprisingly, it is the vocabulary, rather than discussion, that is the focus of the Wellcome document.

Based on a synthesis of hundreds of quantitative studies, Hattie (2012) concluded the most important factor in improving pupil attainment is to increase dialogue. Yet, both Wellcome and the PSQM fail to explicitly include talk for learning as an appropriate pedagogy. There is a PSQM criterion that refers to relevant teaching and learning approaches and this may lead some science subject leaders to introduce strategies supporting talk for learning and vocabulary development.

Alexander (2006:38) describes five types of classroom talk:

- *rote*: repeating facts and ideas
- *recitation*: either asking questions designed to prompt recall of previous learning or asking questions that include a clue to the answer.
- *instruction/exposition*: providing instructions, explanations or information.
- *discussion:* problem solving and information sharing enabled through the exchange of ideas
- *dialogue:* use of a structured series of questions and discussion to facilitate assimilation of new ideas.

Most teaching is based on the first three types yet Alexander (2006:30) claims, "Discussion and dialogue are the rarest yet the most cognitively potent elements in the basic repertoire of classroom talk". I will refer to discussion and dialogue as talk for learning. A further reason to increase talk for learning in the primary classroom is that talk not only supports science learning, but also supports the development of language (Exploratorium, 2016).

A range of strategies may assist teachers to increase talk in the classroom, such as pairs, envoys, jigsawing or concept cartoons (Naylor & Keogh, 2000). Increased wait time between asking a question and expecting a response resulted in better quality discussions, with more pupils prepared to offer an answer, and more alternative answers provided (Rowe, 1986). Teachers can promote and sustain talk through questioning and teachers' questions have an important role to play in scaffolding and cognitive development (Harlen, 1998).

To promote discussion Harlen and Qualter (2018) recommend children's ideas should be taken seriously. Pupils' reasoning should be explored because their answers may well make sense to them but be based on misconceptions or incomplete evidence. Additionally, teachers should promote an ethos where children are happy to share their ideas without fearing they will be wrong. One way to do this is to ask person-centred questions; asking for the child's idea rather than the right answer (Harlen & Qualter, 2018).

Although the correct use of vocabulary is an important part of classroom talk, dialogue and discussion support learning. The evaluation of an intervention, "designed to improve the quality of classroom talk", discovered the initiative had a positive influence on pupil attainment, engagement and confidence (Jay et al., 2017:4). On this basis the more explicit inclusions of talk for learning in both the PSQM criteria and Wellcome's expertise for primary science teaching would be desirable.

3.5.4 Science enquiry

Wellcome (2017a) believe primary teachers should understand and model scientific enquiry methodologies, and one of the PSQM criteria requires pupils to actively engage in science enquiry. Harlen and Qualter (2018:56) state, "inquiry (or enquiry) … skills include physical skills of manipulation and mental skills that are central to reasoning and to the development of understanding."

Wellcome (2017a) also includes practical work as an appropriate pedagogy. Although Harlen (2018) argues enquiry learning is not synonymous with practical work, it is frequently part of the enquiry process, so I have chosen to consider practical work and science enquiry together.

Hofstein and Lunetta (2004:38) identified five aims of practical science, but equally, they are reasons to teach science enquiry, and these are supplemented with details from other authors.

1) Developing understanding of science concepts. Millar (2004) argues scientific ideas do not simply arise from data. Learning about science enquiry should be scaffolded, and a single lesson may be insufficient to allow pupils to develop a concept (Abrahams & Reiss, 2012:8).

2) Scientific practical skills. Unsurprisingly students who engage with more practical work are more skilful at using practical equipment (Millar, 2010).

3) Interest and motivation. Most students report they enjoy practical work (Millar, 2010), however, Murphy (1991), found boys and girls responded quite differently to practical tasks.

4) Understanding the nature of science. This refers to the methods used to generate and verify scientific knowledge. However, science education is usually concerned with teaching pupils to understand scientific concepts and not the process by which those concepts became accepted (Millar, 2010).

5) Learning about the scientific method. The ASE – King's Science Investigations in Schools (AKSiS) project (Goldsworthy et al., 2000) used the term investigation rather than enquiry. They found training teachers to teach investigative skills specifically, as opposed to teaching them as they arose during an investigation, improved the quality of learners' investigative work.

For these reasons, the inclusion of science enquiry involving practical work, in the PSQM criteria and in Wellcome's (2017a) list of expertise required by primary science teachers, is well-founded.

To participate in science enquiry, children need equipment, e.g. measuring equipment, and, sources of information (Harlen, 2006). She argues items should be catalogued and accessible. One of the PSQM criteria requires a range of up-to-date quality resources are available, including information technology. This coincides with Wellcome's (2017a) view that digital technologies are an appropriate pedagogical strategy.

The NC (Department for Education, 2013) states information and communication technology (ICT) should be incorporated into all other subjects, and Hargreaves and Shirley (2012) believe the use of technology should be focused on teaching and learning. However, Harlen and Qualter (2018), while noting ICT may enhance science learning, express concern it may detract from more effective pedagogies. For example, Sharp et al. (2017) caution that creating an electrical circuit by manipulating components supports learning better than using a computer simulation.

3.5.5 Recording and presentation

Wellcome (2017a) states teachers should understand and model appropriate recording and presentation strategies and Harlen (2001) suggests strategies might include discussion, notebooks/journals, drawing, audio recording, painting and modelling. In addition to communicating using words, scientists communicate using diagrams, graphs, symbols and numbers, so pupils should also use a range of these methods. It is not only the method of recording and presenting learning in science that should be considered but also who the learners are presenting their work to. Osborne (2011) states the audience for pupils' writing is usually the teacher, and, changing the audience might increase motivation for writing.

3.5.6 Pedagogic content knowledge

Pedagogic content knowledge (PCK) is included by Wellcome (2017a) in their list of expertise required by primary science teachers. Based on the work of Abell (2007) and Shulman (1987), Gilbert (2010) considers three areas in which teachers need knowledge and skills: subject knowledge, pedagogic knowledge and pedagogic content knowledge (PCK) and Coe et al. (2014) contend the latter has a significant effect on teaching and learning. Magnusson et al. (1999:95) consider PCK, "is a teacher's understanding of how to help students understand specific subject matter", and identifies five aspects of PCK:

1) Orientation towards science teaching – contextualising science in ways that are relevant to pupils.
2) Knowledge of the science curriculum. This has already been covered above under the heading Secure curriculum understanding (see page 62).
3) Knowledge of science assessment.
4) Knowledge of instructional strategies. (Referred to in the Wellcome (2017a) definition as a suitable range of teaching methods.)
5) Student understanding – teachers need to understand the processes of learning science and have an awareness of common misconceptions and ways to address them. The importance of eliciting and addressing misconceptions is discussed below (see page 69).

The Wellcome understanding of PCK covers numbers 2, 3 and 5 above, but the orientation towards the teaching of science, and the understanding of the process of learning science are not included explicitly in the Wellcome (2017a) list of skills required by primary science teachers. Thus, the Wellcome (2017a) and

Magnusson et al. (1999) understandings of PCK include different elements. Further, Wellcome include countering gender stereotypes and understanding formative and summative assessment while Magnusson et al. (1999) do not. PCK is not mentioned explicitly by the PSQM, however, achievement of some of the PSQM criteria could lead to developing PCK as defined by both Wellcome and Magnusson et al.

3.5.7 Pedagogy

Although the curriculum influences what children learn, it is the way teachers teach that has the greatest impact (Wiliam, 2011).

> A bad curriculum well taught is invariably a better experience for students than a good curriculum badly taught: pedagogy trumps curriculum. Or more precisely, pedagogy is curriculum, because what matters is how things are taught, rather than what is taught. (Wiliam, 2011:19)

Wellcome (2017a) list a range of pedagogical strategies appropriate for the teaching of primary science, yet Coe et al. (2014), argue it is difficult to identify the behaviours which lead to effective teaching; so much depends on the way the teacher and class relate to each other. The PSQM criteria are not prescriptive about which teaching and learning strategies are appropriate, and merely specify teachers should use a range of teaching and learning approaches.

From Wellcome's (2017a) list of appropriate pedagogies (pages 61 and 62), above I have already considered practical work and digital technologies. Learning beyond the classroom, independent and group work, and problem solving will now be explored.

3.5.7.1 Learning beyond the classroom

Wellcome's (2017a:3) inclusion of learning beyond the classroom in their list of appropriate pedagogies indicates teachers should embrace opportunities for learning outside the school building. One of the PSQM criteria requires the curriculum is enriched through links with families and other organisations. The primary science curriculum may be enhanced through outdoor learning in the school grounds, parks and farms; visits to places like museums, science centres and industry; and visitors with an interest or career in a scientific field.

The Education and Skills Select Committee (2005) concluded education outside the classroom can lead to significant benefits. King and Glackin (2010) also point out the advantages of outdoor learning which include students experiencing real life at first-hand, understanding science does not only take place in laboratories, making learning more memorable and giving students the opportunity to study resources which may not be available in school.

Despite the perceived advantages of learning beyond the classroom, the House of Commons Children Schools and Families Committee (2010) found provision disappointing with schools in deprived areas, pupils with families on low incomes and with special education needs and disabilities (SEND), least likely to have the opportunity to participate in educational visits. King and Glackin (2010) suggest teachers' inexperience, pressures on curriculum time, and health and safety concerns contribute to the lack of opportunities for curriculum enhancement through visits.

Harlen (2006) also highlights the advantages of arranging for scientists to visit schools: bringing up-to-date information, resources and expertise; providing classroom support; new ideas for teaching; promoting STEM careers; and possibly dispelling stereotypes.

3.5.7.2 Independent and group work

Millar (2010:109) defines practical science as, "Any science teaching and learning activity in which students working individually or in small groups, observe and/or manipulate the objects they are studying". This indicates that both group and individual activities have a place in enquiry. Group work may however extend beyond practical scientific enquiries. McGregor (2012) highlights a range of tasks groups might undertake, for example role play and group presentations, leading to social interactions.

Alexander (2006) claims group work promotes discussion, which, in turn increases learning. Muijs and Reynolds (2017) expand on this suggesting group work is beneficial because, in groups, pupil talk is facilitated, and pupils pool their knowledge to solve more complex problems than they would alone. However, the authors note the importance of pupils interacting in a constructive way, because some students tended to dominate the discussion while others found social interactions difficult (Carter et al., 2003). Mercer et al. (2004) and Howe et al. (2007) advocate pupils should receive training in discussion skills. Research with key stage three pupils found group work could be at least as effective as whole class teaching, especially when the pupils were provided with tuition in how to work effectively in groups (Galton et al., 2009).

While group work may be beneficial, Ofsted (2013b) suggested it was so predominant, pupils were given too few opportunities to work independently and develop their manipulative skills. So, Wellcome's inclusion of group and individual work is supported by the literature but the PSQM criteria fail to explicitly include either. However, the criterion referring to a range of teaching and learning strategies may lead to schools introducing strategies requiring group or individual work.

3.5.7.3 Problem solving

In addition to being an appropriate science pedagogy (Wellcome, 2017a), the PSQM criterion related to science enquiry includes the phrase 'solving real problems', in concert with Harlen (2010), who suggests pupils should, "engage with real objects and with real problems". Problem solving is central to both mathematics and science and, "gives learners the opportunities to use logical reasoning, suggest solutions and try out different approaches to problems" (Borthwick & Cross, 2018:129). They claim these are the skills that children will need in the future. Sharp et al. (2017) suggest that open-ended problem-solving activities have the advantage that pupils with different levels of ability can perform the task in different ways leading to a range of outcomes that reflect their understanding. Furthermore, when pupils work in groups their problem-solving skills may be enhanced (Muijs & Reynolds, 2017).

3.5.8 Countering gender stereotypes

Wellcome (2017a) include countering gender stereotypes in their understanding of PCK and this will now be discussed.

> A gender stereotype is a widely held belief or generalisation about the behaviours and characteristics attributed to women and men. Females are often portrayed as being emotional, caring and in need of protection. Males are often characterised as being rational, career driven and strong… Gender stereotypes shape self-perception, attitudes to relationships and influence participation in the world of work. (Institute of Physics, 2018:3)

Although Wellcome (2017a) state gender stereotypes should be addressed, I believe the problem is broader than gender alone and other attributes are equally important. A report for the Education Endowment Foundation found an association between students' socio-economic status (SES) and both their achievement, and participation in science education. To tackle the poor participation of children with low SES, effective interventions should be implemented early in schooling, thus making the primary phase of education an important time to address this issue (Nunes et al., 2017).

Successful programmes have targeted pupils' scientific reasoning and enquiry skills. One example is the *Thinking, Doing, Talking Science* programme that provided professional development for teachers with the aim of improving pupils' higher order thinking skills. This also relates to the earlier discussion about talk for learning. The project evaluation showed the programme had the greatest impact on pupils entitled to free school meals (FSM) (Hanley et al., 2015).

Until 2017 the PSQM framework did not include a criterion encouraging teachers to address gender stereotypes and support lower SES pupils to increase attainment and participation in science education. Subsequently the criteria have been rewritten.

3.5.9 Formative and summative assessment strategies

The final area of PCK suggested by Wellcome (2017a) is formative and summative assessment which they claim teachers need to understand. One of the PSQM criteria requires a shared understanding of the purposes of science assessment, and that assessment approaches fit those purposes. The descriptors reference both formative and summative assessment strategies.

First, I will consider formative assessment. Black and Harrison (2010) contend formative assessment is synonymous with assessment for learning (AfL) and describe activities where the prime purpose is to promote pupil learning. When a number of formative assessment strategies are combined, significant improvements in attainment may result.

Formative assessment promotes learning when teachers use questions to determine where pupils are in their learning; are flexible, planning their next steps based on the information they gather; pupils engage in open-ended tasks having some autonomy in their learning; pupils use dialogue with others to develop their understanding; pupils understand where they are as they work towards challenging but realistic targets;

pupils use peer and self-assessment; group work allows pupils to collaborate; and, where necessary, teachers scaffold developing pupil understanding (Black & Harrison, 2010).

Harrison and Howard (2009) suggest: the use of probing questions allowing children to articulate their thinking, avoiding ending the discussion when the correct answer has been shared; asking rich questions; increasing wait time; and allowing ideas to be challenged and debated. Younger children may lack the vocabulary or need strategies to develop their discussion skills so should be given support. However, changing pedagogy is challenging for teachers and is most effective when a school-based approach is employed (Black & Harrison, 2010). Some of the above elements were also included in the section on Vocabulary and talk for learning (see page 63).

Moving on to consider summative assessment, McIntosh (2015) suggests schools should develop their own summative assessment processes to measure pupil learning at the end of a topic and to track pupil progress. Although the science SAT was abolished in 2009, tests are regularly used in schools to make summative judgements, yet, Wiliam (1993) questions both the reliability and validity of tests and suggests information gleaned from summative assessment should be used in a formative fashion. Also, research by Warwick et al. (1999) established that, despite showing similar levels of understanding, boys underperformed girls in written tests.

The Teacher Assessment in Primary Science (TAPS)[4] project at Bath Spa University recommends teachers use a range of activities to collect data for summative assessment. This might include pupils' written work, diagrams, and oral contributions, among other evidence. The project is based on research by the Nuffield Foundation (Harlen, 2012) which recommends formative assessment data, based on a wide range of classroom activities, should be used for summative purposes.

3.5.10 Other pedagogic strategies

Although the literature is broadly supportive of the pedagogic strategies outlined by Wellcome (2017a), other strategies, namely eliciting and addressing misconceptions and modelling, have not been included in the Wellcome definition of primary science expertise, nor and the PSQM criteria. These strategies will now be described.

Eliciting and addressing misconceptions has been mentioned above in the sections on PCK and talk for learning. They are also implicit in formative assessment. However, explicit mention of misconceptions is neither in the expertise required by primary science teachers (Wellcome, 2017a), nor in the PSQM criteria. Misconceptions may arise either because children have constructed their understanding based on their unique previous experiences; or might arise during lessons. It is important for teachers to elicit misconceptions as these might be barriers to learning. Misconceptions are difficult to address with some persisting into adulthood (Allen, 2014).

Allen (2014) claims that to address misconceptions, pupils should have opportunities to base ideas on concrete experiences in the real world and independently engage with practical work, preferably in a social setting. Open-ended questions leading to higher order thinking; and, leaving the responsibility for learning

[4] https://pstt.org.uk/resources/curriculum-materials/assessment

with pupils; are the most effective ways to enable misconceptions to be replaced with increasingly accurate conceptions (Allen, 2014). There is a large degree of correspondence between the strategies outlined by Allen (2014) and those advocated in the sections on formative assessment and talk for learning (see pages 68 & 63). Formative assessment is already included in the Wellcome's required primary science teacher expertise and the PSQM criteria, therefore, misconceptions are perhaps implicit. However, the addition of talk for learning, or explicit mentions of misconceptions would give them greater prominence.

One further pedagogoical strategy not mentioned by Wellcome (2017a) nor the PSQM criteria, is modelling. Models, when mediated by teacher support, are helpful in explaining scientific phenomena, and support understanding and reasoning in science (Tytler et al., 2017). However, no model is a totally satisfactory representation of any process or system, hence teachers were more effective when they used a thoughtfully designed sequence of models, including videos, gestures, 3d embodied models, 2d representations, analogies and metaphors making links between them (Tytler et al., 2013). However, Harlen (2006) notes that while analogies can support learning, as with other models, they have weaknesses which might lead to misconceptions. Thus, the limitations of any analogy or other model should be discussed. It is also important that analogies are comprehensible to pupils (Yanowitz, 2001).

Based on many years' classroom experience models are regularly used with little consideration of their effectiveness and weaknesses. Therefore, the Wellcome (2017a) understanding of the requisite expertise for a teacher of primary science and the PSQM criteria would be strengthened by the addition of consideration of models.

Above, I have considered, in detail, the Wellcome (2017a) statement of the expertise required by teachers of primary science and the extent to which this is supported by the literature. When answering research question 2: What changes do the science subject leaders establish in their schools? the extent to which the changes follow the discourse of the broad primary science community of practice can be established. I shall consider the content of the above section to represent the discourses of the broad primary science community. The extent to which the science subject leaders adopted these discourses will indicate their inbound trajectory towards the broad primary science community of practice and their developing identity as a master within their own school.

3.6 Chapter summary

This chapter has considered the literature concerning professional development, including the terminology and inconsistencies. Professional development experiences, as events or activities, have been separated from their outcomes which I refer to as professional learning. Most of the literature reviewed here refers to measurement of teachers' professional learning through tests and examinations of pupils, but like Opfer and Pedder (2010b) I have argued for consideration of a wider range of outcomes. The features of effective professional development experiences have been discussed, as have the contextual factors that facilitate or detract from professional learning.

Evans (2014) calls for a broader conception of professional development experiences including a range of opportunities including workplace, informal and situated learning. I have chosen to use the term situated learning to encompass all aspects of learning in the workplace. This term was proposed by Lave and Wenger (1991) along with the concepts of legitimate peripheral participation and communities of practice.

However, they made clear that although legitimate peripheral participation leads to situated learning as newcomers follow an inbound trajectory towards full participation in a community of practice, the process by which this happens remain unclear.

Themes such as mastery, access, talk and language, and engaging with practice are discussed by Lave and Wenger and these have been explored above, as have the criticisms of the theory of situated learning and subsequent work by Wenger (1998). These critiques of situated learning will be reconsidered in the Findings chapter in light of my data.

Wenger (1998) argued situated learning is evident in identity rather than the acquisition of knowledge and therefore, research into identity has been considered. Rodgers and Scott (2008) suggest an inextricable link between identity and stories and the literature confirming this link was discussed. The stories of my participants are therefore a fundamental part of understanding their developing identity.

Identities have been accepted as being multiple (Akkerman & Meijer, 2011) and as a result it is neither possible nor relevant to study all the many identities of my participants. So, I will follow the suggestion of Carlone (2012) and will bound my study to participants' identities related to their roles as science subject leaders in their schools as well as considering other identities that impact on these roles. For example, their roles as classroom teachers and other responsibilities that influenced the time available to fulfil their roles as science subject leaders. The study of their identities will also be bounded by a time constraint: their PSQM year.

Wenger (1998) believes that a combination of participation and reification leads to five characterisations of identity and each of these has been described. These will be sought in my data. In addition, Wenger (1998) proposed three modes of belonging; engagement, imagination and alignment, are helpful in making sense of identity so these will also be considered.

Finally, this chapter has discussed the discourses of the broad primary science community of practice. These have been identified because "to learn *to* talk" (Lave & Wenger 1991,109) is evidence of legitimate peripheral participation and adoption of certain discourses by my participants will be indicative of their inbound trajectory as they move towards full membership of the broad primary science community of practice, assume the roles of masters in their schools' science communities of practice, and develop practice within this community. During this process evidence of their developing identity is expected to emerge from my data. The methodological considerations and methods of data collection will be considered in the next chapter.

Chapter 4. Methodology

4.1 Ontological considerations

Before consideration of methodology, it will be useful to restate my research questions.

1. What happens to the identities of the science subject leaders during the PSQM year?
2. What changes do science subject leaders establish within their schools?
3. What are the processes involved in these changes?
4. What are the affordances and constraints encountered in these processes by the science subject leaders?

These questions will be answered by science subject leaders as they narrate their stories over the course of the PSQM year. Each has her own unique context in terms of the school she works in, her previous experiences of teaching and subject leadership, the way she relates to science, and the many pressures on her time. Each also has the potential to determine the course of developments in science teaching and learning at her school based on her PSQM **action plans** and the implementation of these plans. Through hearing their real-world experiences, I plan to establish what their engagement with PSQM means to my participants and their schools (Crotty, 1998).

To answer the research questions I need to understand the science subject leaders' backgrounds, their priorities, their actions, their emotions, their attitudes, their values, their knowledge and beliefs about effective primary science education, and the actions of both themselves and others that enabled or impeded their progress. This is in relation to their roles as teacher and science subject leader while completing the PSQM. However, other overlapping roles should be considered as they support or impinge on the participants' ability to carry out their perceptions of their roles as science subject leaders and teachers. The changes they intend and implement in their schools should become clear through the stories they tell. I expect their discourses reveal their understanding of best practice in primary science education and the extent to which they are able to enhance both the profile and quality of science education in their schools.

To answer questions about identities I need to hear participants' stories (Rodgers & Scott, 2008; Clandinin & Huber, 2005) in their own words. Wenger (1998) believes identity is negotiated through a combination of participation, reification, learning trajectory, community membership and the ability to reconcile their membership of other communities. These will become apparent as participants narrate the stories of their PSQM year over the course of half-termly interviews. These stories will also describe the processes and outcomes of changes to science teaching and learning, and the affordances and constraints enabling and obstructing these changes.

4.2 Implications for research approach

The type of knowledge required to answer the research questions implied the need to take an interpretivist approach and to gather qualitative data in the form of both verbal and non-verbal narratives. Each of my participants will discuss her own interpretation of events which Riessman (2005) describes as a refraction rather than a mirror image of events. My own interpretation adds an extra layer. Through this approach each unique experience will be explored by examining participants' meanings and practices.

I decided to view the science subject leaders who participated in my research as cases, bounded by the context of their schools and bounded in time by the duration of their PSQM year (including receipt of the results). I used narrative research methods to elicit science subject leaders' stories, these then became part of the cases.

A further implication for the research approach is my position as an insider with respect to the subjects of my study. Hellawell (2006:484) describes an insider as a researcher who, "possesses *a priori* intimate knowledge of the community and its members." I have previously completed a PSQM while working in a primary school as a science subject leader. I am also currently a PSQM hub leader and senior regional hub leader and thus have an affinity with my participants. I consider myself sufficiently knowledgeable about the PSQM to put the participants at ease (Cohen et al., 2017). But, what I lack, is each individual subject leaders' experience of the process.

Hammersley (1993) contends that insider and outsider researchers have both advantages and disadvantages, and, depending on the context of the research either might be preferable. As an 'insider' regarding the PSQM process, I found it easier to create a rapport with the participants and understood the process they described (Hockey, 1993), but lacked the perspective of a stranger (Burgess, 2002). Hellawell (2006:488) describes a continuum between the extremes of "complete observer" and "complete participant", but while I acknowledge my insider role with respect to the PSQM and the need to ensure I set aside my assumptions and biases about the process, the participants had a level of expertise related to their experiences that I did not share, situating me as an outsider. Dwyer and Buckle (2009) reject the insider, outsider dichotomy and I agree that a continuum is not a helpful concept as simultaneously being at different ends is nonsensical. However, an awareness of the times when I inhabited an insider role, and the ability to try to take a neutral approach (Cohen et al., 2017) when placed in that position, was important and considered during the process of data collection and analysis.

4.2.1 Cases, as applied to my research

Although I will not use a case study approach in my research, the participants are nevertheless cases and many of the considerations related to case studies are applicable. For example, their holistic, flexible and penetrative nature, and the opportunities for exploration (Yin, 2009). Cohen et al. (2017) emphasise the importance of clearly presenting ideas using dynamic, unique, complex, real-world examples, enabling readers to understand more abstract theories.

There are many different beliefs as to what constitutes a case. For example, Stake (1995) regards a 'case' as the object of study rather than a research method. While Cresswell (1994) regards a case as a bounded instance, Yin (2009) suggests there is no clear separation between the instance and the context. The context is an important background element, adding to the richness of the data. Cohen et al. (2017) argue it is unnecessary to have a single definition of a case but researchers should be clear about what constitutes the case in their research and the boundaries within which they will carry out their analysis.

Therefore, I defined my cases as the science subject leaders in the context of their individual schools, also bounded by the period of the PSQM year.

In my study the emphasis was on interpretation; both my participants and my own. Hence it was subjective and not generalisable and this may be regarded as a limitation of this method. Rather than generalisability or validity the researcher should aim for trustworthy, credible and confirmable evidence (Yin, 2009) or transferability (Lincoln, 2007). In contrast, Stake (1995) suggests 'petite generalisations' are possible. To increase generalisability some researchers employ multiple cases. Nevertheless, generalisability remains weak so a chain of evidence should be maintained so the processes are clear and comprehensible to the reader (Yin, 2009), leading to the situation where the conclusions can be regarded as trustworthy. Although I chose to hear the stories, related to their PSQM experiences, of eight science subject leaders, I make no claim that my research is generalisable beyond those eight cases. However, I aim to make the chain of evidence as transparent as possible so readers may draw their own conclusions about the trustworthiness of the research I conducted, and consider the extent to which the conclusions might be more widely applicable.

Drawing on the characteristics of case studies (Hitchcock and Hughes, 1995:317) I am exploring the naure of the learning journey of each of my case science subject leaders. I will therefore be seeking a chronological account from my particpants including a rich and vivid description of events. Subsequently the data will be presented in a way that ensures the richness is retained. Narrative methods will be used to elicit and present data, and these are now considered in more detail.

4.2.2 Narrative research

> "Narrative is present in myth, legend, fable, tale, novella, epic, history, tragedy, drama, comedy, mime, painting, … cinema, comic, news item, conversation. Moreover, under this almost infinite diversity of forms, narrative is present in every age, in every place, in every society." (Barthes, 1982:251 cited in Kim (2016))

There is no agreed definition of narrative methodology (Tamboukou, 2013), and Bryman (2004) suggests it covers a variety of approaches. For example, Meijer et al. (2009) view narrative research as an act of dialogue providing the rich and vivid chronological narratives which is true of my data. Chase (2005:58) describes narrative inquiry as, "an amalgam of interdisciplinary analytic lenses, diverse disciplinary approaches and both traditional and innovative methods", allowing scope for a range of methods of data collection and analysis. Connelly and Clandinin (1990) argue that storytelling is a fundamental part of narrative inquiry and I drew on narrative inquiry methods as I elicited the stories of my participants. It is through narrative research methods applied to my eight cases I was able to collect data to answer my research questions.

Bruner (2004) asserts that humans understand the world and others in terms of stories and Kim (2016) claims that because we understand our own lives in terms of narrative it is a useful tool for understanding the experiences of others. She distinguishes between a story which has a beginning, middle and an end, and narrative which constitutes a part of a story. I wished to understand the parts of my participants lives relating to their experiences of working towards and gaining a PSQM and these narratives are the parts of their stories that I collected.

Kim (2016:120) suggests researchers assumes the role of "metaphorical midwife", as they bring into being the stories of participants. She divides narrative inquiry into three genres: autobiographical, biographical and arts-based. As I was interested in the lived experiences of others and the way they made sense of their pasts, presents and futures, I engaged in biographical narrative inquiry and, while not presenting my research using-arts-based methods, I will use an arts-based research method, among others, to elicit the narratives of my participants.

A narrative approach is also helpful in the negotiation of identities (Søreide, 2006; Clandinin et al., 1999; Mishler, 1991; Tamboukou, 2013) so was supportive in answering my first research question about identities of science subject leaders.

As my participants were generous in giving up their precious time to take part in my research, a method that might offer benefits to them was important to me, and a narrative approach potentially offered advantages to participants. Kelchtermans (2009) noted participants are offered an opportunity to reflect on their thinking and this may be helpful to them. Chase (2005) claimed participants may learn and reflect as they narrate their stories and the process of narrating one's own experiences can lead to positive life changes (Rosenwald & Ochberg, 1992).

This choice of methods has implications for the research instruments and those implications will now be explored.

4.3 Research instruments

> "Humans are complex, and their lives ever changing. The more methods we use to study them, the better our chances will be to gain some understanding of how they construct their lives and the stories they tell us about them." (Fontana & Frey, 2008:152)

Denzin and Lincoln (2008:5) envisage the qualitative researcher as a bricoleur or maker of quilts who, "adds different tools, methods, and techniques of representation and interpretation to a puzzle." Following their vision, a combination of research instruments will be employed to gain a greater understanding of the participants' experiences throughout their PSQM year. The methods used will included minimally-structured interviews, rivers of experience, documents written for the PSQM review and notebooks. Each of these is explained in more detail below.

4.3.1 Minimally-structured interviews

In narrative inquiry the prime function of the interview is to enable a story to be told (Kim, 2016). However, interviews offer more than a device to collect data. Through the discussion and interpretation of events, socially situated research data may be constructed in conversation between interviewer and interviewee, with interviewers increasingly viewed as actively interacting with participants (Fontana &

Frey, 2008; Kvale, 1996). Cohen et al. (2017) describe an interview as a powerful, and flexible tool for data collection, to explore events, concepts, feelings, and answer 'how' and 'why' questions. This will be helpful in developing my understanding of my participants' backgrounds, priorities, actions, emotions, attitudes, knowledge and beliefs about primary science education. I also wish to develop an understanding of the actions of the science subject leaders and others they work with, that support or detract from their ability to improve science teaching and learning in their schools. Thus, interview data will assist me in answering my research questions.

There are disadvantages to interviews, including the possibility of interviewer bias, their time-consuming nature and the possible inconvenience for participants (Cohen et al., 2017). To minimise the time and inconvenience for participants I visited them in their schools at times convenient to them. Being aware of the potential for interviewer bias, I focused on asking open questions about their experiences rather than trying to focus on aspects I considered important. A minimally-structured interview schedule allows the researcher to follow up aspects in subsequent interviews that might have been missed earlier in the data collection process.

There are different possibilities for classifying styles of interviews. For example, Cohen et al. (2017:510) describe four types of interview:

1. Informal conversational interview without predetermined topics or questions.
2. Interview guide approach with areas for discussion predetermined in outline form, but the interviewer being flexible in sequencing and wording questions during the interview.
3. Standardized open-ended interviews where the order and wording of questions is established in advance.
4. Closed quantitative interviewing where both the questions and a choice of responses are predetermined.

One of the strengths of informal conversational interviews is the possibility of exploring individuals' circumstances, however, this makes the data unique to each participant and potentially more difficult to analyse. The interview guide approach makes data collection more systematic while retaining some informality. A disadvantage is the possibility of improvised wording leading to inconsistent responses or omitting certain areas from the discussions. In turn this may lead to responses being incomparable. However, Fontana and Frey (2008) reject traditional views that interviews present an objective way to collect data and believe we need to acknowledge that the histories, motivations, biases and emotions of both interviewer and interviewee all play a part.

Since each participant's PSQM year and context is unique, inevitably different information will collected from each. Therefore, questions will be matched to individual circumstances, indicating an informal conversational style of interview. Topics will be to some extent pre-determined because I need to ask about their progress through the PSQM. Thus, I conclude that my interview type will be somewhere between type one and type two (Cohen et al., 2017).

Cohen et al. (2017) describe a further way to categories interview styles. They define a semi-structured interview as one where the topics and questions are predetermined but the interviewer has freedom in the wording and order of questions and may offer prompts and probes as appropriate. An unstructured interview allows the interviewer complete freedom in the topics covered (although they will be related to the research questions), and the wording and ordering of questions. I describe my interviews as minimally-structured, because topics were predetermined based on previous interviews, but I adopted a more flexible approach when participants wished to share important events that had occurred since we met previously. This is in line with Chase (1995) who assert the narrative interviewer should aim to allow participants to focus on their experiences as opposed to a more traditional question and answer interview.

I chose to take an empathetic approach to interviewing which Kong et al. (2002:154) describe as, "a methodology of friendship". This is in line with the views of Clandinin and Connelly (2000) who believe that researchers employing a narrative methodology should aim to form close relationships with their participants.

During interviews, open questions may be useful in eliciting narratives (Riessman, 2004), although Mishler (1991) contends closed questions may still elicit an answer in the form of narrative. Instead of preparing questions, Paget (1983) suggests a list of topics for discussion may be more productive. I wanted the interviews to flow so the unexpected may emerge (Kim, 2016) and a pre-determined list of questions is less likely to allow participants the opportunity to be spontaneous and share the power to determine the course of the narrative. Therefore, a schedule, listing topics, was prepared for each interview, but participants were encouraged to continue when they diverged from these topics and talk about whatever aspects of their PSQM experiences were important to them. An example of the interview schedule is included in appendix I (see page 242).

Merriam and Tisdell (2015) draw attention to the importance of asking good questions and therefore advocate pilot interviews as a way for researchers to practise, and three pilot participants were recruited. These pilot interviews allowed me to reflect on and improve my skills as an interviewer and to finalise the approach I will take in the main study.

Records of interviews should also include non-verbal communication (Fontana & Frey, 2008) and I therefore used field notes to record other events and actions of interest. Rivers of experience, as a further form of non-verbal communication, were also used to collect, "respondent-generated visual data" (Kim, 2016:179), to supplement interview data.

4.3.2 Rivers of experience

> "We live in a pictorial age, the age of pictures. Pictures represent, mediate it, make it comprehensible." (Elkins, 2003:130)

Eisner (2017) contends there are many ways we can know about the world and including different perspectives may enrich the research process. Visual representations are one way for participants to present a different perspective. Arts-based and visual research methods are increasingly regarded as, "effective ways to address complex questions in social science" (Kara, 2015), because they offer the potential to elicit fresh insights and knowledge, provide participants with alternative ways to express themselves and broaden the range of human experiences that may be elicited (Roberts & Woods, 2018, Mulvihill & Swaminathan, 2019). In fact, Bagnoli (2018) believes arts-based methods allow participants to share their perspectives, allowing the researcher an insight into participants' interpretations. Burge et al. (2016) suggest such methods have typically been used with children and others who might find it easier to express themselves through visual images rather than linguistic representations. Because of their accessibility, there is potential for their use with a wide range of research participants (Bagnoli, 2018).

Mulvihill and Swaminathan (2019) highlight debates about the range of terminology used in relation to arts-based methods, by various authors (for example, Savin-Baden & Major, 2013, Wang et al., 2017 and Phelan & Nunan, 2018). Data produced while using an arts-based method may complement textual data obtained during an interview (Mulvihill & Swaminathan, 2019) and this is the course I will follow.

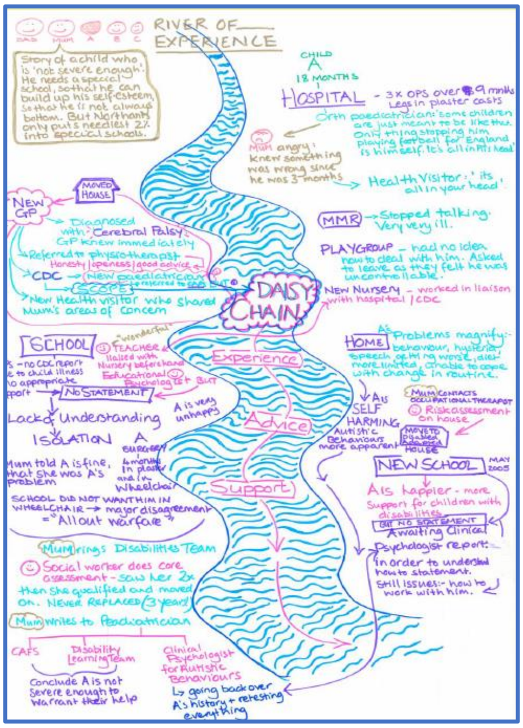
Thus, I shall consider the term arts-based research as referring to the process of using art techniques to collect data from participants.

I wanted an arts-based method that could be added to over the course of a few meetings and a river of experience seemed to fit this requirement. Percy-Smith and Dalrymple (2018:218) describe rivers of experience as a, "qualitative life journey mapping approach", offering the possibility of holistic, in-depth exploration of participant experiences. They argue this method gives greater control and ownership to participants. The river metaphor provides a flexible structure for the task, unlike free drawing, which some may find overwhelming (Sutcliffe et al., 2016).

As an alternative I considered collage because it offers the advantages that participants may work at their own speed and have greater control over the content than an interview where the questions are determined by the interviewer (Roberts and Woods, 2018). The same benefits apply to a river of experience, but this approach perhaps lacks the potential to be understood holistically in the way collage does. However, a more piecemeal approach suits a diagrammatic and textual representation that can be created over a series of interviews. A river of experience can be added to creating a mapping of events, activities and feelings over the PSQM year. In creating a logical chain to enhance the trustworthiness of the data, a river of experience provides an opportunity to look for inconsistencies in participants' stories, in addition to eliciting more information and details that might have been forgotten on the first telling during the interview.

Rivers of experience have been used by Percy-Smith and Dalrymple (2018), allowing children to map their experiences of being on the edge of the care system and Sutcliffe et al. (2016) used this data collection method to explore relationships with nature. In addition, Burnard (2012) and Taylor (2011) adapted critical incident charting to become Rivers of Musical Experience, claiming they offer reflection and insight into complex situations (Burnard, 2012). This, combined with the potential to support participants to describe their experiences in visual ways, encouraged me to ask my participants to create a PSQM river of experience.

To each interview I took a large piece of paper banqueting roll and a selection of coloured felt tip and marker pens. After the participants had told me their experiences during the minimally-structured interview, I then asked them to use the pens and paper to record the information they had described in the form of a river of experience. There were exceptions to this ordering of interview before river of experience. For example, one participant told me before the interview started that she had been thinking about what she wanted to draw on her river of experience. In this case, the river was unrolled at the start of the interview. At the end of each session I rolled up the river of experience and took it away. I then brought it to the next session and after asking some questions about their progress since we last met, unrolled it so the story could be continued. Some participants took a photograph of their river of experience at the end of each session.



A sense of alienation may arise when participants are unexpectedly presented with an unfamiliar method of arts-based research and the researcher may need to provide guidance (Burge et al., 2016). Also, some may feel they lack artistic ability, leading to feelings of insecurity. This was the case with some of my participants who were concerned they might do it wrong. Some asked where they should start. In answer to their questions I told them it was their river of experience and there were no wrong answers. As a prompt they were shown an A4 print out of the image in figure 8. McNiff (2018) argues arts-based research methods should be accessible to all participants and in choosing rivers of experience this was my aim. Some of my participants were confident in their artistic ability, while others were more comfortable taking an approach where they were able to use text and, on that basis, rivers of experience offered an adaptable arts-based method suitable for all.

Figure 8 - Example of a river of experience (Percy-Smith, 2011)

As Sutcliffe et al. (2016) discovered, despite giving participants similar instructions, the participants each produced their own unique river. Some are textually based while others use images and metaphors to supplement any text. Despite the initial hesitation of some of my participants, each expressed pleasure or satisfaction at the end of the research process in seeing her PSQM story recorded on a single, albeit large, sheet of paper. This is in line with the experience of Sutcliffe et al. (2016:184), whose, "participants all engaged very positively with the task, finding it insightful and enjoyable." The participants' rivers of experience are included in appendix U at the conclusion of each of their stories.

The rivers of experience proved a useful tool in promoting metaphorical thinking. Lakoff and Johnson (1980) highlight the ubiquity of metaphorical thought and reasoning, and claim metaphors are useful in communicating experiences. Bailey and Van Harken (2014) also assert that metaphors may be helpful in understanding an experience and the rivers of experience produced powerful visual metaphors. These included the bars of a prison cell, a mountain and a character drowning in her own river of experience. Metaphors can also allow individuals to make sense of their thoughts and feelings (Bailey & Van Harken, 2014) and their use in the rivers of experience allows participant to communicate in different ways compared to the words they may chose during an interview. Messages, shared during the interviews, may thus be reinforced and participants supported to make sense of their own experiences and feelings.

4.3.3 PSQM documents

The core documents and **reflections** uploaded as evidence to the PSQM website by the science subject leaders were collected as further sources of data. However, Martin (2017) highlights the importance of considering the purposes for which any documents were created when considering their credibility. The usefulness of these documents is limited because they are written with the sole purpose of gaining the quality mark and thus focus on the positive achievements over the course of the year, potentially presenting a biased picture. Thus, their use as data for my research has been rare and only to verify or clarify information provided by other research instruments.

The **principles** document**,** however, is an exception. This core document provided helpful data because each was written early in the PSQM year before the collection of evidence was even considered, and, provided a vision for science teaching and learning collaboratively produced between teachers and sometimes other members of the school community. This was useful as a source to support an understanding of the practices for science teaching and learning each school adopted, or, intended to adopt.

4.3.4 Notebooks

Merriam and Tisdell (2015) suggest it might be useful for a participant to keep a diary and, because I expected several weeks to elapse between interviews, I considered this a helpful way for participants to record, and hence recall, intervening events. So, during the first interview participants were given notebooks in which to record, between interviews, anything they considered of relevance in their narrative of their PSQM year. When asked during the second interview if they had recorded anything in their notebooks most had not. Those who had recorded something had made a couple of brief notes and then forgotten about the existence of the notebook until I reminded them at the second interview. The process of asking about the contents of notebooks continued until the third interview, in most cases, but given the lack of use, I did not persist in asking about notebooks in future interviews.

The value of the notebooks was therefore limited and their minimal use by participants perhaps reflected the many demands on their time and the understandable lack of priority given to my research.

4.4 Sampling and recruitment

Pilot participants were recruited to permit me to identify and resolve practical and methodological issues that may arise (Kim, 2011). My only criterion was to recruit science subject leaders who had recently started working towards a PSQM. I wrote an email explaining the purpose and process of my research and, using a local hub leader as a gatekeeper, I indirectly sent this email on to the science subject leaders she had recently started mentoring through the PSQM process. To maintain the anonymity of potential participants, I asked them to reply directly to me and not include the hub leader in the communication. Initially I only had one response from Danielle, and as I intended to recruit three pilot participants, I cast my net wider, approaching a more geographically distant hub leader. Through this process I recruited Mrs Wood and Miss Green. I was interested to meet them because they both worked at the same school sharing the role of science subject leader and working together to complete the PSQM. Mrs Wood, the more experienced teacher, was mentoring Miss Green, a recently qualified teacher, to develop her subject leadership skills. I decided to speak to them separately to ensure Miss Green told her own story rather than deferring to her more experienced colleague. Unfortunately, it was not possible to arrange any subsequent interviews with Miss Green and Mrs Wood. However, Danielle continued to meet me throughout the year.

Main study participants were recruited from the next PSQM round. Having been less successful than I hoped recruiting participants through emails forwarded by hub leaders, I tried a different approach to recruitment for the main study. Two local hub leaders agreed I could attend their first training session and have about 20 minutes to explain my research, answer any questions and collect names and contact details of potential participants. I prepared a brief Power Point presentation explaining who I was, my proposed research questions, my methodology, ethical considerations and their level of participation. Those attending the training who were interested in taking part were given a copy of the participant information sheet and asked to provide their email address, number of years' teaching experience, number of years subject leadership experience, the name of their school and whether they were new to PSQM or were renewing a previous award. From each meeting I collected the above information from six science subject leaders; twelve in total.

Cohen et al. (2017) consider that with qualitative research the extent to which a sample is representative of a group is an irrelevance because these individuals only represent themselves and are not speaking for a larger population. Flick (2018:123) argues the prime consideration should be to provide, "rich and relevant information". However, it seemed most likely this would be provided from a mix of teachers with different levels of experience and a range of schools. Having found out more about the schools' size, age range and levels of deprivation using publicly available school data, I combined this information with the data I had collected about the potential participants' experience to select a diverse range of primary science subject leaders. I emailed ten of them and was successful in arranging interview dates with seven. The one and only male participant withdrew after the first interview, but I recruited an alternative participant. The research was completed with one pilot participant and seven main study participants. None of the participants were known to me personally before they were recruited for the research.

My participants were all volunteers and willing to give up their time to share their stories with me. They may therefore not be representative of the wider population of science subject leaders working towards a PSQM. Because of the time they spent with me they had access to additional advice about the PSQM and opportunities to talk about their progress, above and beyond PSQM training sessions. Some told me they valued this opportunity and had benefited from being involved in my research. Most PSQM science subject leaders are not involved in similar research, so I reiterate my claim that the findings of my research are not generalisable.

A brief outline of the participants' teaching and leadership experience is shown in Table 3.

The stories of the PSQM science subject leaders are self-reported and are therefore based on their perceptions. They included the parts of the story they chose to share and possibly excluded information they chose not to share. However, collecting interview data followed by similar information in the form of rivers of experience, increased my level of confidence in the trustworthiness of the data (Yin, 2009). Further confirmation was provided in the PSQM core documents including photographic evidence in the **portfolio**.

Mrs Peters Experienced teacher Completed PSQM previously "Science is not my sort of subject" Disappointed with PSQM silver. Targeted Gold	**Mrs White** Experienced teacher Slow to start implementing PSQM action plan Asked for additional evidence, but achieved PSQM Silver Moved school after PSQM	**Mrs Collins** Experienced teacher Y6, History & Geography subject leader Passionate about science Left to become assistant head teacher at new school Achieved PSQM Silver
Miss Dean RQT Teach First Shadowed previous SL during NQT year Y6 teacher Achieved PSQM Silver	**Danielle** Originally in pilot study 3rd year teaching Offered to take science from HT "I'm not a scientist" Achieved PSQM Silver NPQML after PSQM	**Miss W** SLT member "Science is rubbish at our school" – at the start Studying for M.Ed. Science A levels Promoted to deputy head teacher Achieved PSQM Silver
Mrs Jones Part-time Science background Internal promotion at end of year Achieved PSQM Silver	**Alice** HLTA & Science graduate Passionate about science Left after PSQM to train as secondary science teacher Achieved PSQM Gold	

Table 3 Brief profile of participants

4.5 Data collection

All interviews were conducted in the participants' schools. Prior to each interview I created a schedule containing themes focused on eliciting the stories of the participants related to their experience of the PSQM. At the start of each interview I briefly reiterated the content of the participant information sheet, covering the purpose of the interview, how it would be conducted, the duration, ethical considerations and what would happen after the interview (Cohen et al., 2017). During the first interview I told my own story, modelling the level of detail I was hoping to elicit from participants as they told their stories. It also allowed me to explain I was familiar with the PSQM process. I asked for their stories to include information about their teaching and subject leadership experiences, plus their reasons for embarking on PSQM. Next, I enquired about their experiences of the first PSQM training sessions and relevant actions to date. Before each subsequent interview I revisited the river of experience, listened to the previous interviews, and reread the transcripts to identify threads of the stories to ensure each thread continued. I created an interview schedule (see sample in appendix I) to remind me to ask about these threads. New threads arose in answer to open questions such as, "What progress have you made since we last met?"

I intended to visit participants once every half term, however, many of my emails to them did not prompt a reply and trying to arrange dates for the interviews proved difficult. I therefore completed between three and five interviews with each participant. Most interviews were arranged at the end of the school day, but a few participants preferred to meet at lunchtime or during other non-contact time. In the latter cases, time for the interviews was more limited.

The dates on which the interviews took place are shown in Table 4.

Participant	**1st Interview**	**2nd Interview**	**3rd Interview**	**4th Interview**	**5th Interview**
Danielle (pilot)	14.11.16	8.2.17	3.5.17	12.7.17	17.1.18
Mrs Wood (pilot)	30.1.16	Not available for further interviews			
Miss Green (pilot)	30.1.16				
Mr Smith	15.5.17	Withdrew from the research			
Miss W	18.5.17	20.7.17	7.12.17	8.3.18	14.6.18
Alice Woods	6.6.17	9.10.17	5.3.18	21.5.18	
Mrs White	14.6.17	6.11.17	22.3.18	20.6.18	
Mrs Jones	15.6.17	9.11.17	23.3.18	18.5.18	
Mrs Collins	22.6.17	23.11.17	21.6.18		
Mrs Peters	26.6.17	2.11.17	13.3.18	28.6.18	
Miss Dean	31.8.17	5.12.17	19.3.18	25.6.18	

Table 4 Pilot and main study participants and dates of interviews

After the first interview the one male participant withdrew from the study. Although he was under no obligation to give reasons, he wrote me an email explaining why. Because it was early in the PSQM year, I was able to find an alternative participant; Miss Dean, which is why her first interview was later than the others.

Cohen et al. (2017) believe it is important for the interviewee to talk more than the interviewer and on replaying the audio-recording of the pilot interviews, after my initial explanation and telling of my own story, I spent the majority of the rest of the interview listening. Chase (2005) advocates the researcher should listen, acknowledge and encourage detailed narratives to gain the richest possible data. During the pilot interviews I focused on establishing a good rapport with interviewees and active listening (Cohen et al., 2017), acknowledging I had heard their comments by making brief responses, such as "I see", or "mmm", nodding, and then encouraging them to continue by being silent. Listening to the recorded interviews I noted I was less adept at allowing the participant to continue uninterrupted. Mishler (1991) believes the interviewer should minimise interruptions because they can change the course of the narrative, and so in subsequent interviews I focused on reducing the frequency of my interruptions.

Denscombe (2014) contends a good interviewer uses prompts and probes effectively, and during the pilot interviews I did this to some extent, however, on listening to the recorded interviews I was able to identify missed opportunities to probe deeper. Because I planned to carry out a series of interviews, I was able to return to themes I wished to explore further during subsequent interviews.

During the process of data collection there were times where I gave advice or opinions which are common failings of interviewers as mentioned by Cohen et al. (2017). However, this was usually in response to interviewees' direct questions about PSQM. As they had kindly given up their time to help me with my research, I judged it was appropriate to provide answers to simple questions where I was able to, but at times I referred them to their hub leader because I considered it was more appropriate for the hub leader to answer the question. Being supportive helped build a relationship with participants and added to the empathetic approach (Kong et al., 2002) I wished to take. However, in doing so I positioned myself as an expert in the PSQM and primary science education, shifting some of the power away from the interviewees (Elwood & Martin, 2000). To redress the balance, I aimed to give power back to the participants through acknowledging their expertise in the telling of their stories. I also made it clear to interviewees, both in the participant information and verbally at the first interview that I would have no influence over the process of hub leadership or the final review and the result.

Interviews were audio recorded and, although Cohen et al. (2017) contend the respondents might be constrained by the presence of an audio-recorder, my experience was that I forgot about the recorder and some participants also commented they had forgotten about it too when I came to switch it off. All interviews were transcribed in full, including the part where they drew and explained more about their rivers of experience. Field notes were made during interviews to capture gestures and other non-verbal communication.

Interviews were transcribed promptly so the transcription was available to me before the next interview. I transcribed some of the interviews myself and some were transcribed by a former colleague. An example of an interview transcript is included in appendix J (see page 245). For all transcripts I went through a process of checking and editing for accuracy, and to become increasingly familiar with my data. Cohen et al. (2017:523) believe that data is lost in the process of transcription because non-verbal communication is not captured. They claim, "Transcriptions are decontextualized, abstracted from the time and space, from the dynamics of the situation, from the live form, and from the social, interactive, dynamic and fluid dimensions of their source; they are frozen." However, an audio-recording device and subsequent transcription were judged to be less intrusive than a video recording. Cohen et al. (2017) make researchers aware that a transcript will not capture the fullest details of the interview, however using their own argument that a transcription is frozen in time, as soon as a video is 'transcribed', possibly including additional notes to capture non-verbal communication, that too becomes "frozen in time" (Cohen et al., 2017:523).

The rivers of experience were added to on each occasion I visited, and I kept a photographic record of the river of experience after each visit. As an example, appendix L (see page 255) includes the five photographs of Danielle's growing river of experience.

Clandinin and Connelly (2000) argue for multiple interpretations and by presenting my data, including anonymised stories and rivers of experience to other educational researchers I was able to glean alternative interpretations. I presented my data and tentative findings at several conferences[5] seeking feedback and questions from those who attended the sessions. This informed my thinking about my interpretations and provided new insights.

I also aimed to ensure my participants were content I had reflected their stories as they intended. Before the final interview with each of my participants, I revisited the transcripts of their previous interviews and wrote a briefer interpretation of their stories. These stories were composed by identifying what I believed to be the most significant actions, events and emotions expressed in the interviews to date and combining data from the interviews into a single narrative. The stories were based on the interview transcripts and, in order to complete them before the final interview, the data from the rivers of experience were not examined.

Before the final visit I emailed them a copy of their story so they could read it before we met. Most were pleased with the content of their stories. For example, Mrs Jones said, "I love it, really good, I thought oh gosh this is me." Alice noted two misunderstandings in my interpretation. My description of the way she selected children to judge the Royal Society Children's Science Book prizes was not strictly accurate, and I had also written that she had developed an assessment system with a year two colleague, but she described it as more of an informal conversation. Where participants wanted me to note corrections these were minor. Overall, they were delighted to be reminded of all they achieved over the PSQM year. This validation process provided another link in the logical chain (Yin, 2009), increasing the trustworthiness of the findings.

4.6 Analysis of the data

Kim (2016) suggests a researcher should 'flirt' playfully with the data she has collected and through this stimulate curiosity, consider less obvious avenues to explore, play with innovative ideas and create a space in which surprises may emerge. She contends this process is important because our experiences may lead us to interpret events in the way we have previously seen them without allowing new interpretations to arise. I therefore engaged in a process of 'playing' with, and becoming immersed in (Wellington, 2015) my data, involving a range of methods of data analysis. Hamilton and Corbett-Whittier (2012) claim there are many options available to analyse data, and there is no one right answer (Cohen et al., 2017). These methods included both inductive and deductive methods, the use of software and the rewriting the stories of my participants in both long and short forms. A more detailed description of this process follows.

4.6.1 Grounded theory

Merriam and Tisdell (2015:201) claim, "qualitative data analysis is primarily *inductive* and *comparative*", and grounded theory (Glaser & Strauss, 1967) uses inductive reasoning and constant comparison to allow theory to arise from data. The researcher sets aside any prior knowledge or thinking and engages with a

[5] The conferences included the International Professional Development Association Conference (2018), University of Hertfordshire, Open Space (2018), ASE Futures Conference (2019), Primary Science Education Conference (2019), ASE Annual Conference (2020), ASE Futures Conference (2020), and University of Hertfordshire, Open Space (2020).

process of coding the data, remaining open to the possibility of new codes. Codes are then combined to create categories, and these are revisited and expanded during further data analysis. Any process of coding tends to fragment the data and risk losing the bigger picture. However, it is necessary to avoid becoming overwhelmed by the quantity of data (Cohen et al., 2017).

Computer Assisted Qualitative Data Analysis Software (CAQDAS) may be used to support the process of organising, accessing, coding and categorising the data (Cohen et al., 2017). NVivo is one example of CAQDAS and I used this to code my transcribed interviews.

Visual data may also be coded, categorised and analysed using grounded theory in a similar way to interview data (Cohen et al., 2017). However, in contrast to grounded theory, Figueroa (2008) contends it is important to see the whole before proceeding to study individual elements of the image. In contrast, I found the whole river of experience limited in value, compared to the smaller elements.

Initially I used open coding (Cohen et al., 2017:718) to explore my some of the interview data, "identifying units of analysis to code for meanings, feelings, actions, events and so on." Codes were identified and created as I examined the data. The process of coding was more complex than I had initially thought. Many of the sentences and phrases transcribed from the interviews fitted into more than one code and many codes were created. My initial codes overlapped in a number of different ways. For example, I initially used the same code 'children' to refer to the pupils in school and to the children of the participants. It became necessary to rename the codes, revisit, revise and refine the coding to ensure consistency, lack of duplication and a more logical approach. In the light of this it became clear it would be an iterative process and that I had further work to do to finesse this approach. It was also apparent that researcher bias had played a part in the codes I had created. In the descriptions of both 'budget' and 'space' I assumed these were constraints, and I had not considered the possibility that they might inspire greater creativity in my participants and thus represent affordances.

Based my early attempts at open coding I created a draft code book (see Appendix K). At this point I was aware of the researcher bias in some of my codes and the complexities of open coding. In addition, I was not confident that this approach would enable me to answer my research questions, so, in the spirit of continuing to 'play' with my data (Kim, 2017), I decided to try a different approach, leaving open the possibility of returning to an inductive approach and my early draft code book in future.

The next method of data analysis I chose to consider was narrative analysis, based on fact that I had been successful in collecting narratives from my participants.

4.6.2 Narrative analysis

> Narratives can not only convey information but bring information to life … Narratives are a wonderful foil to the supremacy of coding and coding-derived analysis. (Cohen et al., 2017:664)

A distinction is drawn between narrative analysis and analysis of narrative (Polkinghorne, 1995). Narrative analysis employs narrative smoothing (Spence, 1986, cited in Kim, 2016) to create stories that are comprehensible to the reader and allows her or him to empathise with the subject of the story. There is no attempt to construct theory.

Although I believed theory would be constructed as I answered my research questions, the retelling of my participants' stories was useful as another way to engage, and become increasingly familiar, with my data. The stories I had written initially had been checked with the participants as part of the final interview. They were therefore incomplete because they did not include the part of the narrative captured during this final interview. The stories also focused on data in the interview transcripts and excluded data from the rivers of experience as a pragmatic approach to ensure they were completed so they could be emailed to the participants in advance of the final interviews. The participants were also familiar with their rivers of experience having added to them during each interview.

Having completed the final interviews and responded to the comments of my participants, based on their reading of their own stories, I listened once again to the audio-recordings, revisited the transcripts and examined the rivers of experience. Where any details were unclear, I checked against the documents submitted to the PSQM for review. The main events in the participants' PSQM experiences were included in these stories, and I also aimed to capture their feelings and emotions. Because threads continued over a number of interviews, I aimed to make the stories more coherent. For example, in the section of the transcript in Appendix J, Danielle told me about the parent workshop she organised. In addition to her words, I recalled her excitement and pride as she described this event and I aimed to capture this in the story. The planning for this event was mentioned in one interview, the event was described and discussed in the second and subsequent interviews, however these references were combined to make a single section of the story. Thus, any duplication and jumping from thread to thread was avoided. As much detail as possible was retained in retelling participants' stories, including many direct quotations. Initially each was approximately 10,000 to 12,000 words long, retaining the richness of the data.

This proved an effective way to become immersed in the science subject leaders' stories and increased my familiarity with the data (Cohen et al., 2017). It also allowed me to check for inconsistencies between the verbal part of the interview and the rivers of experience. Despite looking closely, I failed to find inconsistencies between the verbal and the visual. This provided a further link in the chain of evidence indicating my data were trustworthy (Yin, 2009). The length of these stories was unwieldy and therefore I edited each to approximately 1000 words and these are included in appendix U. To reduce the length of the stories I focused on background information about the participants and the main events in their PSQM years, direct quotations were mostly removed, the language and explanations were simplified leaving what I considered to be the skeleton of the story.

Although the writing and editing of these stories enabled me to become immersed in my data, I wished to analysis these stories more deeply and decided to engage in analysis of narrative.

4.6.3 Analysis of narrative

In contrast to narrative analysis, analysis of narrative is like other qualitative data analysis methods (Kim, 2016) and within this, either inductive or deductive approaches are available (Polkinghorne, 1995). Inductive methods, such as grounded theory (Glaser & Strauss, 1967), allow theory to arise from the data whereas deductive approaches test data against existing theories.

Riessman (2005) proposes four methods of analysis of narrative: thematic, structural, interactional and performative. Interactional analysis applies where interaction is in the form of a conversation, for example, in medical and court settings. Performative approaches extend interactional approaches to see story telling as a performance. Neither of these are appropriate for my research. Thematic analysis places the emphasis on the content of the speech and structural analysis includes elements of thematic analysis but extends this to include an understanding of the way a story is told through an analysis of the language used. While structural analysis would have allowed a deeper analysis of the language used, the large amount of data I am working with made a thematic approach more appropriate.

To identify themes for analysis I revisited the original work by Lave and Wenger (1991) and created a table including these themes as headings. The headings were:

- Masters and mastery
- Legitimacy
- Talk/language
- Teaching and learning
- Learning curriculum
- Self-assessment
- Community
- Peers
- Engaging in practice
- Partial to full participation
- Learning and identity
- Artefacts/Cultural life
- Conflict between continuity/displacement

I sought evidence related to these themes in the long versions of my participants' stories. Where relevant evidence arose in each story this was copied and pasted into the table. A section from this table is included in appendix M (see page 260). In the first column of this table, I expanded on the themes using direct quotations from Lave and Wenger (1991). Sections from the rivers of experience were also referred to in this table. It became clear this process would allow me to answer my research questions and continue a logical chain to increase the trustworthiness of my conclusions (Yin, 2009). At this point I decided not to return to a grounded theory approach and the themes identified in my initial code book, because I felt that this thematic analysis of narrative would be more fruitful in enabling me to answer my research questions.

Having completed the table it became clear that it included sections that overlapped and some that were not relevant. For example, the conflict between continuity and displacement is about tensions and conflicts that arise between apprentices and masters, and these were not apparent in my data. The number of headings was subsequently reduced from 14 to five through a process of combining headings where possible, for example legitimacy and access were combined, and those headings where no or negligible data were found were disregarded, as were those that offered no information that was helpful in answering my research questions. The five headings used in the discussion chapter are:

- Talk and Language
- Engaging in practice
- Apprentices, Master and Mastery
- Learning and Curriculum, and
- Legitimacy and Access

4.6.4 Reflections on analysis of visual data

Cohen et al. (2017) claim visual data can be analysed in a similar way to linguistic data but also note the subjectivity and complexity of the analysis and the potential for a wide range of interpretations. While participants created their rivers of experience, some explained what they were doing while others remained silent. When those who remained silent had finished, I would ask about what they had drawn or written, and this data was captured and analysed as part of the interview. Thus, the interviews and rivers of experience became intertwined (Fontana & Frey, 2008) and explanations were recorded as part of the interview process.

Some of my participants drew images and Cohen et al. (2017) suggest that the effect of images on the audience might be considered. In the spirit of 'playing' with my data I considered the effect of the rivers on me. Images certainly had a more profound effect than words alone. I found Mrs White's prison bars and Mrs Collins drowning in her river of experience more moving and memorable than words written and spoken by other participants. It is unlikely I could ever know whether the participants intended either consciously or subconsciously the impact they had on me as they created and spoke about these images. Loads (2009) discovered that arts-based activities facilitated the use of unexpected metaphors resulting in deeper insights and reflection, and my research supports her finding.

Analysis should be, "conducted at the level of the institution which holds the image" (Cohen et al., 2017). While the images created were not held by a gallery or museum this made me reflect on the fact that I had retained ownership of the rivers of experience; taking them away at the end of each session and returning with them next time. This action rather contradicts my narrative that the participants were the owners of their stories and this is something I would do differently next time.

4.7 Ethics

Fontana and Frey (2008) draw attention to the important ethical considerations of informed consent, right to privacy and protection from harm, and, each of these was attended to.

Before recruitment of either the pilot participants, or the main study participants, full ethics approval was granted by the University of Hertfordshire social sciences, arts and humanities ethics committee (Protocol numbers cEDU/PGR/UH/02689 (see appendix N, page 267) and cEDU/PGR/UH/02951 (see appendix Q, page 271). Separate permissions were granted for the pilot study and main study. All participants were given a copy of the participant information sheet (see appendices P and S, pages 268 and 273) to keep and signed a copy of the consent form (see appendices O and R, pages 267 and 272). I also received an email from each school's head teacher or other senior leader giving me permission to interview the participant on the school's premises.

The participant information sheets outlined the purpose of the study, the right to withdraw at any time, that confidentiality would be maintained, and that data would be destroyed later under secure conditions. Potential participants were also given the contact details of the researcher, so they were able to ask any questions before agreeing to participate. A modification to the main study ethics request was granted by the same committee (protocol number: cEDU/PGR/UH/02951(1) (see appendix T, page 276)) to permit the collection of documents submitted to the PSQM. Data collected from one of the pilot participants was so rich and useful that she was subsequently given a main study participant information sheet and agreed to sign the main study consent form so her data could be analysed and used.

In addition, at the start of interviews I described the nature and purpose of the interviews and how they would be conducted. I also explained the ethical issues and told participants how I would use the data (Cohen et al., 2017).

Cohen et al. (2017) and Clandinin and Connelly (2000) note the use of interviews may make it more difficult to maintain participant confidentiality. To protect their anonymity, participants chose a pseudonym both for themselves and for their schools. Information about their backgrounds and the locations of their schools has been deliberately left vague to maintain confidentiality and information that might identify them or their schools has been obscured on the rivers of experience.

The main study ethics approval also included permission to interview The PSQM Director about the history and background of the PSQM. This interview was conducted, audio-recorded and transcribed. The transcription was checked by her to verify the accuracy of the transcription and allow her to add any additional information she thought important that had been missed during the interview.

Chapter 5. Findings

5.1 Introduction

Based on Wenger's (1998) conceptualisation of a community of practice, the existence of a broad primary science community of practice is established in this chapter. The development of a science community of practice in each school is also considered. While a science community of practice only existed at the start of the year in some of the eight schools, by the end of the year each school had developed either a science community of practice where none existed before, or the existing science community of practice had been strengthened.

The chapter then goes on to consider my data and relationship between these and the work of Lave and Wenger (1991) on situated learning, supporting the view that communities of practice are developing. The data confirmed the science subject leaders were on an inbound trajectory to becoming full members of the broad primary science community of practice, in addition to creating science communities of practice within their own schools. Furthermore, their evolving membership of the broad primary science community of practice supported the developing science teaching and learning practices within their schools.

Lave and Wenger (1991) assert that learning happens as the result of engagement in practice, so this chapter continues with an examination of the way that my participants were both themselves engaged in practice, as well as engaging other members of their school communities. In doing so they simultaneously acted as apprentices in the broad primary science community of practice, and, with the support of aspects of the PSQM, acted as masters in their own schools.

Like the communities of practice observed by Lave and Wenger (1991), the science subject leaders professional learning occurred primarily as a result of engaging in practice, with minimal learning arising as a result of direct instruction. With reference to the PSQM framework they created **action plans**, and these became the learning curriculum for their school communities, and the basis for engagement. Lave and Wenger (1991) contend that legitimacy and access are essential in developing communities of practice and this chapter explores the participants' access to the broad primary science community of practice and their own schools' communities of practice. The extent of their legitimacy within each community of practice is also discussed.

The chapter then goes on to consider the developing identities of my participants drawing on theoretical characterisations of identity and modes of belonging (Wenger, 1998). I conclude the chapter with a summary of the findings.

5.2 Primary Science Communities of Practice

5.2.1 Introduction

Legitimate peripheral participation is, "the process by which newcomers become part of a community of practice" (Lave & Wenger, 1991:29) and for the science subject leaders this commences when they attend the first PSQM training session with their hub leader and other science subject leaders. As a result of this initial training they are given activities to complete in school, including the creation of the **principles**, leading to the engagement of their colleagues in social practice. This conferring of legitimacy is more important than direct instruction (Lave & Wenger, 1991), and the focus of the training is not direct instruction about the teaching and learning of primary science, but the process required to complete the PSQM.

A community of practice exists in the presence of a domain; where members have shared interest and competence; a community; where members build relationships through discussion and activities; and a practice; members are practitioners, sharing resources and problem-solving strategies (Wenger, 1998). The members of the organisations in Table 5 share these attributes and I therefore regard the people involved with them as a community of practice. I shall refer to them as the broad primary science community of practice.

Table 5 Organisations involved in the broad primary science community of practice

The Association for Science Education (ASE)	Royal Society of Biology (RSB)
The Primary Science Teaching Trust (PSTT)	Institute of Physics (IoP)
Centre for Industry Education Collaboration (CIEC)	Science and Engineering Education Research and Innovation Hub (SEERIH)
Primary Science Quality Mark (PSQM)	Wellcome
The Ogden Trust	STEM Learning
Royal Society of Chemistry (RSC)	

Relationships exist between those who are employed by, work with, or are members of these organisations, or engage with them in some other capacity. Examples of fora in which members of these organisations meet and collaborate are the ASE annual conference, the Primary Science Education Conference (organised by the PSTT) and the PSQM Stakeholder Group (White et al., 2016). Lave and Wenger (1991:98) state, "the term community does not necessarily imply co-presence, a well-defined, identifiable group, or socially visible boundaries", and this is true of those involved in this community. The domain, community and practice they share are all related to the teaching and learning of primary science. The shared practice relates to the expertise necessary for a primary science teacher (Wellcome, 2017a) (see page 30). However, based on my literature review, I have noted some omissions from their description so these will also be considered. The discourses of the broad primary science community of practice become evident in the stories shared by the science subject leaders, and will be considered further in the section on Talk and Language (see page 97).

I contend each English primary school constitutes a community of practice because it has its own domain, community and practice, drawing on Wenger's (1998) understanding of a community of practice. While each school may lay claim to a general community of practice, at the start of the PSQM year, some science subject leaders provided evidence there was no science community of practice in their school because the shared competence and interest (the domain) was absent, the discussions and information sharing related to science (the community) was absent, or, the members failed to share a practice related to primary science. In some cases, more than one of the three were absent. For example, Mrs Collins noted, "Some year groups ended up doing science in one big block and then nothing for the rest of the year. So, where do you show the progress?" This is indicative of a lack of domain (or shared competence). Information between year groups was not shared, indicating there was also a lack of a community. "The previous year 5 teacher was doing the experiments they should have been doing in year six, and actually, for progression they are not going to progress next year because you have already done that." She represented this on her river of experience as a boulder partially blocking the river, labelled "coverage of science not acceptable". See Figure 9.

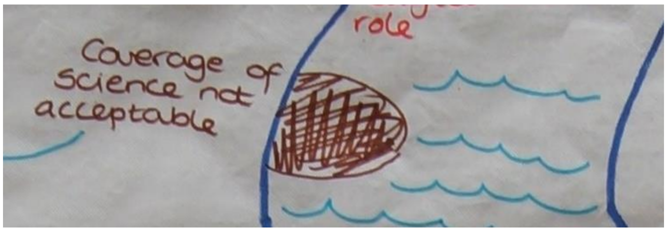


Figure 9 - Section of Mrs Collins' river of experience

Similar situations existed in other schools. Miss W told me, "So, the first book look there was almost no science in year three and four." She told the visiting Ofsted inspector,

> Science isn't good enough here. It's taught in every class, the kids are not enthusiastic about it, they are not doing practical, they are not doing enquiry, they are not really investigating, they're not learning scientific skills, they are just doing science.

Similarly, children at Miss Dean's school were not engaging with practical science. She described the science equipment as, "all over the place. You could not find anything; sets weren't together … people avoided it." She described science teaching and learning as, "a bit stale. A bit shoved to the side." In this example the lack of domain is indicated.

In contrast, at the start of the PSQM year other subject leaders indicated a shared domain, community and practice were all present. In all cases the science subject leaders aimed to develop the school's science community of practice by revisiting and building on that shared competence and interest. For example, at Alice's school the previous Ofsted inspection had identified science as an area for development, so the school improvement partner had been working on developing science and Alice thought it now had a, "reasonably high profile." Teachers had a shared understanding that planning should be downloaded from the Hamilton Trust[6] website. However, Alice considered these lesson plans to be, "a little bit dull and

[6] https://www.hamilton-trust.org.uk/

uninspiring." She therefore purchased the Snap Science scheme[7] which she described as, "really differentiated and it's quite friendly and easy to use and you can dip in and out." Thus, she developed a shared competence leading to improving science lessons, indicating an evolving community of practice.

Because her school had previously completed PSQM silver, Mrs Peters indicated teachers already had shared discussions, practices and competence concerning science teaching and learning, thus a community of practice existed. However, she was keen to change the emphasis of those shared understanding.

> I definitely want to raise the profile of science. It was raised for the silver in a big way and very quickly, and I think everybody is doing a good job, and is maintaining it, but I think we can make it more exciting, and I think it is giving everybody that confidence to step outside their own boundaries and say go on give it a go. So, I would like to change thinking I suppose.

So, even though a science community of practice was evident at the start of the PSQM year, Mrs Peters aimed to increase the extent to which it overlapped with the broad primary science community of practice and supported the school's target to improve children's thinking and reasoning skills.

Over the course of the PSQM year, each school either created or developed a science community of practice, as a result of initiatives instigated by the science subject leader. Over time the discourses of these communities began to overlap with the discourses of the broad primary science community and information external to each school's community of practice was shared within the schools. The developments can be seen in the extent to which shared practices, competence and discussions developed around the teaching and learning of science, along with the relations among people, activity and the world. Participation in the PSQM increased the overlap between each school's community of practice and the broad primary science community of practice. The overlap represents the school's science community of practice. These communities of practice are shown visually in Figure 10 (page 95). This shows just four hypothetical schools; A, B, C and D (represented by four pale blue circles) and the broad primary science community of practice (represented by the darker blue circle). Three of the schools overlap with the broad primary science community of practice, indicating a science community of practice, whereas the fourth, school B, does not. This indicates school B lacks that shared domain, community and practice in the teaching and learning of science, and thus the school does not have a science community of practice.

[7] https://collins.co.uk/pages/primary-science-snap-science

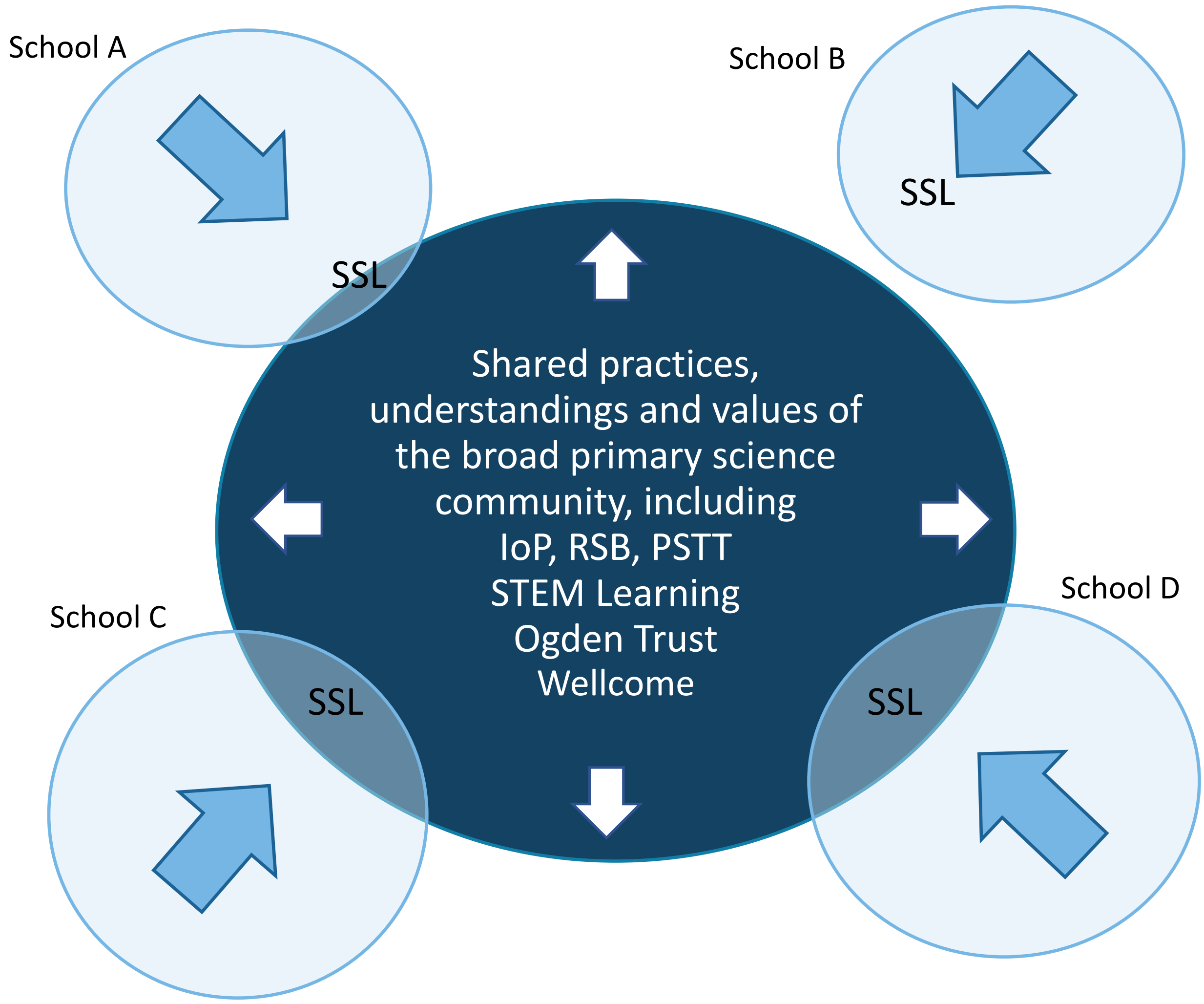


Figure 10 - Overlapping communities of practice

For two reasons, this area of overlap either starts to appear or grows as schools participate in the PSQM. Firstly, due to the expansion of the broad primary science community of practice (expanding blue circle in Figure 10, indicated by white arrows) as more teachers engage with the organisations central to the broad community. Secondly, each school's science community of practice also expands (expanding pale blue circles indicated by blue arrows) as practice in the teaching and learning of science develops, sometimes resulting in improvements to teaching and learning in other curriculum areas.

Having previously stated that limitations of all models should be made clear (Harlen, 2006) I should apply the same approach to my own model. Although it is not apparent in the model, I recognise that science subject leaders, teachers and other members of schools' communities may also belong to other, "overlapping and tangential communities of practice" (Lave and Wenger, 1991:98). For example, Miss W was working towards a PSQM at the same time as studying for a master's degree so belongs to a community of practice for each. The model shown in Figure 10 does not reflect the complexity of all the communities and overlaps which may be present and the context in which it is situated so therefore should be regarded as a simplified model. The sizes of the circles are not indicative of the sizes of the communities.

Fuller et al. (2005) suggested a Russian doll analogy to illustrate the way narrower conceptions of communities of practice nestle within a larger community, however, I prefer to envisage the communities I discuss as overlapping. This is because there is much that happens in schools that is not related to primary science.

By the end of the PSQM year each school had developed a unique science community of practice. In order to be regarded as a community of practice three characteristics are required: the domain, the community, and the practice (Wenger, 2009). The first of these, the domain refers to the way one group of individuals can be distinguished from other groups because of their shared interests and competence. For example, teachers and children at Miss Dean's school demonstrated their shared interest and competence as they participated in a science day towards the end of their PSQM year.

> We did a whole school science day on Friday last week and that, just wandering around that all day was such a lovely experience. To see the whole school excited and engaged and doing something practical... So that summarised the year that we have had, and I just stood back and thought yes, we have got it. We have got it good now.

Miss W had met with her head teacher and the school improvement partner (SIP). Their discussions indicated teachers now had a shared competence in teaching science.

> All of us agreed yesterday that science as a subject is transformed in our school. The SIP felt that, my head teacher felt that, and I definitely felt that. I think that we are there really … I think all the big things that needed doing are done … everybody is enjoying teaching science. The kids are loving it.

Similarly, there was evidence the domain was also present in other schools.

A community of practice requires members to share, support and learn from each other through participation in activities and discussions (Wenger, 2009). The **principles** activity at the start of the year provided an opportunity for collaboration between staff, and shared decision making. It established a shared interest and competence discussed with reference to the domain as described above. Miss Dean sent home a Christmas science task that gave parents and children the opportunity to share science activities thus increasing the spread of the science community of practice.

The sharing of support and professional learning applied not only to the communities formed within schools but also within the hub. Even after their PSQM year was completed Mrs Peters thought, "It would be really good to get the group back together again to talk through what they have achieved during the year."

The practice (Wenger, 2009) requires community members to be practitioners sharing resources including experiences, tools and stories. While teachers engaged with the practice of teaching science, the children increasingly engaged with practical activities. For example, Danielle borrowed microscopes from the Royal Microscopical Society and created a timetable to ensure each class shared the equipment and had discussions about what they had seen under the microscopes. Alice arranged for science visitors to come to school and tell the children about science in their work. She also organised a live link up with a polar scientist in Antarctica to share stories of her experiences.

Mrs Peters told me about shared practice developing across the school.

> With those open-ended lessons … they are developing their thinking, so they are not just accepting that's it, they then develop it further. Like the year one experiment, in the homework I have seen it. I have also seen it in general lessons as well. They are not just accepting that everything you tell them is right which is great. How often do they get to do that, especially in year two?

In summary, each of the science subject leaders I interviewed was pleased with the outcome of her PSQM year and provided evidence that the domain, community and practice related to science teaching and learning had developed. This happened because they were able to engage their school community and, through participation, the teachers learned about science pedagogy, and the children learned science. In some schools, parents and governors also participated in science fairs, as visitors and contributing ideas for the **principles**, resulting in their inclusion in the school's science community of practice, albeit at the periphery.

However, a closer examination of the concept of situated learning (Lave and Wenger, 1991) confirms other ways schools and science subject leaders corresponded, or not, to understandings of communities of practice and the extent to which situated learning occurred. The discussion focuses on:

- Talk and Language
- Engaging in practice
- Apprentices, Master and Mastery
- Learning and Curriculum, and
- Legitimacy and Access

This discussion also provides a more nuanced understanding of how the science subject leaders created and developed school science communities of practice. No attempt was made to measure situated learning, because, as noted by Fevre et al. (2000), it is impossible to measure.

5.2.2 Talk and language

One purpose for newcomers is, "to learn *to* talk as a key to legitimate peripheral participation" (Lave and Wenger (1991:109). However, participants should be engaging in the practice as opposed to simply engaging in the appropriate linguistic practice (Lave & Wenger, 1991). This talk, backed up by appropriate actions, has various functions including, "engaging, focusing, and shifting attention, bringing about coordination … supporting communal forms of memory and reflection, as well as signalling membership" (Lave & Wenger, 1991:109). Thus, the participants' adoption of the discourses of the broad science community of practice indicated their evolving membership of this group. Some of their discourses related to the PSQM criteria and some arose for other reasons. By adopting these discourses, they demonstrated competence in primary science education. Through talk the growing overlap between their schools' science communities of practice and the broad primary science community of practice became apparent.

One of the discourses of the broad primary science community relates to raising the profile of science since its decline following the removal of the key stage two science SAT in 2009 (Ofsted, 2019b, Wellcome, 2012). Participants in my research used this talk and language and recognised the importance of raising the profile of science within their schools. Danielle commented that the PSQM, "focuses on so much; that's what helps raise the profile. It really raises it a lot." At the start of the year Mrs Peters stated that, "I definitely want to raise the profile of science." This aspiration probably arises because of the A4 criterion: "*There is* *a shared and demonstrated understanding of the importance and value of science to children's learning."* (PSQM framework – see appendix A). One of the aims of Mrs Jones' science days was to raise the profile, but she also saw them as an opportunity to allow her colleagues to experiment with new pedagogies. She planned the days, so her colleagues had time to focus on child-led enquiry rather than telling the children what and how to investigate. So, although the science subject leaders were focused on raising the profile their aspirations were broader, incorporating other PSQM criteria and wider discourses of the primary science community of practice.

So, the participants adopted the talk and language of the board primary science community of practice related to raising the profile of science in primary schools. The remainder of this section about talk and language will consider the science subject leaders' discourses in relation to the Wellcome (2017a) description of the expertise required by a teacher of primary science. This ensures the changes they are implementing in their schools are focused on improvements to science teaching and learning. It also impacts their identity as they assume the discourses of full members of the broad primary science community of practice.

5.2.2.1 Science enquiry

Primary science teachers should, "understand and model a range of appropriate methodologies for science enquiry," and, "have a good knowledge of appropriate pedagogies, including practical work." (Wellcome, 2017a:3). Discussion about practical work and science enquiry were initiated by all participants. For example, Mrs Jones reference to child-led enquiry is mentioned above, but others also assumed this discourse. Miss Dean, for example, told me, "The children are making decisions for themselves, whether it be how to investigate something, or make up their own question, their own investigative questions; they are deciding for themselves." Alice noted teachers needed some working scientifically training to increase the amount of child-led enquiry in school, which she then provided. Mrs Peters planned to, "almost give the children ownership of it, to find out what they want to find out." This is likely to be in response to the C1 criterion. "*All pupils are actively engaged in science enquiry; using a variety of enquiry strategies; independently making decisions, using evidence to answer their own questions, solving real problems, evaluating their work.*" (PSQM Framework – see appendix A.)

"Taking part in practical work is an integral and essential part of learning the sciences", (SCORE, 2013:3), and the participants recognised the importance of opportunities for children to carry out practical work. At the start of the year Danielle recognised the, "great potential for engaging pupils with hands-on activities". By the end of the year Mrs Collins was pleased to, "have seen a lot more practical lessons on like my lesson walks and learning walks and in the books." However, there was no explicit recognition that science needs to be minds-on in addition to hands-on (Abrahams et al., 2011). While practical work is recognised as important by the broad primary science community of practice, there is no explicit reference to children engaging with practical work in the PSQM criteria. However, practical work might be implicit in the criteria about science enquiry (C1) and resources (B3).

Equipment is necessary to support practical work and Harlen (2006) notes the importance of accessible resources to ensure teachers can find what they need for the children's investigations. An audit and reorganisation of resources is required by PSQM criterion B3. The descriptor for silver begins, "*Science resources are used across the school and are well-maintained and organised. They are audited regularly* *and the school has identified suitable further resources to purchase that will enhance teaching opportunities." (*PSQM framework – see appendix A*).* Danielle noted everything in the science cupboard was dusty and disorganised indicating it was not being used. She therefore considered an audit and reorganisation an important job. However, it proved difficult to achieve because opening the cupboard doors blocked the corridor that led to the staff room. She resolved this issue by going to school, along with a colleague who volunteered to help, during a Bank Holiday weekend. Mrs White also found it difficult to find a suitable time to carry out the task. Mrs Peters, in contrast, completed her audit and reorganisation of science equipment during one of the school's training days. The increase in the number of practical lessons following the improved accessibility of resources has been discussed above.

5.2.2.2 Science vocabulary

Another area in which teachers of primary science should have expertise, is in the use of age appropriate vocabulary with an expectation their pupils should do the same (Wellcome, 2017a). Scientific vocabulary is not mentioned specifically in the PSQM criteria. However, the discourses of some of the subject leaders demonstrated they understood its importance. Alice mentioned her school's, "focus on improving scientific vocabulary". Mrs Jones aimed to increase the scientific vocabulary that children used and mentioned that key vocabulary was now displayed on notice board. She knew that staff were trying to make greater use of word banks for SEND children and those who struggled to write. The **principles** developed by Mrs White and her colleagues included, "Children can explain and suggest reasons why, using scientific vocabulary".

5.2.2.3 Recording and presenting science work

In line with Wellcome's (2017a) view of the skills and knowledge required by primary science teachers, each of my participants introduced new ways for children to record and present their work in science. In several schools, writing and worksheets were the predominant method of recording in science lessons at the start of the PSQM year. Mrs White told me pupils, "don't like doing the writing." Historically worksheets were used in Miss Dean's school for each piece of science work to prove children had covered science topics, but she thought a picture, "speaks a thousand words", and worksheets were unnecessary. To try to shift her colleagues' practice away from reliance on worksheets and formal writing up of investigations Miss Dean organised two consecutive science days during which the children did no writing, although they did have access to iPads to record in other ways, and Miss Dean said, "they absolutely loved it!" Mrs Jones also persuaded her colleagues to reduce the number of worksheets used.

> I am now seeing progression in books. I am seeing the lesson stages building up more, and there is less worksheets, and there is more photographs of them doing work in different ways. For example, they are doing drama, acting as a solid or they have done a poster or a news report.

5.2.2.4 Secure understanding of the primary science curriculum

Wellcome (2017a:3) also include, "have a secure understanding of the primary science curriculum and, where necessary, address areas of insecure understanding", in their list of required expertise for a primary science teacher. The PSQM criteria make no specific reference to a secure understanding of the science curriculum and the level of understanding of science varied between my participants. Danielle described herself as "not a scientist", but showed a willingness to, "research it and look it up and try my best to find out". In a pupil voice activity at the end of the PSQM year Danielle reported, "All of the year groups said their teacher liked science more. I don't think it is the teacher likes science more, I think there are probably a few more ideas on how to deliver it." It was Danielle's suggestions and training that provided her colleagues with the support they needed. For her own professional development Mrs Peters completed one of the free on-line modules from Reach Out CPD[8] and encouraged her colleagues to do the same. "One of interest per term, just so they have got that little bit of CPD." Thus, the science subject leaders and their colleagues became more secure in their understanding of the science curriculum.

Miss Dean and her colleagues also completed Reach Out CPD modules and she attended other professional development experiences. In addition, she planned and jointly taught lessons with her colleagues. At the end of the year I suggested to Miss Dean that the way she now spoke about science indicated an increasing confidence in her own subject knowledge and she agreed. "It has massively, and I think my whole understanding of the different scientific areas which are covered from foundation stage right up to year six and beyond as well I think has grown and expanded." Therefore, science subject knowledge was strengthened through subject specific CPD that has been shown to be more effective that generic CPD (Cordingley et al., 2015).

5.2.2.5 Problem-solving

Wellcome (2017a) include problem solving as an appropriate pedagogy teachers should employ. Mrs Collins described problem solving as part of her ethos for the teaching and learning of science. "I think a big part of it is hands-on, asking questions and problem solving so looking at it in a different way and considering why it happens." Miss Dean did not use the phrase problem-solving but this approach to learning became apparent as she described a lesson linked to their World War II topic. The children researched how messages were sent during the war and were given electrical equipment and challenged to send and receive messages. "We didn't do any teaching, we just said off you go. So, they spent all afternoon working out how to do it." While there was some evidence of problem-solving activities, this was not explicitly articulated by most of the science subject leader. Problem-solving was not discussed by all the science subject leaders, probably because it is not included in the PSQM criteria.

[8] https://www.reachoutcpd.com/

5.2.2.6 Assessment

Wellcome (2017a) include the understanding of formative and summative assessment strategies in the expertise required by primary science teachers, and the science subject leaders I interviewed developed assessment practice in their schools. The C2 criterion for PSQM silver states, "*Teachers across the school build different assessment strategies in their science lessons and the outcomes of these in their planning. The science SL is pro-active in introducing new strategies.*" Mrs White aimed to support colleagues to develop their assessment practice in line with the discourse of the broad primary science community of practice that suggests a range of assessment evidence should be considered by teachers with summative science assessment based on teachers' formative judgements of a range of classroom activities (Harlen, 2012). "I think also helping the teachers to look for ways of assessing during the lesson, knowing what to look out for and just helping them with that." Similarly, Miss Dean wished to share her view with colleagues that science should be assessed through observation of practical tasks. Miss Dean considered the **reflection** based on the assessment criterion was the most difficult to write and in doing so revealed a misunderstanding about the criterion which she interpreted as meaning PSQM was promoting the use of tests.

> The whole formative and summative assessment thing doesn't sit well with us because that is not what we want for our children so it, that was the one I found the hardest because if I was to re-word it, it would be something along the lines of, the assessment of science teaching and learning within the school fits the schools values. It is what we think science should be like actually. If that is in our policy, do we match that and that is all that matters. It is not trying to fit in with what every other school is trying to do, where is your test data and where is your blah blah. We don't need that.

Hodkinson and Hodkinson (2004) criticise Lave and Wenger's (1991) assumption that all learning is desirable, and they believe learning through engagement in practice can lead, in some cases, to poor quality learning. In this case Miss Dean follows the discourse of the broad primary science community of practice but claims this is not what is required by the PSQM. This example illustrates how misunderstandings may arise.

Interestingly Mrs Jones also misinterpreted the same criterion. While acknowledging the importance of formative assessment, she diverged from the broad primary science community of practice discourse that testing lacks validity and reliability (Wiliam, 1993). "I would like to introduce summative assessments into school at the end of each unit as well so there is more testing for science so that teachers have more core results as well as their formative." While the PSQM criterion guides the science subject leaders towards improving assessment practice it could be more explicit, regarding the discourses of the broad primary science community of practice.

While Mrs Peters purchased an assessment system based on teachers' observations of pupils as they completed practical tasks, and Miss W and Mrs Collins both created assessment systems to match the needs of the school, by the end of the year other participants were still in the process of developing assessment practice. For example, Danielle planned to incorporate science enquiry skills and subject knowledge into a single, simplified assessment document.

5.2.2.7 Countering gender stereotypes

Another area of expertise required by science teachers relates to countering gender stereotypes (Wellcome, 2017a). Mrs Collins was aware that girls, in particular, held negative and gendered views of science. She asked the children in her class to draw a scientist and was disappointed when almost all of them drew a man. She began, "promoting strong female characters within the sciences because we have a lot of girls here who don't have a lot of self-esteem, so we are pushing it."

Alice commented, "There can be a bit of a perception you have to be unusually brainy or something to do science." The ASPIRES research (Archer et al., 2013b) discovered over 80 per cent of young people surveyed agreed 'scientists are brainy'. Even those who found science interesting could be deterred from further science study because they did not consider they were sufficiently brainy. For many girls an identity as brainy conflicted with their constructions of femininity, causing them to reject science aspirations (Archer et al., 2013a).

In the Literature Review Chapter (see page 68) I argued the problem is not just with girls deciding science is not of interest to them. It is those pupils with lower socio-economic status (SES) who are least likely to participate and achieve in science. While all my participants referred to children now gaining greater enjoyment from their science lessons and other science activities, Archer et al. (2013b) contends that despite enjoying science in school, too few students go on to choose to study science, adversely affecting the economy and scientific literacy among the population. She identified science capital as influential in determining the likelihood a student would continue to study science after the age of 16. Those with low science capital are most likely to come from deprived backgrounds. Although she did not use the term science capital Mrs Collins was aware of the low aspirations of her pupils many of whom came from backgrounds with low socio-economic status.

At the time my participants gained a PSQM, criterion C3 stated, "*Children enjoy their science experiences in school". * However, in the 2017 criteria review this was replaced by, *"There is a commitment to developing all children's science capital."* Given the criterion at the time, it is not surprising that children enjoying science was one of the discourses employed by my participants. For example, Miss Dean's school included the statement, "Children and adults enjoy science", as their final **principle**.

However, it is interesting to note that in some cases the science subject leaders linked enjoyment to other areas included in the Wellcome (2017a) description of primary science teacher expertise. Miss W recognised that while enjoyment was important, perhaps there were other important factors. During a forthcoming activity day, she expected to, "See all of the activities and that will give me a really good sense of buzz around science, and the language, and the enjoyment, and what children are learning, and how much they are extending their learning." Alice told me, "The children really enjoy it [Explorify]", then continued, telling me the school had a, "focus on improving scientific vocabulary and scientific reasoning skills". So, when she saw Explorify, "I thought right let's do this."

5.2.2.8 Learning outside the classroom

Wellcome (2017a) contend primary science teachers should include out-of-classroom learning as a strategy. The PSQM silver descriptor for the D2 criterion reads," *A programme of regular visits/visitors, outreach* *experiences and workshop activities is being developed for all classes to enhance specific science units/themes. Fieldwork is carried out in the local area and sometimes, beyond it. Contact by pupils and teachers, is made to other schools/community to enrich scientific understanding."* The PSQM criterion therefore includes visitors to supplement the out-of-class learning advocated by Wellcome.

One of the **principles** for Alice's school reads, "It is done outdoors – Investigations can be taken outside and involve nature and therefore real-life." Similarly, the **principles** for Mrs White's school included, "Children use a range of equipment and are working outside". Mrs Jones arranged a professional development experience on outdoor learning related to science. "We had outdoor learning training from an external company to use our outdoor environment because we secured a bid to get funding to improve outdoor learning environment and then we had the training on it." Mrs Peters' school employed a Forest School leader and the children regularly engaged with outdoor learning.

In addition to outdoor learning most of the schools arranged science-related visits for the children and arranged visitors from science-related industries to visit the school and talk to the children. Miss W told me, "This year I took year 5 and 6 to the science museum and I'm planning to do that again." Other visits were reflected on her river of experience. See Figure 11.

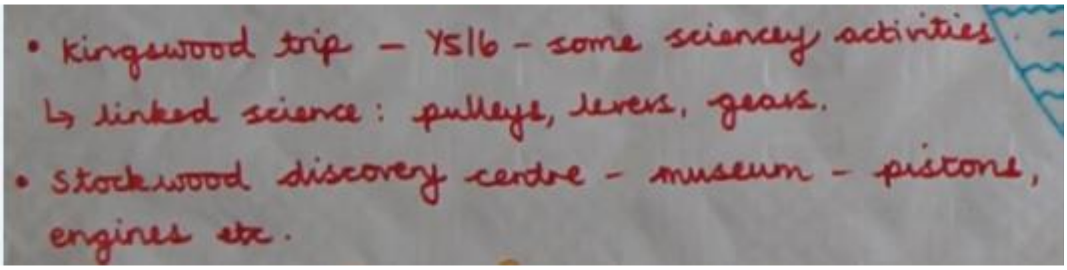


Figure 11 - Section of Miss W's river of experience

As another example, Miss W welcomed visitors from Mitsubishi Electric who ran a workshop for years five and six. Alice's and Mrs White's schools both received visitors from a local pharmaceutical company who shared practical activities with the children. The Rocket Man visited Miss Dean's school and launched a rocket in the playground. She proudly showed me photographs demonstrating the children's excitement. Mrs Collins told me that during a pupil voice activity she discovered children particularly liked engaging with the science visitors. Even once her submission was complete, Danielle was still seeking opportunities to involve outside organisations to enrich science teaching and learning. "I am still looking at science emails and visitors and outreach programmes and things."

Although not all subject leaders told me about outdoor learning, visitors and visits there was evidence at least some of these were happening in each school. Given the PSQM criteria they were aiming to achieve this is not surprising. However, the House of Commons Children Schools and Families Committee (2010) noted that children in the most deprived areas were least likely to experience learning beyond the school and this was true of Mrs Collins' school. This was the school with the highest measures of deprivation of the schools I visited. Although Mrs Collins mentioned a selection of visitors to the school, no visits, taking the children to places of scientific interest, were mentioned.

5.2.2.9 Independent and group work

Independent and group work are mentioned as appropriate teaching methods (Wellcome, 2017a), yet neither is mentioned explicitly in the PSQM criteria although both could be considered teaching and learning approaches (B2). Millar (2010:109) defines practical work as, "Any science teaching and learning activity in which students working individually or in small groups, observe and/or manipulate the objects they are studying." Thus, if the pupils are engaged in hands-on science enquiry (C1) they will be working in groups or individually.

Mrs Peters provided descriptions of group work she observed. For example, a visit to the reception where Isaac told her about the dinosaur bone his group were going to study or watching children in her own class carry out an open-ended task in groups. Alice's school included the **principle**, "It is collaborative – The children begin to understand the importance of working together with a shared objective", indicating the importance placed on group work in her school. Miss Dean's school had included, "Children are allowed to work with one another to explore and investigate", as one of their **principles**." Thus, while there was evidence of pupils engaging in group work to carry out investigations, the individual work mentioned by Millar (2010) and Wellcome (2017a) was not referred to.

Ofsted (2013b) discovered pupils typically work in groups thus restricting opportunities to carry out individual work and develop manipulative skills. Wellcome (2017a) include mention of both individual and group tasks but, although group work was evident in my data, references to individual work were not apparent in my data nor the PSQM criteria.

5.2.2.10 Digital technologies

Wellcome (2017a) include digital technologies in their list of suitable teaching methods for primary science and the PSQM B3 criterion includes, *"ICT is used as both a tool and a resource for teaching."* However, the PSQM bronze, silver and gold descriptors do not mention ICT. Despite this, use of digital technologies was mentioned during the interviews. Alice discovered Explorify, a digital resource for teaching she used herself, and persuaded her colleagues to use. Other subject leaders completed Reach Out CPD on-line training modules themselves and encouraged their colleagues to do the same. Mrs Jones contacted STEM Ambassadors through the STEM Learning website and arranged for them to visit the children and talk about science in their work. Thus, the subject leaders used technology as a resource.

Pupils having access to digital technologies was less evident in my data. Miss Dean told me pupils used iPads to record their learning during science days, but she was aware that although digital resources like Beebots, digital microscopes, visualisers and dataloggers were available, they were not being used because colleagues did not have the knowledge of how to use them. Mrs Peters briefly mentioned digital resources. "I think people have managed to step outside the box a little bit and try and use things like … data loggers … well they are there; we should be using them more." Overall, references to pupils using digital technologies were minimal, although it could be that examples occurred but were not mentioned during the interviews.

5.2.2.11 Cross-curricular links

PSQM criterion D1 includes, *"science supports and links with other curriculum areas",* however, Wellcome's (2017a) view of the expertise required by primary science teachers does not include making cross-curricular links. The extent of cross-curricular learning among the schools in my research supports the view there are many understandings of cross-curricular learning (Hayes, 2010). Miss W's and Mrs Collins' schools purchased the Cornerstones curriculum in which science and other subjects are taught using a topic-based approach. Alice's and Mrs White's schools developed their own topics. Mrs White specifically mentioned the topic of potions as an example. Miss Dean told me about links between her World War II topic and science but appeared to teach science lessons separately at times. Mrs Peters indicated science was incorporated where possible in topic plans. Mrs Jones and Danielle included a few examples where science had been linked to learning in other topics in their **portfolios.** The balance between cross-curricular and subject specific lessons varies across schools and there was negligible discussion of the benefits and drawbacks of each method and the times when each might be more appropriate.

5.2.2.12 Science linked whole school initiatives

PSQM criterion D1 also requires science, *"contributes to maximising whole school initiatives while retaining its unique status".* Each of my participants organised either whole school science days or a science week as well as science related assemblies. In addition, home learning tasks were sometimes set. The science subject leaders often employed these events as opportunities for colleagues to experiment with alternative pedagogies so they can be perceived as professional learning experiences, in addition to being of benefit to pupils. Despite its inclusion in the PSQM framework, organising science linked whole school initiatives is not mentioned in the list of expertise required of a primary science teacher (Wellcome, 2017a).

5.2.2.13 Talk for learning

Alexander (2006:30) states, "Discussion and dialogue are the rarest yet most cognitively potent elements in the repertoire of classroom talk", and Hattie (2012) concluded increasing dialogue is the most important factor in improving pupil attainment. The omission of talk for learning from both the PSQM criteria and list of appropriate pedagogies suggested by Wellcome (2017a) should be questioned. This is especially significant when we consider Wellcome commissioned the Explorify website that is described as a, "resource of engaging, creative science activities has been designed to spark curiosity, discussion and debate" (Explorify, n.d.).

Despite the omission from the PSQM criteria and the Wellcome (2017a) list of appropriate pedagogies many of the participants implemented pedagogies to support talk for learning. For example, Mrs Jones reported, "the teachers have said the children won't stop talking about it." Alice used Explorify to promote pupil talk and persuaded her colleagues to use it as well. Mrs Peters' whole school focus on thinking and reasoning led to numerous activities involving pupil talk. She noted how during one of the science days, "the children were engaging with reasoning skills." The context of the discussion and the age of the pupils involved indicated these were verbal reasoning skills. Miss W observed another teacher and noted, "Year two were doing mould on bread, so their science for that two weeks was let's talk about what is happening to the bread." At Alice's school the **principles** included, "Scientific enquiry by practical investigation is key.

Lessons are well planned and resourced, children are focused on the task, talking about what they are doing and can see the results for themselves." Further down the list they included, "They can talk about how they might improve their experiment." So, talk was a key feature of lessons that followed the **principles**.

5.2.3 Summary of section 5.2.2

Overall, the themes of the PSQM criteria were referenced by my participants in our discussions, even when my questions were not directly about them. Some of the criteria correspond with the expertise required by a teacher of primary science (Wellcome, 2017a), while others do not. Given the science subject leaders wrote their **action plans** and **reflections** with respect to the PSQM criteria it is to be expected that their discourses correspond to the PSQM framework. However, there are elements of good practice in primary science teaching and learning that were absent from the PSQM framework at the time my participants completed their PSQM submission. These elements were, in some cases, missing from the science subject leaders' discourses but not always. For example, talk for learning is explicit in neither the PSQM criteria nor the Wellcome (2017a) document, however some of the science subject leaders developed pedagogies to increase productive pupil talk. At the time of the interviews, science capital was not included in the criteria, yet Mrs Collins was aware of the lack of aspiration among her pupils, especially the girls, and to address this she was making pupils aware of female science role models.

5.2.4 Engaging in practice

Engagement in practice is the second of the themes to be explored (Lave & Wenger, 1991). Learning occurs through participation and, at the same time, apprentices are both absorbing and being absorbed in the "culture of practice" (Lave & Wenger, 1991:95). Some of the many and varied ways the participants engaged in practice are referred to as part of their stories and included in their rivers of experience (see appendix U). These vary from events like attending PSQM training sessions, to activities like Danielle's parent and child workshop involving the whole school community.

Projects are most successful when teachers take an active approach, referred to as "leadership as activism" (Muijs & Harris, 2006:964), and, the number of activities participants initiated demonstrates this active approach. It was not just the science subject leaders who engaged in practice, in each case they initiated and organised community building activities for children, other school staff, parents, governors and other organisations, leading to professional learning and changes in identity. The extent of these changes to the identities of other members of the wider schools' communities presents an opportunity for further research.

The active participation of the science subject leaders was extensive. Miss Dean was clear about the impact across the whole school but also noted the extent of her own participation. When asked if she would recommend PSQM to other science subject leaders. She replied,

> Yes, because it has a great impact on the school, and the children and the teaching, and every aspect you could possibly think of, and yes it has been a lot of work, but if you want something to be successful you have to work hard at it and there are no quick fixes. There are parts that have frustrated me and that I think could be less time consuming, thinking about teachers who are also

> in the classroom and have three million other jobs to do, but at the end it is the children that are important and it has done the world of good for them so yea, I would.

Mrs Collins also took the view that to gain the maximum benefit a high level of engagement was necessary.

> I think it [PSQM] could help anybody, but I think they have got to be willing to fully participate in the process. I don't think it is something you can do half-heartedly. I think if you are keen on learning how to improve your subject you would benefit the most because you are putting the same amount of effort into it as the PSQM would do for you.

This section discusses engagement in practice, but engagement is also one of the three modes of belonging (Wenger, 1998). There is considerable overlap between the two, so additional examples of engagement in practice can be found in the section on engagement as a mode of belonging starting on page 149.

The science subject leaders engaged in each of the four main workplace activities resulting in learning: participation in group activities; working alongside others; tackling challenging problems; and, working with clients, if I substitute pupils and parents for clients (Eraut, 2004). The five conditions for workplace learning (Hoekstra et al., 2009): teachers' autonomy; teacher collaboration; reflective dialogue; receiving feedback; and experience of shared norms and responsibilities within the school, were also present. Although there is some evidence of reflective dialogue the evidence for reflective writing is stronger as participants wrote their reflections on each of the PSQM criteria. The experience of shared norms was, to a large extent, through the negotiation and implementation of the **principles** of science teaching and learning which, in each case, was negotiated with all teachers, sometimes with input from other members of the schools' communities.

5.2.5 Apprentices, Masters and Mastery

The third theme (Lave & Wenger, 1991) relates to the roles of masters and apprentices, and the location of mastery in the community of practice. The science subject leaders in my study brought a range of experiences to the role but generally could be regarded as apprentices in the broad primary science community of practice, as conceptualised by Lave and Wenger (1991). However, there are two crucial differences. Firstly, most had at least a few years' teaching experience, so, apart from Miss Dean and Alice, my participants could not be regarded as apprentice classroom teachers. Secondly, once they had attended the first PSQM training session they assumed the roles of masters within their own schools. Lave and Wenger (1991:91) acknowledge the, "roles of masters are variable across time and place", and, note participation at multiple levels is possible. This is clear from the science subject leaders' unique experiences and their dual roles as apprentices within the broad primary science community of practice but masters in their own schools.

Some science subject leaders had prior experince leading one or more other subjects, but experience leading one subject does not mean it is automatically possible to lead another subject (Spillane, 2005). Different subjects require different skills. However, despite limited experience and knowledge of primary science subject leadership, science subject leaders fulfilled the role of master within their school because, "mastery resides not in the master but in the organisation" (Lave and Wenger, 1991:94). In this case, mastery resided within the PSQM framework and criteria, and in the broad primary science community of practice. Additionally, based on the activities completed during PSQM training session one, the science subject leaders had sufficient access to 'mastery' enabling them to work with their colleagues to complete the activity and agree the school's **principles**, conduct a pupil voice activity and complete their initial self-evaluation of science teaching and learning. Each of my participants completed these tasks relatively early during the PSQM year as recorded in their **subject leader logs,** sending a clear message that mastery was accessible within the school. Evidence of their development from apprentice towards master in the broad primary science community appears in their talk and language. (See page 97).

Apprentices require access to a, "field of mature practice of what they are learning to do" (Lave & Wenger, 1991:110). They can access this through the PSQM hub leaders who could be regarded as masters since they are, "PSQM-trained experts in primary science" (White et al., 2016:9). It is the hub leaders who usually introduce the subject leaders to the organisations and discourses of the broad primary science community of practice.

However, the hub leaders were rarely mentioned by my participants, and when they were, it usually occurred in response to a direct question. In fact, Mrs Peters even states, "PSQM doesn't give you much", yet, when she discusses the changes to her confidence plus her teaching and leadership skills (see sections on Leadership and Teaching, page 135) she clearly regards these changes as considerable. Thus, she exemplifies, "Opportunities for learning are, more often than not, given structure by work practices instead of strongly asymmetrical master-apprentice relations" (Lave & Wenger, 1991:93).

5.2.6 Learning and curriculum

A teaching curriculum which is "constructed for the instruction of newcomers" (Lave & Wenger, 1991:97), can be distinguished from a learning curriculum, which is situated and provides opportunities for developing practice (Lave, 1989). As one of his principles of effective professional development Gilbert (2010) included the view that learning should be a social activity with groups working together to attain a common goal and direct instruction should be limited. The PSQM **action plan** created a learning curriculum related to the teaching and learning of science. Science subject leaders involved their communities in working towards common goals. However, some direct instruction took place through external and Reach Out CPD, or was provided by the science subject leaders, in the form of staff meetings.

Evans (2019) claims the impact of collaborative and interactive learning is greater than the impact of a more didactic approach but the participants in my research facilitated both. They initiated increasing participation in science activities in their school communities, as well as addressing the perceived development needs of their colleagues through direct instruction either in staff meeting or more informal discussions with colleagues. Thus, they co-participated with colleagues, and sometimes other members of the school community, in addition to providing more directed activities to enhance the skills and knowledge of their colleagues.

In writing their **action plans** to achieve the PSQM criteria, science subject leaders created their own unique learning curriculum. For example, Mrs Jones redesigned the school's science lesson plan format to include sections for vocabulary, skills and resources. Danielle created a slip to be stuck in books where children or teachers could tick which type of science enquiry had been included in the lesson and which of the **principles** applied. Mrs Peters introduced half termly science days because she thought previous science weeks did not maintain momentum over the year. Through monitoring, they ensured changes in practice they introduced were implemented in classes across the school. Thus, following direct instruction, the focus for professional learning then became active participation. Cordingley et al. (2015:13) state a "rhythm" of "follow-up, consolidation and support activities", are contributary factors in ensuring the effectiveness of professional development activities. Regular monitoring activities, with subsequent actions, where necessary, ensured the effectiveness of direct instruction. This view is supported by Hager (2005) who believes participation alone is not able to account for all learning. My data provides evidence that through a combination of professional learning experiences with subsequent opportunities to embed their learning in practice, both science subject leaders and their colleagues were able to improve their practice.

Examples from Miss Dean's experience are offered here to demonstrate the extent to which science subject leaders increased participation for others in their school communities. In some cases Miss Dean employed direct instruction to make colleagues aware of the changes in practice she wished to implement. Other participants used different strategies to influence their colleagues' practices. Further examples can be found in the section on Engagement (see page 149).

Miss Dean planned and implemented a whole school science day, at the start of which, "different components for experiments" were laid out. It was then up to the children to decide which to use to investigate their own questions. They spent the rest of the day carrying out their investigations, and the next day presented their findings to governors and parents at a science fair. She believed this event was crucial in, "shifting that mindset" away from teacher-led investigations and formal recording strategies. Through active participation, learning for both teachers and children was evident. This also exemplified how pupils might develop their own learning curriculum.

In addition to examples of activities that engaged pupils, Miss Dean also engaged colleagues to meet their development needs through on-line CPD and team teaching. She made colleagues aware of the Reach Out CPD website where teachers can complete 20-minute CPD modules on a choice of topics related to the science curriculum. "So, we have had several staff members logging onto there now and they have emailed back saying that you that is really good, and it is. It is perfect just for a quick brush up." Thus, teachers were able to determine their own needs as learners and respond using Reach Out CPD to strengthen their subject knowledge.

Miss Dean also jointly planned and presented science lessons with her colleagues and then discussed what went well afterwards. This intervention was effective as an example of collaborative and interactive learning (Evans, 2019). By demonstrating the pedagogies she was promoting, she had started to change her colleagues' practices. In addition, she felt she had learned from them. Whether team teaching can be regarded as co-participation or acting on the person to be changed is open to debate, but Miss Dean was pleased with the resulting improvements. "The teachers are doing everything that I have asked of them, so they are letting the children have a bit more freedom." As evidence she provided an example from her visit to the reception class where children had made a discovery. She reported Isaac told her, "It was very smelly because … this morning we found a dinosaur bone in our classroom. It was very big and now we are working out which dinosaur it came from by doing measuring."

Miss Dean also highlighted the participation of three children from her class whom she appointed as Science Ambassadors (SAs). Their engagement and learning resulted from increased participation of both themselves and others as they visited lessons, speaking to children in other classes about their science learning, wrote reports on their visits and organised a whole school science day. "I think in the same way my leadership role has developed, theirs has as well." She described the SAs as, "not the most sociable and they sometimes struggle when there is unstructured time in the playground; lunch time; break time. If they have got free time in the class, they are the ones that struggle to mix a little bit." She tasked them with planning a whole school space-themed science day; an opportunity for them to learn through participation.

> So now this has given them a real focus, a real purpose and, actually, everyone in the school is going to be doing what they say, because it is their day, and they have made it up. So, it has given them a real confidence boost. They know the curriculum inside out for every year group.

After the day she reflected, "It was just a really good day; they did a stunning job organising it." Miss Dean stated, "that has probably done them the world of good actually going up to secondary school." A further example of effective professional development (Gilbert, 2010), but this time applying to the SAs.

"Learning understood as legitimate peripheral participation is not necessarily dependent on pedagogical goals or official agenda, even in situations in which these goals appear to be the central factor" (Lave and Wenger, 1991: 113.) While the PSQM has an 'official agenda' in that certain core documents must be submitted, and the **action plan** and **reflections** need to address specific criteria, the ways in which schools address these criteria are diverse, as can be seen from the participants' stories. (See appendix U.) Professional learning resulting from a combination of direct instruction and legitimate peripheral participation was unique to each school's science community of practice.

Thus, science subject leaders participating in my research were guided by the PSQM criteria to create a learning curriculum for themselves and other members of their school communities. Their **action plans** consisted of multiple situated opportunities. In addition, direct instruction, was provided by subject leaders to make colleagues aware of the changes they wished to make.

5.2.7 Legitimacy and access

Numerous affordances and constraints, in terms of legitimacy and access for the science subject leaders, were revealed in the data. As I consider them to be apprentices in the broad primary science community of practice, and masters in their school's science community of practice, I will consider separately their legitimacy and access in each of these communities.

5.2.7.1 Legitimacy and access to the broad primary science community of practice

Participating in the PSQM programme gives both legitimacy and access to the broad primary science community. Legitimacy within a community of practice is achieved through, "acceptance by and interaction with acknowledged, adept practitioners make learning legitimate" (Lave & Wenger, 1991:110). PSQM training sessions with hub leaders provide access to, and interaction with a hub leader who assumes the role of master, thus giving legitimacy to the subject leaders' participation and learning. Through information gleaned from the PSQM hub leader, training, website and other information, the science subject leaders were granted both access to and legitimacy within the broad primary science community of practice.

Some participants sought further interactions with adept practitioners. For example, Alice interacted with other organisations forming part of the broad primary science community by reading their publications, acting on the content and attending the ASE Conference. When she previously completed a PSQM, as part of a local authority project, Mrs Peters had gained access to the discourses of the broad primary science community of practice through additional CPD funded by the local authority. She bemoaned the fact that it had not been available the second time. "I would say the one thing I have missed this year is PSQM training. It was having those practical sessions and giving ideas. By only having the two we have not really had the chance to explore."

Legitimate peripheral participation should also offer the potential for learners to evaluate themselves (Lave & Wenger, 1991). One of the actions subject leaders completed during the first training session was to evaluate science teaching and learning across their school against the PQSM framework. This had the added benefit of creating or improving their awareness of the values and discourses of the broad primary science community of practice as presented in the PSQM criteria. Cordingley et al. (2015) include the requirement that professional development activities should be perceived by the participants as relevant, supporting teachers at different point in their careers. It is through evaluation against the PSQM framework that science subject leaders identify their own needs as well as those of their colleagues and pupils and ensure they are addressed when action planning, making the actions relevant to the needs of the members of the school community.

Implementing the **action plan** over the year enables science subject leaders to achieve the criteria for their chosen quality mark and provide evidence of this for the submission. **Reflections** are written at the end of the year to evaluate their success in meeting the criteria. So, evaluation is required at both the start and end of the PSQM process.

Apprentices should not be subjected to, "tests, praise or blame" (Lave and Wenger, 1991:111). However, PSQM reviews could be regarded as a form of 'test' because evidence is 'judged' to decide which quality mark is awarded. Reviews are typically written praising the progress made in developing science teaching and learning, and, provide suggested next steps to address areas for development. The importance of receiving feedback is also highlighted as a condition for workplace learning (Hoekstra et al., 2009). Science subject leaders received praise and reification from within their school communities which will be discussed further in the section on identity as negotiated experience (see page 129). While Lave and Wenger consider there is an absence of praise for apprentices, Wenger (1998) notes the importance of reification when considering identity as negotiated experience. While reification and praise are not synonymous, I believe there is enough overlap to identify a contradiction between the assertion that there is a lack of praise and the importance of reification (Wenger, 1998).

Mrs Jones and Miss W both arranged for the local primary science adviser to provide training during INSET days or staff meetings. This provided direct instruction and access to the broad primary science community of practice for the teaching staff. In other schools this was not possible because of budgetary constraints. Danielle, for example, thought she would have benefited from additional science CPD but noted the school had no budget. Mrs White told me, "I can usually go on a course if it's free." Thus, the access to adept practitioners in the broad primary science community of practice was restricted in schools where there was insufficient budget. The science subject leaders were then reliant on access to the broad primary science community of practice through the PSQM framework, online and printed resources. Time out of class to explore such resources also limited their access. This will be considered along with time out of class for other subject leadership responsibilities (see page 113). Alice thought PSQM had helped her find her way into the primary science community. "I think a lot of the funding, where people have said you can have free ASE membership, or you can have a free, we will pay your expenses to go here. When you mention PSQM they are like, oh yes we will support that."

Some of my participants indicated that speaking to me during their PSQM year had supported access to the broad primary science community of practice. Unprompted Miss Dean told me,

> So, I think having you here and knowing the process as well as you do and knowing the subject as well as you do, it has triggered me to think more than I would if somebody just came in and asked me a few questions about what they thought they knew about science. So, I think having your subject knowledge and your involvement with the PSQM process has made me think… which is good.

Because the opportunity to participate in research of this sort is not typically available to science subject leaders embarking on the PSQM, it will not be considered in detail, other than to note my participants had a different experience to others participating in the PSQM. I reiterate that no claims of generalisability are made.

5.2.7.2 Legitimacy and access within each school's community of practice

Regarding legitimacy and access within their own schools, my participants were aiming to raise the profile and quality of science teaching and learning through gaining the legitimate peripheral participation (Lave & Wenger, 1991) of other members of their schools' communities. "Depending on the organisation of access, legitimate peripherality can either promote or prevent legitimate participation" (Lave & Wenger, 1991:103). Other members of their schools' communities therefore needed to regard science as a legitimate subject for development and the science subject leader as legitimate in her role. Bell (1992) notes the influence of the perceptions of other staff in school, and numerous examples of the ways the science subject leaders were reified by other members of their school communities are discussed below in the section on Identity as negotiated experience. (See page 129).

Science subject leaders also require access to various resources in order to promote participation and learning throughout their school communities. Such resources might include time out of the classroom to monitor science teaching and learning, staff meeting time to provide CPD for colleagues, having an ethos in schools where staff are supportive, and having a budget to pay for external CPD and for replacing and enhancing the range of science equipment. In summary, three contextual factors may mitigate against effective subject leadership: confidence, time and money (Hammersley-Fletcher and Brundrett, 2005). These, plus other factors, were apparent in my data, for example the support of senior leaders and colleagues. Each of these factors will now be considered.

5.2.7.2.1 Budget

Hargreaves and Shirley (2012) believe that sufficient funding should be available to meet the aims of quality and equity. However, a survey showed that lack of budget was the main barrier to the effective teaching or leading of primary science (Wellcome, 2016). Analysis by the National Education Union (2019a) shows that between 2015 and 2020 the average cut in funding per primary pupil was £245, and lack of money available to pay for CPD and other resources was mentioned by some of my participants. The impact of lack of budget for CPD for the science subject leader has already been mentioned, but lack of funds also impacted the ability of subject leaders to arrange external CPD for their colleagues.

When funds limit opportunities for teachers to attend CPD then the quality of that CPD becomes increasingly important. Cordingley et al. (2015) assert that subject specific CPD is more effective in raising pupil attainment than generic pedagogic CPD yet, the House of Commons Education Committee (2017) found much of the CPD available to teachers was generic and driven by legislation or regulations, rather than subject specific. PSQM increases demand for science subject specific CPD, with those science subject leaders doing PSQM more likely to access subject specific CPD than other science subject leaders (Leonardi et al., 2017). While recognising the value of CPD for her colleagues, Mrs Peters was aware funds were limited so introduced them to Reach Out CPD. "One of interest per term, just so they have got that little bit of CPD, because there is not a lot of budget for them to go elsewhere."

In some schools, budget was available to purchase additional science equipment. For example, the head teacher at Miss W's school made budget available for new science equipment for the Early Years classroom and a box of science kit for the children to use at playtimes. Where the central school budget was restricted teachers found other sources of finance for equipment. Mrs Peters approached the PTA for funds to purchase new equipment and some experiences like hatching eggs, watching caterpillars change into butterflies, and a wormery. A grandma at Danielle's school worked for a local pharmaceutical company which offered grants. Together they applied for and received a grant of £500 for new equipment. So subject leaders found other ways to fund additional resources but did not find alternative methods to fund CPD or time out of class.

5.2.7.2.2 Time available for teaching and subject leader responsibilities

Time is needed, as noted above, to access the broad primary science community of practice, but it is also necessary to organise opportunities for participation in science activities for the whole school community. Hammersley-Fletcher and Brundrett (2005) noted there were already too many demands on the time of a class teacher without taking on additional subject leadership responsibilities and, unfortunately, budgets limited the availability of time out of class, as discussed above. Mrs White told me, "We used to get time out on a Friday afternoon … but because of budget cuts that has been stopped as well, so anything I do is in my own time." Miss Dean was also mentioned this as a concern. "We don't get any release time for subjects unless you are on the SLT." However, during her performance management meeting she mentioned she needed some release time to complete her PSQM actions and documentation, and the head agreed.

Those who were entitled to time out of class for their subject leadership role seemed to view it as good fortune rather than an entitlement. Miss W stated, "We're really fortunate here, you get subject leadership time", and Mrs Collins said, "I think I am quite lucky where we are given that time. It makes a real big difference."

Mrs Peters told me she and other subject leaders, "Generally get an afternoon every term, and sometimes every half term. It really depends, so we do have time for book scrutinies and things like that to move it forward, and obviously staff meeting times are built in for me as well." However, she was reluctant to take too much time away from her "difficult class". "I go out and they're off the ball, so it is difficult and when we do take time out of class, TAs then have to cover, and I don't feel it's fair on her either." In this example it was not the head teacher restricting the release time.

Completing the PSQM documentation was one of many demands on the time of the science subject leaders, and in some cases competing demands caused stress. For example, the wider demands of being a year six teacher increased pressure on Mrs Collins. During the year she took on other responsibilities, including the mentoring of two Newly Qualified Teachers (NQTs) and a School Direct student. Following the departure of the subject leader for history and geography she took on the leadership of these subjects. Taking on multiple roles was one of the issues hindering science subject leaders mentioned by Hammersley-Fletcher (2004). While Mrs Collins considered herself fortunate to be given two half days each term to carry out her subject leadership responsibilities, this was insufficient to cope with the workload. She felt under pressure that her class should achieve well in their SATs, including two new pupils who spoke no English but were expected to reach age-related expectations in their English SATs a few month later. She was also getting used to the new maths scheme and the Interim Teacher Assessment Framework (ITAF), running a breakfast club from 8am each morning, and applying for Education, Health and Care Plans (EHCPs) for three children in her class. Her teaching assistant had also taken time off work due to sickness. Hammersley-Fletcher and Kirkham (2007) noted the negative impact of centrally imposed initiatives on teachers and subject leaders, and the ITAF and EHCPs provide examples of these.

> I will admit this has been the worst teaching year I have had in my career. I have been stressed. I have been grumpy. I have been crabby. I have snapped at my class and I have taken it out on them, and I have not given them my best because of the pressure I am under. I was told I needed to get 23 out of 28 to greater depth in reading – no chance.

Mrs Collins represented this time with a picture of herself drowning in her river of experience as sharks circled (Figure 12). She sought help from her head teacher who allowed her two afternoons out of class. She represented this as a life belt which then enabled her to get in the boat and continue in, "the right direction".

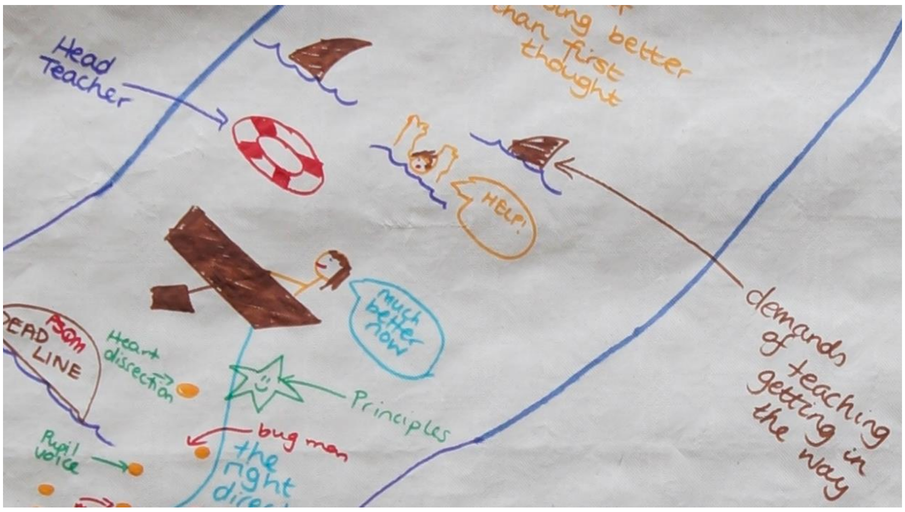


Figure 12 - Section of Mrs Collins' river of experience

Muijs and Harris (2006) note the mechanisms for accountability may adversely impact effective leadership and the pressure to achieve good results in the pupils' SATs have been a factor impacting on the wellbeing of Mrs Collins, reducing her effectiveness as subject leader. Many of the characteristics of GERM (Sahlberg, 2016) are apparent in her experience.

Other participants were also aware of the many competing demands on teachers. Alice recognised the potential of the workload to lead to mental health issues. She thought working towards PSQM gold substantially increased her workload. "It has been a very busy year. I would not advise anyone to carry on at this pace because you could burn out." To collate her PSQM evidence, "I worked on it solidly this weekend."

Miss W explained how hard she worked and that other teachers were doing much the same.

> I still work very, very long hours. I leave the house at seven, and I don't get home till half seven, and quite often I work for a couple of hours when I get home. I work at the weekend. I work most of Sunday that's standard. I'm not unusual in that I know that.

She explained the many competing pressure on her time.

> The trouble is that I am acting deputy, so I have got a lot of that stuff as well. My supervisor at uni for my masters will say to me, well come on you need to get me some writing, and I think yes, but my PSQM deadline is before that … So yes, it is quite challenging because I have got my final [assignment] due in August. This is March and I'm getting married on the first [of April], so it's just kind of too much. So, it is difficult to know what order to go in, but I have submitted a first draft of everything… I have also finished planning science week which takes place next week.

She also described herself as stressed, reflecting the high levels of stress in the teaching profession (Innstrand et al., 2011).

> I distinctly remember saying to my other half that I was stressed and the reason I was stressed because I didn't feel like I was doing anything well. I am managing everything … I am not doing anything well … I don't like to be like that.

Despite being under pressure herself, Miss W was aware of similar pressures on her colleagues and tried to be reasonable in her expectations. "Actually, I really want to do that now, but I am not going to. I am going to hold fire with that one." Miss Dean also empathised with her colleagues who had pressures from many other sources. "I know what I am like when other subjects want me to do something, and then you have also got the other three thousand things to do."

Mrs Jones was unique among my participants because she worked part-time which presented both challenges and benefits. "I am two days a week and that's really hard for me." However, she found a solution to her own lack of time in school by working closely with the subject leader for mathematics who was a presence representing science leadership in school in Mrs Jones' absence. "We are both feeding each other with leadership knowledge on both the subjects, and we have done team teaching together … and be critical friends." "She said that she feels she understands more about the science curriculum and I understand more about maths. So, we have helped each other really." Thus, she turned lack of time from a constraint to an affordance.

Bell (1992) noted the combination of pressure on science subject leaders time, while coping with responsibility for their own classes, and other responsibilities within school. Despite these pressures, all the participants managed to create opportunities for their colleagues, and other members of the school community, to have access to and become legitimate peripheral participants in their school's science community of practice benefiting, from the associated learning. Although many of them were provided with release time, the process of creating the documentation for their PSQM submission required a huge personal commitment with many of them mentioning this as a stressful time. Campbell and Neill (1994) noted the additional pressure that subject leadership activities would place on already busy class teachers and my participants provide evidence this issue remains unresolved. The pressure is further intensified when the creation of PSQM **action plans** and other core documents are added to their responsibilities.

5.2.7.2.3 Time to fit science into the curriculum

Time for teaching and leadership responsibilities were not the only factors restricting opportunities for teachers and children to participate in the school's science community of practice. A survey commissioned by Wellcome (2016) listed lack of time and curricular importance second in barriers experienced when teaching or leading science. Leonardi et al. (2017) found 58% of primary schools in the UK taught science for less than two hours each week; the OECD average. Other curriculum areas and their subject leaders were all competing for curriculum time. This problem was particularly acute for Miss Dean, who worked in a Catholic school because, each week, three hours were devoted to teaching religious education (RE). "Because we teach so much RE it is so easy to just sweep everything else under the rug." Alice also noted the competing demands on curriculum time, "It's just trying to fit it into a school day is frustrating," and she noted other subject leaders were also trying to ensure coverage and quality teaching of their subjects. Thus, competing demands for curriculum time restricted access to science activities for both teachers and children.

5.2.7.2.4 Support of SLT and governors

Despite their struggles to find time for science teaching and learning, the science subject leaders I spoke to generally regarded the schools' leaders as supportive of their efforts. Hammersley-Fletcher and Brundrett (2005) claim there is a tension between subject leaders' desire to lead and head teachers being willing to relinquish their power, however, for my participants, this did not appear to be an issue.

Danielle felt she had the support of the senior leadership team when she needed it and this managing and organising role of senior leaders was highlighted by Cordingley (2008) as an important factor in ensuring the effectiveness of CPD. Danielle described how she had woken up in a panic and because she was behind with completion of her **logs**. She told her head teacher who responded by finding cover for the class so Danielle could have an additional hour out of class each week leading up the final PSQM submission deadline.

Others felt they were supported and trusted by their head teachers. Mrs Peters credited, "Having really good support in my head and governors and PTA and staff here as well. Having all that support definitely. I suppose with people feeding ideas that I can cling on to and run with and expand."

Alice described her head teacher as, "one of those people who says if you have got an idea, there you go, you get on with it." While Alice was happy with the extent to which she was supported by the head teacher, she wished this had extended to greater support from the governors.

> It might have been useful to have one governor, who was tasked alongside me, with the PSQM process … perhaps it would have been useful to say, right, we will have someone assigned to be PSQM person on the governors and that would have been a good thing.

The School Development Plan (SDP) is written by the school's leaders and records the school's priorities for strategic development, thus is a crucial document for school leaders in determining their priorities. Having science on the SDP was helpful for Mrs Jones because it ensured cover was available so she could leave her classroom to engage with subject leadership activities. It also meant the head teacher was willing to pay her for additional hours if she came in to carry out subject leadership tasks on her days off. In a different way Mrs Peters also considered she benefited from the inclusion of science in the SDP.

> I think the school development plan has helped because one of the main points was thinking and reasoning, and science and maths were mentioned in it. So, I think generally as a whole school ethos that has changed which has helped drastically with the science teaching.

Overall, the participants considered the support from their schools' senior leaders was forthcoming and helped members of their schools' communities access the schools' science communities of practice.

Ofsted (2006) believe too few senior leaders are explicit in stating the desired outcome of professional development experiences and the required measures of success. While some of my participants had achieving a PSQM as a performance management target they did not mention more specific targets related to the teaching and learning of science. Each set her own agenda or learning curriculum based on her knowledge of the school and the requirements of the PSQM criteria. In this case it was the science subject leaders who specified the desired outcomes of the professional development experiences and the related measures of success, if any.

Cordingley et al. (2015) contend school leaders have four key roles in enabling effective professional development. The first is in developing a vision and alternative views of pedagogy and curriculum. However, it was the subject leaders who initiated the PSQM **principles** activity to create a school vision for science teaching and learning. Hargreaves and Shirley (2012) also highlight the importance of a shared vision. The science subject leaders also implemented more child-led science enquiry and other changes to pedagogy and curriculum.

The second key role (Cordingley et al., 2015), is managing and organising the time and funds for teachers to take part in professional development episodes. In some cases, it was the head teacher who proposed the school should work towards gaining a PSQM while in other instances it was initiated by the subject leader. The extent to which the head teacher made both funds and time available has been discussed.

The third key role of school leader is to model professional learning and encouraging teachers to consider their own effectiveness and future development needs (Cordingley et al., 2015). While the senior leaders may also have done this, each of the participants also took part in professional development experiences and shared some of these with colleagues during staff meetings. Some, for example, Miss W and Mrs Jones were able to arrange for an external expert to facilitate CPD while others introduced their colleagues to Reach Out CPD or ran their own staff meetings where funds were not available. The monitoring activities they carried out led to the identification of future development needs both for themselves and their colleagues. Thus, they modelled professional learning and worked with colleagues to identify areas for development.

The final key role for school leaders (Cordingley et al., 2015) is to lead colleagues to develop curriculum or pedagogy. The science subject leaders did both through providing training in staff meetings and supporting colleagues individually. Cordingley et al. (2015) found minimal evidence for the effectiveness of the cascade model of professional learning. However, where subject leaders cascaded training to their colleagues, they later found evidence of the impact. For example, at the start of the year Mrs Peters aspired to change the thinking of her colleagues and encourage them to try new things. Due to support she offered, she thought that by the end of the year her colleagues were allowing children more autonomy in asking questions and deciding their own ways to answer those questions. Later she reported, "staff have said how it is much more easy to see them working scientifically through the open-ended tasks which is what I've been saying." So, in this instance, and for other schools involved in my research, the cascade model was regarded as effective.

Based on Cordingley's four roles for senior leaders the science subject leaders were able to fulfil most of these. They therefore assumed roles typically performed by more senior leaders. This is not to say that their head teachers were not supportive, but it provides evidence that PSQM facilitates teacher leadership. Without legitimacy and access this would not be possible.

5.2.7.2.5 Support of colleagues

Having considered the extent to which the schools' senior leaders were supportive, it is also appropriate to consider the support of other colleagues. Muijs and Harris (2006) believe this is important in the development of teacher leaders. Effective professional development includes opportunities for learners to form a mutually supportive group and such support allows or restricts access of others, primarily children, to increasing peripheral participation in the school's growing science community of practice (Cordingley et al,. 2015). Various factors affected the extent to which the science subject leaders' colleagues were able to access the school's developing science community of practice and become legitimate peripheral participants. Generally, the science subject leaders thought their colleagues were understanding and supportive of their efforts to improve science teaching and learning, however, vocalised support for certain activities did not always translate into actions.

Miss Dean considered having supportive colleagues was part of the school's ethos.

> I think as a school we are naturally helpful and cooperative with one another. I think what really helps is because we are such a small school. There are some teachers who have two subjects to lead, and everybody is sinking at some point and I think there is that understanding that we are a small school, me being new to subject leadership as well, I think people have tried to help as much as they can, especially being put in year six.

Miss Dean's words are also indicative of, "shared norms and responsibilities within the school", that Hoekstra et al. (2009:280) identified as a condition for workplace learning. When Miss Dean was gathering evidence for PSQM she was particularly impressed by the support from her colleagues. "There were constantly people coming in and saying, especially if I had release time coming up, like what can we do to help, and things like that which is really nice." She did however note that even in such a supportive environment there are many competing pressures. "I have been lucky to be in a school where people do get on with each other and listen and support each other … but that doesn't mean it gets any easier to raise your voice in the first place, because it would be very easy to go with the flow. "

For others, although colleagues were supportive, other factors such as staff turnover mitigated access to colleagues to support legitimate peripheral participation for the whole school community. While Alice considered, "I think there has been lots of collaboration between the teaching staff to make sure we do everything", one new teacher needed support. "I don't think she's quite on with it yet. But she has been doing a lot practically." Others also experienced staff turnover as an issue reducing the impact of support offered to colleagues. Miss W repeated staff training on science enquiry because, "We have had lots of people leave … and some that were on maternity leave have come back, so we did that again." Mrs Collins felt staff turnover restricted her ability to implement changes to science teaching and learning across the school. "We have got a lot of staff movement due to visas. So, I think at the moment, it is securing our staffing base and then maybe in the summer, moving on."

Mrs Jones thought other pressures on colleagues meant they were not always able to follow through on their good intentions and so she took responsibility for reminding them. "Everyone is really helpful at the time I asked them, but then they forget. So, it is about them remembering, but it is not their responsibility to remember. It is my responsibility to chase them, so I am chasing them." This therefore increased her workload in chasing up her colleagues. Similarly, Mrs Collins was aware of the many demands on colleagues' time and the way this impeded her ability to support them to develop science teaching and learning.

> There is never just going to be 'we are just focussing on science this year', because obviously us teachers are always focusing on absolutely everything and obviously something has to give, and I think for a lot of members of staff, because they don't run science and they weren't doing the award, it wasn't at the forefront of their mind.

Miss W was the only participant who was also a member of the SLT which led to unique challenges. She felt it necessary to invest time in building relationships, because her colleagues were reluctant to talk to her.

> Building that relationship and getting people to realise that OK, I am a leader, and I might be SLT, but I am still your colleague and you can still talk to me. It's fine and you are not going to get told off. I might have to have difficult conversations with them like, oh, I can't see any marking in your science books, but nothing bad is going to happen and that really helped. It should be obvious really, I suppose, but you have to work harder at it as a member of the SLT than you do as a teacher.

So far, I have considered colleagues within school, but in the context of PSQM other members of the hubs could also be regarded as colleagues. Potentially there were opportunities for further mutual support within the hub. A desire for greater access to this forum might have led to increased effectiveness of the professional development experience (Cordingley et al., 2015). Mrs White thought more regular meetings with the hub leader and others in her hub would have been helpful. "Just the chance of getting together with other people who were doing it on a more regular basis and talking through what problems they were having, or what sort of things they were doing would have been helpful." Danielle agreed more support from other science subject leaders would have been useful. "I think we could have got a lot from each other which is something we never done [did], and I wish we could have done that, but there is only so much time."

Cordingley et al. (2005) noted the impact of collaborative activities was greater than the impact when only individuals participated. Collaboration is also highlighted by Hoekstra et al. (2009) as a condition for workplace learning and by Muijs and Harris (2006) as a condition for teacher leadership. Although my participants expressed a desire for more collaboration, both within the PSQM hub, and from colleagues, in providing evidence for the PSQM, collaboration in developing the teaching and learning of science was evident within schools, for example, in the development of the **principles**. The impact of collaboration is clear from both the interview data and the evidence submitted to the PSQM for review. Lave and Wenger (1991) state the focus within a community of practice should be on increasing engagement in practice and all my participants engaged their colleagues in developing their practice in teaching primary science.

The legitimacy granted to science subject leaders by their colleagues enabled collaboration, and working towards a recognised award also provided legitimacy.

5.2.7.2.6 Working towards a quality mark

Billett and Boud (2001) contend agency is important for those engaging with professional development experiences because it influences the extent of their learning and the degree to which they can transfer their learning to change their work practices. Fraser et al. (2007) also claim teachers need autonomy or agency within a school ethos of collaboration, and, working towards a quality mark appeared to provide this. Miss Dean told me,

> I think going for an award gives you a better status in school, because actually if you are not going for anything, then you are just doing it because it is that subject, because you want to do it, rather than something the school is going to gain for altogether.

Danielle used analogies to explain how PSQM helped her make her voice heard.

> So, I think rather than stand at ground level and shouting, it was a platform so that your voice is heard a bit more and I think science wouldn't look how it does now without PSQM… It almost puts you up, not on a pedestal, but it raises you a little because any time a child thinks of science they think of [me]. So, it raises your profile as a teacher.

Alice thought working towards a quality mark extended the range of activities she initiated. "So, you push to always do something a bit different, find things out that you wouldn't normally do", and Mrs Jones also thought something similar. "I don't think we would have come as far as we have if we had not done the PSQM for sure." "I would have probably had half the ideas and achieved half the amount." "My view was like if you are a really good subject leader anyway you will be doing these things, so it won't be brand new, but I've done more."

Hammersley-Fletcher and Brundrett (2005:74) claim, "that in order to have an active involvement in distributed leadership schools need some method to force staff 'out of their nest'. This results, as one subject leader put it, '… in being allowed to fly …'". Mrs White was perhaps the most reluctant to fly and initially resented the PSQM deadline, but by the end of the year, she had changed her view. "I think left to your own devices it is more difficult, because with PSQM it really focuses you on what you have to do, whereas if you are a subject leader you say, oh I will do that next year. So, things get pushed back." Miss

Dean also thought, "I have been forced to look at it rather than being tucked away in my own year six world," indicating greater engagement than might otherwise have been the case.

Active participation in the PSQM increased the confidence of the science subject leaders leading to greater participation, for both themselves and the whole school community, leading to a rapid development of the schools' science communities of practice.

5.2.7.2.7 PSQM Core Documents

The PSQM requires documentation as evidence of the activities science subject leaders implemented in their quest to improve the quality of science teaching and learning and raise the profile of science. I will now consider the creation of the PSQM core documents, a process that Mrs Jones referred to as "time consuming". Danielle thought similarly, preferring to focus her energies on actions to develop science teaching and learning. "The fact that all this brilliant stuff is going on, but I haven't been as organised as I would like to have been … with the uploading, getting your lists done and your **logs**." She drew, "a big ball of craziness" (Figure 13) on her river of experience. Although she considered herself behind where she should be in completing the PSQM documents, she was pleased with the level of engagement for both herself and others in her school community. "Excellent things are happening, except the paper-based stuff. It's not that there isn't evidence of really good stuff going on." This suggests Danielle was placing a higher priority on engagement and participation in the school's community of practice than on providing documentary evidence. The time taken to complete the core documents thus restricted her access to time to further develop science teaching and learning.

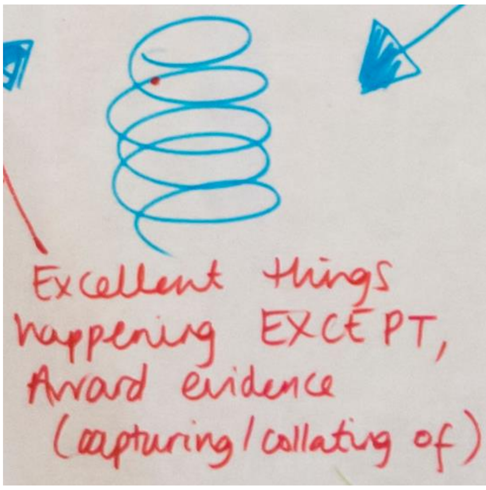


Figure 13 - Section of Danielle's river of experience

Similarly, other participants were pleased with the activities related to science teaching and learning but felt behind with documenting this for PSQM. During the second interview Mrs Collins told me she was behind where she wanted to be with collecting PSQM evidence and listed a wide range of other activities related to teaching a year six class with a diverse range of needs as necessary distractions which slowed her progress collecting and collating evidence.

Of the core documents, Mrs Jones considered the PSQM **action plan** to be the most useful. "I think initially how detailed the **action plan** is to really focus you and think right this is something really important … So that initially was overwhelming, but so helpful." She then went on to tell me that she had done more monitoring as a result of doing PSQM and, "I am reflecting more on my actions because of doing PSQM." She then returned to the importance of the **action plan.** "The **action plan**, how detailed it is for sure, gives you a clear direction of where you are going."

Miss W also valued the **action plan.** "The **action plan** has been useful for me to review where I am and look at the next steps. Yes, I think that is a key tool; it has been really useful." As an **action plan** is written for each criterion in the framework the two are inextricably linked. Miss W noted the importance of the framework.

> What I do think has had an impact from PSQM is that it has given me a framework in which to enact change. So otherwise I would probably have been going, oh, I don't really know where to go, I don't know how to make these changes. I knew what needed to be done but it has helped me to prioritise … and helped me to drill down to specific actions which can then help me meet the outcomes that I need.

Miss Dean shared a similar view, indicating that her level of engagement was greater than it might have been without PSQM.

> I think this has given really good pointers in terms of coverage for everything you could possibly do for your subject from yourself to staff members, to the children, to teachers, learning, assessment, outside agencies, other schools. I think it has covered everything and actually if I was to try and make up A1 to D2 I would not be able to fill in all the boxes myself. Therefore, I wouldn't have done everything that I have done this year.

Mrs White stated that without doing PSQM, "I would not have thought of doing some of the things. I would not have thought of doing **principles** of science."

> I probably would not have done an **action plan**. I would have looked at what was happening perhaps. I probably would not have even looked at what was happening. I would probably would have focused on resources and made sure that they were organised… And monitored the books and planning and do the things I was doing before I did PSQM.

Here Mrs White is reflecting the distinction between the passive, reactive subject leader and the proactive subject leader noted by Bell and Ritchie (1999), and her transition between the two.

Miss Dean valued the **subject leader log**. She considered it helpful because it made her aware of the impact she was having and she used this as a tool for reflection. Miss W agreed on the value of the **log**.

> The thing I have enjoyed most from the PSQM process is the **subject leader log** because sometimes you … think you haven't done very much and then you look at the **subject leader log** and actually, I have done quite a lot, it just maybe isn't out there in the public domain … It helps you to be more positive because we all have those moments when you get a bit down in the dumps and are rubbish and it helps you … to see that you might not have achieved anything massive yet, but you have achieved something… I will definitely be doing that for reading. [She was about to become subject leader for reading.]

The **principles** were also viewed as an important document, although some subject leaders recognised the potential for greater impact which could result from a sustained focus on them. The House of Commons Education Committee (2017) stated school leaders had a role to play in creating a vision, yet in the case of PSQM it is the science subject leaders who initiate the **principles** activity to create a vision for good teaching and learning of science. This is evidence that leadership is becoming distributed through the school.

The **principles** were also important because in many cases this gave the science subject leaders their first opportunity to lead a staff meeting, thus staking a claim to their legitimacy as science subject leader. For example, Danielle noted that staff meetings were usually boring but when she ran the staff meeting to create the **principles,** she watched the faces of her colleagues and noted how engaged they were. She regarded this as a success, building her confidence.

Mrs White considered the **principles** the most important of the core documents because of the collaborative way in which it had been created.

> Because everybody had a say in that, so everybody has ownership of it, and it is what science looks like when it is good. So, if everybody aspires to those **principles** in every lesson. I think that is probably the one that has the main effect on the children and their learning.

Mrs Peters also found the **principles** a useful focus while observing lessons. Following a team-teaching lesson with a colleague, his feedback had been, "more like a lesson observation", whereas her feedback related to the **principles** and she thought, "focusing on the **principles** of science was always probably more beneficial." Her colleague agreed.

Miss Dean believed the **principles** were becoming embedded in science teaching and learning and described a good lesson she observed. "It was such a successful lesson because all of the **principles** that we had spoken about were being followed." Danielle launched the **principles** with an assembly and promoted them in other ways. She was pleased with the impact which resulted in teachers, "seeking out **principles** in their planning, especially if one of the **principles** is my teacher loves science and it's science today and the children are engaged." Mrs Jones considered the **principles** sufficiently important to check children were aware of them during a pupil voice activity. She found that awareness among pupils was high except for some year three pupils. Overall, this pleased her, but she planned to speak to the year three teacher. Soon after describing her staff meeting to develop the **principles** Mrs Collins told me she wanted to make them "a really big thing". She ran a competition for children to design a mascot for the **principles** which was then displayed in every class.

Some of the science subject leaders thought the **principles** were yet to achieve their full potential impact. For example, Miss W said, "I think the **principles** will be useful once they are really embedded." Mrs Peters thought she might have missed an opportunity to make greater use of the **principles**.

> I must admit I should have used it as a focus, but I haven't because I have had other things to look at, but yes, I should really use it as a focus and look back and see if that had a big impact. It is everywhere. It is up in every classroom. It is up in the hall and I know people are aware of it, but how much it has been influenced, I don't know.

Unlike the **principles,** most participants viewed writing **reflections** as overly time consuming and of minimal benefit. Although Miss Dean and Miss W used time when their schools were closed because of snow to write **reflections** and create their **portfolios**, both thought they provided little or no benefit. Miss Dean needed to edit each of her thirteen **reflections** to around 300 words. [The word limit specified by

PSQM]. "I find it really time consuming to cut them down to 300 words". Mrs Peters found editing her **reflections** to within the 300-word limit "really tricky". Miss Dean also considered she had already reflected while completing the impact column of the **subject leader log** and, "so I found it a bit of a doubling of the workload." Miss W also thought writing **reflections** had been unnecessary.

> I don't find them that helpful because I, this is all linked to my appraisal, so I am reflecting in my own way anyway. I am talking about it constantly in SLT meetings, with my appraisal review. I am having to talk about it so, to be honest, I don't need the **reflections**.

While others were critical of **reflection** writing, they could also see benefits. Alice said, "It is quite difficult to be concise and get all the information into 300 words. How that relates to the **portfolio** and finding evidence and explaining it in a clear way, so they can get everything they need from it. It's harder than you think." However, it later became clear to Alice that the ability to reflect would be helpful during her forthcoming teacher training. Mrs Jones also found the process of writing **reflections** time-consuming and difficult. "I think the hard work is when you have to write up your **reflections**, and be really reflective, and talk about the impact and that is a hard skill, so that was what I found more difficult." However, she indicated this skill had helped her develop as a leader.

> I am reflecting more on my actions because of doing PSQM, because we have to write **reflections**. I am saying if I do do this what is the value and impact of it. … So, I probably think that aspect of it has been the most important as a leader.

Mrs White also valued the **reflections.** "I think the written **reflections** really make you focus on the impact of what you have done and that has been quite useful".

Overall, while the **action plan, principles** and **subject leader log** were regarded positively by my participants, the **reflections** were generally regarded as time-consuming, difficult, and in some cases, as unnecessarily increasing workload. However, both Alice and Mrs Jones were grateful for their new ability to reflect. Gilbert (2010) included reflection as one of his five principles of effective professional development and while they may have considered it overly time-consuming each of the participants reflected on her actions. Hoekstra et al. (2009) include reflective dialogue as one of their five conditions for workplace learning and Marsick and Watkins (2015) and Clarke and Hollingsworth (2002) also draw attention to the role of reflection in learning. It is through reflective practice, collaborating with colleagues and taking part in professional development that teachers' professional behaviour is enhanced (Coe et al., 2014). While my participants did all these things, it is not possible to separate the impact of each.

Further I question the impact of writing 13 reflections, each with a 300-word limit, on the reflective skills of the participants and the additional benefits this provides in developing the teaching and leadership of science.

Even when the workplace was not configured to support learning, teachers still learned from their classroom experiences (Hoekstra et al., 2007). Because the teachers did not identify themselves as learners the learning was constrained, and they failed to notice and act on learning opportunities. Therefore, teachers should be encouraged to link their practice with theory (Hoekstra et al., 2007). Through access to the broad primary science community of practice the science subject leaders self-assessing their school against the PSQM criteria and writing **action plans** and **reflections** to meet the criteria, the PSQM frameworks make the link between practice and theory more explicit enabling teachers to identify their learning.

So, the PSQM core documents were generally supportive, with the framework and linked core documents, providing both legitimacy and access to the broad primary science community of practice.

5.2.7.2.7 Other factors

Factors promoting access and legitimacy for both science subject leaders and their colleagues will be considered before those that restricted access and legitimacy. Wenger et al. (2002:58) focus on the importance of passion and energy when they state, "Because communities of practice are living things they require an approach to organizational design that more fully acknowledges the importance of passion, relationships and voluntary activities in organizations ... design focuses on energising participants." Hargreaves (1995) also considers passion an underestimated attribute in effective teaching and Mrs Peters felt her attachment to the school was an affordance. "I think having a passion for the school as well helps, because I have been here a long time and my children went here and that sort of thing."

Miss W considered that because an Ofsted report included developing science as a key action, this gave her greater access and legitimacy with other school staff.

> It very much helped […] that science was a key action because we didn't have any choice but to improve science. Not that we wouldn't anyway, but it almost gives you more clout, you know. Well it is not just me, Ofsted said. So, no one was is any doubt that we had to do something. So that really helped because it meant people had that extra motivation, oh yer, it is science we have to do it.

She also wanted to be able to tell Ofsted, "Yes I knew we had to improve, and here it is improved. New and improved."

However, factors which restricted the access and legitimacy of some potential members of the schools' science communities of practice gained mentions from subject leaders. Miss W noted the school's catchment area had high pupil mobility. "I have tried, spent ages putting in some year two data when they were in reception to track progress. There are only eleven kids that have been here since reception." This turnover of pupils thus restricted the ability to build a school science community of practice.

In addition to pupil turnover, parents were also an influential factor in constraining access. Mrs Collins noted the lack of parental engagement was a barrier restricting both pupil and parental access and legitimacy in her school's science community of practice. "I did want them to do it more at home, but I still think that is a bit more of a battle I have got to face."

For some teachers, Christmas activities restricted the curriculum time available for science. Miss W told me,

> Actually, I haven't done it [science] this week. But then this week we have had the panto, we went to church today, more than half of my class went out to choir yesterday, so you know, and I am out of class tomorrow afternoon so … I will just do a full afternoon next week on science.

Similarly, Danielle drew a Santa on her river of experience (see Figure 14) while telling me that her 'to do' list was growing and explaining that because of Christmas, "You don't have time to be a teacher."

Figure 14 - Section of Danielle's river of experience

Mrs Peters' hub leader booked a holiday so was not around for the final weeks before the submission had to be completed, reducing her access to the support she needed.

> That became a bit of a stress for me, and I struggled to cope with that because I had got my plan; my timeline was ready … but I also wanted my **reflections** checked… I did find it really stressful and it was out of my hands as well and I found I was working a lot of weekends in February which I would not normally do as I have quite a good work/life balance.

She was also disappointed with the support she received from the hub leader who took over in her own hub leader's absence.

> I felt I got far more last time. I think I got one response back which told me how to change one **reflection,** which I did, and then I went through the others from the point of that, but I felt perhaps the support wasn't there because you were swapping people.

In summary, this section has explored the legitimacy and access of the participants to the broad primary science community of practice. It has also discussed the ways they have facilitated legitimacy and access for other members of their school communities, to their own school science community of practice. Science subject leaders participated in both communities of practice and subsequent learning occurred for the subject leaders, their colleagues, children, and, in some cases, their wider school communities. Teacher leadership has also become apparent. Factors which both supported and hindered legitimacy and access and hence participation have been considered.

5.2.8 Relating criticisms of the work of Lave and Wenger to my data

Several authors have identified criticisms of the work of Lave and Wenger and the extent to which my data support their criticisms will now be considered. For example, Hughes (2007), Fuller (2007) and Edwards (2005), are critical of the theory of situated learning because it fails to establish how new communities of practice are created and focuses solely on the reproduction cycles of existing communities. However, the science subject leaders who participated in my research created a community of practice where none existed before, or, transformed an existing community of practice. This can be explained using Wenger's (1998) conception of constellations of communities of practice. Practices and discourses within the schools' science communities of practice increasingly overlapped with those of the broad primary science community of practice. (See Figure 10, page 95). This was facilitated through an introduction by the PSQM hub leaders to the broad primary science community of practice, and support with action planning through the framework and hub leaders. While Lave and Wenger (1991) do not theorise about the creation of new communities of practice or the short-term transformation of communities of practice, Wenger et al. (2002) claim it is possible to create a new community of practice. However, new communities may be dependent on existing networks. There is evidence in my data that through enabling legitimate peripheral participation, PSQM supports both new and transformed communities to occur, however the existing broad primary science community of practice has been shown to be crucial, as predicted by Wenger et al. (2002).

Hodkinson and Hodkinson (2004) and Hager (2005) believe situated learning theory overestimates the importance of participation and neglects the possibility of learning through acquisition. Hager (2005) further argues participation and acquisition views of learning are complementary rather than mutually exclusive. Learning as change in identity is discussed in section 5.3 (see page 129) and learning as acquisition is rejected (Lave & Wenger, 1991), but Hager (2005) argues that alongside changing identity individuals acquire the products of learning. These are evident through the science subject leaders' discourse and this has already been considered in the section on talk and language (see page 97). Thus, PSQM enables learning through both active participation and acquisition (Sfard, 1998) with empirical evidence supporting both Hodkinson and Hodkinson's (2004) and Hager's (2005) criticisms of the work of Lave and Wenger (1991).

Hodkinson and Hodkinson (2004) criticise Lave and Wenger's (1991) broad definition of communities of practice because their examples are based on smaller, co-located individuals sharing work practices. While the school science communities of practice I explored might be perceived as corresponding to the narrower definition, the broader primary science community might be regarded as an example of Lave and Wenger's broader understanding. Although I accept they are different in their breadth, I consider the term community of practice an adequate description of both.

Gee (2005) believes the term community infers agreement and harmony. Hughes et al. (2007) argue that conflict and resistance are neglected by Lave and Wenger (1991). My participants did not mention conflict and asymmetries of power, although, at times, there were difficulties in finding the time to access the broad primary science community of practice. Examples of conflict and resistance are negligible in my data. It is not possible to say whether Lave and Wenger (1991) underrepresent struggles and confrontation but my findings are also reflective of harmony and agreement.

One further criticism of the work of Lave and Wenger, is the extent to which communities of practice may perpetuate poor or malpractices (Hodkinson & Hodkinson, 2004). I found no evidence of unethical practices, although there were examples where my participants' understanding of the PSQM framework were different to those of the broad primary science community of practice. As an example, Miss Dean interpreted the PSQM framework as requiring tests as a form of assessment while the discourses of the primary science community are in line with the work of Harlen (2012) who asserts a range of assessment data provides more reliable information.

Boylan (2010) suggests the roles of apprentices and masters are binary. However, my data lead me to agree with Lave and Wenger's conception that legitimate peripheral participation can occur in multiple and varied ways. To put it another way; "Good community architecture invites many different levels of participation" (Wenger et al., 2002:49). Science subject leaders engaging with PSQM are synchronously, apprentices in the broad primary science community of practice, and masters in their own schools' science communities of practice. The PSQM grants them legitimacy and access to the broad primary science community of practice where they operate as apprentices. Mastery may reside in the organisation rather than in individuals (Lave and Wenger, 1991) and, thanks to the mastery within the PSQM framework and the support from the PSQM hub leaders, the science subject leaders are able to fulfil their roles as masters in school. They provide opportunities for participation, legitimacy and access to their school science communities of practice, for other members of their school communities.

5.2.9 Summary of section on Communities of Practice

This section examined the extent to which there was evidence of a domain, community and practice present in the broad primary science community of practice and each school's science community of practice. These three elements establish that a community of practice exists according to the definition I have chosen. For some schools these were not apparent at the start of the year. In others there was some evidence a school science community of practice was present. In every school, the school science community of practice developed through participation in a range of science related activities. These either created or increased the extent of the domain, community and practice which frequently had elements in common with the discourses of the broad primary science community of practice. The overlap between each school's primary science community of practice and the broad primary science community of practice also expanded as teachers became engaged with the organisations included in Figure 10 (see page 95). In addition to developing a domain, community and practice, consideration of Lave and Wenger's (1991) work on situated learning identified other features establishing the existence of school science communities of practice.

Engagement in practice is crucial to the development of communities of practice and the year-long PSQM process ensures time to engage the wider school community in participation in a range of science activities. Opfer and Pedder (2010) draw attention to the failure of single event professional development experiences, and, with a duration of at least two terms the effectiveness of CPD activities increases (Cordingley et al., 2015). The year-long PSQM programme appears to support their findings. The range of PSQM criteria leads to the creation and implementation of wide-ranging **action plans**, offering many opportunities for engagement. While the participants in my research talked enthusiastically about the activities that developed science teaching and learning, including creating the **principles** and the **actions plans**, some were less positive about the benefits of completing the **reflections** they were required to submit as evidence.

Having established that, through participation, school science communities of practice are created and strengthened as a result of engaging with the PSQM, I will now examine how identities are constructed in relation to these communities.

5.3 Wenger's five characterisations of identity

Having concluded in the Literature Review that I will understand identity as a process and adopt Wenger's conception of identity, I will now explore the identities of my research participants in terms of each of Wenger's (1998) five characterisations:

- Identity as negotiated experience
- Identity as community membership
- Identity as learning trajectory
- Identity as a nexus of multimembership
- Identity as the relationship between the local and the global.

5.3.1 Identity as negotiated experience.

> *"We define who we are by the ways we experience our selves through participation as well as by the ways we and others reify ourselves." (Wenger, 1998:149)*

I examined the ways my participants engaged in activities to develop science teaching and learning. Through this process they defined, experienced and reified themselves as science subject leaders and teachers. The way others within their school communities experienced and reified them was also examined.

The Oxford English Dictionary (n.d.b) defines 'reify' as, "To make (something abstract) more concrete or real; to regard or treat (an idea, concept, etc.) as if having material existence". For example, Wenger (1998:150) discusses the way Ariel is reified within the insurance company she works for as a 'level 6 claims processor'. Similarly, the label 'science subject leader' is applied to one or more persons in 95% of primary schools in England (Leonardi et al., 2017). However, through engagement with the PSQM programme, my participants became more widely known throughout their school communities as science subject leaders, making their roles more concrete or real.

I have noticed it is rare for primary pupils to be aware which teachers lead which subjects, yet most of my participants became known to the children as science subject leaders. Danielle confirmed children in her school would not know which teacher was leader for any of the other curriculum areas. However, she recalled an assembly where the head teacher had asked the children if they knew what other responsibility Danielle had, in addition to being class teacher, "and genuinely, genuinely 90% of them put their hands up and they all knew I had something to do with science … That was a … personal highlight. It was like wow that's making a stamp." Through, for example, leading assemblies, organising the parent and child workshop, and presenting science developments to the governors, Danielle became reified by the wider school community as science subject leader.

For Danielle, the school's PSQM certificate also provided reification of her effectiveness as science subject leader. She considered this was evidence she knew what she was talking about, leading to her having the confidence to speak in front of other science subject leaders at local network meetings.

Other participants also became known by children throughout their schools as science subject leaders. This increased acknowledgement led to them being treated and regarded differently and thus they were reified by their pupils as science subject leaders. Like Danielle, Mrs Jones ran an assembly to launch the **principles** and after this,

> They knew I was in charge of science, so the children are saying, oh it's really good, we did this experiment where we did this, this and this … and they talk to me more independently. That is not just through pupil voice; they come and speak to me in the playground or wherever.

The children at Mrs Collins' school were aware of her interest in science and she reported children would talk to her about science they had seen on television. Alice also shared informal science conversations with children. "The children all know me as the science person. They say I did this at the weekend." Such informal conversations about science indicate science subject leaders are identified by the children as someone who is interested in science and learning about science, further reifying them in their roles as science subject leaders.

It was not just the children who changed their perceptions of the science subject leaders. Support from the schools' senior leaders was evidence my participants were increasingly reified as science subject leaders by the schools' management teams. Danielle thought her school's senior leaders had confidence in her ability. "I have never had a suggestion or a thought or an idea criticised or played down. I have completely been listened to about everything." Mrs Peters was the recipient of positive feedback. "My head is supportive and said if there is anybody that could lead us through this it is you, which was a very big compliment. She said you have got the enthusiasm, the motivation and you have got the respect from other members of staff." This indicated Mrs Peters was reified by both the head teacher and other members of staff as an effective science subject leader.

During the PSQM year, school governors became more informed about science teaching and learning due to the efforts of the science subject leaders. Mrs Peters completed a learning walk with some of the governors and it was reported back to her that they were, "very impressed, just with the reasoning and thinking [the children] displayed." Danielle was asked to present the work she had done towards gaining a PSQM to a governors' meeting and she described her presentation as, "going down a treat." She had also completed a learning walk with the chair of governors, who, according to Danielle was "mega-impressed". The chair wrote a report for the full governing body and recommended that a science link governor should be appointed which Danielle interpreted as a positive response. Mrs Jones received praise and recognition from the governors when she presented her PSQM **portfolio** to them.

> They loved it. They thought it was incredible. They were just, oh my goodness, wow, what a lot of work you have done. Thank you so much for everything. You have definitely raised the profile now and from it being on the school development plan, it is now being removed from the school development plan after everything I have done. So, I really impressed them.

For each of these science subject leaders, recognition from the school's leadership team and the governing body meant their roles became more meaningful and real.

Feedback from organisations outside school was sought by some of the science subject leaders. Miss Dean approached the visiting Ofsted inspector to impress upon her the improved science teaching and learning throughout the school. She told me the Ofsted report included a comment along the lines of,

> [I] was impressed by the high quality of science work on display following a recent science based thematic lesson, which was really good because I went and shoved everything under her nose I possibly could about science. She wasn't entirely interested but it made the report which is lovely. I kept popping in and saying, oh, and another thing ….

Miss Dean also noted, "I think even from what the Ofsted lady said is the fact she knew about science before I had gone and thrown it at her." In contrast, Alice was disappointed when Ofsted visited the school and did not ask her about science, they did not look for evidence of science teaching and learning, and science was not mentioned in their report. Perhaps, for Alice, this represented a missed opportunity for further reification of her role as science subject leader.

However, Alice seized other opportunities to engage with the broad primary science community. Her engagement was recognised by several organisations making her role as science subject leader more tangible. Wellcome acknowledged Alice's use of, promotion of, and feedback on Explorify[9], granting her the designation of 'Explorify Pioneer', and she was given a free ticket to the ASE conference as a result. She applied for children in her school to review books for the Royal Society (RS) children's science book competition and a group of eight children made a video which was submitted to the RS. As a result, the school was designated an 'Associate School of the RS'. A brief article in an ASE journal noted the school's participation and Alice was proud to see the school's name in print. Alice also promoted the BBC Terrific Scientific campaign to her colleagues, as well as using the lessons herself. This was recognised by a Terrific Scientific School of Excellence certificate. Alice was keen to record the links with these organisations on her river of experience (see Figure 15) demonstrating the value of this reification to her.

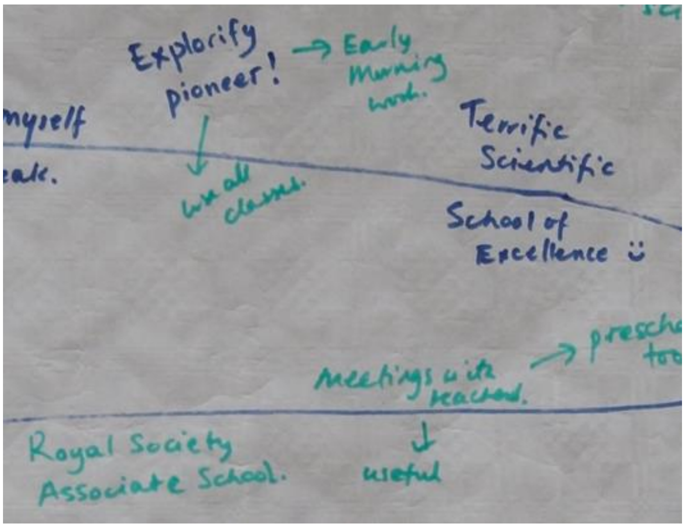


Figure 15 - Section of Alice's river of experience

[9] Explorify – prompts for discussion and investigation for primary pupils https://explorify.wellcome.ac.uk/

At the end of the year, each PSQM submission is reviewed by a hub leader from a different hub. Along with the email to confirm the quality mark awarded, the science subject leaders receive written responses to each of their thirteen **reflections** along with overall comments. Some of the science subject leaders were unaware they would receive such detailed feedback and Miss Dean was pleasantly surprised by the PSQM review document she received. "It is good to see that your work has been recognised." She felt the reviewer had seen it from a different perspective and noted aspects which had pleased Miss Dean.

Mrs Jones was also pleased with the reification evident in the PSQM review. She recalled it said something like, "[Mrs Jones] is an effective subject leader and she has implemented all these changes and it has clearly had a big impact across the school. Like everything you are hoping for, that you are striving for all the time." Danielle also valued positive feedback from the reviewer who she perceived as an outsider. She thought the reviewer could see the amount of effort she had put in over the year. Alice was a little more reserved in her response to the review. "It was good. It was interesting."

Mrs White, in contrast, was disappointed to be asked for additional evidence.

> It was so disappointing to see that they couldn't award silver and it was a bit gut wrenching because you put all that hard work and effort into it … I thought the comments when I looked back and really read them through, I thought yes that is fair enough; what they said are fair comments to make.

Mrs Peters' disappointment at the outcome of the review was palpable and will be discussed in detail later. (See page 134).

Although there are examples of occasions where the science subject leaders received negative or disappointing messages, overwhelmingly the feedback from colleagues, children, senior leaders, governors and outside agencies was positive. In line with the earlier definition of 'reify', this feedback made the role of science subject leader more meaningful and real for my participants and the way they have been regarded and treated by others has given an increasingly material existence to their subject leadership role. Thus, they have reified themselves, and become reified by others, as science subject leaders to a greater extent than they were before the PSQM year started.

Wenger (1998:150) notes such reification fails to acknowledge the "richness of the actual process of belonging to the community and contributing to its practice." He concluded, through engagement in practice, relationships among claims processors developed and they became acknowledged as having certain expertise or attributes. Therefore, I will examine some of the ways my participants' expertise and attributes were acknowledged within their school communities as they led improvements in science teaching and learning.

Danielle's contribution in organising the parent and child science workshop was acknowledged by the head teacher. The head described it as, "the best workshop the school has ever seen … and I was so happy and she came, and she rubbed my arm and said whatever you've got I want to bottle it." The event was also regarded as a success by her colleagues, children and parents, leading her to describe it as "a glory moment." Thus, through belonging to and contributing to the school's science community of practice, her own view and the views of others indicate the label of science subject leader has taken on a "deeper meaning" (Wenger, 1998:151).

Similarly, other participants gained deeper meaning from their roles as science subject leaders. Through engaging with colleagues to offer them support Miss Dean's relationships with them changed. An increase in the support offered, resulted in teachers seeking further support, reifying her as a source of advice about science teaching.

> I think people have realised that from being in lessons and offering advice, then that has come full circle and they have come back to me and said, what do you think about this? Do you think this would be a good idea?

Miss Dean's role as science subject leader was given "deeper meaning" (Wenger, 1998:151) by her colleagues. Through seeking her advice and support on science teaching and learning, they positioned her as a knowledgeable and approachable science subject leader. Similarly, Alice's colleagues took on board her suggestions and made her aware they were implementing them, indicating her advice was acted on. "The other day [another teacher] was using Explorify for early morning work and she said [Mrs Wood], come and see what I am doing."

In summary, each participant initiated science related activities within her school, some related to staff development, and some activities were targeted at the children. The reactions of various members of their school communities gave deeper meaning to their roles as science subject leaders and thus developed their identities. This may extend the, "deeper meaning" Wenger (1998:151) discusses because, not only do they belong and contribute to the community, they are the ones who created and developed their school communities of practice.

Having confirmed that the science subject leaders were reified by a range of members of their school communities, I will now consider some of the ways their identities have changed. In line with Wenger's understanding of negotiated experience (see page 129) through participation in the PSQM programme, the way the science subject leaders experienced, and subsequently defined themselves changed over the year. Resulting from their experiences related to developing science teaching and learning, some defined themselves as more confident, some considered they were better leaders, and some thought they were better teachers. Examples are provided under the next three headings. The evidence I collected also indicated that for one science subject leader, despite an initial boost, at the end of the PSQM year, her confidence was substantially dented as discussed below.

5.3.1.1 Confidence

Miss Dean was one of those who now defined herself as more confident. As a recently qualified teacher (RQT) she, "was worried that people would look at me and think she's not doing it properly, or what's she on about? … But I think I have grown massively in confidence and actually realised that I do know what I'm doing and how to tell people." Mrs White was more tentative explaining her growing confidence. "I think it has made me, not hugely confident, but a bit more confident in talking to staff as a whole and asking them to do things." "I think PSQM also gave me enough confidence to apply for a new job, because it has been so long … So, I felt as if I had something really positive to talk about at interview." Having completed PSQM, Alice began training as a secondary science teacher.

> I think [PSQM] might have affected my confidence to put forward for teacher training. I have gone through a process where I think I can do this, and maybe I can do the next thing for my career. So, I think it helps your self-esteem, doesn't it, and your 'can do' attitude?

Mrs Jones' confidence also developed. "I am confident to talk about my subject because I feel I have got all the knowledge of how to do a detailed science award with it." During our final interview she was delighted to tell me she had applied for, and been appointed to, a new position within the school as phase leader and head of English. As part of the selection process she had presented, "Explain your subject leadership experience and its impact across the whole school, so I was like, I am not worried about that." This indicates her growth in confidence as a subject leader.

The first time Mrs Peters completed the PSQM it, "really helped me develop that confidence actually." Unfortunately, Mrs Peters' claimed her confidence was dented during her second PSQM experience through a misunderstanding over the outreach element required for PSQM gold. Her initial reaction was, "I would say that knocked my confidence quite a lot." There was a further setback when Mrs Peters tried to develop outdoor learning with the local nursery school, however, it was the result of the review of her PSQM submission which led to her greatest disappointment. The school was awarded PSQM silver rather than the PSQM gold she had worked towards. She returned to this theme of disappointment a few times.

> I put a lot more time into it than I did last time ... I was given [science subject leadership] last time and I picked it up and did what I needed to do, but I didn't really understand why I was doing it or anything like that. Whereas this time I have put a lot more time and effort into it and … coming out with effectively the same award and also you have got to tell the staff.

She reiterated her view about the negative impact on colleagues. "I think it has got to be quite demotivational for quite a lot of staff that have really jumped on board with it and really tried." When we unrolled her river of experience her immediate reaction was, "the disappointment has got to go on." (See Figure 16 – writing in black).

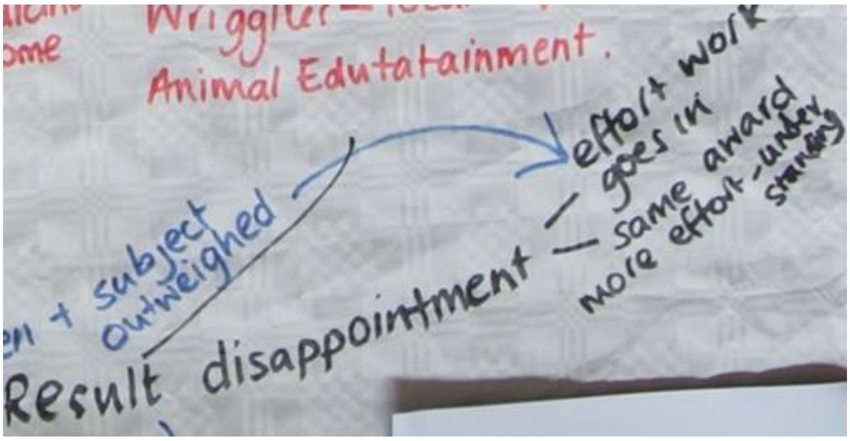


Figure 16 - Section of Mrs Peters' river of experience

Previously Mrs Peters told me, "they would have to fight me to give up my subject", but following her disappointment I asked if she would do PSQM again in three years and she replied, "No, I think personally, from my point of view, I would hope to be changing subject by then." Thus, she rejected the role of science subject leader. Contrary to the overwhelmingly positive way she experienced herself through her initial PSQM year and through working towards the PSQM for a second time, the resulting PSQM review reified Mrs Peters somewhat differently. In line with Wenger's understanding of negotiated experience, she has redefined herself as someone who no longer wishes to be science subject leader. However, she had commented on how she was now a better leader and teacher

5.3.1.2 Leadership

Through negotiated experience more general leadership skills also developed. Despite the difficulties she experienced, Mrs Peters thought she had developed as a leader.

> I can't label it a CPD session, but the journey I have come on … with my leadership skills … I never thought I would be able to go externally and develop a programme, support Forest School Lead, engaging with another outside agency … to bring them round and bring them on board and actually see a success for the programme.

Others also described developing leadership qualities. Mrs Collins attributed developing skills as a leader to PSQM and concluded PSQM, "has made me grow as a teacher, as a middle leader." Thus, she now experienced her leadership skills as stronger and defined herself as a middle leader. She regarded her improving ability to question as an important skill. "It has made me question things I would never have thought even to question, which is good and the whole point, … I think I have gained more out of it than the school will."

Miss W was already a member of the school's SLT, but she credited a combination of working towards PSQM and studying for a master's degree for her developing leadership skills. "Certainly, over the last two years, I have learned a lot about being a leader … I am not sure if it has changed the way I teach, but I think it has probably changed the way I interact with my colleagues." By the end of the year she had concluded that creating an ethos where teachers could talk to her honestly was important. "I think developing a culture where you can lead others."

5.3.1.3 Teaching

Another area in which Mrs Peters claimed improvement was her teaching practice.

> I would say that my teaching over the last year to 18 months has drastically changed. I put science and maths together and I had always classed them both as types of subjects where … you have got a right or wrong, there is no creativity about them … Whereas I can now see, and it has started to affect my maths teaching as well, that actually you open it up more, you don't have to have a right or wrong … it is just you discover … So, it has opened me up as a person I suppose, as a teacher.

Miss Dean also developed her knowledge of science teaching and learning. Towards the end of the PSQM year I suggested the way she spoke about teaching science indicated improving science subject knowledge. "It has massively, and I think my whole understanding of the different subject areas which are covered right from foundation stage right up to year six and beyond as well. I think it has grown and expanded."

So, considering Wenger's (1998) understanding of identity as negotiated experience, over the course of the PSQM year, this has changed for the science subject leaders who participated in my research. Through participation in activities related to gaining a PSQM, they have worked with members of their school communities and sometimes beyond them, to develop science teaching and learning. This work has led to changes in the ways they have experienced and defined themselves. Some recognise they have gained confidence, some have developed their leadership skills, while some have stated their ability to teach science and other subjects has improved. For one of my participants the awarding of PSQM silver, rather than gold, knocked her confidence to the extent that she wished to withdraw from leading science. Although she recognised improvements in her leadership and teaching skills, it is significant that she was the only one of my participants who wished to hand over leadership of science because of the negative experience of the outcome.

The science subject leaders have been reified by themselves and by others. The way they are regarded by a range of members of their wider school communities has changed, and they are now identified by the children as science leaders. This recognition has led to the role of science subject leader becoming increasingly concrete or real for both themselves and those they work with, thus giving deeper meaning to the role. Their capacity to initiate and implement change perhaps creates even deeper meaning than that suggested by Wenger (1998).

5.3.2 Identity as community membership.

> *We define who we are by the familiar and unfamiliar. (Wenger, 1998:149)*

Whereas, identity as negotiated experience relies on reification (Wenger, 1998) the second characterisation of identity claims, "membership may not carry a label or other reified marker" (Wenger, 1998:152). As discussed earlier, my participants are designated science subject leaders and hence have labels. Once they have their PSQM certificates they have reified markers. However, for Wenger, it is through what is familiar and unfamiliar we know what we are and what we are not. As an example, when Mrs Collins spoke about science week she provided clues to her identity through her familiarity with the view of the broad primary science community that, "It is not necessary for primary age children to produce a written scientific report (e.g. method, results, conclusions) every time they carry out an investigation" (PSTT, 2017). Mrs Collins told me, "The children expected to have to write something, however, actually you don't have to write in science. Sometimes science is actually learning about it and doing practical which was my dissertation." Her colleagues were unfamiliar with this view and her mission became to persuade her colleagues to think similarly to herself in this regard and thus develop a science community of practice within her school and consequently develop their identities as primary science teachers.

Wenger (1998) considers there are three dimensions of identity as community membership. Each of these will be considered with respect to my participants.

5.3.2.1 Mutuality of engagement

In this respect Wenger considers identity as, "a certain way of being part of a whole through mutual engagement" (1998:152). In their own individual ways, my participants became central to their schools' science communities of practice. Wenger (1998:152) asserts, "We become who we are by being able to play our part in the relations of engagement that constitute our community", and through their engagement their identities evolved. For example, through Mrs Peters' engagement with her school's science community of practice she became increasing familiar with science in the world around her.

> When I first took it, I really did not want it to be totally honest, but now I am quite confident. I can see more science in everything, whereas before I saw it as a discreet subject … OK I have this to teach and that is it, but now it is much more reaching out and thinking there is science involved in that and actually we can take this to the next level. It opened my mind I would say.

Even though Mrs White was required to submit additional evidence before her school was awarded a silver PSQM, she stated she would be happy to lead her new school to gain a PSQM. "Yes, definitely second time round I would do it again." Despite a slow start, her engagement with her school's science community of practice to complete the PSQM, gave her the confidence to consider repeating the process and potentially create or develop a science community of practice at her new school.

5.3.2.2 Accountability to enterprise

Identity, "manifests as a tendency to come up with certain interpretation, to engage in certain actions, to make certain choices, to value certain experiences – all by virtue of participating in certain enterprises." Wenger (1998:153). Therefore, accountability to enterprise is related to the extent that science subject leaders can align their actions towards achieving a common purpose and relate the school's primary science community of practice to the broad primary science community of practice. Although members of a community may have their own individual perspectives, Wenger (1998) suggests their views of the world, their perspectives and foci will have much in common.

Through their participation in the PSQM many of the perspectives and foci of the broad primary science community of practice became adopted by the science subject leaders. For example, by the end of the PSQM year Danielle focused on child-led enquiry as an area for further development. This coincides with the views of the broad primary science community of practice summarised by Harlen and Qualter (2018) who argue that children should be able to explore their own ideas.

Mrs White adopted a similar perspective showing that she valued children's questions; one of the discourses of the broad primary science community; "that children's questions that arise from curiosity and the desire to understand have a key part to play in learning science" (Harlen & Qualter, 2018:149). At the start of the year, while looking through children's books she had noted they were all doing something very similar. "They had been exposed to really interesting science, but they are not actually becoming scientists because they are not thinking of their own questions to ask. They are not making those sort of decisions about what they are going to investigate." This focus on child-led enquiry is apparent in the PSQM criteria and was common among my participants. The PSQM framework also ensured they engaged in some common actions. For example, all created a **principles** of good science teaching and learning document that is required by PSQM. All arranged science weeks or days which are not required by the PSQM but are often implemented to raise the profile of science.

Further examples of the ways in which the science subject leaders aligned their discourses to the broader primary science community of practice are provided in section on Alignment (page 155).

5.3.2.3 Negotiability of repertoire

Negotiability of repertoire is concerned with an individual's history of participation and through that their familiarity with certain language, action and artefacts. Wenger (1998:153) argues, "sustained engagement in practice yields an ability to interpret and make use of the repertoire of that practice… As an identity this translates into a personal set of events, references, memories, and experiences."

Alice credits her sustained engagement with the broad primary science community to her involvement with a rocket project the school community took part in prior to signing up for the PSQM. This led to further events, references, memories and experiences for both herself and other members of the school community.

> I think one thing leads to another doesn't it? If you have done the rocket science project, then you get all the emails about why don't you do the polar project and then you find you are on everybody's mailing list before long … The STEM Learning website is good as well to catch things as they come out.

Through one of the projects, Alice successfully applied for a transition grant to work with the local secondary school. She contacted a teacher at this school who worked with her on the project and subsequently encouraged Alice to apply for a job as a secondary science teacher. The next academic year Alice started training at that school.

Mrs Peters was able to make use of her developing repertoire of practice when working with a colleague. Together they planned an assessment lesson linked to animals and growth that involved asking their year two children an open-ended question and providing some resources for independent investigation. "Our honest opinion was this is going to be carnage with the classes we have got." However, for Mrs Peters the result was a memorable experience.

> We were both so stunned … every single group approached it in a different way. One group …said well if it is the tallest person that is the oldest person, we need to find out when their birthday is. We need to measure them but if that is the case then their hands are going to be bigger too, so we could all measure our hands. So, they took it completely down another level and so they ended up drawing their hands, putting their birthdays inside, and the measurement, then cutting them out and putting them in order … The reasoning that came off of that … This isn't the biggest hand, but they are the oldest person … You are both born on the same day, but you are a lot taller than you are; how does that work?

The level of detail Mrs Peters provided when describing the lesson indicated just how memorable it was. During a staff meeting Mrs Peters and her colleague had shared their experience with the other teachers and were hopeful others might try this approach. Mrs Peters also applied a similar approach when teaching other subjects. "I have used it in history, and it has worked. Give them an open-ended question to investigate and let them run with it and you get much deeper thinking." As Wenger (1998) argues these memorable events helped shape Mrs Peters' identity as a teacher who can ask questions to promote deeper thinking.

5.3.2.4 The inverse

Wenger (1998) discusses the inverse of the three facets of identity, because those new to a community of practice are unfamiliar with its practices. This may manifest itself in situations where engagement, common perspectives, common focus, shared references and experiences are lacking. However, for most of my participants, including those who were new to science subject leadership, the common perspectives, common foci and shared references became available through the initial PSQM training session, completion of the self-evaluation and the PSQM framework. This ensured only the common experiences were lacking, and most quickly embarked on initiating a range of events for the children, monitoring activities and CPD for colleagues, creating those experiences.

One exception was Mrs White who found it difficult to make any headway implementing her plans, and her level of engagement initially appeared lower than other participants. Although she remained engaged with her everyday teaching duties her relative lack of engagement with the PSQM process troubled her. During the second interview, when she started adding to her river of experience, she drew prison bars (see Figure 17). She explained they related to the guilt she felt because of incomplete tasks. Science currently did not appear on the school development plan (SDP) as required by one of the PSQM criteria, she had been disappointed with the number of 'science is good when …' cards completed by her colleagues, and she had only just completed the **principles**. Because of school closure and her own family holiday she had failed to complete the resources audit at half term, and although agreed in principle, she had not yet carried out any team teaching. The everyday pressures of teaching and home life had slowed progress.

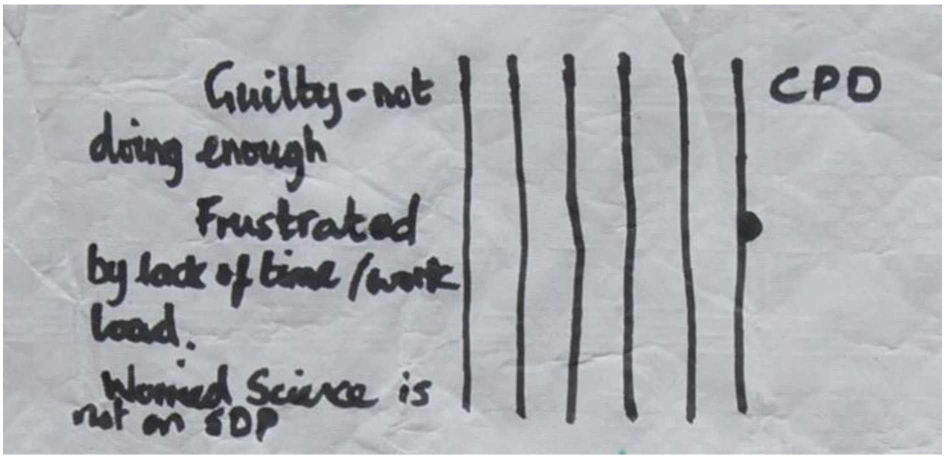


Figure 17 - Section of Mrs White's river of experience

By the time you have done the marking it is half five, six o'clock and it's time to go home and the family takes over then … I find it really difficult to do extra stuff on top of that, so that's why things have not been getting done. Well they have, but I don't feel as if it's enough.

Initially the common focus and shared experiences indicating negotiability of repertoire were lacking for Mrs White. Her lack of participation within her school's science community of practice was remedied through engagement, at first with other science subject leaders at the PSQM training, and then with actions within her school that she was eventually able to fully engage and began to create those common experiences. Consequently, her identity as a teacher and science subject leader evolved.

I did get quite low about it and wondered why am I doing this? What's it all for? And all that sort of stuff, but I think I really knuckled down to it and put it as a priority and really got stuck into it and I think I turned a corner … I went on the training again … that really helped … being there with the other ladies who are doing it and talking to them about what they are finding difficult and what they are doing.

Fuller and Unwin (2004) noted the greater opportunities for apprentices to learn when they participated across a range of contexts, and, having the opportunity to share experiences with other science subject leaders, allowed Mrs White access to other contexts.

Despite engagement with science teaching and learning before her PSQM year started, Danielle still experienced nervousness at becoming a member of an unfamiliar community of practice. She initiated a popular summer home learning task which was well received by children, parents and her colleagues leading her to want to, "Keep it up." At the start of the year in September she wrote on her river of experience. "Thrown in at the deep end – no experience as a subject leader – nervous about doing a good job." (See Figure 18). Yet despite this nervousness she started confidently and continued to engage others to develop science teaching and learning. Through all the activities and events she initiated, she began to share common perspectives and foci, and developed a primary science community of practice within her school. She thus moved to demonstrating mutuality of engagement from a situation where the inverse applied.

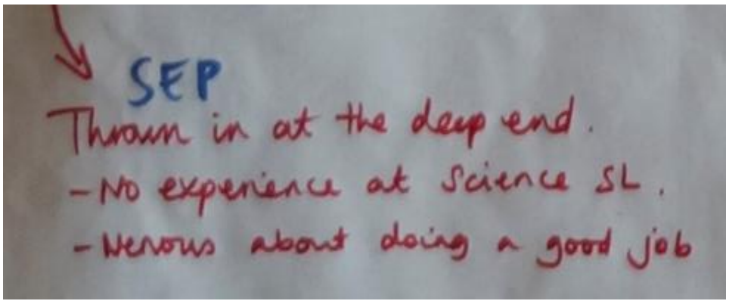


Figure 18 - Section of Danielle's river of experience

Wenger (1998) emphasises the importance of the familiar and the unfamiliar in changes to identity. "In practice, we know who we are by what is familiar, understandable, usable, negotiable; we know who we are not by what is foreign, opaque, unwieldy, unproductive" (Wenger, 1998:153). So, while both Mrs White and Danielle were relatively new to and unfamiliar with science subject leadership and the PSQM, Danielle's participation happened more rapidly and following positive feedback led to further participation and her identity as a science subject leader evolved more quickly.

5.3.3 Identity as learning trajectory

> *We define ourselves as where we have been and where we are going. (Wenger, 1998:149)*

Wenger (1998:154) argues identity is a "constant becoming …. Something we constantly negotiate during the course of our lives" and trajectories are not fixed paths. This reflects the understanding of identity as an on-going process rather than a fixed state. He classifies five different trajectories.

5.3.3.1 Peripheral Trajectories

> *Some trajectories never lead to full participation. Yet they may well provide some kind of access to a community and its practice that become significant enough to contribute to one's identity. (Wenger, 1998:154).*

My participants were not just members of their school's science community of practice, but were central to it, so rather than having peripheral access, their role in leading the creation of the science community of practice makes this form of trajectory irrelevant to the science subject leaders. Nevertheless, others in the school community, for example, governors and parents might be on a peripheral trajectory with respect to the school's science community of practice. Wenger et al. (2002) claim that a significant proportion of the community members may be peripheral with infrequent participation.

5.3.3.2 Inbound trajectories

"Newcomers are joining the community with the prospect of becoming full participants … Their identities are invested in their future participation" (Wenger, 1998:154). Thus, the aim for newcomers is an eventual shift from an inbound to an insider trajectory (see below).

This is exemplified by Danielle who, when I first met her, was in her third year of teaching. I asked about her career ambitions, and she told me she aspired to be a, "well established and really, really good teacher"; someone her colleagues could turn to for advice. After her first year of teaching she had become subject leader for history and geography, but she wanted to lead a subject with a higher profile and considered science would be a good place to start. Thus, Danielle was on an inbound trajectory.

It was a shift from an inbound to insider trajectory with respect to both science teaching and science subject leadership that Mrs Collins reflected on.

> I am very passionate about science. I am a big nerd and quite proud about it, but I think I would be saying, right that's it, all good … a really nice science lesson because you are passionate but what else? …What else can I do that is going to make my science teaching even better … that I can pass onto my colleagues?

Mrs Collins also recognised participating in PSQM had enabled her to become more reflective. "The whole process of actually sitting back and going well actually are we doing this? Being that critical friend, looking and going well, we kind of do that and maybe we need to do more of that. Kind of reflective." Evidence of her development from inbound to insider trajectory.

5.3.3.3 Insider trajectories

> *The evolution of identity does not end with full membership. The evolution of practice continues. (Wenger, 1998:154)*

Participants started the year on an inbound trajectory, but their levels of participation in the schools' science communities of practice by the end of the year are indicative of full membership and thus insider trajectories. Even when they received notification they had been awarded a PSQM, they continued to seek to develop practice within their schools. Those who were leaving the school wished to ensure improvements were sustained. For example, Mrs Collins noted the PSQM has, "heightened [science] and made it worthwhile and obviously when I pass it on to the next subject leader I am going to go, right, there you go. Keep it up."

Those who remained in the same school looked to continue to evolve practice. Unprompted Danielle mentioned she was setting her sights on PSQM gold. "I know I can't go for gold and it's going to be quite a while before we can, but we are really quite a way there … It's definitely something to look at in the future. Going for gold!" Miss W also mentioned the possibility of PSQM gold in the future. "I certainly think we could achieve silver again because I think we have created a bit of a legacy."

5.3.3.4 Boundary trajectories

> *Some trajectories find their value in spanning boundaries and linking communities of practice. (Wenger, 1998:154)*

Through engaging with the PSQM and their local hub leaders, science subject leaders set out on an inbound trajectory towards full participation in the broad primary science community and have crossed boundaries to develop a science community of practice within their own schools. While acknowledging that boundary crossing is not easy, Wenger et al. (2002) note that deep learning may result. The science subject leader is central in linking overlapping communities of practice and creating constellations of primary science practice. This results in each school's community increasingly sharing more of the values and discourses of the broad primary science community of practice. At the same time my participants learned much about primary science education and about themselves.

Communities are most effective when leadership at the boundaries ensures the communities are not closed to newcomers (Wenger et al.,2002). The hub leaders and PSQM framework opened the boundaries of the broad primary science communities of practice to the science subject leader, and they in turn opened the boundaries of primary science communities of practice to their colleagues and others in the school community.

5.3.3.5 Outbound trajectories

> *Some trajectories lead out of a community … being on the way out of a community also involves … seeing the world and oneself in new ways. (Wenger, 1998:155)*

At the end of the school year some of my participants left their school communities, while others gained an internal promotion meaning they were no longer responsible for leading science. Thus, they embarked on an outbound trajectory. To a greater or lesser extent they were seeing themselves and possibly the world in different ways to enable their trajectory out of a community.

When I first met Alice, she described herself as in two minds about whether to train as a secondary science teacher. However, she began to see herself as a secondary science teacher in the future and secured a training place, signalling a new trajectory.

Mrs White remained within the primary education community but decided after 12 years at her current school it was time for a change. Her husband worked as a head teacher and she was not interested in a senior leadership role because she thought they would never see each other. However, she told me she would be happy to lead science at her new school and work towards a PSQM, creating a new or improved school science community of practice.

Mrs Collins also left her school at the end of the academic year to take up the post of assistant head teacher as another local school. When I asked if she would like to lead science at her new school she replied, "I hope I am because I have hinted quite subtlety, quite a lot. Please give me science." So, although she is moving on from the primary science community of practice she developed, she is keen to create a science community in her new school.

While the other participants in my study stayed within their schools, most took on new responsibilities. Mrs Jones was promoted to phase leader and subject leader for English, as well as continuing to be part of science team. Although she was not leaving the school's science community of practice, she wished to create a new and overlapping community of practice related to the teaching and learning of English.

Most others who remained in their schools were on an inbound trajectory to more senior leadership roles. Miss W was appointed acting deputy head teacher and at the end of the academic year she was passing the leadership of science to a colleague and taking on leadership of reading alongside other responsibilities. Danielle told me she would continue to lead science, but, had also been invited to work towards the National Professional Qualification in Middle Leadership (NPQML) suggesting an inbound trajectory to more senior leadership roles. As already discussed, Mrs Peters was intending to hand over the leadership of science following the disappointing review. However, she had been asked to moderate key stage one English and mathematics teacher assessments for schools across the county, so was on a new trajectory. Despite being relatively new to the teaching profession, Miss Dean began to think about the possibility of future leadership roles.

> You have made me think of the future … the future of my subject and my future as well actually as a leader … I had said I'm just a class teacher and that is what I want to be, but then with your provoking questions into what about down the line … I think that has opened that up a little bit more to me.

Interestingly only Mrs Collins ever mentioned she was considering an outbound trajectory that involved leaving the teaching profession, although others may have considered it and not mentioned it. Given a survey by the National Education Union (2018) stating that during the year 80% of teachers considered leaving the profession, the fact that only one out of my eight participants mentioned the possibility, indicates PSQM might support retention and career progression. In fact, Wenger et al. (2002) claim part of the long-term value of engaging with a community of practice is improved retention.

Fraser et al. (2007) believe a broad range of outcomes should be considered in evaluating professional development experiences and these might include teacher retention and career progression. This view is reinforced by Hargreaves and Shirley (2012) who state that pupils' learning should not merely focus on passing tests but instead focus on in-depth learning. There are indications participation in the PSQM has positive benefits and the extent of this in terms of retention and career progression would warrant further investigation. In contrast, Cordingley et al. (2015) believe the focus should be on pupil outcomes. Although the PSQM asks subject leaders to reflect on the broad impact on pupils, there is no requirement to present improving assessment data as measured through tests.

5.3.3.6 Paradigmatic identities

> *A set of models for negotiating trajectories … it is the members … who create the set of possibilities to which newcomers are exposed. (Wenger, 1998:156)*

In school my participants were exposed to senior leaders who acted as paradigms or models of the possibilities for their future career development, and thus they tended to aspire to inbound trajectories involving more senior roles within their own or other schools. The hub leader potentially modelled a trajectory as an expert in primary science education yet none of the subject leaders mentioned this possibility.

5.3.4 Identity as nexus of multimembership

> *We define who we are by the ways we reconcile our various forms of membership into one identity. (Wenger, 1998:149)*

The Oxford English Dictionary (n.d.a) defines 'nexus' as, "A bond, link, or junction; a means of connection between things or parts; (also) the state of being connected or linked." I will therefore examine the ways the science subject leader identities of my participants were linked or connected to their identities as members of other communities. Wenger (1998) asserts we all participate to a greater or lesser extent in many communities and identity arises from these multiple memberships and the way they are reconciled to cope with competing pressures. While he claims a single identity, I prefer to conceive of identities as multiple, but the point remains that some identities do not comfortably co-exist and need to be reconciled. Wenger (1998) acknowledges it is possible that some tensions may never be resolved and may lead to an on-going struggle.

The participants in my research each had their own unique perceptions of which communities they were and were not members of. Over the course of the PSQM year, they found ways to reconcile memberships, and, in some cases, lack of membership of these multiple communities. Only those memberships related to or impacting on their identities as teachers or science subject leaders will be considered.

Miss Dean initially found it difficult to reconcile her status as a recently qualified teacher with her role as subject leader, showing discomfort with part of her role (Hammersley-Fletcher & Brundrett, 2002). She expressed concern about how training or advice she offered more experienced colleagues might be received. "Like she has only been here two years and she is telling us what to do." However, by the end of the year she had found a way to reconcile this multimembership. When I asked Miss Dean where she would now place herself on her river of experience, she drew herself at the centre. (See black stick character at the centre of Figure 19).

> Probably here aren't I? Because … I am not just looking at what has gone wrong or where we are going in the future… I am seeing the bigger picture and I am able to move forward by asking questions … Now I feel I can look at that and see it a lot more quickly, then think right well, in the future we need to do this then. So, I think at the beginning … it was tunnel vision … but now I feel I can see where I was as an NQT, I can see where I was as a new subject leader. So, my head can turn 360 degrees now.

This reflects the way she has been able to reconcile her role as science subject leader with her status as an inexperienced teacher.

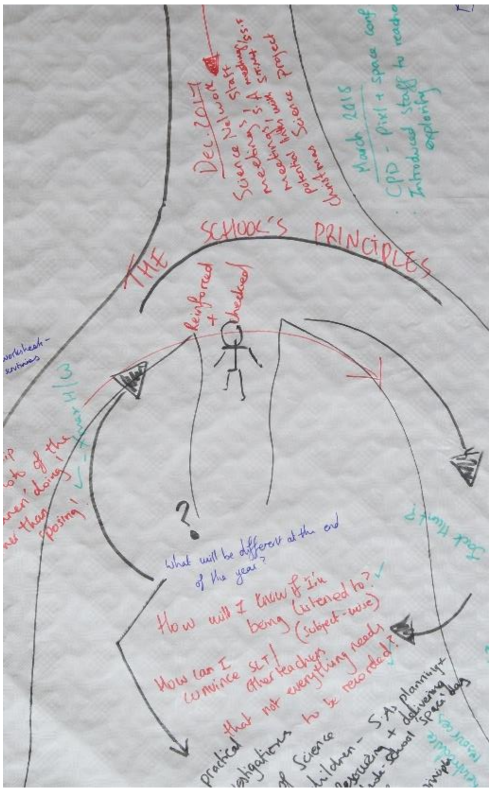


Figure 19 - Section of Miss Dean's river of experience

Miss Dean was further able to reconcile membership of the community of primary classroom teachers with her membership of the community of science subject leaders.

> You made me think about it being hand in hand as being class teacher and as a leader. I think before it was merged; both these things swirling round, but I am both of them doing both all the time, but actually with the class teacher hat on, then the science leader hat on. They are different hats; different principles.

This indicates her developing thinking, and her reconciliation of two of her multiple roles.

Alice was unique among my participants and rare among PSQM science subject leaders in that she was a higher-level teaching assistant (HLTA) and was not a member of the community of qualified teachers. Her previous career and qualifications as a scientist gave her confidence with science subject knowledge and Alice described herself as naturally interested in science. She regularly read about primary science education in magazines, emails and on websites. "This is the part of the job that I enjoy the most to be honest; the science part, because I am a TA [teaching assistant] the rest of the time, but the science is what really gets me. I love it." Despite not being a member of the teaching community, the process of completing PSQM allowed her to reconcile her HLTA role with being science subject leader.

> I have not got the teaching background … so that [PSQM] has helped me understand why you are doing the things you are doing in school and I just think it is a good process to evaluate the whole. Where you are at, where you want to be and what you achieve.

She also expressed the view that other TAs should be given the opportunity to lead curriculum areas, indicating her belief that others might be able to reconcile non-teaching roles alongside subject leadership.

In our discussions Mrs Peters adopted what Danielsson and Warwick (2016:78) would refer to as a, "traditional primary teacher discourse", typified by a warm, enthusiastic and caring attitude, an emphasis on the pastoral role, and an overriding interest in children's development. "At the end of the day, the children are what I'm here for and I want to make it as exciting as possible for them." She reconciled her role as class teacher with her role as science subject leader. "I … think that my science leadership would actually make me delve a bit deeper and find some different activities for science for my own class which I would probably try out first."

When Miss W experienced conflicting priorities she chose to put the immediate needs of the children ahead of a science staff meeting. "So, I was going to do it next week [the staff meeting to create the **principles**] and then I had a transition meeting for year six and they are more important than the **principles** of science and these kids are going and I need to talk to their teachers."

Mrs Collins also adopted a traditional primary teacher discourse and showed acute awareness of the deprived home lives of many in her class.

> I could name 15 out of my class of 28 that I would say are going to end up with mental health issues. It is horrific and it keeps me up at night worrying about them. I am genuinely quite scared that some of these kids are going off to high school because I don't think they are going to cope, and I really do worry that they are not going to cope in life because of the state of education system.

She reconciled this with her passion for science by taking pride in nurturing their future aspirations.

> So, pushing them towards this hands-on is actually the best for them even in an educational sense, but also in a life sense as well. Now we are starting to see children that actually go, Miss I would quite like to be a vet or doctor; so brilliant, this is what we are after.

Mrs Jones saw benefits of multimembership; combining a class teaching role with that of science subject leader. She felt better able to identify those children who were perhaps not so good at writing but could access the science learning. She believed the dual roles also gave her greater empathy with her colleagues.

Some of my participants found it necessary to reconcile their role as science subject leader with their previous lack of interest in science. For example, before starting PSQM, Mrs Peters told me science, "wasn't an area that inspired me at the time", and this led her to her being, "initially very timid" about being science subject leader. However, through her first experience of the PSQM, and growing confidence to teach and lead science, she noted, "Science does inspire me much more."

Mrs White was able to reconcile being science subject leader with her more negative views of science through identifying it as a challenge. "It is not my sort of subject, as English is more my subject." However, when the previous science subject leader moved on and Mrs White was asked if she would lead science, "I was quite happy to do science as I saw it as a bit of a challenge."

Bentley and Watts (1994) suggest that teachers without an academic science background may have difficulty believing they have sufficient knowledge to teach science. Danielle steadfastly refused to identify herself as a scientist demonstrating her discomfort with the expectation of expertise the title of science subject leader can bring (Hammersley-Fletcher, 2002). During the second interview she wrote on her river of experience. "I'm still no expert a science just because we are a term in." See Figure 20.

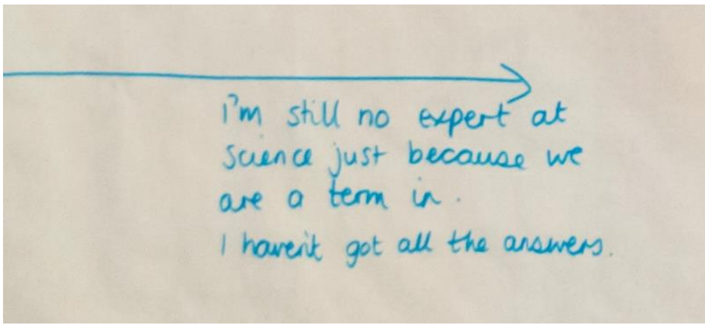


Figure 20 - Section of Danielle's river of experience

Hammersley-Fletcher (2002) and Cordingley et al. (2015) reported the reluctance of some teachers to assume the role of expert and this was certainly true of Danielle, although despite her protestations she was happy to offer suggestions to colleagues. This view of herself as 'not a scientist' persisted through the year. Yet, later in the year she told me how teachers were now approaching her for advice and she was able to support them, "even though I'm not a great scientist", viewing herself as, "still learning and I learn on the job." When I asked about her scientific knowledge compared to her knowledge of primary science education she replied,

> I think my subject knowledge would be here [holds one hand horizontally level with shoulder], but teaching it would probably be here [holds other hand horizontally just above head level] which is quite strange isn't it? So really you think that to be able to teach it you would know a lot about it but, actually you need to be enthusiastic and know about the area that you are talking about at the time. It doesn't mean you are a good scientist; it means you are a good teacher.

Thus, Danielle reconciled her identity as 'not a scientist' with being an effective science teacher and subject leader.

So, the teachers I interviewed provided evidence of other related identities in addition to their developing identity as a science subject leader and sometimes as a leader more generally. As Wenger (1998) suggests they were able to reconcile membership of different communities alongside their inbound trajectory to membership of the broad primary science community of practice, although the on-going struggle Wenger refers to perhaps persisted longer for Danielle than it did for other participants.

5.3.5 Identity as relation between the local and the global

> *We define who we are by negotiating local ways of belonging to the broader constellations and of manifesting broader styles and discourses. (Wenger, 1998:149)*

Identity for Wenger (1998) is about the interplay between the communities he studied and the wider global issues. For example, Alinsu claims processors discussed television viewing and sports events, and Wenger explains how this became a way of participating in their community. Although such conversations no doubt happened within each school, I was not privy to these. So, for the purposes of my research, while accepting such conversations contributed to the identity of my participants, this is not an area I was able to explore further.

5.4 Wenger's three modes of belonging

It is useful to consider three distinct modes of belonging: engagement, imagination and alignment to make sense of the processes of identity formation and learning (Wenger, 1998:173). I will therefore consider the ways my participants demonstrated these three modes of belonging. See Figure 21.

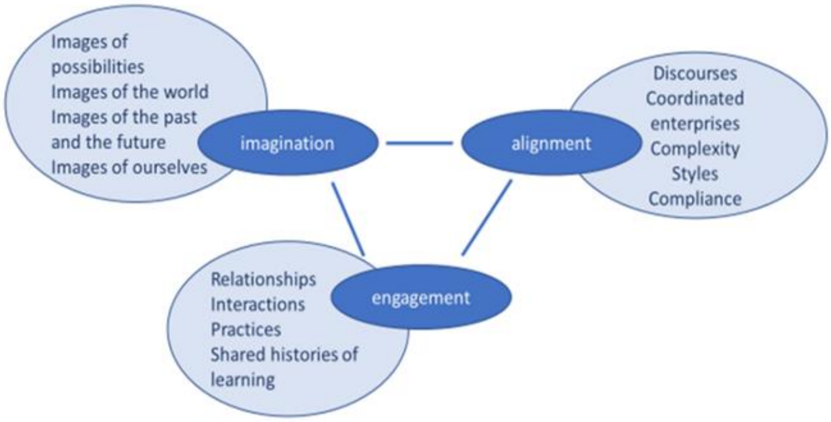


Figure 21 - Modes of belonging (Wenger, 1998:174)

5.4.1 Engagement

> *The work of engagement is basically the work of forming communities of practice. As such it requires the ability to take part in meaningful activities and interactions in the production of shareable artefacts, in community building conversations, and in the negotiation of new situations. (Wenger, 1998:184)*

Hammersley-Fletcher and Brundrett (2005) claimed some science subject leaders were more focused on maintaining resources and writing policies and schemes of work. In doing so they avoided implementing change and improving teaching and learning. However, as can be seen from their stories and rivers of experience, (see appendix U) my participants engaged in a wide range of initiatives.

Wenger (1998:184) states, "engagement requires authentic access to both the participative and reificative aspects of practice in concert." Regarding the participative aspect, Wenger points out the necessity of access to and interaction with other participants, alongside the legitimacy and ability to contribute to the development of a shared practice. Billett and Boud (2001) use the term agency and suggest this is influential in the way it allows individuals to learn from the experience of professional development and change their work practices as a result. Hoekstra et al. (2009) include teacher autonomy as one of their five conditions for workplace learning and I consider this closely related to legitimacy. I prefer to use the term legitimacy to describe the understanding of my participants that they have the authority to initiate meaningful activities, interactions and community building conversations and to create shareable artefacts, (Wenger, 1998).

Each of my participants had access to and interaction with her colleagues in her efforts to improve science provision across the school. For example, to support and develop her colleagues, Miss Dean worked with them in their own classes. Hammersley-Fletcher (2002) state that some subject leaders might feel uncomfortable observing colleagues and, rather than observing their lessons, which she thought would "feel a bit weird", given they all had more experience than she did, she initiated community building conversations as they jointly planned and taught lessons. Afterwards the conversations continued as they discussed what went well. By demonstrating the pedagogies she was promoting, she moved colleagues' practices away from lessons where there was a strong focus on recording through writing or worksheets, to one where there was a greater focus on practical hands-on investigations. Thus, she also demonstrated the ability, through engagement, to develop a shared practice.

However, the school's science community of practice involved more than just the staff. Miss Dean offered the children an optional home learning task during the Christmas holidays and 193 out of 201 children chose to complete the task.

> There wasn't any writing. It was just get your mum or dad to take a photo and email it to me, which went down really well. I have parents commenting … There was one child … doing some science. She sent me this on Christmas Eve. Bless her. [Showing me a photo as she spoke.]

By agreeing to the setting of the task the head teacher had given Miss Dean access to and interaction with both children and their parents or carers, in addition to the legitimacy to contribute to shared practice. Furthermore, the positive response from colleagues, children and parents provided reification for Miss Dean.

The creation of shareable artefacts is one of the forms of engagement highlighted by Wenger (1998). Danielle engaged both pupils and teachers in community building conversations to create the school's **principles**; a shareable artefact. She interacted with the children in a whole school assembly raising the children's awareness of the **principles**. She followed this up by creating a slip of paper for children to stick in their books, on which they could tick which of the **principles** had applied during their science lessons. Thus, the **principles**, became a focus of community building conversations.

Alice also engaged teachers and children in the creation of the school's **principles** but additionally asked parents for ideas. As a result, some parents with careers in science offered to come into school to work with the children. To ensure the **principles** were accessible she created both adult and child-friendly versions, and then went on to create a pictorial one which was displayed in all classes. To support her colleagues in considering the **principles** when planning, she created a further shareable artefact; a tick sheet where they could record which of the **principles** might apply during the lesson.

Alice was particularly active in arranging a wide range of meaningful activities for the children to engage with, including visits, visitors, British Science Week, The Great Science Share, a science themed World Book Day and an eco-club. Children, teachers and some parents engaged with these activities leading to both participation, conversations and reification.

Community building conversations began happening spontaneously among Mrs Collins colleagues. She demonstrated her ability and legitimacy in the development of shared practice using the school's science week as an opportunity for her colleagues to try teaching in a different way. "The teachers would teach a very specific science experiment, very hands-on, not worrying about the recording, but literally getting them immersed, drowning in the scientific enquiry." As a result of this and other actions, Mrs Collins felt there were now more, "informal chats in the staff room of, wow, this worked really well."

Miss W also engaged in community building conversations with the children.

> I did a pupil voice only a couple of weeks ago and the kids said we love science. Science at our school is nine out of ten now. We do it nearly all ourselves now. We work in groups. We work in pairs. We could all tell me some science they had done and what was coming up. They all talked about science week and what their favourite thing was, and they were really enthusiastic.

This provides another example of, "participative and reificative aspects of practice in concert" (Wenger, 1998:184), in that the feedback from the children acknowledged the difference in science teaching and learning that Miss W's actions had instigated.

Miss W also engaged with community building conversation within the broad primary science community through Facebook.

> I am on the Facebook group for PSQM. I am also on the Facebook group for primary science coordinators, or something like that, and a lot of people ask a lot of questions and a lot of the answers I give are to do with PSQM… I don't think it is the be all and end all … it is a very clear framework of how to improve, rather than do it on your own.

Through offering advice to other science subject leaders, she demonstrates the belief that she can legitimately share her opinions and engage with others outside her school.

Like the other science subject leaders, Mrs Jones engaged in community building conversations. She carried out a pupil voice activity and asked her colleagues to participate in a staff voice activity. To support them with areas they requested, she provided CPD during staff meetings and arranged external CPD for some. She gave them notice when she would be carrying out book scrutinies and what she would be looking for. The science week was an opportunity for teachers and children to participate, but, following this up by seeking feedback led to reification and further community building conversations.

> Every single staff questionnaire and pupil voice, they have all said science week was amazing. Wow science day; really engaged. Going home doing science experiments at home. All the teachers have said the children won't stop talking about it and if I walk around the school and say how is it going in science? … They will say we did this, and it was really fun. I learnt how to do this, and they know who I am and want to share it with me more.

Fuller et al. (2005) are critical of Wenger (1998) because while highlighting the importance of learning through participation, he fails to take account of peoples' prior learning and dispositions. Initially Mrs White found it difficult to engage both her colleagues and the children with meaningful activities and community building conversations. Mrs White recognised in herself a predisposition to procrastinate, affecting her ability to participate. However, a PSQM training session appears to have given her authentic access and the ability and legitimacy to begin to develop shared science practice.

> I felt very much like I was doing it alone and I know that is probably my fault because there are lots of people I could get in touch with to help… I did get quite low about it and wondered why am I doing this? What's it all for? … I think I really knuckled down to it and put it as a priority and really got stuck into it and I think I turned a corner … I went on the [PSQM] training again … and that really helped … being there with the other ladies who are doing it and talking to them about what they are finding difficult and what they were doing. That was quite reassuring and, having the hub leader there … that really helped because up until that point I still wasn't sure what I was supposed to be, what the end product was going to be.

Therefore, the access and legitimacy Wenger (1998) claims are necessary for participation, initially seemed to be lacking for Mrs White. However, through community building conversations at the PSQM training and a clearer focus on the product, Mrs White then felt able to engage more fully.

I asked Mrs White, at what point had she managed to engage others.

> I had to update everybody on what was happening, and at the staff meeting, that would have been in the spring term, I had to feedback on the book monitoring with the governor, so that involved everybody. There was quite a few actually, staff meetings, in that spring term.

So, it appears that once Mrs White engaged with her colleagues in community building conversations her ability and legitimacy to continue to develop shared practice became enhanced and she no longer felt she was doing it on her own.

She also felt her conversations with me had been meaningful activities. Unprompted she mentioned that speaking to me had been useful.

> I know there is a lot to do, but it is trying to piece it all together in my head and making those links … and that is why it is good to talk about it because I would never have really. It would have taken me much longer time to get there in the end.

This was a different type of community building conversation, but one which Mrs White found beneficial.

At the end of the year Mrs White reflected on the ways the PSQM had given her the ability and legitimacy to contribute to the development of shared practice. Now she felt she was, "delving a bit deeper. Asking a few more … focused questions. So that sort of brought out that they didn't, they liked the practical side but not the writing side." Having discovered this, Mrs White felt she had the legitimacy to begin a community building conversation with her colleagues. "Just getting children to focus on one thing, rather than writing the whole investigation up. So, I would probably not have done that."

Muijs and Harris (2006) discovered that when teachers took an active approach, the chances of the initiative being successful was increased. "Participation in group activities", and "working alongside others" were two of the workplace activities Eraut (2004) identified as resulting in learning. The science subject leaders participating in my research were all active in initiating group activities. They worked alongside others to engage members of their communities, including both colleagues and children to work towards a shared practice. They implemented many meaningful activities and interactions, and in some cases produced shareable artefacts. In each case new situations were negotiated demonstrating the engagement discussed by Wenger (1998).

5.4.2 Imagination

> *The work of imagination … requires the ability to explore, take risks, and create unlikely connections. (Wenger, 1998:185)*

Wenger (1998:185) states,

> imagination requires an opening. It needs the willingness, freedom, energy and time to expose ourselves to the exotic, move around, try new identities, and explore new relations … to accept non-participation as an adventure, and to suspend judgement.

The PSQM gave my participants the legitimacy to work towards developing shared practice. Hence an opening was created for them, and their school communities gave them the freedom to try new identities. Many bemoaned the lack of time, however, they each found the time and energy to engage in community building.

Although Danielle was new to science subject leadership, she was willing to suspend judgement and begin a new adventure. Her first initiative was sending a science learning task home to be completed over the summer holiday immediately before the start of her PSQM year. She did this entirely of her own volition demonstrating her confidence to take risks and experiment. The response from the children, colleagues and parents was overwhelmingly positive and the outcome of her exploratory venture into home learning tasks led to further hands-on activities being sent home. Wenger (1998) suggests reification is essential in supporting engagement to ensure, "enough material to play with, to bounce off from, and to shake free from time and place", and the reification resulting from this home learning task appears sufficient to maintain Danielle's willingness to initiate other meaningful activities.

Miss Dean used her imagination to innovate and explore new relations. When I asked where the idea of Science Ambassadors had come from, she replied,

> Because I think I can stand at the front and preach as much as I want, but actually it is the kids that make a difference. If they are telling other kids it is good, they are going to listen to them more, rather than me. I think that is where it came from if I am honest… my head.

She also came up with the idea of 'Challenge me' lanyards which featured question stems based on Bloom's taxonomy (Bloom, 1956). When children completed the work set by Miss Dean, they chose a lanyard and asked either an adult or child to use the question stem to begin a question to challenge their thinking. She gave an example of a maths question which was extended by children asking increasingly complex 'what if' questions.

> Honestly it went on and on and on and they kept pushing each other and pushing each other and adding more things in, so it was really nice to sit back and think actually they know exactly what they can do next.

This response provided memorable evidence of the success of this initiative. "Now they are not ready to say I am finished, because they know they have not finished, and they are never going to finish… It took a lot of training, but I think it is worth it."

Eraut (2002b) considers one of the reasons for the failure of professional development experiences to be effective is the reluctance of teachers to take risks. He claims they do not change their practice because 'unlearning' is risky and stressful. Mrs Collins demonstrated she was willing to take risks with her teaching.

> We dissected a pig's heart in year six as part of the human body topic and they absolutely loved it. I thought there is no way most primary schools would even risk to take that, but I thought why not. They are supposed to learn about it, and we can show them a video of it, brilliant, CGI, but what is wrong with getting a real pig heart and there you go and look at it. Yes, it's smelly but that is what is going on in your body and that is my approach to teaching science.

Mrs Peters believed she had the freedom to try new teaching and learning strategies and was, "forever looking for more interesting ways to present things, and more interesting ways to do things, and trying to engage the children more." One example of an imaginative approach she used was when she took her year two class for a walk wearing old socks over their shoes. "We went for a walk across the field and then we filled the socks with compost and hung them outside to see what happened and what grows from them." Mrs Jones mentioned her colleagues were gaining, "the confidence to take risks with science, rather than just worrying about the knowledge. Like just letting the children ask questions and going off at a tangent."

This ability to, "shake free" (Wenger, 1998:186) and explore new relations, provided a rearrangement of the world (Wenger, 1998) for Mrs White, who took the risk of speaking to colleagues and increased her confidence to do so. I asked how the PSQM had given her more confidence and she replied, "Because I had to speak to them." She also thought the PSQM had boosted her confidence and allowed her to take a risk by applying for a new job.

I suggested to Mrs White that her new approach of allowing children to ask and answer their own questions was also taking a risk and she agreed, yet suggested it was not an easy process and it was necessary to suspend judgement. "Yes, and you think God, this is chaos; he's not doing anything over there. But I think you have to go through the pain threshold I think and let them explore and investigate."

For Alice, risk taking extended beyond herself to her colleagues allowing them to reinvent their practices and the school's science community.

> I think we are doing, teaching things in more adventurous ways and being a bit bolder about trying new things and not just following lesson plans that you might have used twice already, and I think people are trying and linking to the experience outcome, so we link it to our topic as much as possible… Everyone knows that science is the focus, so they're making sure that what they are doing is not the easy option.

Wenger et al.'s (2002) conceptualisation of communities of practice supports the idea of individuals taking risks. The inability of individuals to take risk is noted by Eraut (2002b) as a reason why professional development opportunities failed to improve pupil outcomes. However, active participation in the PSQM provided opportunities to break away from repeated behaviours (Seger and Spiering, 2011) and encouraged community members to explore, take risks and make unlikely connections (Wenger, 1998). Lave and Wenger (1991) claim the inexperience of newcomers brings new ideas to the community and each of the participants showed imagination in the initiatives she introduced.

5.4.3 Alignment

> *The work of alignment … requires the ability to co-ordinate perspectives and actions in order to direct energies to a common purpose … to connect local efforts to broader styles and discourses. (Wenger, 1998:186)*

Alignment is quite separate from imagination and engagement. "Neither engagement in shared practice nor imagination entails alignment and, in turn, alignment does not entail mutual engagement or imagination" (Wenger, 1998:179). However, despite engaging with the work of imagination each of my participants directed her energies to the common purpose of achieving a PSQM. In the process of creating and implementing the **principles**, and in aiming to meet the PSQM criteria each began to align the local practices of herself and her colleagues to the discourses of the broad primary science community.

Miss W changed her practice in line with PSQM criterion C1. *"All pupils are actively engaged in science enquiry; using a variety of enquiry strategies; independently making decisions, using evidence to answer their own questions, solving real world problems, evaluating their work."* (PSQM Framework – see appendix A.) So, she no longer demonstrated practical activities to the children. "I never do experiments anymore. The kids do it all and they love it." She then went on the describe an investigation using, "jelly balls … ones for expanding in water."

> Then they predicted that when we left them on the paper towel, they would stay the same size, and of course, they didn't, they shrunk, but they stayed soft. Then we talked about whether it was reversible or irreversible and they decided it was partly reversible… Then they talked about what they would do next time. So, some of them said well, we didn't quite trust our results and would like to do it again and maybe have two lots of them.

Thus, the children began to adopt broader science discourses and vocabulary. This indicates membership of the school science community of practice. So, not only has Miss W negotiated a local way of belonging to the broad primary science community, the children are also manifesting the broader styles and discourses of scientists, albeit primary ones.

Mrs White noted her colleagues were more regularly discussing science lessons. "They talk about what they are doing in science a lot more … to each other. I just hear, oh, in science we are doing this, more than I have done in the past." This demonstrates that her colleagues starting to "negotiate local ways of belonging to the broader constellations" (Wenger, 1998:149).

The link between science and other curriculum areas is also strengthened. PSQM criterion D1 reads: "S*cience supports and links with other curriculum areas and contributes to maximising whole school initiatives" (*PSQM framework – see appendix A). Mrs Collins hoped to see less writing at the end of the PSQM year and when I asked if this had been achieved, she told me, "We have still got the writing because that is our focus as a whole school, and obviously an Ofsted thing, writing in other areas, but I would definitely say there are more photos across the school." She then showed me some of her own class' science books that included writing in science in several different genres to reflect the year six English curriculum. She mentioned they had also shared their science learning through drama.

Mrs Jones demonstrated alignment with the discourses of the broad science community of practice. When I asked how she would know science teaching and learning were improving she told me she hoped to see, "teachers using more skills-based and vocabulary and writing, displays and trying to include a hands-on table."

One of the discourses of the broad primary science community was discussed by Mrs Peters. With her half-termly science days she planned to, "almost give the children ownership of it to find out what they wanted to find out." At the end of the year she reflected on the way science teaching had changed. "It is basically much more open-ended." She also reflected the broader discourse about science. "It is all around us and that's what I would like to radiate out."

Science was now being presented in a way that reflected the broad primary science community's views. Mrs Peters told me,

> It is not so worksheet based anymore. It is much more what the children are learning… actually, they are not recording everything, … they are just writing in their reasoning and thinking which, I think, teachers have found more beneficial.

Thus, her colleagues are aligning their practices with the broad primary science community. Mrs Peters also displayed knowledge of the importance of independent learners.

> From the children's point of view they are taking a lot more responsibility for their own learning and if they want to carry it forward in their homework they are doing, and if they want to carry it forward in lessons they are coming up with their own suggestions and being allowed to develop those ideas which is a huge change.

Alice also noted, "Science is everywhere, and I do think if you are lucky enough to be in charge of science then you get to stick your finger in a lot of pies." She contrasted this with the view that, "we put things into compartments", which she felt did not reflect real life. This demonstrated her familiarity with the discourses of the broad primary science community of practice.

Evidence Miss Dean was aligning her discourses with those of the primary science community of practice was forthcoming when she described a science CPD day that her head teacher had booked for her. While she had enjoyed a day of practical, hands-on science she considered it had minimal impact on her practice because that was what she was doing anyway.

Danielle told me about a pupil voice activity she conducted at the end of the PSQM year. "All the year groups said their teacher liked science more. I don't think it is the teacher likes science more, I think there are probably a few more ideas on how to deliver it … and they are seeking out the **principles** in their planning." The **principles**, written with input from teachers and children at her school, also reflected the discourses of the broad primary science community and demonstrated Danielle's, "ability to coordinate perspectives and actions in order to direct energies to a common purpose" (Wenger, 1998:186).

5.5 Summary of chapter 5

In this chapter I have explained why I believe a broad primary science community of practice exists. At the start of the PSQM year, for some schools there was no evidence of a science community of practice. For others there was an overlap with the broad primary science community of practice and a school's science community of practice existed. During the year a community was either created or developed that increasingly overlapped with the broad primary science community of practice as evidenced by the discourses of my participants. This existence of the schools' science communities of practice was clear because the domain, the community and the practice were all present. In this chapter the literature on professional development has also been considered where it supports or contradicts the findings of my research.

I have discussed situated learning and Lave and Wenger's (1991) foci on talk and language; engaging in practice; apprentices, masters and mastery; learning and curriculum; and legitimacy and access. Each of these aspects has been considered in turn in relation to the data I gathered from my participants.

In respect of talk and learning the expertise required by a primary science teacher (Wellcome, 2017a) has been regarded as representative of the discourses of the broad primary science community and the discourses of my participants have been compared to these. Broadly their discourses match the discourses of the primary science community of practice. In terms used by Lave and Wenger (1991), they have learned *to* talk, and this is crucial to legitimate peripheral participation. This is to be expected given that the PSQM criteria lead them in this direction. Nevertheless, this is important in terms of their legitimacy.

There is substantial evidence that the science subject leaders have engaged both themselves, their colleagues and the pupils in a school science community of practice. Because of the PSQM criteria there were commonalities in the range of activities that took place in each school, such as the creation of the **principles** and monitoring activities. Further examples can be found, in the participants' stories and rivers of experience (see appendix U).

Lave and Wenger (1991) also consider the roles of apprentices and masters and the location of mastery in a community of practice. Although the science subject leaders could be regarded as apprentices in the broad primary science community of practice, they were able to perform the role of masters in their own schools. They were able to do this because mastery does not necessarily reside with the master (Lave and Wenger, 1991) and in this case the participants had access to mastery through the PSQM framework, the hub leader and signposting to the broad primary science community of practice.

A teaching curriculum is based on predetermined outcomes specified by the teacher, leading to direct instruction. This contrasts with a learning curriculum that is determined by learners based on their needs (Lave and Wenger, 1991). While Lave and Wenger contend that situated learning occurs solely through participation, the experience of my participants indicates that an official agenda, in terms of the PSQM framework, and direct instruction also have value.

Legitimacy and access are fundamental to communities of practice and the science subject leaders needed both to connect to the broad primary science community of practice, while the rest of their school communities needed legitimacy and access to the schools' science communities of practice. While participation in the PSQM allowed science subject leaders legitimacy and access to the broad primary science community of practice this access was limited by the amount of time they had available. Access was possible through the PSQM criteria, written material and websites. All had access to a hub leader and some also managed to attend training events and conferences, increasing access to the broad primary science community of practice.

In addition to access to the broad primary science community of practice, the participants ensured members of their own schools' communities had access to a school science community of practice. However, there were constraints limiting access including budget to pay for CPD and allow the participants time away from their classes to carry out the subject leadership activities; and, time for science teaching and learning. For some, writing the **reflections** as part of their PSQM evidence was time consuming and unnecessary, while others believed the process was important in developing their ability to reflect.

There were however affordances including support from colleagues and senior leaders; the fact that they were working towards a quality mark with a deadline, seeming to give them greater legitimacy. The PSQM framework, the **principles,** and the **action plan** also supported developments**.**

This chapter considered the participants' identities drawing on Wenger's (1998) conceptualisation. They were redefined by the way both themselves and others experienced and reified them as they engaged with their role as science subject leader. Some grew in confidence, some viewed themselves as better leaders and some improved their pedagogy. Their familiarity with the discourses of the broad primary science community of practice was testament to their community membership. Their ability to play their part in their schools' science communities of practice and take on similar perspectives and foci indicates growing identities as science subject leaders.

Trajectories changed over the course of the year with participants starting the year on an inbound trajectory with respect to the broad primary science community of practice. They also created opportunities for members of their school communities to assume inbound trajectories with respect to their own schools' science communities of practice. By the end of the year, three of the eight had adopted outbound trajectories and were moving schools and two had gained internal promotions.

Wenger (1998) asserts that multimembership of communities of practice may lead to competing pressures that need to be resolved. Some of my participants were clear that they were not scientists, others were reluctant to be seen as leaders, yet in all cases they were able to resolve their membership of these groups with being science subject leaders.

Three modes of belonging enable us to make sense of the process of identity formation; engagement, imagination and alignment (Wenger, 1998). The participants initiated and took part in meaningful activities that were fundamental to the formation of the schools' science communities of practice. They engaged other members of their school communities in these activities. The participants used their imagination to create artefacts to support improvements to teaching and learning and to create opportunities for further engagement. Their activities were generally aligned to the values and practices of the broad primary science community.

Chapter 6. Conclusion and recommendations for practice

> *A notion of knowing and learning as embodied shifts the emphasis of research away from the mind of the individual toward a socially constructed practice and potentially shifts the focus of continuing professional learning toward support for such authentic lived practice. (Webster-Wright, 2009:717)*

6.1 Introduction

In this chapter I will return to my research questions and discuss the answers I have discovered. I will then consider the implications of my findings for science subject leaders, school leaders, PSQM hub leaders, for the design of the PSQM programme and for policy makers. The contribution to knowledge, and further research questions that have arisen, will be discussed.

6.2 Research Question 1 asked, 'What happens to the identities of the science subject leaders during the PSQM year?'

Hodkinson and Hodkinson (2004) argue that in the work of Wenger (1998), individuals deserve greater prominence and the answer to research question one focuses on individuals. In line with the understanding that identities are multiple (Akkerman and Meijer, 2011), Wenger (1998) highlights five conceptions of identity. Identity as:

- Negotiated experience
- Community membership
- Learning trajectory
- Nexus of multimembership
- A relation between the local and global. However, this aspect was not explored in my research.

The identities of my participants will be considered in relation to the first four of the above conceptions.

6.2.1 Identity as negotiated experience

For Wenger (1998) reification is an important element in this conception of identity, and my research shows that the participants were reified by their schools' senior leaders, colleagues, children and in some cases by parents and governors. In addition, they were reified by the PSQM reviewers whose comments were, in the main, gratefully received. The exception was Mrs Peters who gained a PSQM silver award rather than the gold she aimed for. Her disappointment was palpable and led to her rejecting the role of science subject leader. Others were also reified by bodies external to the school, for example Ofsted, and, organisations associated with the broad primary science community of practice.

The science subject leaders identified themselves as either more confident, better leaders or better teachers, or some combination of these three. In terms of confidence Mrs Peters was again an exception and although her first experience of PSQM, three years ago, had increased her confidence, on more than one occasion during her second time working towards a PSQM she told me her confidence had been dented. However, she did point out how she had grown as a leader and how her teaching practice had developed. Most of the other participants claimed an increase in confidence, especially the less experienced teachers.

Wenger (1998) claims reification is only part of the story and deeper meaning arises from playing a part in, and contributing to, a community of practice. Acknowledgement of expertise and attributes by others and self has a part to play in creating this deeper meaning. There are numerous examples of children, colleagues, senior leaders and others seeking advice from the science subject leaders and acknowledging their expertise and positive attributes in other ways. I argue that because they have instigated the changes to science teaching and learning, the meaning for them is even deeper than that suggested by Wenger (1998).

6.2.2 Identity as community membership

Although my participants were all designated science subject leaders, Wenger (1998) contends familiarity with the discourses and practices of the community is more important than having a label. I previously discussed how the participants became more familiar with the discourses of the broad primary science community of practice and introduced these discourses in their own school science communities of practice. They therefore have common foci and ways of seeing the world in line with Wenger's contention. However, because they were guided by the PSQM criteria, I consider this to be expected.

Wenger (1998) believes sustained engagement in practice is necessary, and because PSQM is a process continuing over the greater part of a school year, the process is prolonged. Each science subject leader was also interested in the continuation of developments in science teaching and learning at the end of the year, sustaining the development of science teaching and learning over an even longer period. Memorable experiences are additionally a part of identity as community membership, and the level of detail with which the science subject leaders recalled and described lessons they visited and other science events, leads me to believe these experiences were memorable.

6.2.3 Identity as learning trajectory

While Avraamidou (2014) describes identity as a process, Wenger (1998) prefers the term 'constant becoming' and defines five trajectories. The previous work (Lave & Wenger, 1991) only considered inbound trajectories of apprentices as they worked towards full membership of a community of practice. The four additional trajectories identified by Wenger (1998) are peripheral, insider, boundary and outbound. I found evidence of participants and others on different combinations of these trajectories, again indicating the uniqueness of their experiences.

All science subject leaders were on an inbound trajectory with respect to the broad primary science community of practice, however, Mrs White was initially on a peripheral trajectory. Each was also a full participant in her own school's science community of practice, and thus on an insider trajectory. By the end of the year, some were on an outbound trajectory as they took up posts elsewhere, however, two of these were keen to take on the science subject leader role in their new schools. The third, Alice, started training to become a secondary science teacher. Those who remained science leaders in their own schools had plans to ensure the, "evolution of practice continues" (Wenger, 1998:154). Even those taking up other roles in school and handing science leadership to someone else were interested in its on-going development. The only person to actively reject the role of science subject leader was Mrs Peters who wanted to pass it on to a colleague.

Boundary trajectories were present for all the science subject leaders and were essential in enabling participants to cross borders between the broad primary science community of practice and their own schools' science communities of practice. This facilitated the creation of a constellation of primary science practice.

6.2.4 Identity as a nexus of multimembership

Wenger (1998) claims individuals attempt to reconcile their memberships of many different communities; however, this might not always be possible. Participants' membership of other related communities became apparent. Many adopted the discourses of a traditional primary teacher. Miss Dean was a recently qualified teacher, and Alice was a higher-level teaching assistant (HLTA). While some of my participants described themselves as passionate about science, others did not perceive themselves as 'sciency'. Whatever other related communities they considered themselves belonging to, all appeared able to reconcile any conflicting identities with their identities as science subject leaders. For example, those who regarded themselves as having little interest in science at the start of the year, were in various ways, able to reconcile this with becoming effective science subject leaders as the year progressed.

Thus, based on four of Wenger's (1998) conceptions of identity, my participants' identities developed. Reification played a fundamental role in developing their identities as negotiated experience and their initiation of activities to raise the profile and improve the quality of science teaching and learning led to "deeper meaning" (Wenger, 1998:151). The exception was Mrs Peters for who rejected the role of science subject leader, although her identity as a teacher and leader developed. The familiarity of the participants with the practices and discourses of the broad primary science community of practice signalled their identity as community members. Their inbound trajectory with respect to the broad community of practice and their boundary trajectories enabled the development of primary science teaching and learning, but significantly enabled some of them to adopt outbound trajectories. All were able to reconcile any conflicts in their multimemberships allowing their identities as effective science subject leaders to emerge.

6.2.5 Wenger's three modes of belonging

Wenger (1998) believes that to make sense of the process of forming an identity three complementary modes of belonging should be considered, each requiring the work of belonging. The three modes of belonging are: engagement, imagination and alignment. I argued in the findings chapter, that all my participants engaged in the work of belonging in each of the three modes, and their identities changed as a result.

6.2.5.1 Engagement

Communities of practice are formed through engagement, and findings have demonstrated the ways my participants engaged others in their school communities, thus forming school science communities of practice. They were able to do this because they had legitimacy and access (Wenger, 1998) to both the broad primary science community of practice, and their own school's science community of practice, plus the ability to cross borders. They negotiated constraints, such as a lack of budget and limited time away from their classes to initiate activities to engage others in their school communities and to complete the documentation ready for their PSQM submissions.

Engagement requires community building conversations (Wenger, 1998) and many of these were evident in my data. The production of the **principles** in each school created an example of a shareable artefact; another requirement for engagement (Wenger, 1998). Further, engagement requires participation in meaningful activities, and these included staff meetings, science days, and hub meetings with other subject leaders. Miss W also engaged in meaningful social media conversations with teachers beyond her school.

6.2.5.2 Imagination

Each school's community of practice was unique, because all the science subject leaders used their imagination in different ways. Wenger (1998) considers exploration and the taking of risks to be part of this mode of belonging. Each science subject leader took different risks and was successful in encouraging their colleagues, and sometimes the children, to do the same. The importance of risk taking has also been highlighted as important in effective professional learning (Eraut, 2002b). Wenger (1998) suggests openings need to be created and each of my participants felt able to experiment with new initiatives. For example, allowing children greater independence when conducting science enquiry, changes to planning formats or the way children recorded their work in science lessons. The introduction of science days enabled colleagues to experiment with changes to pedagogy.

6.2.5.3 Alignment

Alignment is concerned with the ability to cross borders, taking ideas from one community of practice and transferring the knowledge and skills to a different community. In this case, the participants aligned perspectives in their own schools with the values and practices of the broad primary science community of practice. Partly through the **principles,** and action planning, based on the PSQM framework, these perspectives became apparent within the schools' science communities of practice.

Therefore, each of Wenger's (1998) three modes of belonging was present in my data and my participants were able to develop their identities through engagement with both the broad primary science community of practice and their own school's community of practice. In many ways they aligned practice in their schools with the broad primary science of practice, but they also found imaginative and innovative ways to engage.

So, in summary, reification and participation have been shown to be important factors in the developing identity of the science subject leaders who participated in my research. By the end of the PSQM year the participants identified themselves, and were identified by others, as effective science subject leaders, better teachers or had gained in confidence, or some combination of the three. Their roles as science subject leaders took on deeper meaning as their expertise and attributes were acknowledge by themselves and others. Their sustained engagement with the broad primary science community of practice led to increasing familiarity with its discourses and to common foci. Where they made me aware that conflict existed with their membership of other communities, my participants were able to reconcile any such conflict.

All of Wenger's (1998) trajectories were evident in my data, with an inbound trajectory towards the broad primary science community of practice and insider trajectories in their own schools' communities of practice evident for all participants. In some cases, their changing attitudes, knowledge and beliefs led to an outbound trajectory. Boundary trajectories were also important in enabling border crossings and in the creation of constellations of practice (Wenger, 1998). Parents and governors were sometimes on peripheral trajectories.

Data confirmed the science subject leaders participated in the work of belonging in each of Wenger's (1998) three modes of belonging: engagement, imagination and alignment. Through this work their identities developed.

6.3 Research Question 2 asked, 'What changes do the science subject leaders establish within their schools?'

The science subject leaders who participated in my research either established a science community of practice within their school, or substantially developed one that already existed. Because of the overlap between the schools' science community of practice and the broad primary science community of practice, constellations of practice have evolved. Each school's science community of practice aligns with Wenger's (1998:1-2) three characteristics: the domain, community and practice. The domain is evident in the shared interests of the pupils and staff, and in their more frequent discussions about science. The children and teachers gained a shared competence in primary science with, for example, more practical science enquiry, and increasingly child-led investigations. In some cases, parents and governors were also involved, although to a lesser extent, probably on a peripheral trajectory (Wenger, 1998).

The collaborative activities such as staff meetings, creation of the **principles**, and science days or weeks provided evidence of community, the second of Wenger's (1998) characteristics. In addition, there were many examples where the science subject leaders shared information with and helped their colleagues. Relationships were built with the children who knew the science subject leaders were interested in science, and conversation about science ensued.

The practice, the third of Wenger's (1998) characteristics, is evident because the teachers and children are practitioners using shared resources like the reorganised science equipment, the slips of paper that children stuck in their books to indicate which type of science enquiry they had used to answer questions, or which of the **principles** applied during their lessons. Discussions took place with children during pupil voice activities where stories of their science lessons were shared.

Thus, all three characteristics of a community of practice identified by Wenger (1998) are present. The previous work by Lave and Wenger (1991) suggested 'shared understandings' was a condition for a community of practice. However, at the start of the year, there was a shared understanding among Danielle's colleagues that avoidance strategies (Harlen & Holroyd, 1997) like leaving science out of the curriculum for that week if singing practice took place, or asking supply teachers to teach science, were acceptable. While this corresponds with Lave and Wenger's (1991) conception of a community of practice as having shared understandings, this certainly does not have the depth of engagement evident in Wenger's (1998) conceptualisation as discussed above. Hence, the three characteristics as discussed by Wenger (1998) provide a better way to identify a community of practice, than the original work by Lave and Wenger (1991).

One further change that took place in school was that the profile of science was raised, making it more visible throughout the school community, and science subject leaders credited the PSQM for this change. Alexander (2010) noted the decline in the importance of science and Spielman (2020) confirms that science remains lower priority than English and mathematics. My participants at least partially redressed the balance.

The thirteen PSQM criteria create a diverse framework, so the focus in each school was on a broad range of outcomes (Opfer & Pedder, 2010b). This led to changes in pedagogy, assessment, enquiry, curriculum enrichment and in other areas too. Contrary to the work of Cordingley et al. (2015), none of the foci of the PSQM framework were on outcomes for pupils that were measurable through testing.

The science teaching and learning practices developed within schools corresponded, to a large extent, with the broad primary science community of practice's discourses around effective primary science practice. Not surprisingly, many of the discourses were closely related to the PSQM framework. For example, the science subject leaders told me about more child-led enquiry and hands-on practical work; raising the profile of science; more outdoor learning, visits and visitors; moving away from worksheets and more formal ways to write up practical work; and more group work. Assessment was also an area developed by the science subject leaders, but there were two examples where the PSQM criterion about assessment was misinterpreted by participants.

Other discourses became apparent that were not explicitly included in the PSQM framework but were in the Wellcome (2017a) statement of expertise required to be an effective primary science teacher. These included problem-solving and a focus on age appropriate scientific vocabulary. Talk for learning (see page 63) is an omission from the PSQM criteria and Wellcome's (2017a) list of primary science teaching expertise. However, there was evidence that classroom discussion and dialogue had increased in many of the schools. Therefore, even when some of the discourses of the broad primary science community of practice were not included in the PSQM criteria, some science subject leaders adopted them, due to the science subject leaders' peripheral participation in the broad primary science community of practice.

I further argue that by the end of the PSQM year the science subject leaders have each of the six dimensions of teacher leaders in my definition (Muijs and Harris, 2006; Timperley, 2005). In the findings chapter I have presented evidence of:

- Shared decision making
- Collaboration
- Active participation
- Professional learning

- Leadership as activism – teachers instigating change to improve the learning of pupils
- Authority

In some cases, the school, where the science subject leader completed the PSQM, benefited from their developing leadership skills after the PSQM year was completed. In other cases, where subject leaders moved schools, those new schools gained the benefit of their learning.

In summary, the changes to science teaching and learning brought about by the science subject leaders who participated in my research, included either the creation or transformation of science communities of practice. This was evident through the domain, the community and the practice. A broad range of changes to science teaching and learning in each school included the raised profile of science, improved pedagogy and other changes in line with the discourses of the broad primary science community of practice. I further argue that those who previously did not regard themselves as leaders adopted six dimensions of teacher leadership.

6.4 Research Question 3 asked, 'What are the processes involved in these changes?'

The processes that facilitated the changes discussed in research questions one and two will now be considered. The science subject leaders were enabled to cross borders and act as masters in their school communities, thus creating or transforming a school science community of practice. This was facilitated through their legitimate peripheral participation (Wenger, 1998) in the broad primary science community of practice and access to mastery through the PSQM framework. Lave and Wenger (1991:35) describe legitimate peripheral participation as, "a descriptor of engagement in social practice that entails learning as an integral constituent." Within their school communities my participants engaged others, ensuring the discourses of the broad primary science community of practice were spread more widely. Bell and Ritchie (1999) discuss the need for a subject leader to be proactive rather than responsive and my participants initiated many opportunities to engage their school communities in science activities and discussions.

The implicit emphasis on legitimate peripheral participation within the PSQM programme, in contrast to direct instruction, shifts the focus away from individuals and their cognitive processes and focuses on engagement until the submission of evidence and the review. My findings indicate that through the PSQM action planning and implementation process, the value of participation becomes more important than the results of examinations or tests. However, the PSQM evidence presented by the science subject leader is reviewed and an award made at the end of the year. The evidence submitted and the review process focus on two elements. The legitimate participation of the school community in developing science teaching and learning, and the ability of the science subject leader to write reflectively, which could be regarded as a form of test. This contrast is clearest for Mrs Peters who was disappointed to receive a silver rather than gold quality mark, which she took as a failure in the 'test', or negative 'reification', but she remained very proud of the difference it had made to the children and their learning; the outcomes of participation.

My participants successfully crossed boundaries between the broad primary science community of practice and their own schools' science communities of practice. Hoekstra et al. (2009) contend that teachers find it problematic to link practice and theory but by crossing borders my participants were able to do this. Interestingly, Mrs White initially found this process more difficult than others, and was slower to engage with her school community. Eventually she began to engage her colleagues in a series of staff meetings and borders were finally crossed, resulting in the development of the school's community of practice.

Despite being newcomers to the broad primary science community of practice, the science subject leaders were able to operate as masters in their schools. Because mastery can be located outside the master (Lave & Wenger, 1991), and in this case was situated in the PSQM framework, and through access to the broad primary science community of practice, the science subject leaders were simultaneously able to operate as both apprentices and masters, and border crossings were facilitated.

Lave and Wenger (1991) argue, in communities of practice there is minimal direct instruction and learning happens through engagement in social practice. In both interviews and rivers of experience there are numerous examples of participation in social practice occurring in schools. So, by engaging both colleagues and pupils in these activities, learning was spread beyond the science subject leaders into the wider school communities. Despite Lave and Wenger's view that direct instruction in communities of practice is minimal, there were examples where the subject leaders booked subject specific professional development experiences for their colleagues or attended courses themselves. As they implemented change throughout the school, they were able to incorporate the products of learning from these courses. Thus, professional development experiences led to further or more informed engagement in practice. This supports Hughes et al.'s (2007) view that learning as participation and acquisition are complementary.

Kuijpers et al. (2010) state that when related to a whole school initiative, a professional development experience is more likely to be effective than when a teacher participates in training alone. The PSQM appears to support this contention that the involvement of the whole school leads to effective professional development.

Many of the participants suggested they would have benefited from more opportunities to engage in social practice with other science subject leaders in their hubs. The interviews indicated how useful they found the opportunities to meet as a hub, and generally the opportunity to network with other science subject leaders was described as valuable, more so than interactions with hub leaders. Lave and Wenger (1991) believe knowledge spreads rapidly between apprentices, and this was true in the view of the science subject leaders who appreciated opportunities to share ideas and experiences.

The participants carried out their roles as science subject leaders closely matching the summary of knowledge and responsibilities of the primary science subject leader as shown in Figure 4 (see page 34). Even those who had science subject leadership experience prior to starting the PSQM believed the PSQM had supported them to fulfil their role more effectively. The deadline was important, as was the PSQM framework in ensuring timely engagement and development in a wide range of activities related to teaching and learning.

While some participants considered their ability to reflect was valuable learning from completing the PSQM, others felt writing numerous **reflections** was not the best use of their time and they gained minimal benefit.

In summary, research question three asked about the processes involved in the changes discussed in research questions one and two. The legitimate peripheral participation of the science subject leaders in the broad primary science community of practice, and full participation in the schools' science communities of practice were key in facilitating those changes. Border crossings between the two communities enabled the science subject leaders to simultaneously fulfil the role of master in their own schools while acting as apprentices in the broad primary science community of practice.

Participation in practice was a key element in enabling learning. There are examples of direct instruction having an impact, however, the opportunities for engagement were crucial either where this provided opportunities to embed learning from direct instruction or where no direct instruction was present. Engagement with other science subject leaders in their hubs was valuable and more opportunities to do this was requested by participants.

Lave and Wenger (1991) emphasise the importance of legitimacy and access to support legitimate peripheral participation. The answer to the next research question provides information about the affordances and constraints that supported or restricted the legitimacy of the science subject leaders and their access to both the broad primary science community of practice and their own school's community of practice.

6.5 Research Question 4 asked, 'What are the affordances and constraints encountered in this process by the science subject leaders?'

Each schools' unique context and development needs meant the affordances and constraints were also unique. Overall, the science subject leaders were pleased with the support they received from the schools' senior leaders. Harris (2009) argues that for leadership to become distributed power needs to shift away from head teachers and resources similarly need to be distributed. While my participants' head teachers appeared content to relinquish power in terms of leading the subject, budget remained an issue restricting opportunities to attend professional development experiences, limiting time out of class for leadership duties, and the purchase of equipment for practical science. However, it may be that head teachers were working with restricted budgets following cuts in school funding (NEU, 2019) and it was not in their gift to distribute funds to subject leaders. In some cases, but not all, funding from other sources was found to purchase equipment for practical science lessons.

The participants felt their colleagues were supportive, and therefore an affordance, as they worked to raise the profile and quality of science teaching and learning in their schools. However, when it came to collecting evidence to submit to PSQM for review, the picture was not so positive, and some subject leaders felt they were less well supported by colleagues in this aspect of the process.

Working towards a quality mark was a significant affordance mentioned by some of the science subject leaders. It helped their voices to be heard and for science to be prioritised by senior leaders. It also provided a deadline for implementing **action plans**. Two of the science subject leaders found the workload overwhelming at times, but the PSQM was only one of their many responsibilities. When Mrs Collins requested an extension to the deadline this was supported by her hub leader and granted by PSQM headquarters. Others noted it was hard work but expressed the view that meaningful and significant changes inevitably require hard work.

For some, the **principles** activity was a significant affordance. In most cases this was the first collaborative activity related to developing science involving colleagues and, in some cases, children, parents and governors. This provided a vision for science teaching and learning, that the House of Commons Education Committee (2017) believes is important. It was also an opportunity to engage colleagues as they participated in the process of discussing the **principles** and collaborated to decide what they should be. Some science subject leaders considered the **principles** an affordance in improving the quality and consistency of science teaching and learning, whereas others thought they had yet to implement them fully and gain the maximum possible benefit.

The PSQM framework provided the science subject leaders with access to mastery. This view is supported by the participants who noted the comprehensive nature of the framework and suggested they were reliant on the direction it provided. This highlights the importance of the content of the framework in ensuring the most effective use of the science subject leaders' time and energy. Some of them considered the **action plan,** which is based on the framework so the two are inextricably linked, was an important part of the process.

Time was consistently mentioned as a constraint. More time out of the classroom to engage in activities related to their roles as science subject leaders would have been appreciated. Some were given no regular time away from their classes for their leadership responsibilities and those who regularly had release time considered themselves fortunate rather than viewing it as an entitlement. Many regarded preparing the PSQM evidence, especially writing the PSQM **reflections**, as time consuming. Despite some initial reluctance to ask, most requested additional time out of the classroom to complete their PSQM submissions and this was granted by their head teachers. However, all the science subject leaders told me they invested considerable amounts of their own time in preparing their evidence. One activity required by the PSQM is an audit and reorganisation of science equipment and many of the science subject leaders noted how time consuming this task was, yet all were positive about the impact of this. Overall, the science subject leaders were positive about the actions they carried out to improve teaching and learning of science, but, writing PSQM **reflections** was regarded more negatively.

Time to fit science lessons into a crowded curriculum was also discussed. Most confirmed the removal of the science SAT and the Ofsted focus on English and mathematics as a constraint. This led to science being regarded as a less important core subject than English or mathematics, the other two core subjects. The introduction of science days or science weeks was one way in which the participants increased the curriculum time for science. By boosting their colleagues' confidence, avoidance of science teaching was reduced. In schools where staff turnover was higher the impact of the science subject leaders on transforming teaching across the school was reduced.

So, to summarise, the affordances and constraints experienced by the science subject leaders as they developed their identities and science teaching and learning within their schools were unique to each school. The participants all claimed their colleagues and senior leaders were broadly supportive, more so in engaging in activities to support the development of teaching and learning in science, than in collecting and collating evidence to be submitted to the PSQM for review. The collection and preparation of evidence to be submitted to the PSQM was generally seen as less impactful than activities promoting participation of the school community in science learning.

Many noted the extent of the workload, in addition to their regular classroom teaching, and a few felt this to be overwhelming at times, however, none expressed regret at engaging with the PSQM. The amount of non-contact time was inconsistent across schools but even those who were granted more time away from their classes by senior leaders still felt they worked hard. Where teachers were allowed time out of class for subject leadership activities, they tended to regard this as fortunate rather than an entitlement.

Of the PSQM documents, the **principles** of science teaching and learning were perceived as important, not only for their contents but also because members of the school community participated in their creation. **Action plans** were also viewed favourably and the PSQM framework was praised as a structure for developing science teaching and learning. Staff turnover in some schools was an issue in sustaining improvements in the quality of science teaching and learning.

6.6 Contribution to knowledge

The PSQM programme enabled science subject leaders to create science communities of practice in their schools. It was through engagement that learning became embedded in practice. The collection of evidence and the associated deadline provided an incentive to embed learning in practice. The failure of many professional development experiences to be effective (Guskey, 2003) often results from inadequate attention being paid to the way in which learning becomes embedded in practice (Opfer & Pedder, 2011), yet the opposite appears true of the PSQM. Webster-Wright (2009) notes an increasing acceptance of workplace learning as supporting professional development and through engagement in practice the science subject leaders were able to embed their learning from the broad science community of practice, not only in their own practice, but also in the practices of many of their colleagues. They have therefore adopted a leadership role and have become teacher leaders with all the benefits that brings to the school community.

These developments are represented diagrammatically in Figure 22 (see page 170), and this can be compared to Figure 10, (see page 95). The large dark blue circle expanded as more science subject leaders became involved with the organisations in the large circle and began to adopt their practices. The smaller light blue circles also expanded as the schools' primary science communities of practice developed, resulting in growth in the overall schools' communities of practice. The area of overlap is also larger showing an expanded school science community of practice. Where no overlap existed previously, there is now an overlap indicating the school's science community of practice has been established. There is some criticism that the theory of situated learning (Lave & Wenger, 1991) fails to explain how communities of practice can be created (Edwards, 2005; Fuller, 2007; Fuller & Unwin, 2004; Hughes, 2007). My data supports the view of Wenger et al. (2002) who assert that, through legitimate peripheral participation, communities of practice can be brought into being. I contend that border crossings are a vital part of the process.

In figure 22, the area of overlap for each hypothetical school is different, recognising the unique developments occurring in each school and the varying extent to which best practice in primary science education was adopted within each school community. The learning curriculum is unique to each school and science subject leader. Elements of alignment are present due to the PSQM framework and the ability of the science subject leaders to cross borders between the broad primary science community of practice and their own school science community. However, the extent of the science subject leaders' inbound trajectories towards the broad primary science community of practice, and their ability to cross borders and implement changes within their own schools are significant reasons in explaining the difference in the amount of overlap.

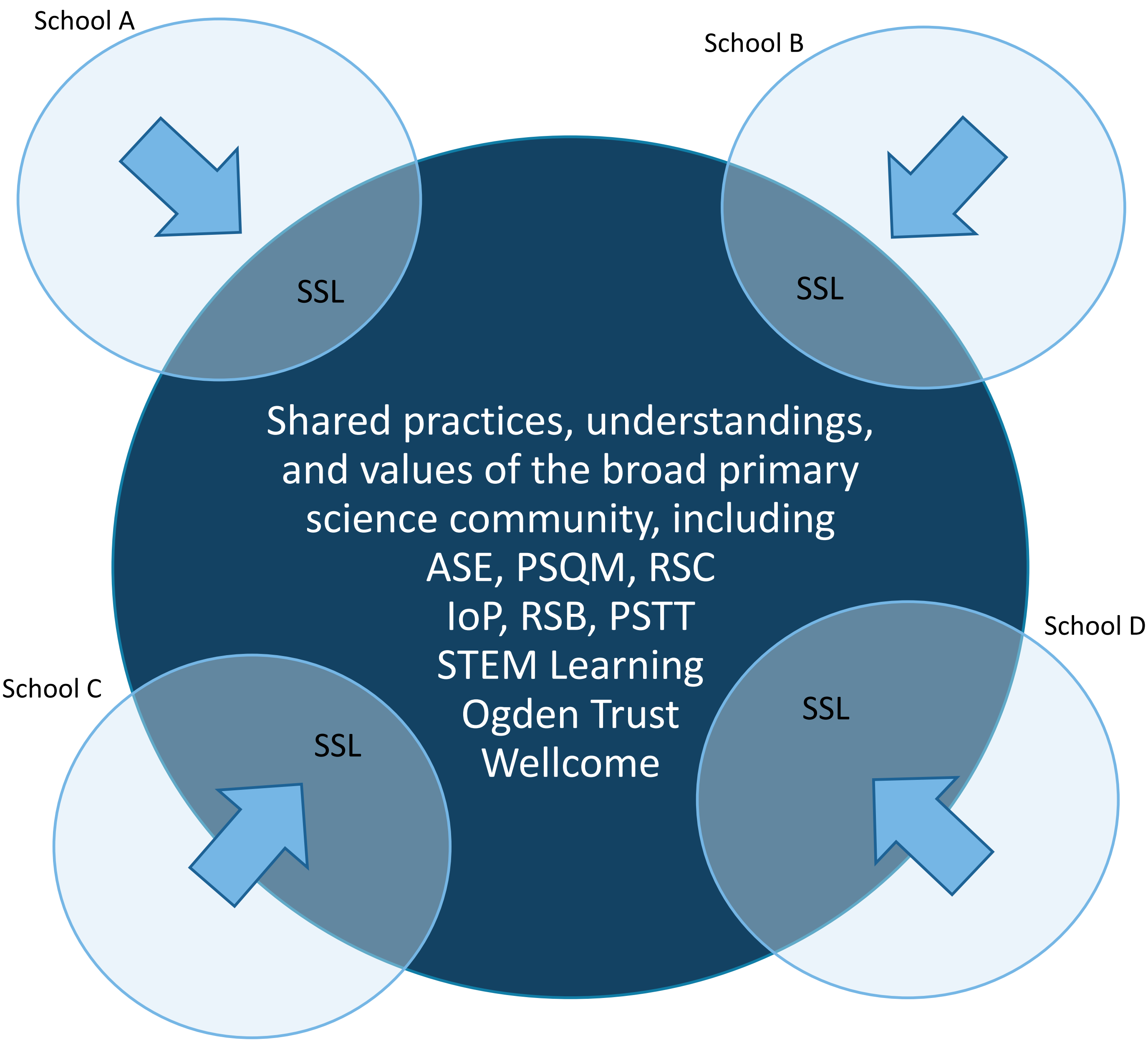


Figure 22 - Overlapping communities of practice

In summary my contribution to knowledge is that the PSQM enables science subject leader to create and expand communities and constellations of practice because they are enabled to embed learning, from the broad primary science community of practice throughout their schools.

The answers to the research questions and the contributions to knowledge discussed above have implications for practice and these will now be discussed.

6.7 Implications of the research

6.7.1 Implication for science subject leaders

The PSQM programme's focus on embedding learning in practice, supported both the raised profile of science and the development of science teaching and learning throughout the schools. It also facilitated changes to the identities of the science subject leaders. Working towards a quality mark provided greater status in school for the science subject leaders and the deadlines were important in providing the impetus to work within a timeframe. It therefore appears more productive to work on engaging the whole school community in developing science teaching and learning rather than simply attending professional development events. Science subject leaders should be made aware of this.

It is through participation and reification that my participants' identities developed and science teaching and learning improved throughout their schools. However, the workload required to complete the PSQM is considerable when added to a teacher's other responsibilities. The teaching and learning international survey (TALIS) (Jerrim & Sims, 2019) found teachers in England working longer hours than their international counterparts and the discourse of working long hours was adopted by my participants. When the PSQM workload was added, two of my participants went through times when they described themselves as stressed, although none regretted working towards and gaining a PSQM. Science subject leaders therefore need the support of the schools' senior leaders in providing time to ensure the participation of the wider school community in the development of science teaching and learning. Before embarking on the PSQM science subject leaders should be aware of the workload and ensure they will be supported with release time.

Border crossings are fundamental, but an understanding of their importance might provide greater support to science subject leaders in understanding how they facilitate change. Science subject leaders also need to be aware of the broad primary science community of practice and the ways they may access this.

Science subject leaders considering participating in the PSQM should be aware of the potential for their own development in confidence, leadership skills and teaching practice, alongside the potential changes to teaching and learning of science throughout the school.

6.7.2 Implications for school leaders

In each of the cases examined during my research, the science subject leader developed science teaching and learning across the school, in line with the discourses of the broad primary science community of practice. They did this through a process of participation and reification. Reification from senior leaders was important to my participants as they initiated a wide range of activities involving other members of their school communities. Therefore, reification of all subject leaders is likely to support their development. However, this reification should occur in response to engagement in practice. Reification of expertise and attributes can lead to the role of science subject leader taking on a deeper meaning for the incumbent and school leaders and others should ensure they act on opportunities to offer such acknowledgement.

Additional release time could support engagement with the organisations and individuals involved in the broad primary science community of practice and, through border crossings, and engagement with the school community, developments in science teaching and learning might be facilitated. The PSQM deadline was helpful in ensuring timely participation in practice and in preventing procrastination. Given the long hours that teachers work and the many pressures on their time it is understandable for teachers to put off science leadership activities and prioritise their day-to-day teaching. As discussed above, primary teachers are working longer hours than their international peers and therefore support in the form of non-contact time for subject leadership responsibilities is necessary. Where budget was available, additional professional development experiences were helpful in enabling the science subject leaders to access the broad primary science community of practice and become aware of the discourses and practices of this community.

The PSQM continued over the greater part of a school year and this was important in allowing the science subject leaders the time to write and implement their **action plans**. The longer duration of professional development experiences is also recommended by Cordingley et al. (2015). Thus, school leaders need to be aware that it takes time to develop teaching and learning.

6.7.3 Implications for PSQM hub leaders

While hub leaders are trained to focus on supporting the reflective aspects of the PSQM, the focus on participation and reification is somewhat overlooked, although both were present in my data Therefore, the hub leaders might seek out and recommend further opportunities for the participants to engage in practice. This might either be opportunities within their hub or in school. In addition, although science subject leaders were reified within their school communities and sometimes beyond, hub leaders could provide further reification, as and when the opportunity arises. Recognition of expertise and attributes can lead to the role of science subject leader taking on a deeper meaning for the incumbent, so opportunities to recognise expertise and other positive attributes should be taken.

Participants valued opportunities to meet as a hub and would have appreciated more opportunities to do so. Therefore, any additional opportunities to meet, beyond the four half days of PSQM training, would facilitate greater opportunities for collaboration.

Hub leaders would also benefit from a greater understanding of the importance of border crossings and the ways in which these can be facilitated. Increasing the awareness of the science subject leaders to the organisations and local individuals involved in the broad primary science community of practice is important in enabling them to adopt the discourses of this community, cross borders, and develop science teaching and learning in school.

6.7.4 Implications for the PSQM programme design

The PSQM framework and the hub leaders are important factors in providing the science subject leaders with access to the discourses of the broad primary science community of practice. Therefore, PSQM should ensure these discourses continue to be reflected in the PSQM framework and hub leaders are up to date with the developing discourses of this community. The role of the hub leader as part of the PSQM process was rarely discussed by my participants and where the hub leaders were mentioned comments were positive, so I feel unable to make any recommendations regarding the role of hub leaders in the programme design.

The PSQM framework, made up of the criteria and descriptors at bronze, silver and gold, was apparent in my research and below are recommendations for changes to the criteria and descriptors. Because none of the participants in my research worked towards or gained a bronze PSQM my comments below mainly focus on the silver and gold awards, although the bronze descriptor has been included for completeness. It should be noted that the criteria have subsequently been rewritten and some of the recommendations have already been implemented.

6.7.4.1 Critique of the PSQM criteria

Criterion A1

There is an effective SL for Science

Bronze descriptor: There is an identified member of staff who oversees the subject, may have a background in the subject and can demonstrate their enthusiasm for leading it.

Silver descriptor: There is a named member of staff responsible for the leadership of the subject. They have received subject-specific training in the last three years, have shared this with all colleagues in the school.

Gold descriptor: The SL has shared their training and subject knowledge with a broader audience beyond their own school.

I perceive a mismatch between this criterion and the three descriptor statements. Previously, I stated that the role of science subject leader is complex, thus to be an effective science subject leader requires more than enthusiasm for science and participation in subject specific CPD that is subsequently shared within school and maybe beyond. Given that the remainder of the criteria cover many of the skills and attributes necessary to be an effective science subject leader I argue this criterion is redundant. Reducing the number of criteria would also reduce the workload in writing reflections which was an area of concern for some of my participants.

Criterion A2

There is a clear vision for the teaching and learning of science

Bronze descriptor - Staff know and follow the school's principles for teaching and learning Science and some of them may have been part of the team which developed them. The school's scheme of work for Science reflects these principles.

Silver Descriptor - A staff team has been involved in developing the school's principles for teaching and learning Science. They are reviewed regularly along with the scheme of work for Science which promotes these principles.

Gold Descriptor - A school wide team has recently reviewed the school's principles for teaching Science, and ensured that the principles are implemented through the scheme of work for Science. Progression in skills, knowledge and understanding is evident in the scheme of work and children's outcomes.

Hargreaves and Shirley (2012) and Cordingley (2008) both highlight the importance of a vision and my research participants clearly valued the **principles** of science teaching and learning. This document was considered important by many of them. The involvement of other staff and sometimes members of the wider school community was perceived as important in ensuring they were communicated, valued and adhered to. The participative way in which the vision was created was also regarded as beneficial. This criterion has value, but I believe that evidence for its implementation should go beyond the science scheme of work and be embedded in both pedagogy and curriculum.

Criterion A3

The current School Development Plan has appropriate and active targets for Science

Bronze descriptor – The School Development Plan includes actions and targets for Science.

Silver descriptor – The Science SL has worked with the Senior Management Team to agree School Development Targets for Science based on identified strengths and weaknesses. The Science SL had led staff in the implementation of actions to meet these targets across the school.

Gold descriptor - The School Development targets for Science include maintenance and development strands, with clear strategies for improvement outlined plus actions to extend Science links beyond the school. Successes are already highlighted in the School Development Plan and plans for the future are underway.

Some of the participants in my research were aware that active targets for science were included in the school development plan (SDP) while others knew the SDP lacked specific science targets. The presence or absence of science specific targets did not appear to make a substantive difference to the actions of the science subject leaders. Mrs White was nervous about approaching the head teacher to ask for science targets to be included and this may be one reason for her hesitation in moving forward. Mrs Jones thought that the presence of science targets in the SDP ensured she was paid for the additional hours she worked leading science, but at the end of the year was pleased to see science removed from the SDP because it reflected the progress she had made in developing the subject.

Other factors, such as the support of the head teacher and colleagues, had more impact on the subject leaders' capacity to create and develop science communities of practice in their schools. The impact of having science mentioned on the SDP seemed minimal and given the substantial workload of teachers in preparing their PSQM submissions I advocate it should be removed.

Criterion A4

There is shared and demonstrated understanding of the importance and value of science to children's learning

Bronze descriptor – There is a shared understanding of the importance of science, clearly evidenced in the subject leaders' class and developing wider.

Silver descriptor – There is shared understanding of the importance of science, clearly evidenced throughout the school, including the grounds.

Gold descriptor - There is a shared understanding of the importance of science, clearly evidenced throughout the school, the grounds and from the wider community.

Throughout the evidence submitted to PSQM, the interviews I conducted and the rivers of experience, it became clear that in all schools, science became increasingly valued and important. But I believe this would have been the case without this criterion because the participants' response to the other criteria provided sufficient activity to ensure science was increasingly valued and important.

The inclusion of school grounds in the descriptors is interesting as only Mrs Jones referred to developing her school grounds, although others referred to using the school grounds. In schools, the grounds may or may not be a priority for development and the requirement to develop the grounds in the silver and gold descriptors did not happen in some cases. I suggest the submissions were not adversely impacted as a result.

I assert this criterion should be removed because evidence for the growing importance and value of science would be evident without it, and the element about the school grounds pre-judges a school's priorities.

Criterion A5

The science SL knows about science teaching and learning across the school

Bronze descriptor – The science SL works with, or monitors, the work of a colleague. School-wide work book scrutiny takes place.

Silver descriptor – Peer assessment and team teaching of science takes place across the school. School-wide work book scrutiny takes place.

Gold descriptor - There is a robust process of monitoring science teaching & learning in place. Outcomes are shared with staff and actions taken when issues are identified. Regular discussions take place between SL and SMT about science in the school.

All participants took part in monitoring activities during the year. These activities developed their understanding of the ways in which the teaching and learning of science was changing. Some used the **principles** as a focus for their monitoring activities and believed this was useful. Team teaching was felt to be an effective strategy by the few subject leaders who chose this in preference to observing colleagues' lessons. But despite the silver criterion explicitly requiring team teaching not all subject leaders employed this strategy. A book scrutiny was carried out in all schools.

The gold descriptor requires that action is taken when issues are identified, but the participants who were working towards the silver award also took actions based on the outcomes of their monitoring activities. All participants used pupil voice to monitor the teaching and learning of science, but it is not explicit in the criterion and I would recommend its inclusion. Monitoring activities were useful in providing evidence of the impact of their actions on science teaching and learning and this criterion should remain in place, although the requirement for specific monitoring activities might be loosened to allow subject leaders to decide on the most appropriate monitoring activities based on their context and foci.

Criterion B1

Staff continue to have opportunities for CPD within science that increases their skills, knowledge and understanding.

Bronze descriptor – The SL maintains an interest in the subject outside the school and this impacts on his/her teaching. The SL has taken part in some CPD that has had an impact in his/her classroom. Although other staff may not have received CPD, there is evidence of support being provided, when requested.

Silver descriptor – Internal monitoring and performance management processes are used to inform decisions regarding staff CPD needs in science. The science SL has delivered CPD to some other teachers.

Gold descriptor - The science SL has reflected on CPD needs as evidenced by internal monitoring and performance management processes and planned and developed a range of whole school CPD for science that is regularly monitored for impact.

All participants provided CPD for their colleagues in the form of staff meetings or more individual support, but, as suggested in the literature review, they did not recognise the value of learning through participation or situated learning in the same way that they did when they attended and facilitated training events. I recommend that the broader view of professional development experiences is highlighted by the PSQM to encourage science subject leaders and their colleagues to consider the potential impact of learning through participation. Despite the availability of formal CPD opportunities being restricted by lack of budget, I contend that the learning of the science subject leaders through participation was more significant than their learning through more formal CPD experiences.

The silver and gold descriptors require internal monitoring and performance management processes to inform decisions about staff CPD needs and I believe that science subject leaders could have made the link more strongly. There may be possibilities for rewording or combining the A5 and B1 criteria to strengthen the link between monitoring outcomes and CPD provision.

Teachers need a secure understanding of the subject matter they teach (Wellcome, 2017) and pedagogic content knowledge may have a significant effect on pupil learning (Coe et al.,2014). Therefore, it may be beneficial to include wording in this criterion that highlights the importance of these forms of knowledge.

Criterion B2

There are a range of teaching and learning approaches

Bronze descriptor – There are some relevant teaching and learning approaches in science being adopted by the science SL in response to class and school development targets. He/she is beginning to share these with colleagues.

Silver descriptor – There are several relevant teaching and learning approaches in science being adopted by teachers across the school in response to school development targets. The science SL is pro- active in introducing new strategies.

Gold descriptor - There is a wide range of relevant teaching and learning approaches in science adopted by the whole school and shared with other schools. The science SL is pro- active in introducing new strategies and innovations.

The descriptors for this criterion suggest that the teaching and learning approaches adopted should be relevant, however, there is minimal further information on which approaches might be considered relevant. However, the silver descriptor indicates that strategies responding to school development targets would be relevant. The literature, including the document detailing the expertise required by a primary science teacher (Wellcome, 2017), includes a range of strategies considered effective and perhaps this criterion should signpost this document or other literature offering more guidance regarding what teaching and learning strategies might prove effective. I recommend that talk for learning and vocabulary acquisition should be two such strategies. The use of independent and group work, eliciting and addressing misconceptions, and the appropriate use of models could also be considered.

The gold and silver descriptors require the science subject leader to introduce new strategies, however, I would suggest that a review of the effectiveness of existing strategies might be a more appropriate starting point. Further strategies could then be introduced in response to the outcome of monitoring activities in response to specific development needs. This could also be linked to CPD ensuring a joined up approach where A5 (monitoring), A1 and B1 (CPD) and B2 (range of teaching and learning strategies) become interwoven.

Criterion B3

There are a range of up-to-date, quality resources specifically for teaching and learning science. IT is used both as a tool and as a resource for teaching

Bronze descriptor – There is a well-organised, well-maintained, plentiful, appealing range of appropriate school-bought practical science and ICT resources, plus freely obtainable ones, which are available for all staff and children and are regularly used. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities.

Silver descriptor – Science resources are used across the school and are well maintained and organised. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities. Resources are audited regularly and the school has identified suitable further resources to purchase that will enhance teaching opportunities. Use of 'free' resources, such as rock samples, fabric collections and plants has been developed.

Gold descriptor - There is a well-organised, well-maintained, plentiful, appealing range of appropriate school-bought practical science and ICT resources, plus freely obtainable ones, which are available for all staff and children and are regularly used. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities.

Harlen (2006) draws attention to the importance of the accessibility of resources in enabling teachers to engage their pupils in practical work. Therefore, the organisation and availability of resources are important in supporting opportunities for pupils to engage in practical work. All eight science subject leaders audited and reorganised the resources available in school. The initial disorganised state of the resources led them to believe the resources were not being used but after their respective reorganisations accessibility improved, as did their usage. This was therefore perceived as an important step in increasing the access of pupils to practical science lessons. Where the school was unable to support the cost of additional resources, science subject leaders found sources of funding for additional resources through grants or approaching the PTA or equivalent body. It seems strange that ICT is only mentioned in the bronze descriptor and I would question the rationale for the inclusion of 'free' resources in the silver descriptor, and only the silver descriptor.

Criterion C1

All pupils are actively engaged in a science enquiry; using a variety of enquiry strategies, independently making decisions, using evidence to answer their own questions, solving real problems, evaluating their work

Bronze descriptor – Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home.

Silver descriptor – Children's curiosity is encouraged and valued. They ask questions, encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able, and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupils are encouraged to participate in school-based science initiatives.

Gold descriptor - Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupils are encouraged to participate in school and national science initiatives.

Valuing and encouraging the curiosity of children is an important factor in science teaching and learning (Harlen and Qualter, 2018) and this links closely to children asking their own questions. Furthermore, the literature indicates science enquiry is an important part of learning about science. The use of a range of enquiry strategies and children asking their own questions, independently making their own decisions about how to investigate them and evaluating their work are all included in the national curriculum.

Therefore, the inclusion of enquiry in the criteria when other elements of the curriculum are not included in the criteria might be questioned. However, based on my experience of working with schools, working scientifically (the enquiry element of the science curriculum), is typically the most neglected part of the science curriculum. There is considerable evidence that coverage of science enquiry skills improved considerably in my participants' schools, thus a criterion related to science enquiry is warranted.

Differentiated activities as mentioned in the silver and gold descriptors would be more appropriate as an element of the B2 criteria; teaching and learning strategies, and, would indicate in greater detail which strategies might be regarded as relevant.

Engaging in science activities at home is included in all three descriptors and participation in school and national science initiatives would be better placed in a criterion related to curriculum enhancement rather than science enquiry. However, some of my participants used science days and weeks as an opportunity to allow pupils to follow their own lines of enquiry and for teachers to experiment with different pedagogies linked to science enquiry. This approach may be something that the PSQM could promote. The use of science days and weeks to experiment with new pedagogies was not explicit in the criterion and would probably happen regardless of which criterion includes statements about school based and national initiatives. I therefore propose that statements about school-based and national initiatives be relocated to a criterion about science enrichment.

Criterion C2

The purpose of science assessment is well understood and shared by members of the school community. Assessment approaches are designed to fit those purposes.

Bronze descriptor – The SL builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues. The SL supports other staff in making summative assessments of children's science attainment.

Silver descriptor – The SL builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues. The SL supports other staff in making summative assessments of children's science attainment.

Gold descriptor - The SL builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues. The SL supports other staff in making summative assessments of children's science attainment.

Based on my experience of speaking to participants, working with science subject leaders as they work towards a PSQM, and reviewing submissions, many subject leaders remain focused on summative assessment at the expense of formative assessment. The misunderstanding of two of the participants who inferred that assessment should be based on tests, indicates the participants either, did not read carefully and respond to the descriptor as written, or they misunderstand the terms formative and summative. While the descriptor wording is clear about the contribution of both summative and formative assessment there is perhaps a training need to support better understanding of the purposes of assessment, the terms used, and best practice in assessing primary science. The criterion also neglects statutory teacher assessment in science at the end of key stages one and two.

Criterion C3

Children enjoy their science experiences in school

Bronze descriptor – When questioned, children in the science SLs class talk with enthusiasm about their current and past school science activities. Children's opinions are valued & responded to.

Silver descriptor – A high percentage of children across the school make positive and enthusiastic comments about science activities in school. Children's opinions are valued and responded to.

Gold descriptor - Scientific activities are identified by pupils as something they enjoy and remember the most. Many express positive comments, attitudes and values. Children's opinions are valued and responded to.

Research into science capital shows that primary pupils already enjoy their experience of learning science. However, few pupils choose to continue to study science once it is no longer a compulsory part of the curriculum and consider that careers in science might be for them. Whether one considers that we need an increasingly scientifically literate population, or for the economic imperative of increasing the supply of scientists and engineers, there are benefits to increasing the number of pupils who continue to study science. I therefore argue that the focus should be on raising pupils' science capital and thus the uptake of science rather than a straightforward focus on pupils enjoying themselves.

Pupils' opinions being valued and responded to is a form of monitoring and thus belongs as part of the criterion on monitoring (A5) or links to the creation of the **principles** (A1) where pupils are given a say in their content.

Criterion D1

Science supports and links with other curriculum areas and contributes to maximising whole school initiatives while retaining its unique status

Bronze descriptor – Teachers maximise curriculum opportunities by making appropriate links with other subject areas.

Silver descriptor – Through their planning, teachers have successfully identified appropriate links with other subject areas. Pupil work demonstrates the use of Science as a context for work in core curriculum areas

Gold descriptor - Effective links with other subject areas are made explicit via planning documentation, with Science maintaining its distinctive character. The contribution of Science to whole school initiatives and issues is clear e.g. PHSE and Citizenship, the spiritual development of pupils, and environmental and sustainability concerns.

The literature on cross-curricular learning suggests that pupils benefit when they make links to other learning, however, disadvantages are also identified. Alexander (2010) and Rose (2009) suggest that pupils need subject specific science lessons to learn skills that they are then able to apply in cross-curricular contexts. This criterion should be amended to reflect this understanding that cross-curricular and subject specific learning are complimentary.

The gold descriptor mentions whole school initiatives which overlaps with criterion C1 and should be rationalised by including school-based initiatives in D2.

Criterion D2

There are clear links to other schools and outside agencies/organisations/communities to enrich science teaching and learning

Bronze descriptor – The science SL has enhanced the learning opportunities for his/her class and others by, e.g., developing the use of the school grounds for science activity, working with science outreach organisations organising onsite and offsite enquiry activities, visiting speakers and in-school workshop activities, or working with local secondary schools.

Silver descriptor – A programme of regular visits/visitors, outreach experiences and workshop activities is being developed for all classes to enhance specific science units/themes. Fieldwork is carried out in the local area and sometimes, beyond it. Contact by pupils and teachers, is made to other schools/community to enrich scientific understanding.

Gold descriptor - There is a full programme of regular visits/visitors, outreach experiences and workshop activities which involve all classes. Regular contact by pupils and teachers is made to other schools/community to enrich scientific understanding. Fieldwork is regularly carried out in and beyond the immediate local area. Some is residential.

Harlen (2006) recommends the inclusion of visitors and visits to enhance the curriculum. There is also considerable literature supporting the benefits of learning outside the classroom, for example King and Glackin (2010), and fieldwork would be a good example of outdoor learning. On that basis this criterion should remain to ensure that enrichment opportunities are available to pupils.

6.7.4.2 Other implications for programme design

Most science subject leaders found writing **reflections** very time consuming and situated learning relies primarily on engagement in practice. So, although some authors (for example, Marsick & Watkins, 2015; Pollard et al., 2014) regard reflection as important, my data supports Lave and Wenger's (1991) view that learning occurs through primarily through participation. Science subject leaders appeared to gain more from participation and the resulting reification, than they did from writing **reflections**. The PSQM should consider the extent to which the current focus on reflection is at the expense of participation and reification and the balance could be reconsidered. The reductions in the number of reflections as recommended in section 6.7.4.1 above would reduce the workload.

The impact of the workload on my participants has been discussed and they would have welcomed a reduction in the quantity of evidence required for the PSQM for review. They noted the PSQM, although worthwhile, was hard work. If evidence of participation, reification and the existence of a science community of practice across the whole school has been provided, it might be inferred that learning and changes in identity and practice will also have happened.

Mrs Peters' experience raises issues. The first being the support science subject leaders receive if their own hub leader is unavailable, especially in the last few weeks before they submit their evidence. Mrs Peters was disappointed with the support received compared to the first time she completed PSQM. In the absence of her usual hub leader a substitute was provided who only gave feedback on one of her written **reflections** and Mrs Peters then tried to apply the same principles to other **reflections**. With greater support she might have achieved the PSQM gold she had worked towards and avoided the considerable disappointment that led to her rejecting the role of science subject leader. Consideration should therefore be given to providing adequate support to science subject leaders in the absence of a hub leader.

The PSQM currently has no appeals procedure, but there might be an opportunity to allow appeals in cases where hub leader support has been of a lower standard than might be expected. The PSQM should also be aware of the potential impact on science subject leaders when they do not achieve the quality mark they were aiming for.

6.7.5 Implications for policymakers

The National Education Union (2019b) has raised concerns that in primary schools, subject leaders have neither additional non-contact time, nor additional payments for subject leadership responsibilities, and my research reinforces this message. Policymakers should consider the potential of subject leaders to improve teaching and learning in their subject and ensure they are provided with the necessary time to do this.

O'Neill (1996:25) asked, "where the role of classroom teacher begins and that of coordinator ends?" The participants in my research saw their role, first and foremost, as classroom teachers, so perhaps the question should be where the role of classroom teacher ends, and the role of science subject leader begins? Mrs White felt guilty about not having the time available for her role as subject leader once she had completed the tasks required of her as class teacher. Other participants talked about hard work or times of stress when fulfilling their roles as science subject leaders and completing the PSQM documentation alongside their other responsibilities. Teachers in England already work longer hours than teachers in other countries (Jerrim & Sims, 2019), yet the new school inspection handbook (Ofsted, 2019c) places greater emphasis on the role of subject leaders in Ofsted inspections.

The PSQM provides a model for the development of science subject leadership and improvements in science teaching and learning in primary schools. The focus of the programme is on learning as participation, rather than professional development experiences that assume an acquisition metaphor for learning (Sfard, 1998). Similar programmes could be constructed to develop subject leadership and improve teaching and learning in other curriculum areas, although some programmes for other subjects currently exist. However, science has an active broad primary science community of practice, including learned societies, the ASE, and organisations funded by industry. The strength of this community may need to be replicated elsewhere in order to develop broad communities of practice to support leaders of other subjects.

6.8 Opportunities for further research

A few of the science subject leaders I interviewed told me they intended to apply some of the features and requirements of the PSQM to other curriculum areas. The emphasis on learning as participation, as opposed to acquisition, is an unusual feature of the PSQM programme when compared to other CPD providers. Learning as acquisition has a part to play in the PSQM programme, but the focus of the programme is on embedding good practice. Therefore, it would be interesting to see if an equivalent professional development programme could be effectively applied to other subjects in the primary curriculum. This could prove a fruitful area for further research. The less active broad communities of practice in other subjects might be a factor restricting the impact.

Another opportunity for research would be the changing identities of the science subject leaders' colleagues and pupils. I studied the identities of the science subject leaders but, by applying the same conceptualisation of identity (Wenger, 1998), the developing identities of other members of the schools' communities of practice could be investigated. Other teachers have changed their practices but whether they might now be reified as effective primary science teachers, consider they are part of the community of primary science teachers, and reconcile this membership with other conflicting memberships could be investigated. An analysis of their trajectories could also indicate the extent of the impact of the PSQM on other teachers. The children most likely to be impacted by their legitimate peripheral participation and, on an inbound trajectory, would be Miss Dean's and Danielle's Science Ambassadors and Mrs Peters' Junior Park Rangers. Other pupils would probably be on a peripheral trajectory. An examination of their situated learning would warrant further research.

The PSQM submission is reviewed with respect to the criteria, and pupil attainment is not a focus of the review process. Therefore, the PSQM is does not align with Cordingley et al. (2015) who suggest a strong focus on pupil progress is important in effective professional development. However, this is based on a circular argument where effective professional development experiences are judged based on pupil attainment as measured by tests. Instead, the PSQM is more closely aligned with the work of Opfer and Pedder (2010b) who believe outcomes such as enhancing career prospects and improving recruitment and retention should be considered. Further research into whether working towards a PSQM improves retention within the teaching profession, and may enhance careers prospects, would be of interest to those working to retain teachers in the profession and develop the next generation of school leaders.

The PSQM is based on the premise that learning results from reflective practice (Clarke & Hollingsworth, 2002; Hoekstra et al., 2009; O'Brien & Jones, 2014; Marsick & Watkins, 2015), however it would be interesting to determine if the writing of reflections in the context of the PSQM, results in learning and more reflective practitioners.

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Appendix A – PSQM framework for schools submitting June 2017 to March 2018

		BRONZE	SILVER	GOLD
A: SUBJECT MANAGEMENT	A1: There is an effective SL for Science	There is an identified member of staff who oversees the subject, may have a background in the subject and can demonstrate their enthusiasm for leading it.	There is a named member of staff responsible for the leadership of the subject. They have received subject-specific training in the last three years, have shared this with all colleagues in the school.	The SL has shared their training and subject knowledge with a broader audience beyond their own school.
	A2: There is a clear vision for the teaching and learning of Science.	Staff know and follow the school's principles for teaching and learning Science and some of them may have been part of the team which developed them. The school's scheme of work for Science reflects these principles.	A staff team has been involved in developing the school's principles for teaching and learning Science. They are reviewed regularly along with the scheme of work for Science which promotes these principles.	A school wide team has recently reviewed the school's principles for teaching Science, and ensured that the principles are implemented through the scheme of work for Science. Progression in skills, knowledge and understanding is evident in the scheme of work and children's outcomes.
	A3: The current School Development Plan has appropriate and active targets for Science	The School Development plan includes actions and targets for Science.	The Science SL has worked with the Senior Management Team to agree School Development Targets for Science based on identified strengths and weaknesses. The Science SL had led staff in the implementation of actions to meet these targets across the school.	The School Development targets for Science include maintenance and development strands, with clear strategies for improvement outlined plus actions to extend Science links beyond the school. Successes are already highlighted in the School Development Plan and plans for the future are underway.
	A4: There is shared and demonstrated understanding of the importance and value of science to children's learning	There is a shared understanding of the importance of science, clearly evidenced in the subject leader's class and developing wider.	There is shared understanding of the importance of science, clearly evidenced throughout the school, including the grounds.	There is a shared understanding of the importance of science, clearly evidenced throughout the school, the grounds and from the wider community.
	A5: The science SL knows about science teaching and learning across the school	The science SL works with, or monitors, the work of a colleague. School-wide work book scrutiny takes place.	Peer assessment and team teaching of science takes place across the school. School-wide work book scrutiny takes place.	There is a robust process of monitoring science teaching & learning in place. Outcomes are shared with staff and actions taken when issues are identified. Regular discussions take place between SL and SMT about science in the school.
B: TEACHING	B1: Staff continue to have opportunities for CPD within science that increases their skills, knowledge and understanding.	The SL maintains an interest in the subject outside the school and this impacts on his/her teaching. The SL has taken part in some CPD that has had an impact in his/her classroom. Although other staff may not have received CPD, there is evidence of support being provided, when requested.	Internal monitoring and performance management processes are used to inform decisions regarding staff CPD needs in science.	The science SL has reflected on CPD needs as evidenced by internal monitoring and performance management processes and planned and developed a range of whole school CPD for science that is regularly monitored for impact.
	B2: There are a range of teaching and learning approaches	There are some relevant teaching and learning approaches in science being adopted by the science SL in response to class and school development targets. He/she is beginning to share these with colleagues.	There are several relevant teaching and learning approaches in science being adopted by teachers across the school in response to school development targets. The science SL is pro- active in introducing new strategies.	There is a wide range of relevant teaching and learning approaches in science adopted by the whole school and shared with other schools. The science SL is pro- active in introducing new strategies and innovations.
	B3: There are a range of up-to-date, quality resources specifically for teaching and learning science. IT is used both as a tool and as a resource for teaching	There is a well-organised, well- maintained, plentiful, appealing range of appropriate school-bought practical science and ICT resources, plus freely obtainable ones, which are available for all staff and children and are regularly used. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities. in science activities.	Science resources are used across the school and are well maintained and organised. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities. Resources are audited regularly and the school has identified suitable further resources to purchase that will enhance teaching opportunities. Use of 'free' resources, such as rock samples, fabric collections and plants has been developed.	There is a well-organised, well- maintained, plentiful, appealing range of appropriate school-bought practical science and ICT resources, plus freely obtainable ones, which are available for all staff and children and are regularly used. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities.
C: PUPILS AND LEARNING	C1: All pupils are actively engaged in a science enquiry; using a variety of enquiry strategies, independently making decisions, using evidence to answer their own questions, solving real problems, evaluating their work	Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home.	Children's curiosity is encouraged and valued. They ask questions, encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able, and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupils are encouraged to participate in school-based science initiatives.	Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupils are encouraged to participate in school and national science initiatives.
	C2: The purpose of science assessment is well understood and shared by members of the school community. Assessment approaches are designed to fit those purposes	The science subject leader builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues. The science subject leader supports other staff in making summative assessments of children's science attainment.	The science subject leader builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues.	The science subject leader builds different formative assessment strategies and the outcomes of these into his/her planning. He/she is beginning to share these strategies with colleagues. The science subject leader supports other staff in making summative assessments of children's science attainment.
	C3: Children enjoy their science experiences in school	When questioned, children in the science SLs class talk with enthusiasm about their current and past school science activities. Children's opinions are valued & responded to.	A high percentage of children across the school make positive and enthusiastic comments about science activities in school.	Scientific activities are identified by pupils as something they enjoy and remember the most. Many express positive comments, attitudes and values. Children's opinions are valued and responded to
D: BROADER OPPORTUNITIES	D1: Science supports and links with other curriculum areas and contributes to maximising whole school initiatives while retaining its unique status	Teachers maximise curriculum opportunities by making appropriate links with other subject areas.	Through their planning, teachers have successfully identified appropriate links with other subject areas. Pupil work demonstrates the use of Science as a context for work in core curriculum areas	Effective links with other subject areas are made explicit via planning documentation, with Science maintaining its distinctive character. The contribution of Science to whole school initiatives and issues is clear e.g. PHSE and Citizenship, the spiritual development of pupils, and environmental and sustainability concerns.
	D2: There are clear links to other schools and outside agencies/organisations/ communities to enrich science teaching and learning	The science SL has enhanced the learning opportunities for his/her class and others by, e.g., developing the use of the school grounds for science activity, working with science outreach organisations organising onsite and offsite enquiry activities, visiting speakers and in- school workshop activities, or working with local secondary schools.	A programme of regular visits/visitors, outreach experiences and workshop activities is being developed for all classes to enhance specific science units/themes. Fieldwork is carried out in the local area and sometimes, beyond it. Contact by pupils and teachers, is made to other schools/community to enrich scientific understanding.	There is a full programme of regular visits/visitors, outreach experiences and workshop activities which involve all classes. Regular contact by pupils and teachers is made to other schools/community to enrich scientific understanding. Fieldwork is regularly carried out in and beyond the immediate local area. Some is residential.

Appendix B – Cherry Tree School principles

Core Principles of Science

We know Science teaching and learning is good in our school when…

For adults:	For children:
Science is fun: Children are engaged in Science and look forward to lessons	"Yes…we've got Science today!"
Children are curious because they are interested. Children are aware that generating questions can deepen their understanding	"But why?" "What about if…?"
Exploration and discovery, through practical, hands-on activities are the path to meaningful learning	"Let's play!" "Let's do it and find out!"
Children make links to real life contexts: pushing the boundaries of what they already know	"I've seen this before!" "It's like when…"
Collaborative learning happens and children draw on each other's ideas.	"That's a good idea - let's try and do this bit together!"
Teachers are enthusiastic and enjoy science teaching	"Our teacher loves science!"

Appendix C - Cherry Tree School action plans

CRITERIA	KEY QUESTIONS	SILVER INDICATORS	ACTIONS NEEDED What do I need to do to achieve the indicator?	WHO is involved?	WHEN by?	IMPACT What changes will I see?	EVIDENCE What can I use to show this?
SECTION A: SUBJECT LEADERSHIP							
A1	There is an effective subject leader for science	There is a named member of staff responsible for the leadership of the subject. They have received subject-specific training in the last three years and have shared this with all colleagues in the school.	Introduce myself as SL for Science – explain PSQM Review science curriculum and expectations to all members of teaching staff through staff meetings. Lead staff meeting to demonstrate use of new '[redacted] assessment criteria. To work closely with NQT teachers who feel they need more support. Attend PSQM hub meetings	[redacted] All staff NQT	Nov 16	Staff aware and on board with PSQM award Staff more confident in using new assessment tools for tracking scientific enquiry. Staff will see VS as school leader for science and available for support in teaching/assessing	SL Log CPD Log
A2	There is a clear vision for the teaching and learning of science.	A school wide team has been involved in developing the school's principles for teaching and learning science. They are reviewed regularly along with the scheme of work for science	Following pupil voice on same activity - complete whole staff "science is great when…" activity. Agree, as a staff on chosen principles. Discuss how to present core principle.	[redacted] – all staff – children	Dec 16	Teachers aware of school principles and importance of these in planning and teaching to promote good learning.	Core principles SL log Portfolio: Copy of MTPs

		which promotes these principles.	Display in every classroom and as main feature of central display in entrance corridor Principles in front of children's books for reference in each lesson 'Which principle did you meet today?' Head to include current science focus (PSQM) on SIP	All staff/All children [redacted]Gover nors	On next review (End Autumn 16)	Children introduced to principles and these are frequently being fed into learning – children know that learning matches principles and therefore helps their learning. SIP shows staff, governors and parents importance and value of science at our school.	Portfolio – children's work, pupil view SIP
A3	The current School Developmen t Plan has appropriate and active targets for science	The science subject leader has worked with the Senior Management Team to agree School Development Targets for science based on identified strengths and weaknesses. The science subject leader had led staff in the implementation of actions to meet these targets across the school.	Head agreed to science being reflected on SIP – To begin with an awareness that as a school we aim to raise profile by working towards award – specific targets to follow upon next review. Review of SIP to include more specific targets. Higher priority for children using a range of enquiry skills	[redacted] Governor s review	Dec 16 Apr 16	SIP shows staff, governors and parents importance and value of science at our school. An increase in active learning is evident in chn's work and in book scrutiny.	SIP SL log

A4	There is a shared and demonstrated understanding of the importance and value of science to children's learning.	There is a shared understanding of the importance of science, clearly evidenced throughout the school, including the grounds.	Create central display (permanent) in main school corridor – ensure it is interactive and engaging plus acts as a tool for reinforcing school principles Science displays – [redacted] to arrange a learning walk with Governors led by school science ambassadors of class, and after science week, central displays View to creating wildlife watching area including 'minibeast mansion' and 'bird watch station' – possible nature club. All classrooms display school principles and 'Scientist of the week' (SOW sent to [redacted] weekly from each class – with book for review)	VS [redacted] Governors Children - Science ambassadors [redacted] Expansion team All staff	March 17 End of year (after expansion complete) Ongoing	Children will engage with display and become more aware of/ embed principles Governors will see value of science at school Children will understand science isn't just something that happened in the classroom. Outdoor learning Reinforcing value and high priority – teacher in constant loop with good practice evident in children's books.	Portfolio – photos of displays SL log Portfolio – photos, pupil voice.

A5	The science subject leader knows about science teaching and learning across the school	Peer assessment and team teaching of science takes place across the school. School-wide work book scrutiny takes place.	Book scrutiny – all teachers With personalised feedback including shared models of good practice Science ambassadors – agree to meet two-weekly with ambassadors to discuss learning that has been happening in year group. Ask for pupil feedback and discuss how teaching/learning might be better? Feed back to teachers at staff meetings Scientist of the week – sent to [redacted] to celebrate good learning that week. [redacted] to look at book and allow children to explain why they are scientist of the week "Which enquiry skill did you try?" "Which of our school principles do you feel you have met this week?"	[redacted]/all staff [redacted]children – science ambassador [redacted]children	Ongoing – termly Ongoing – termly Ongoing - termly	Teachers are aware books/evidence of work is valued and will be used as examples to others. Teachers, after feedback, are equipped with new ideas to trial or suggestions for teaching. [redacted] is aware of the teaching that is happening and take into consideration how children feel about it. This is fed back to teachers to Children are enthused to see subject leader and receive praise for their effort/outcomes in science learning. This in turn reflects on future effort and outcomes in learning.	SL log Portfolio – book scrutiny feedback. Portfolio. Portfolio – pupil feedback – evidence in books

SECTION B: TEACHER AND TEACHING							
B1	Staff continue to have opportunities for CPD within science that increases their skills, knowledge and understanding.	Internal monitoring and performance management processes are used to inform decisions regarding staff CPD needs in science. The science subject leader has delivered CPD to some other teachers.	Use staff meetings as opportunity to discuss/raise issues with any area of science teaching. Organise support from SL or CPD as appropriate.	[redacted]all staff as appropriate	Ongoing	Staff feel confident to discuss areas they might need support with in teaching science and SL offers support/ideas in these situations	Portfolio – emails from staff with suggestions in reply.
			Specific science subject staff meeting – looking at expectations of teaching and learning/ensure coverage/opportunities to share planning and book samples.	[redacted]/all staff	Ongoing	As above plus opportunities for teachers to see/hear about science throughout the school and not just in their own class or year group.	CPD log SL log
			Send [redacted] on CPD course – re: encouraging engagement in science – (as result of concern raised in last staff meeting)	[redacted]	May 2017	NQT from LKS2 and teacher from UKS2 to attend CPD and feedback to all teachers and following staff meeting. New teaching ideas available to all but previously unaware.	CPD log SL log Portfolio – teacher evaluation of CPD
			Use of Free Online CPD tools – inc Terrific Science 'Live Lessons' and material from [redacted]	All staff	Ongoing		CPD log

B2	There is a range of teaching and learning approaches for Science.	There are several relevant different teaching and learning approaches in science being adopted by teachers across the school in response to school development targets. The science subject leader is pro-active in introducing new strategies.	SL to regularly check topic areas and coverage across the school. SL to be aware of when science is timetabled throughout the school. Email suggestions/websites/activities etc that are relevant to current learning. Introduce a simple 'scientific enquiry skills and principles check list' For front cover of all science books. Teachers to ensure children refer to this each science lesson to identify which enquiry skills has been used and which of our school science principles have been met.	[redacted] All staff	Ongoing	Teachers are supported in teaching (gathering ideas for teaching) types of activities that support scientific enquiry and reinforcement of our new science principles. By having children complete these checklists they have ownership of own understanding and assessment in addition to a consistent referral to principles and enquiry skills we as a school should be continually meeting. Teacher can use checklists as an assessment tool to gain understanding if a child is finding understanding of any area challenging.	Portfolio – photo of checklist from child's book. Marking feedback from teachers. SL log

B3	There is a range of up-to-date, quality resources specifically for teaching and learning Science. ICT is used both as a tool and as a resource for teaching	Science resources are used across the school and are well maintained and organised. There are clear processes in place to ensure that children and teachers keep themselves safe in science activities. Resources are audited regularly and the school has identified suitable further resources to purchase that will enhance teaching opportunities. Use of 'free' resources, such as rock samples, fabric collections and plants has been developed.	Conduct an audit of science resources and match them to topic areas. Purchase mirrors – identified by a class teacher from unit on light reflection Purchase rock samples to replace existing set that are broken/missing. Stock free resources from various companies Save sunflower seeds from this year to replant Make communication explicit so teachers know if they need a resource for an activity it must be ordered and then restocked/stored appropriately. Trial a 'Live lesson' – interactive lesson using pc and ipads where data from lesson is sent off and shared with other schools. Ct to feedback on views of lesson and impact on engagement and learning.	[redacted]Other staff [redacted]Admin [redacted] Year 4 trial	February 2017 February 2017	Teachers will not avoid practical sessions if they can find equipment easily in a well organised state. Restocked/new resources allows teachers to meet specific needs of learning, providing models as a teaching tool Interactive lesson to encourage teachers to trial new things and explore ICT options – engaging and relevant to children today.	SL log Portfolio – audit

SECTION C: PUPILS AND LEARNING

C1	All pupils are actively engaged in a science enquiry; using a variety of enquiry strategies, independently making decisions, using evidence to answering their own questions, solving real problems, evaluating their work.	Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able, and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupils are encouraged to participate in school-based science initiatives.	Science lesson – children to use checklist of enquiry skills and principles Children to explore own channels of investigation – children know that they can ask their own questions. Teachers use KWHL girds at start of units Set half termly whole school home learning (science investigation) Organise weekly lunchtime science club – initially to Y3 this term. Different year group each half term Whole school recognition of 'British Science Week 2017' Children off timetable to do a different practical and engaging science investigation each afternoon with a different teacher. Use Crest superstar investigations.	All teachers All teachers/ children All teachers [redacted] [redacted] with ambassa dor helpers Whole school	Ongoing Ongoing Ongoing Every half term Weekly – ongoing W/C March 13th 2017	By having children complete these checklists they have ownership of own understanding and assessment in addition to a consistent referral to principles and enquiry skills we as a school should be continually meeting. Children reinforce science principle and put it into practice by asking questions/planning own investigations. Home learning – involves parents and supports adults from home in recognising importance of science in school and beyond. Children who has added passion for STEM encouraged to come to science club – get a chance to engage in practical activities – 'wow' moments of science they might not have seen at home or even in classroom. Raising profile of science by enthusing children. Science club – very successful last year – huge impact on science profile. Children talking about science and using technical vocabulary. Experiences of different styles of science teaching through different adults.	SL log Portfolio Evidence of science week – photos, childrens' books, pupil voice.

C2	The purpose of science assessment is well understood and shared by the members of the school community. Assessment approaches are designed to fit those purposes.	Teachers across the school build different formative assessment strategies in their science lessons and the outcomes of these into their planning. The science subject leader is pro-active in introducing new strategies. Teachers are aware of the expectations for the pupils in their class and are able to make summative assessments confidently.	Children use core principles and 'scientific enquiry skills' checklist to self-reflect on learning. Staff keep 6 focus child 'tracking sheet' as developed by [redacted] and implemented by SL Staff CPD on assessing in science through specific staff meeting.	[redacted] All teachers All class teachers [redacted]	Ongoing Ongoing Dec 16	Children assessing own work from set criteria overseen by class teacher – children begin to identify own gaps in understanding. Teachers understand where to access assessment documents and feel more confident in assessing as a result of shared practice and in house CPD	Portfolio SL log Core Principles
C3	Children enjoy their science experiences in school	A high percentage of children across the school make positive and enthusiastic comments about science activities in school. Children's opinions are valued and responded to.	Pupil voice – organise for each year group. Feedback to teachers. Hold pupil interviews for science ambassadors and deputies. Weekly science club Organise and hold British Science week activities Visits/trips and workshops Organise and hold parent and child science workshop	[redacted] [redacted]Head teacher [redacted] and Science ambassa dor [redacted] [redacted]Head teacher/ Admin/C aretaker.	End of half term	Children feel opinion about science are valued. Teachers receive valuable feedback to inform planning. Teachers understand Science is a school learning priority. They are aware of the roles of an ambassador and has a deep understanding of our school principles for science which they transfer to peers during. Trips and visits encourage children to understand that science is not only for the classroom – it reinforces and supports curriculum taught in class. Parent involvement supports science at home. Feedback will inform SL and teachers of understanding and engagement.	SL log Core principles – photos, pupil voice feedback, Parent workshop evaluations

SECTION D: BROADER OPPORTUNITIES							
D1	Science supports and links with other curriculum areas and contributes to maximising whole school initiatives while retaining its unique status	Through their planning, teachers have successfully identified appropriate links with other subject areas. Pupil work demonstrates the use of Science as a context for work in core curriculum areas.	Monitor planning to ensure science curriculum is being delivered in a cross-curricular way with links to other subject areas	[redacted]	Termly	Planning time to reflect opportunities for cross curricular science/other subjects	Planning, portfolio, children's work
D2	There are clear links to other schools and outside agencies/organisations/ communities to enrich science teaching and learning	A programme of regular visits/visitors, outreach experiences and workshop activities is being developed for all classes to enhance specific science units/themes. Fieldwork is carried out in the local area and sometimes, beyond it. Contact by pupils and teachers is made to other schools/community to enrich scientific understanding.	- Plan and implement science week in collaboration with British Science Week - Participate in Tim Peake Primary Project - 'Affinity Water' to deliver workshops across KS2 - Monitor planning to ensure teachers are planning for fieldwork opportunities - Work with link secondary schools [redacted] to arrange science experiences at an advanced level	[redacted] all staff [redacted] [redacted] [redacted] [redacted]	March 2017 (and annually thereafter) April 17 Termly Throughout Summer term	The school provides a range of wider opportunities for science. Children are positive and enthusiastic about science teaching. Children take part in fieldwork activities regularly	Portfolio – photos of events, Feedback from children, Events log

Appendix D - Cherry Tree School continuing professional development log

Date	CPD	By	For	Impact
19.9.16	Snap Science Seminar	Snap Science	SL	Opportunity to look at schemes of work available linked to new curriculum and how these can promote engaging science
23.9.16	PSQM Training day 1	[redacted]	SL	Introduced to award and set some target dates and given guidance on how to be a good subject leader and work effectively towards the award of PSQM
27.1.17	Engaging primary science course	SETPOINT	SL	Was able to look at interesting ways to deliver specific areas of the curriculum and therefore improve teaching and delivery.
6.2.17	Tim Peake Primary project CPD	[redacted]	Whole teaching staff	Especially relevant to Year 5 teacher who teach topic of Earth and Space. Teachers supported in delivering lessons on this topic. Reflected in feedback from children of enjoyment in this topic.
3.3.17	Briefing of Parent-child workshop/general meeting	SL	Relevant staff	SL discussed science activities planned for the forthcoming workshop. Discussed most effective way to deliver activity and which scientific vocabulary or ideas to focus on when discussing with parents/children. As a result workshop run very smoothly because teachers were well prepared and knew in advance expectations.
3.3.17	Introduction to and briefing on Science week activities. Each teacher given a science activity and all resources to teach it. Offered 1:1 time for any teachers who wanted support/ideas on delivery	SL	Whole teaching staff	Teacher were informed about what they needed to teach during science week and had time to think about how they might deliver it.
7.3.17	PSQM training DAY 2	[redacted]	SL	Opportunity to network with other schools working towards award and other subject leaders of science. Target/deadline dates set for core documents to assist us in

				being on track with award – ideas shared for innovative ways to meet criteria.
17.3.17	Science staff meeting.	[redacted]	Whole Staff	Shared ideas on how to deliver interesting, practical science activities and link these into curriculum areas. Promoting better teaching of science. Some follow up discussions on assessment ensured teachers have a clear vision on how to assess children in science.
22.5.17	Science engagement for teachers	Talk Science	Year 4 Teachers	Opportunities for teachers to have some CPD in delivering engaging science and how to promote children's enjoyment as well as the teacher's
8.6.17	CPD delivered to teachers	Secondary school science co-ordinator	Year 5/6 teachers	Our teachers were given opportunity to see how using resources to support teaching can support understanding. Links made to secondary teaching and teachers will feel confident in delivering science that prepares children for science learning as the progress into KS3.

Appendix E – Cherry Tree School calendar of science events

Date	Event	Year group	Impact
24.11.16	'Stardome'	Y5	Regular visit from Stardome to accompany Y5 Earth and Space unit. Children able to see visual representations of constellations etc that they may have never seen before therefore supporting understanding from learning in class.
28.11.17	School assembly – introduced new science principles as a whole school.	Whole School	Children now aware of expectations of science teaching and learning. Children engaged and enthused to be involved in good science learning.
19.12.16	AMEY waste awareness assembly	Whole School	Children aware of need to recycle – linked to keeping school clean. Had chance to share and enhance knowledge on properties of materials.
23.1.17	Loan of class set of microscopes from RMS	Whole School	Children have chance to use resources never experienced before. New insights to what things look like so magnified and engagement/questions raised – linking to principles.
6.2.17	[redacted]	Y5	Y5 children workshop led/taught by a real life space scientist – links to principles and current learning on Earth and Space. Massive enjoyment and knowledge taught from all involved. [redacted] returning to work with Y3 in summer term.
7.2.17	Forces workshop	Y3	Y3 seeing science in action linked to current literacy unit (cross curricular links) – links to school principle 'I've seen this before'
10.2.17	'Lighting it up' Workshop	Y4	Y4 seeing science in action linked to current science topic (electricity) – links to school principle 'I've seen this before'
10.3.17	Co-ordinated Parent and Child science workshop. Workstations provided for parents and children to engage in science together. Handouts provided with good websites and information sheets etc.	Whole School	Overwhelming success. 120 attended. Fantastic feedback. Parents more equipped to engage their children in science at home. Feedback suggests it was a great opportunity for parents to explore the types of activities/learning they can expect their children to be learning in science at school.

	Science ambassadors involvement – leaders at workstations.		
13.3.17	British Science Week 2017	Y3, Y4, Y5	Engagement in science
30.3.17	School publication being photographed for prospective parents. Science is a feature	Science ambassadors (Y3,4,5 and 6)	Showing future parents that science has a high profile.
31.3.17	Half term science project sent out	Whole School	All children asked to participate in given science activity over holiday period. Keeping profile and engagement high even when children at home.
18.5.17	[redacted] publication on child-led enquiry	Y3/4	Children interested in science selected to participate in several activities that promote child-led enquiry. Children have opportunity to practice some fun science outside of the classroom.
19.5.17	Booked assembly from H2O Mad Science in association with 'Affinity Water'. Interactive water themed whole school assembly	Whole school (Split Y3/4 and Y5/6)	Children will become aware of how we use and waste water and how our drinking water is produced. This will support understanding of water use especially in lead up to summer holidays – use of hose pipes etc. Use of class eco-monitors to promote using water effectively with minimum waste.
23.5.17	Lesson Observations from secondary link school science coordinator	Y5/6	Secondary school gain insight into knowledge, understanding and pitch of lessons of future Y7 students. This benefits children and their science learning as they move into secondary school.
2.6.17	Resources audit	ALL	Resources sorted and organised into ones that are regularly used/not used with view of replenishing stock and re-evaluating resources that could help future teaching.
8.6.17	Science morning at secondary link school	Y5	First step in making links with a newly popular secondary school for our Y5/6 children. This will help Y7 teachers to be aware of the ability of our Y6 children making KS3 learning more seamless with less gaps in knowledge and understanding. Children will also be introduced to some of the science investigations and equipment they can expect to do/use at secondary school
26.6.17	Science morning at secondary link school	Y6	As Year 5 above
July 2017	Science day	Y6	Just for Y6 as these children did not participate in science afternoons during British Science week dues to SATS.

Appendix F – Cherry Tree School subject leader log

Cherry Trees Junior School   Science Subject Leader Log

Date	Action	What will I/we gain
30.6.16	Shared second release of assessment materials from [redacted] with all staff. Showed examples of working documents as models	All staff aware of assessment materials and can access to support teaching and learning. Model appreciated and used by staff
19.9.17	Science CPD at [redacted]	Subject leader opportunity to familiarise with expectations of role and network with contacts, magpie ideas for leading subject well.
24.9.16	Shared information with all staff regarding amendments to 'working scientifically' documentation	All staff aware of and on board with, using this documentation to support assessment in this area.
23.9.16	PSQM introduction– shared information regarding award to all staff through email	Informed teachers we would be working towards a science award to raise profile. Informed there would be a staff meeting to follow with more information. Teachers aware that expectation is science is to become a higher priority at our school.
29.9.16	Staff Meeting – (time allocated for updates). Shared updates on PSQM award. Explained first role to create set of principles and asked staff to gather ideas on this in preparation for next staff meeting.	Staff given time to think about what they feel makes good science. Teachers know their opinions on science are valued and will be listened to.
31.10.16	Self- assessment for PSQM sent	Chance to self-assess and reflect on current practice and provision and how to make it better.
24.11.16	Y5 Stardome visit	Regular visit from Stardome to accompany Y5 Earth and Space unit. Children able to see visual representations of constellations etc that they may have never seen before therefore supporting understanding from learning in class.
1.12.16	Staff Meeting – Science specific Created set of school principles for science.	Teachers have a clear vision on what makes science teaching and learning good at our school creating a positive impact on enjoyment and outcomes. Being involved in the process of creating principles makes them more likely to be on board

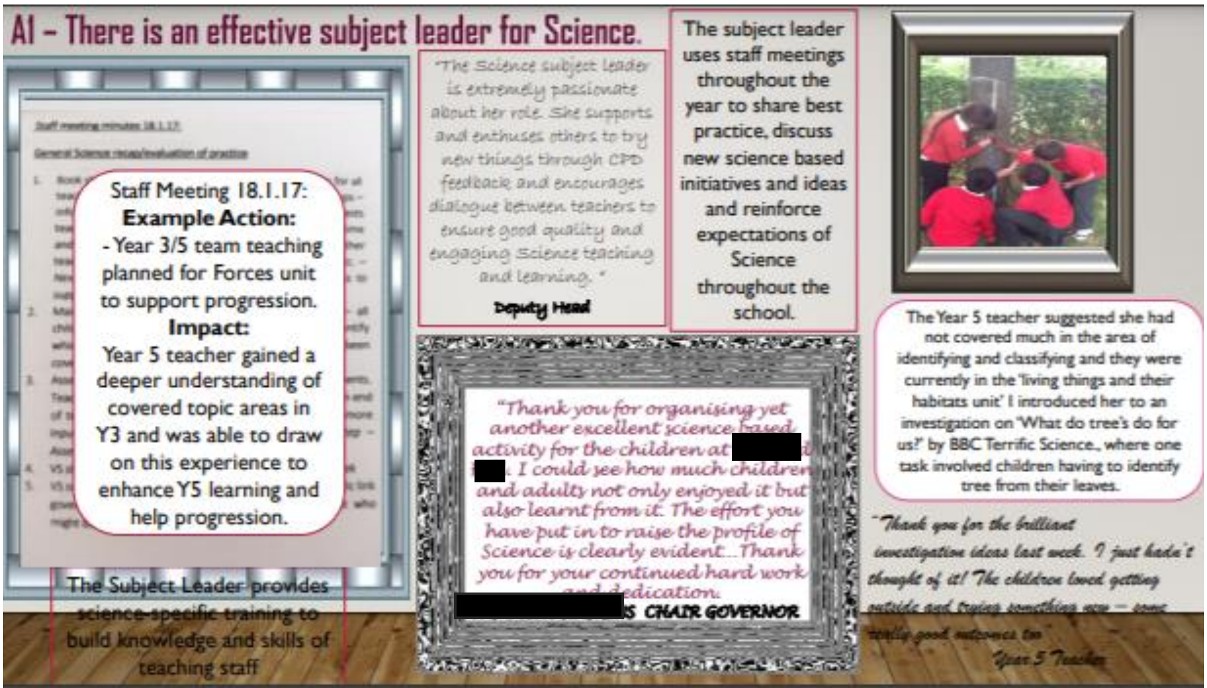
8.12.16	Created central display outlining school science values	Display in a focus position. Children see it daily and can refer to principles therefore embedding what good science looks like at our school.
9.12.16	School assembly – introduced new science principles as a whole school.	Children now aware of expectations of science teaching and learning. Children engaged and enthused to be involved in good science learning.
19.12.16	AMEY waste awareness assembly (whole school)	Children aware of need to recycle – linked to keeping school clean. Had chance to share and enhance knowledge on properties of materials.
10.1.17	Meet with Head to request SIP update. SIP now includes science reference (working towards PSQM award) With a view to more specific targets by Summer term. Co-ordinated 'Scientist of the week' scheme. Each lesson in each class will have a scientist of the week who has met school principles and can indentify which scientific enquiry skills they have used in their learning. Picture of child goes onto class science display and child sent to SL weekly.	Science now recognised on school improvement plan. Raises profile amongst teachers, parent and governors. Children see SOTW as a valued reward. They place emphasis on engagement and asking questions which not only gives them a chance to get the award but also to develop their understanding in a topic/subject area.
13.1.17	Lesson observations (LKS2)	Greater understanding of teaching and learning in Science in Y4. Feedback from observation resulted in one teacher completing a follow up lesson to embed children's understanding based on ideas from science SL.

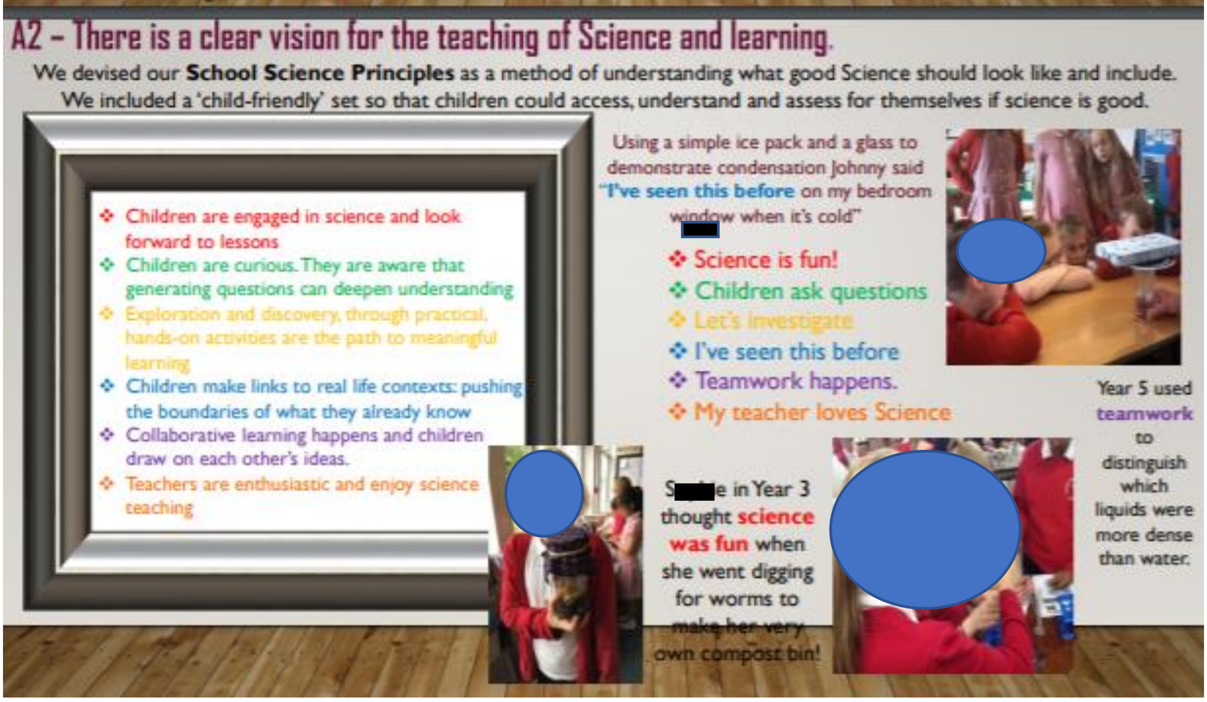
16.1.17	Book scrutiny/Monitoring (Whole School)	Understanding of progression in science across school. Discussed strengths and next steps with individual teams and fed back to Head Teacher. Informing and improving future teaching
16.1.17	Pupil voice (Whole School)	Insight into how children feel their science is going. Children feel valued as they had chance to express what they enjoyed and how they would improve science if they could.
17.1.17	Co-ordinated purchase of full size skeleton.	Used as a focal point in display plus used to enhance learning in 'animals including humans' topic areas.
18.1.17	Snap Science – plus feedback to staff.	Chance to see different planning schemes available. We can make decisions on which is a best fit for teachers at our school – making planning and teaching enjoyable yet stress free.
23.1.17	Secure loan of class set of microscopes for spring term from RMS (Royal microscopy society). Arranged a teaching timetable to allow time for all teachers to use them with their classes and provided ideas on how they could link their use into current working unit.	Children have chance to use resources never experienced before. New insights to what things look like so magnified and engagement/questions raised – linking to principles.
26.1.17	Staff meeting to discuss science planning and the curriculum requirements.	Ensured all staff are planning/teaching using correct units and objectives.
3.2.17	Day out of class for PSQM SL time	Completed action plan
6.2.17	Arranged participation in Tim Peake Primary project and had half day visit from [redacted] – space scientist. (UKS2)	Y5 children workshop led/taught by a real life space scientist – links to principles and current learning on Earth and Space. Massive enjoyment and knowledge taught from all involved. [redacted] returning to work with Y3 in summer term.
7.2.17	Science Forces workshop Y3	Y3 seeing science in action linked to current literacy unit (cross curricular links) – links to school principle 'I've seen this before'
10.2.17	'Lighting it up' Workshop Y4	Y4 seeing science in action linked to current science topic (electricity) – links to school principle 'I've seen this before'
7.3.17	Second day of PSQM training	Updated and reminded teachers of expectations in class displays.

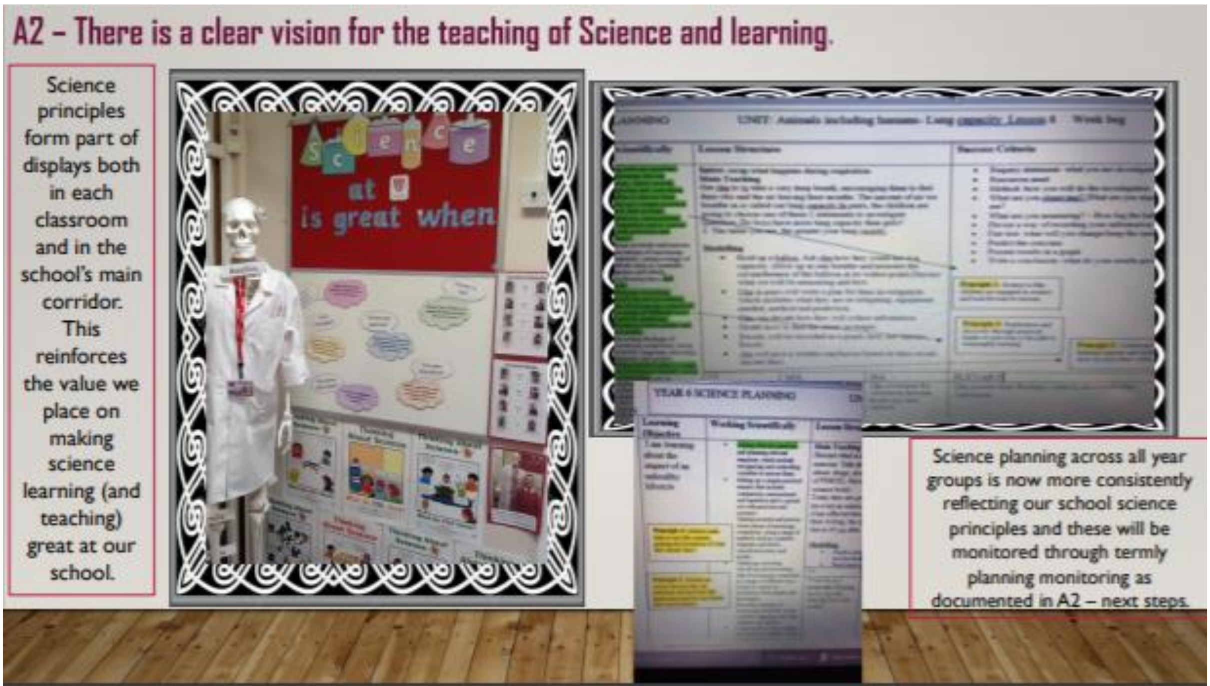
		Chance to share ideas with others working toward awards
10.3.17	Co-ordinated Parent and Child science workshop. Workstations provided for parents and children to engage in science together. Handouts provided with good websites and information sheets etc. Science ambassadors involvement – leaders at workstations.	Overwhelming success. 120 attended. Fantastic feedback. Parents more equipped to engage their children in science at home. Feedback suggests it was a great opportunity for parents to explore the types of activities/learning they can expect their children to be learning in science at school.
13.3.17	Co-ordinating British Science Week [redacted]	Engagement in science
14.3.17	Subject leader cluster	Chance to share practices with science SL in other local schools. Discussed collection of assessment data.
17.3.17	Secured grant from [redacted](£500) through grandparent of science ambassador child at school – impressed with science workshop!	Enables us to make a 'special' purchase linked to science. Possibly our own set of microscopes. New product to support teaching and learning and engage children further in science. 3
30.3.17	School publication being photographed for prospective parents. Science is a feature (LKS2)	Showing future parents that science has a high profile.
31.3.17	Half term science project sent out (Whole School)	All children asked to participate in given science activity over holiday period. Keeping profile and engagement high even when children at home.
20.4.17	Lead governor learning walk/meeting	Talked through progress of this year's action plan and PSQM and thought about what we could do moving forward. (Specific governor for science and making links with secondary schools) – Impact – keeping science in the forefront as a priority of our curriculum.
2.5.17	Presentation to whole governing body for teaching and learning.	Great opportunity to ensure governors understand what we have been doing this year in science. Made links with feeder infant school – arranged some dates for ambassador mentoring
8.5.17	Meeting with SL at link secondary school - Arranged dates for A-level children to teach our children. (All year groups but Y6 specific)	Making links with secondary schools. Reinforcing levels of knowledge and understanding of our Y6 children as they move into KS3

19.5.17	Booked assembly from H2O Mad Science in association with 'Affinity Water'. Interactive water themed whole school assembly (Whole School)	Children will become aware of how we use and waste water and how our drinking water is produced. This will support understanding of water use especially in lead up to summer holidays – use of hose pipes etc. Use of class eco-monitors to promote using water effectively with minimum waste.
8.6.17	Y5 visit to [redacted] Secondary school to be involved in some 'wow' science activities led by staff and A level students	First step in making links with a newly popular secondary school for our Y5/6 children. This will help Y7 teachers to be aware of the ability of our Y6 children making KS3 learning more seamless with less gaps in knowledge and understanding. Children will also be introduced to some of the science investigations and equipment they can expect to do/use at secondary school
18.1.17	Time allocated at staff meeting for Science updates	Update/refresh on science expectations. SL allow time for staff to share planning highlighted with principles and to share examples of good practice.
20.6.17	Science subject leader cluster	Opportunity to share practice with other subject leaders and gain ideas for better leading the subject.
26.6.17	Y6 visit to [redacted] Secondary school to be involved in some 'wow' science activities led by staff and A level students	As Year 5 above

Appendix G - Cherry Tree School portfolio (2 slides per page)






A2 – There is a clear vision for the teaching of Science and learning.
Science principles form part of displays both in each classroom and in the school's main corridor. This reinforces the value we place on making science learning (and teaching) great at our school.
Science at is great when
YEAR 6 SCIENCE PLANNING
Science planning across all year groups is now more consistently reflecting our school science principles and these will be monitored through termly planning monitoring as documented in A2 – next steps.


A2 – There is a clear vision for the teaching of Science and learning.
"I know all of our science principles…I tick 'Science is fun' every week. Some weeks we don't use all of the principles but we know that if you are using some every week that means we are doing great science." [redacted] Year 4
Teamwork!
Children ask questions to extend investigations and learning.
What would you like to know next?
"I've seen this before – a patella is like my K'nex at home. There's a ball part which swivels" [redacted]ear 3
"Mrs Day…Are we really going to build and race rockets? "Science is fun" [redacted]ear 5
Racing Rockets

A3 – The current school development plan has appropriate and active target for Science.

Targets on the school improvement plan are designed to best reflect the needs of our school at any given time. Targets are reviewed frequently and adaptations can be made at interim points if any circumstances change and the targets are no longer appropriately reflecting needs.

School achieves Primary School Quality	Continue to improve the quality of	SSL	Ong oing	£700 SSL training/staff mtngs
Mark - almost all pupils achieve ARE in	teaching in science – focus on scientific enquiry skills – evidenced trough outcomes, pupil view, assessments.	CTs		
science by July 18				

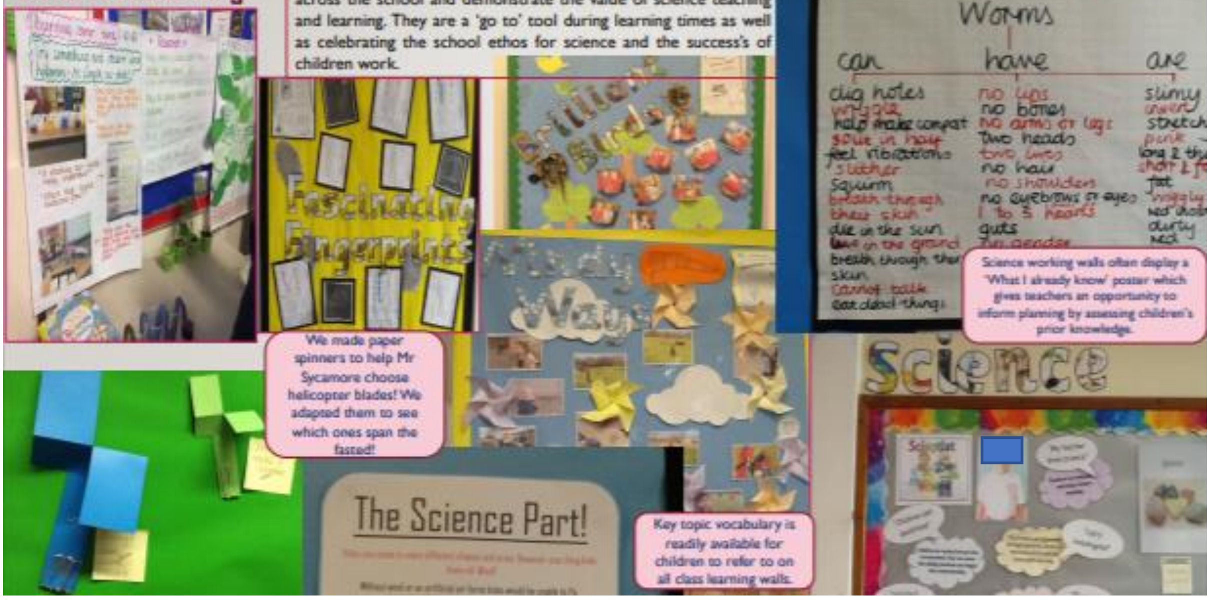
Targets for science on the school improvement plan are discussed and devised between subject leader and Head Teacher/Deputy Head.

Our first entry on school improvement plan was simply to raise profile of science by working towards PSQM award. Since then, and after monitoring, we decided to include the need to focus on children using scientific enquiry skills. Target are to be re-reviewed by end of July 2017 and added to or be made more specific accordingly.

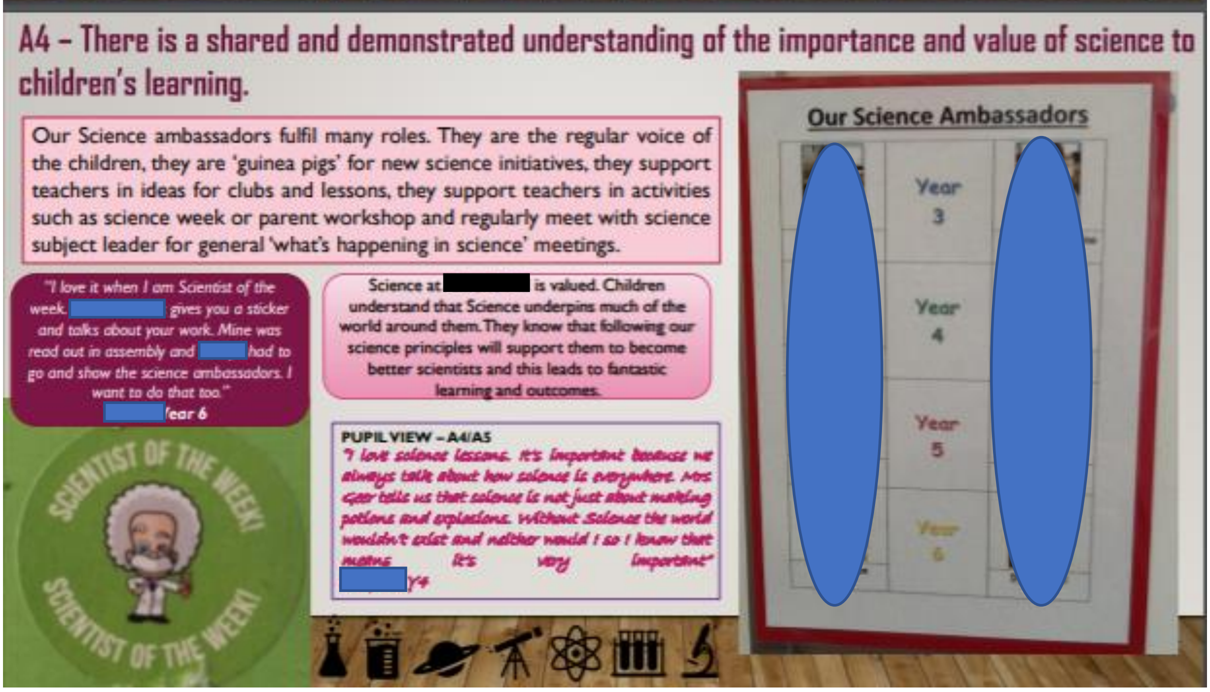
Next Steps – To develop an ongoing school action plan for science in conjunction with whole teaching staff. From this we can choose high profile elements to include in school improvement plan which better reflect our needs as these are constantly changing as the science profile in our school is strengthened and raised.

A4 – There is a shared and demonstrated understanding of the importance and value of science to children's learning.

Science displays around the school represent the efforts in science across the school and demonstrate the value of science teaching and learning. They are a 'go to' tool during learning times as well as celebrating the school ethos for science and the success's of children work.

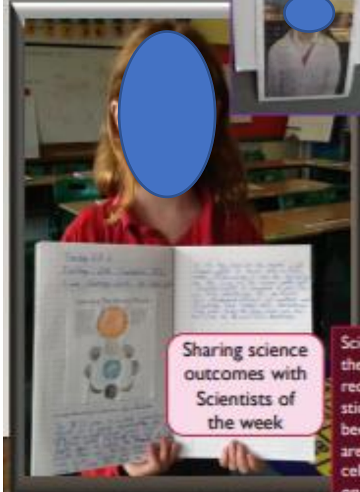



A4 – There is a shared and demonstrated understanding of the importance and value of science to children's learning.
EGG DROP
"Most of all I like the home Learning you give us in the holidays for science. It's always fun and I can do it with my Dad."
[redacted] Year 5
"My favourite home learning was the one where we had to clean money. My 2p shined so brightly
[redacted] Year 4
"I liked the kitchen cupboard science homework. My Mum and brother helped me. We had to blow up a balloon without using out mouths. We explored how substance meet and create gas. It's called a chemical reactions.
[redacted] Year 6
Objective:
To build a system to protect an egg from cracking or breaking from a drop of at least 2 metres.
You can choose from the following materials: Paper towels, elastic bands, sandwich/plastic bags, lollipop sticks and straws, cardboard tubes and sticky tape.
Vocabulary:
Air resistance, aero dynamics, gravity, velocity (speed), travel, prediction, fair test.
Safety first!
Releasing your egg drop system
from a height might involve dropping from a window or step ladder. Make sure an adult does this.
If you stand at ground level and wait for the drop you will get the see the outcomes quicker and stay safe.
Have fun!
Due date Tuesday 1st November – Lots of time to plan, build and evaluate!
Things to remember:
-You must complete your planning sheet before building your egg drop system.
-Use 'trial and error' to evaluate and improve your designs
-Try using boiled eggs to start! Not as messy!
-Think: Scientist! (ask questions, investigate, find evidence, evaluate, improve, present finding)


A4 – There is a shared and demonstrated understanding of the importance and value of science to children's learning.
Our Science ambassadors fulfil many roles. They are the regular voice of the children, they are 'guinea pigs' for new science initiatives, they support teachers in ideas for clubs and lessons, they support teachers in activities such as science week or parent workshop and regularly meet with science subject leader for general 'what's happening in science' meetings.
"I love it when I am Scientist of the week, [redacted] gives you a sticker and talks about your work. Mine was read out in assembly and [redacted] had to go and show the science ambassadors. I want to do that too."
[redacted] Year 6
Science at [redacted] is valued. Children understand that Science underpins much of the world around them. They know that following our science principles will support them to become better scientists and this leads to fantastic learning and outcomes.
PUPIL VIEW – A4/A5
"I love science lessons. It's important because we always talk about how science is everywhere. Mrs Geer tells us that science is not just about making potions and explosions. Without Science the world wouldn't exist and neither would I so I know that means it's very important"
[redacted] Y4
SCIENTIST OF THE WEEK!
Our Science Ambassadors
Year 3
Year 4
Year 5
Year 6

A5 – The subject leader knows about science teaching and learning across the school.

Scientists of the week enjoy discussing their learning with the subject leader.



Sharing science outcomes with Scientists of the week

"The materials and recycling assembly linked extremely well to our current Science learning on 'Materials and their Properties' – Children used the content to support accessing remaining lessons." **Y5 Teacher**

Scientists of the week from each class visit the science subject leader weekly. They receive a special 'Scientist of the week' sticker and discuss the reason they have been selected. On occasions their books are shown to the science ambassadors to celebrate all the great science work going on across the school.

Feedback from a staff questionnaire:

"I often struggle to make learning accessible for my lowest attaining children for whom writing is a barrier. We are soon due to research David Attenborough and would like a way of enabling RD to not only access this but also demonstrate a good understanding" Mrs D

Subject leader suggested:

"You could organise for RD to watch some David Attenborough video clips (available from BBC archive website), whilst other children are researching on the internet. Once he has an idea on what David Attenborough does, give him a partner, an I-Pad, a magnifying glass. And some sentence starter prompts. He can make an Attenborough style short film"

"I am David Attenborough….I look at different animals and their habitats. I can tell you why animals behave in strange ways and help you to understand why it is important to keep some animals safe"

[redacted] **Year 6**

B1 – Staff continue to have opportunities for CPD within Science that increases their skills, knowledge and understanding.

Throughout the year the subject leader holds staff meetings to ensure the profile of science remains high. Such meetings are used to ensure teachers are confident with all areas of teaching and assessing in their current unit, curriculum changes, book looks across key stages and general recap on expectations for science teaching and learning.

"I truly enjoy teaching Science now – more than ever before. I think regular visitors and staff meetings you have led have helped everyone's confidence in teaching Science. [redacted]

Regular short meetings and discussions allow teachers the opportunity to see Science teaching across the school and even magpie ideas to help keep the teaching + learning engaging. Staff here are aware that the subject leader is here for support and guidance when needed. She regularly feeds back from CPD courses and there is always something useful we can take forward into the classroom to support our learning. One example is when the subject leader highlighted we did not have evidence of some scientific enquiry skills, in a book scrutiny. Unsure how to cover this, she led year group CPD on 'observing over time' and 'Research'. This was really useful and the examples given worked really successfully in class.

[redacted] – Y3 Teacher Training

"My class really don't have a solid understanding on the 'make up' of blood"

The Science subject leader gave me feedback from an 'engaging Science' course she attended from SNAP Science. We used these ideas and made blood!

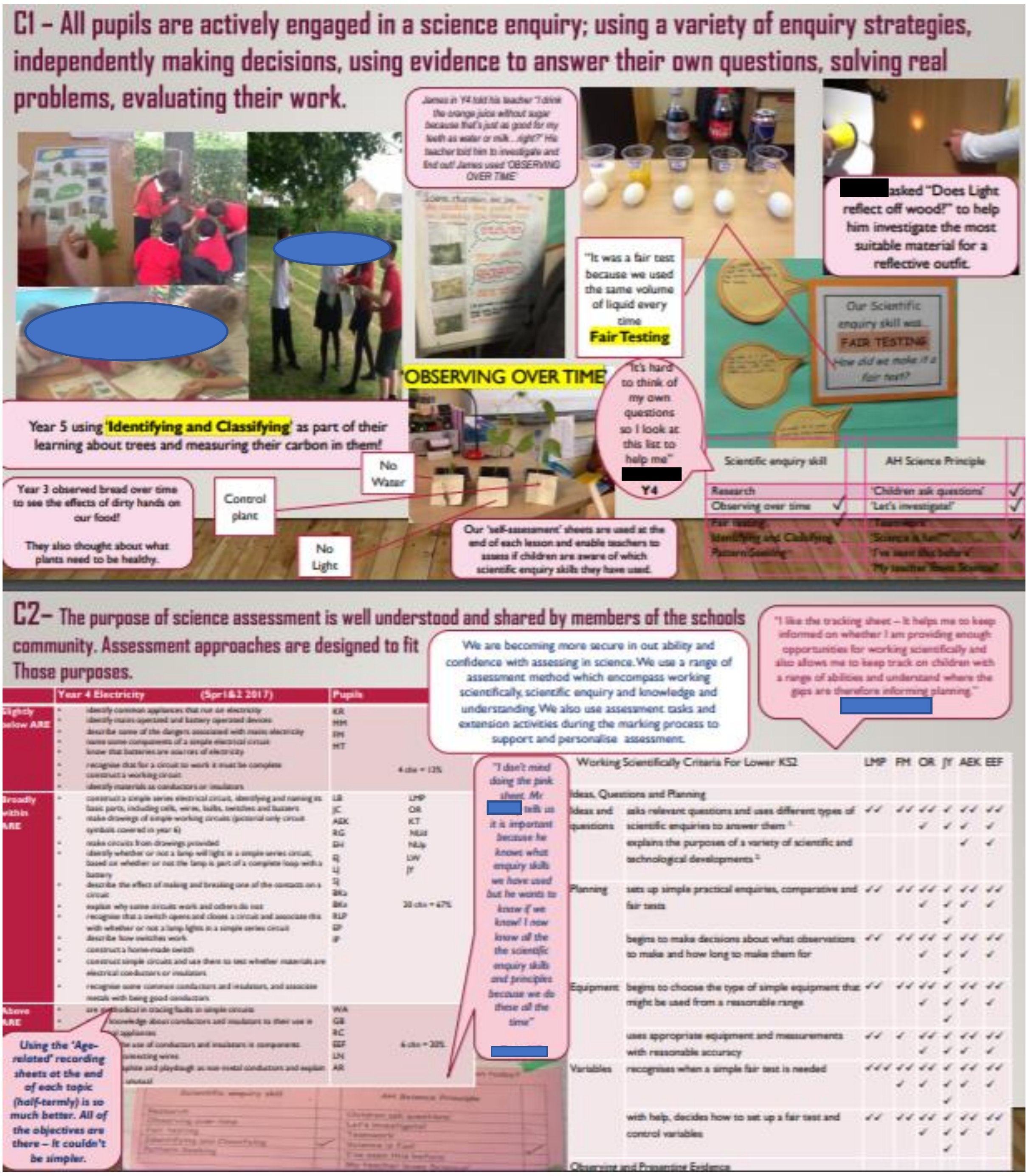
[redacted]

"We used yellow food colouring in water for plasma, rice for white blood cells and small cubes of strawberry jelly for red blood cells. We learnt how much of each are in our blood – It was fun – We even got to take our blood home!"

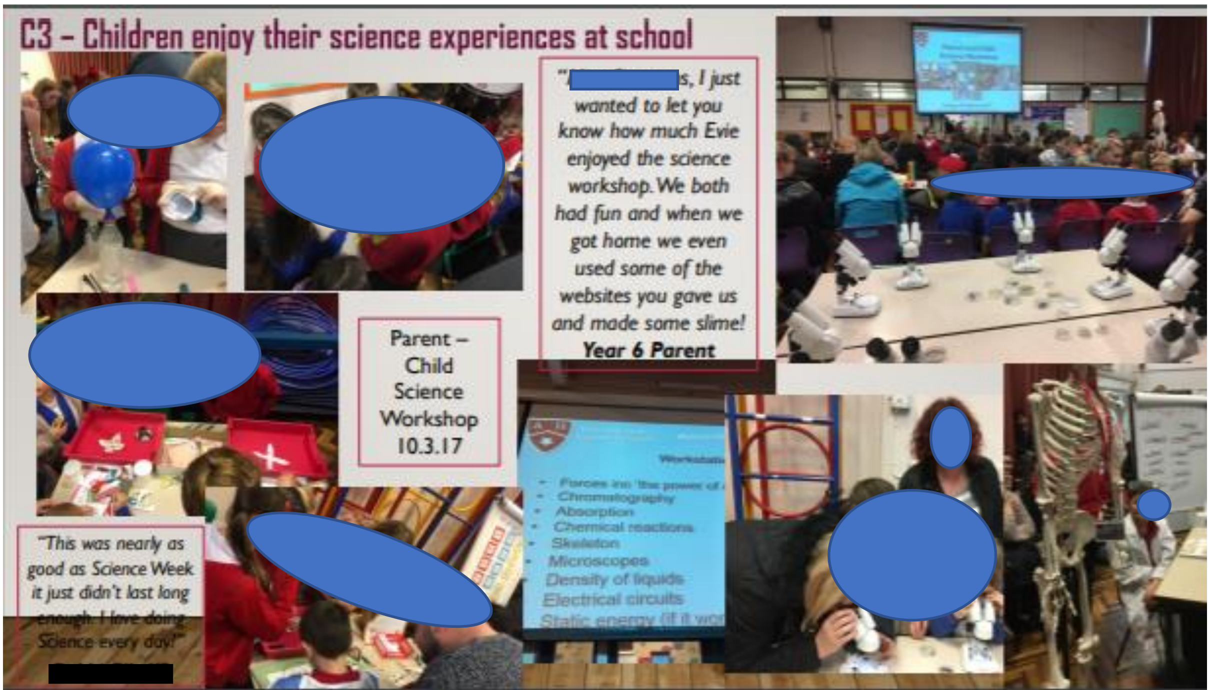
[redacted]

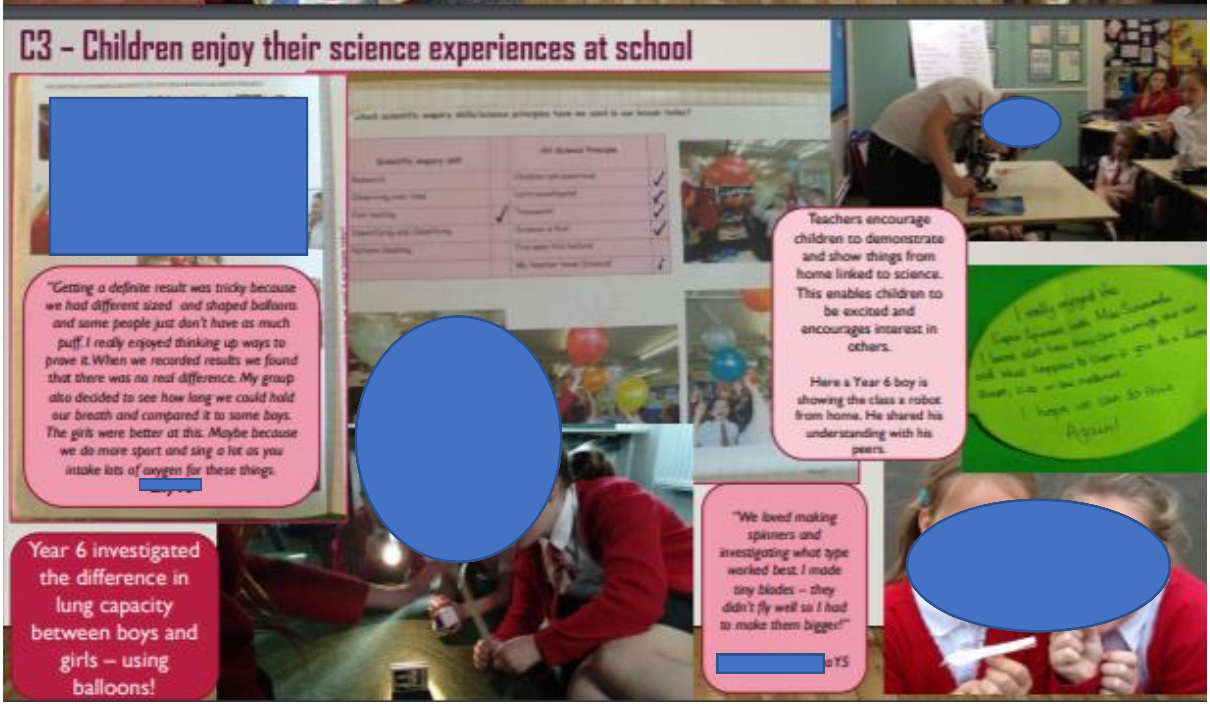
[redacted]e subject leader) – Thanks for sending me out on the science course today. It was really worthwhile and I have picked up lots of things I plan to use the next time we teach forces and sound. I will let you know when I use some of the strategies! It was really nice to share some practices with other teachers too. [redacted] Y4


B2 – There is a range of teaching and learning approaches
LiVE LESSONS
Y4 and Y5 have used BBC 'Live Lessons' to support, consolidate and enhance science learning matched to current topic area.
Year 3 children responded to an 'Agony Aunt' column and wrote to readers to help them with their nutritional worries! This gave the children the opportunity to use a different approach to express understanding.
Teachers are encouraged to use as much practical learning as possible.
Outdoor learning environment is used whenever possible. Here Y5 are measuring carbon in trees and Y4 are searching for invertebrates.
B3 – There are a range of up to date quality resources specifically for teaching and learning science. IT is used both as a tool and a resource for teaching.
We use free resources where possible. Why buy compost when we can dig for worms and make our own!
From this… To this! Now we can find resources and more importantly USE THEM to support and enhance great Science learning!
Year 4 used circuit components, motors, crocodile clips, switches etc to create an electrical circuit
"I love using the torso. I never realised my stomach was so small compared to other organs" [redacted] Y6
children had learnt – Some children shared their findings in an assembly.
More free resources – A class set of Microscopes loaned from RMS

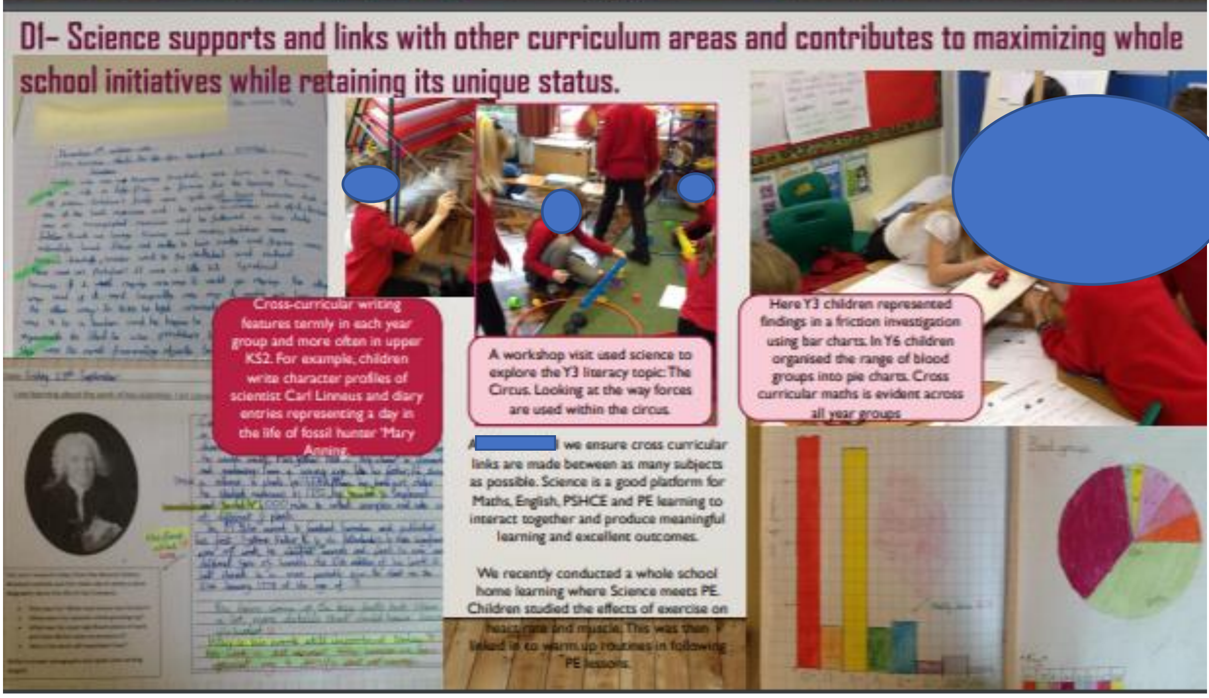


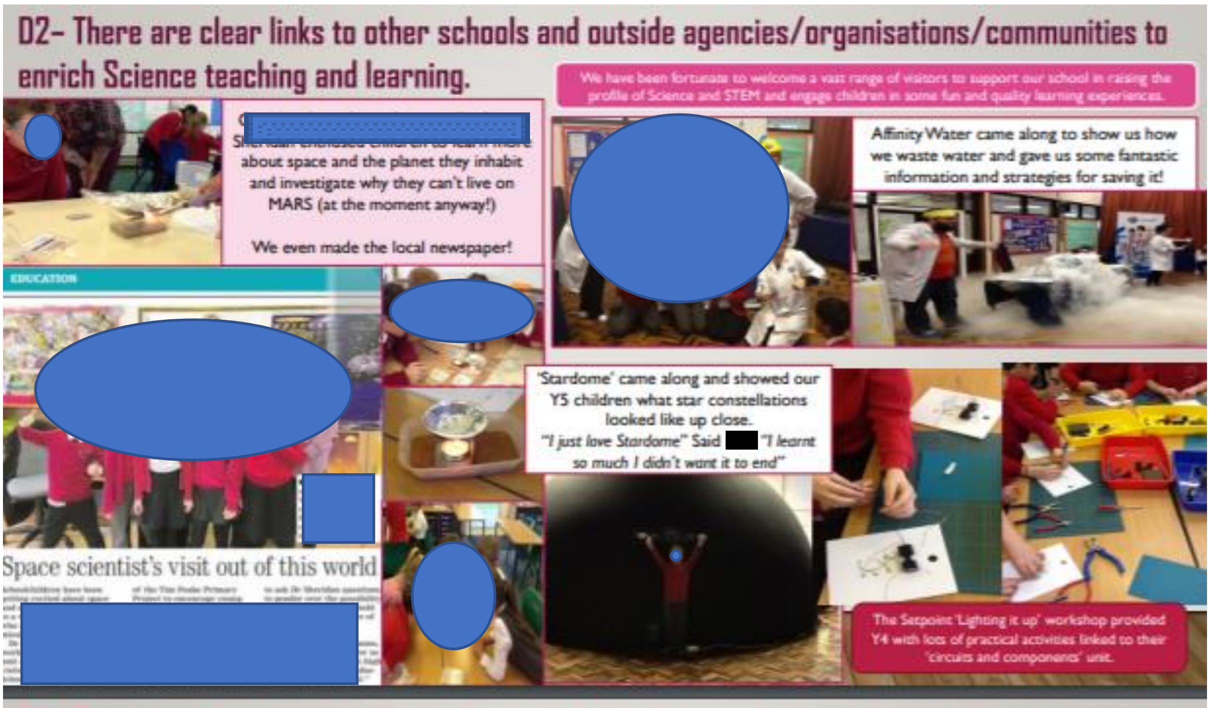
C1 – All pupils are actively engaged in a science enquiry; using a variety of enquiry strategies, independently making decisions, using evidence to answer their own questions, solving real problems, evaluating their work.
James in Y4 told his teacher "I drink the orange juice without sugar because that's just as good for my teeth as water or milk…right?" His teacher told him to investigate and find out! James used 'OBSERVING OVER TIME'
[redacted] asked "Does Light reflect off wood?" to help him investigate the most suitable material for a reflective outfit.
"It was a fair test because we used the same volume of liquid every time
Fair Testing
Our Scientific enquiry skill was…
FAIR TESTING
How did we make it a fair test?
'OBSERVING OVER TIME'
"It's hard to think of my own questions so I look at this list to help me"
[redacted]
Y4
Year 5 using 'Identifying and Classifying' as part of their learning about trees and measuring their carbon in them!
No Water
Control plant
No Light
Year 3 observed bread over time to see the effects of dirty hands on our food!
They also thought about what plants need to be healthy.
Our 'self-assessment' sheets are used at the end of each lesson and enable teachers to assess if children are aware of which scientific enquiry skills they have used.
Scientific enquiry skill
AH Science Principle
Research
Observing over time
'Children ask questions'
'Let's investigate!'
C2– The purpose of science assessment is well understood and shared by members of the schools community. Assessment approaches are designed to fit Those purposes.
We are becoming more secure in out ability and confidence with assessing in science. We use a range of assessment method which encompass working scientifically, scientific enquiry and knowledge and understanding. We also use assessment tasks and extension activities during the marking process to support and personalise assessment.
"I like the tracking sheet – It helps me to keep informed on whether I am providing enough opportunities for working scientifically and also allows me to keep track on children with a range of abilities and understand where the gaps are therefore informing planning."
Year 4 Electricity (Spr1&2 2017)
Pupils
"I don't mind doing the pink sheet. Mr tells us it is important because he knows what enquiry skills we have used but he wants to know if we know! I now know all the the scientific enquiry skills and principles because we do these all the time"
Working Scientifically Criteria For Lower KS2
LMP FM OR JY AEK EEF
Ideas, Questions and Planning
Planning
Equipment
Variables
Using the 'Age-related' recording sheets at the end of each topic (half-termly) is so much better. All of the objectives are there – It couldn't be simpler.

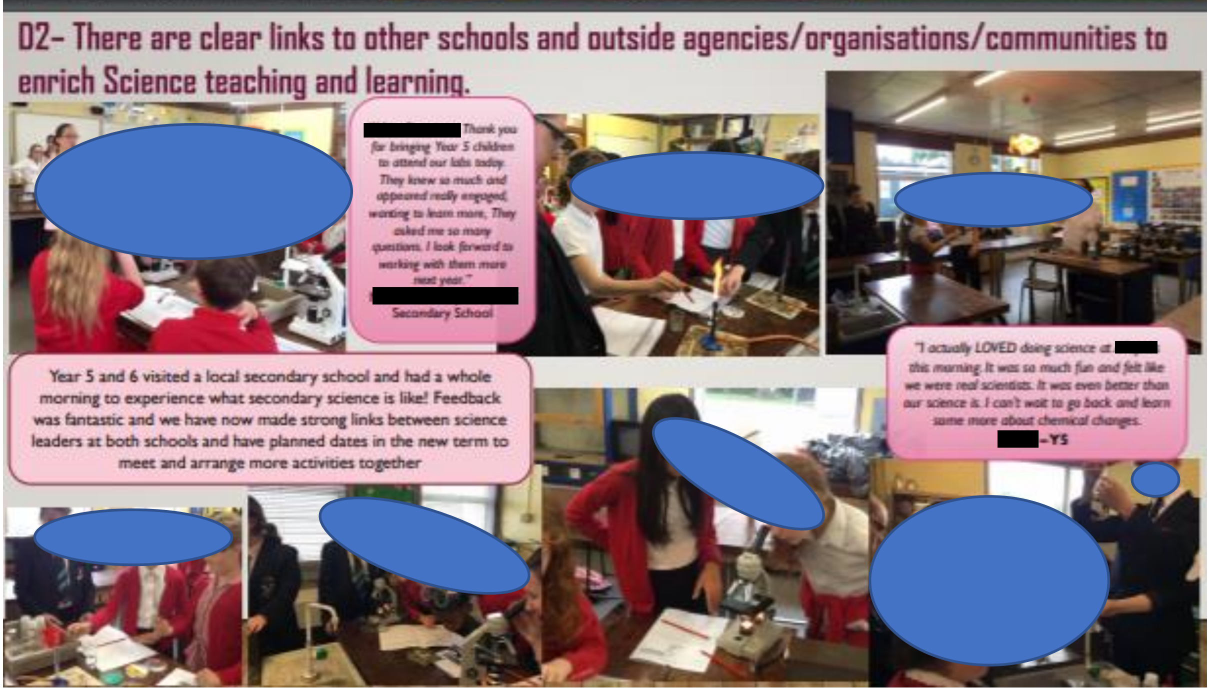

C3 – Children enjoy their science experiences at school
"[redacted]s, I just wanted to let you know how much Evie enjoyed the science workshop. We both had fun and when we got home we even used some of the websites you gave us and made some slime!
Year 6 Parent
Parent – Child Science Workshop 10.3.17
Forces inc 'the power of
Chromatography
Absorption
Chemical reactions
Skeleton
Microscopes
Density of liquids
Electrical circuits
"This was nearly as good as Science Week it just didn't last long enough. I love doing Science every day!"
[redacted]


C3 – Children enjoy their science experiences at school
"Getting a definite result was tricky because we had different sized and shaped balloons and some people just don't have as much puff. I really enjoyed thinking up ways to prove it. When we recorded results we found that there was no real difference. My group also decided to see how long we could hold our breath and compared it to some boys. The girls were better at this. Maybe because we do more sport and sing a lot as you intake lots of oxygen for these things.
[redacted]
Year 6 investigated the difference in lung capacity between boys and girls – using balloons!
Teachers encourage children to demonstrate and show things from home linked to science. This enables children to be excited and encourages interest in others.
Here a Year 6 boy is showing the class a robot from home. He shared his understanding with his peers.
"We loved making spinners and investigating what type worked best. I made tiny blades – they didn't fly well so I had to make them bigger!"
[redacted] Y5


C3 – Children enjoy their science experiences at school
Here Year 3 children are enjoying observing 'walking water'
"In science club today I learnt that you can move water without touching it! – It's called absorption"
[redacted] Y3
Science club runs throughout the year and all year groups have an opportunity to join in. They is an undertone of scientific theory and vocabulary threaded through but the emphasis is on fun!
"We looked at different types of fingerprints. We learned that patterns can be similar but each one is slightly different.
"I had loop fingerprints but Grace had lots of whorls"
[redacted] Y3
We learned about chromatography and how ink contains different colours. Leo wondered what would happen if we did the same experiment with sweets instead of pens!


D1– Science supports and links with other curriculum areas and contributes to maximizing whole school initiatives while retaining its unique status.
Cross-curricular writing features termly in each year group and more often in upper KS2. For example, children write character profiles of scientist Carl Linneus and diary entries representing a day in the life of fossil hunter 'Mary Anning.
A workshop visit used science to explore the Y3 literacy topic: The Circus. Looking at the way forces are used within the circus.
Here Y3 children represented findings in a friction investigation using bar charts. In Y6 children organised the range of blood groups into pie charts. Cross curricular maths is evident across all year groups
[redacted] we ensure cross curricular links are made between as many subjects as possible. Science is a good platform for Maths, English, PSHCE and PE learning to interact together and produce meaningful learning and excellent outcomes.
We recently conducted a whole school home learning where Science meets PE. Children studied the effects of exercise on heart rate and muscle. This was then linked in to warm up routines in following PE lessons.


D2– There are clear links to other schools and outside agencies/organisations/communities to enrich Science teaching and learning.
We have been fortunate to welcome a vast range of visitors to support our school in raising the profile of Science and STEM and engage children in some fun and quality learning experiences.
[redacted] about space and the planet they inhabit and investigate why they can't live on MARS (at the moment anyway!)
We even made the local newspaper!
EDUCATION
Space scientist's visit out of this world
Affinity Water came along to show us how we waste water and gave us some fantastic information and strategies for saving it!
'Stardome' came along and showed our Y5 children what star constellations looked like up close.
"I just love Stardome" Said [redacted] "I learnt so much I didn't want it to end"
The Setpoint 'Lighting it up' workshop provided Y4 with lots of practical activities linked to their 'circuits and components' unit.


D2– There are clear links to other schools and outside agencies/organisations/communities to enrich Science teaching and learning.
[redacted] Thank you for bringing Year 5 children to attend our labs today. They knew so much and appeared really engaged, wanting to learn more. They asked me so many questions. I look forward to working with them more next year."
[redacted]
Secondary School
Year 5 and 6 visited a local secondary school and had a whole morning to experience what secondary science is like! Feedback was fantastic and we have now made strong links between science leaders at both schools and have planned dates in the new term to meet and arrange more activities together
"I actually LOVED doing science at [redacted] this morning. It was so much fun and felt like we were real scientists. It was even better than our science is. I can't wait to go back and learn some more about chemical changes.
[redacted] –Y5

Appendix H - Cherry Tree School – Reflections

A: Subject Management

A1: There is an effective subject leader for science

There is a named member of staff responsible for the leadership of the subject . They have participated in subject specific training in the last three years and have shared this with all colleagues in the school and can demonstrate the impact this has had.

After only partially taking on role of subject leader the term before I was officially appointed as Science subject leader in September 2016 I have made big steps in becoming familiar with what being a good subject leader of science looks like and become aware of the responsibilities it holds. Science has always been taught at our school yet never pushed as a 'core subject' or promoted in a way that made children and teachers enthused for teaching and learning. This was something that I felt strongly about addressing and working towards the award gave me a great opportunity to do this well. After discussions with our science advisor at a staff training session I was informed about the PSQM and was informed that this would be a great way to develop science within the school. I researched the award a little and couldn't have agreed more. I asked the Head Teacher if this was something that would be possible and she agreed for us to participate and this is where our journey began.

To support my role as subject leader I attended a number of CPD course, including engaging children in science and developing the role as a science leader and all of the information I gathered was fed back to staff through meetings, keeping science news and updates in the forefront. I have delivered whole staff meetings with science as the main agenda. Initially I used the training to support teachers in understanding the need for science principles in our school. This has impacted on helping teachers to understand what 'good' science looks like and where we want to be heading with all science taught at our school, therefore enhancing teaching and learning experiences and supporting teachers in understanding expectations and fulfilling roles. I also attended a 'Snap Science' session which looked at different schemes of work available to purchase, linked to the Science curriculum. The impact of feeding this back to staff was that we agreed we would first attempt to raise the profile of science without the need to buy into schemes and planning packages. Collectively we decided that despite feedback of 'Snap' sounding good, it was quite expensive and actually if we were all 'on board' with raising the profile of science and being reflective teachers of engaging science we should and could do this without this extra expense which could instead be well spent on other budget areas such as quality resources. Recognising this, in turn, helped us as a whole staff to realise we were all working toward the same thing: excellent teaching and learning in science regardless.

I have gained in confidence in my role as subject leader as the year has progressed. I have been given very positive feedback not only from our teachers, who now feel they are more engaged and confident in teaching science, but also from governors (including a personally issued letter of thanks from our lead governor) parents, links schools and visitors. I am open to staff approaching me with any queries or support needed and we work together to overcome any issues in the teaching of science. (Portfolio Slide 1)

My next steps as subject leader would be to attend more regular CPD. I would like to engage in new ways to deliver exciting learning to upper key stage 2 topic areas as I feel this year, although crossing both year groups, has had a stronger focus on supporting lower KS2 because of the year group I am currently part of.

A2: There is a clear vision for the teaching and learning of science

A staff team has been involved in developing the school's principles for teaching and learning science. They are reviewed regularly along with the scheme of work for science which promotes these principles.

After compiling a set of principles for science, using feedback from children, parents and staff, we began using these as a foundation for good, effective science teaching and learning. This process impacted positively on the profile of science at our school. Parents began to understand our expectations linked to science learning and through parent feedback it was evident that this impacted on their children's engagement in science and learning at home, thus broadening understanding that science is everywhere at not just as school in a classroom. As a further result of developing the principles, teachers have a clearer understanding on what good teaching and learning looks like. Principles occasionally form part of teachers planning for science (portfolio slide 3) Teachers from one year group reported that the principles acted as a focal point on which they have planned their lessons, and as a result they provide quality teaching consistently. By creating a 'child-friendly' version of the principles (portfolio slide 2) children are also aware of what good science learning (and teaching) looks like. They also have an awareness of the value of science at our school. Our principles form not only part of the main hall school display (portfolio slide 3) but also appear on science learning walls in each classroom and children are encouraged to refer to these principles to give the teacher feedback on whether the science learning has been good or better as judged by our principles. Moving forward, our next step is to implement a requirement for all planning, regardless of source, to reflect school principles.

A3: The current School Development Plan has appropriate and active targets for science

The science subject leader has worked with the Senior Management Team to agree School Development Targets for science based on identified strengths and weaknesses. The science subject leader had led staff in the implementation of actions to meet these targets across the school.

When beginning the PSQM journey we (Subject Leader and Head Teacher) added a discrete section to the School Improvement Plan to reflect that we were making engagement in science a whole school focus and working toward this award. This was shared with whole staff. Once established in our journey we felt that this was not specific enough and in fact so much had changed and improved with science at [redacted] that on reflection, the targets on the SIP needed an early review with a view to being more specific. We decided that we would make 'scientific enquiry' a key focus to begin with (portfolio slide 5). I believed this is a key element of children succeeding and getting the most from science. We added this point to the SIP and feel that this better reflects the needs of the school when compared to the initial section. The impact of making these points more specific is that it gives teachers more focus on what we are trying to deliver in science across the school. Actions are to be viewed at the end of the year. Moving forward it is possible we will add a further target related to assessment in science (percentages of children working at age-related or above) but feel that this should not be added at a mid-point through the year and in fact next year, we will be in a better position to make data comparisons and so this will be addressed when next reviewing SIP at end of July.

A4: There is a shared and demonstrated understanding of the importance and value of science to children's learning.

There is a shared understanding of the importance of science, clearly evidenced throughout the school, including the grounds.

There is evidence throughout the school which shows that science is valued and enjoyed by the children and teachers. A central display in the main entrance highlights our school principles and celebrates our science ambassadors (Portfolio slide 8). There are science working walls in all classrooms, celebrating Science outcomes, children's work, vocabulary/prompts for learning and our school Science principles (Portfolio slide 6). The impact of these displays is that children are becoming not only more aware of how science is valued in our school but also are becoming more independent in seeking resources to support their learning. Key school events such as Science week, science workshops, visits and visitors are well promoted and publicised through home learning books, emails, social media feeds and newsletters. Showing value to parents (Portfolio slide 15).

Half termly whole school science projects are issued and embraced by parents and feedback from both children, parents and teachers indicate these are a pivotal part of engagement and enjoyment in science at school and home (Portfolio slide 7) Both Pupil voice and teacher feedback show how science is valued and the importance of science to children's learning is evident (Portfolio slide 8). Another way in which we value science learning is by selecting a scientist of the week for each class. This child visits the subject leader with their learning and discusses work carried out in class. They receive a special sticker which are worn with pride (Portfolio slide 8). Some examples from scientist of the week books are shared in meetings with science ambassadors – reinforcing value of science across the school. The impact of demonstrating the value of science in these ways is positive, and seen in the attitudes and engagement of children where they now are able to recognise that 'science is everywhere' and not just in the classroom, pushing boundaries of what they already know in new and real-life contexts, thus deepening understanding of science across the curriculum. Moving forward I would like our science ambassadors to begin a science blog at school which will be promoted through all avenues to further promote and celebrate Science at our school. This could also be rolled out to other children.

A5: The science subject leader knows about science teaching and learning across the school

Peer assessment and team teaching of science takes place across the school. School-wide work book scrutiny takes place.

I began my role of science subject leader by familiarising myself with the science curriculum and the timetable for science taught. I looked at the progression through the key stages and feel like this put me in a good position to monitor science in our school. During staff meetings and insets, I have discussed the teaching of science across the school with staff and welcomed their feedback and thoughts through informal discussions and teacher questionnaires (Portfolio slide 9). I schedule time for termly book scrutiny to monitor how science is taught across the school and strengths and questions arising are discussed with all year group teachers via written feedback and follow up email. As a result of monitoring, science teaching has improved. Feedback from a Y6 teacher indicates she took on board monitoring notes where it was suggested that a low ability writer could use 'role-play' to demonstrate his understanding. She used the suggestions for differentiation in a recent lesson and this enabled to learner to be successful (Portfolio slide 9). The impact on being aware of science across the school means that I can not only effectively monitor science taught but also successfully organise CPD, visits, trips, assemblies, visitors etc to link and enhance current learning. For example the 'AMEY' waste assembly linked into Y5 learning on changes and properties of materials and one teacher in this year group explained how she felt this assembly consolidated their understanding and prepared them for their next lessons (portfolio slide 9) I am visited weekly by 'scientists of the week' (portfolio slide 9) and this gives me more regular opportunities to talk with children and understand what learning has happened recently and how children feel about this. This has taught me that children are engaged and enthusiastic about science and there is pride in the work they complete and this is supported by positive comments noted during pupil voice.

Whilst I have been able to observe some science lessons in different year groups, moving forward I would like this to be a termly arrangement linked in to termly book scrutiny in order for feedback to be most effective.

B1: Staff continue to have opportunities for CPD within science including training and support that increases their skills, knowledge and understanding

Internal monitoring and performance management processes are used to inform decisions regarding staff CPD needs in science.

The subject leader has delivered CPD to some other teachers

Regular staff meeting slots have provided me with an opportunity to share some examples of not only my own CPD courses and insets but also the work that goes on around the school that I have experienced through observations and book scrutiny (Portfolio slide 10). I have arranged for various professionals to come in to school and deliver CPD to all staff with a view of improving subject knowledge, confidence in delivery and assessment. One example of this is where a county advisor came in and demonstrated to staff how to engage children in short experiments/investigation that promote scientific enquiry skills. Several of the activities shown were used in a very successful parent workshop which engaged children and parents and encouraged them to think about the science behind the activity. Beginning this dialogue opened up the path for understanding. I have communicated through questionnaire with all teachers who had fed back any areas they are less confident in with regard to their science teaching and organised CPD or given advice where necessary. I feel confident that this year teachers are all more confident in their abilities to teach science which children not only learn lots from but also they enjoy delivering (linking to our science principle: 'My teacher loves science') (portfolio slide 10). Moving forward I would like to send teachers, as a year group to a CPD course to address teaching science in an engaging way with a range of teaching strategies as despite getting better at this we could improve further and add to our developing bank of engaging strategies used. I believe this would utilise our teaching and be beneficial to year group science planning to support teachers in making links to all principles in their weekly plans. I would also like to use more free online 'Reachout' CPD as I have personally discovered some of this recently and will be sharing this with staff to further support teaching and learning.

B2: There is a range of teaching and learning approaches

There are several relevant teaching and learning approaches in science being adopted by teachers across the school in response to school development targets. The science subject leader is pro-active in introducing new strategies.

There are a wide range of teaching and learning approaches within the school. As seen in our science principles we encourage and use open ended enquiries generated by children's own curiosity

(Portfolio slide 4). Teacher have reported feeling confident to adapt planning to suit the varying needs of the classes and the activities they are participating in. They are aware and on board with our SIP focus of more opportunities for working scientifically and this is displayed in the range of strategies for teaching used

ICT is used as a learning tool across all subjects in our school. For example, we regularly use I-pads for researching famous scientists. Our Y4 and Y5 classes have also participated in Terrific Scientific 'Live Lesson's (Portfolio slide 11) where they join in on a country-wide science investigation live on the internet and upload data and working examples to the producers as they are learning. However, moving forward I am proposing the use of ICT in science become more frequent and whole school wide, and is clearly planned to support and enhance science learning. In Autumn term 2017/2018 year 'BBC Terrific Science' are launching a live lesson based on 'exercise' and we plan for the whole school to take part in this.

I have used and successfully shared strategies from CPD courses to explore producing outcomes from investigations in different ways. For example, using an 'agony aunt' column (with role play for less able writers) where they gave advice on health and nutrition based on their specific problem (Portfolio slide 11) The impact of these strategies are positive where outcomes allows our teachers to gain an insight into the knowledge held by children in an imaginative way that might not have been the case if simply asked to write a 'conclusion' for example.

B3: There is a range of up-to-date, quality resources specifically for teaching and learning science. ICT is used both as a tool and as a resource for teaching

Science resources are used across the school and are well maintained and organised. They are audited regularly, and school has identified suitable further resources to purchase that will enhance teaching opportunities. Use of 'free' resources, such as rock samples, fabric collections and plants has been developed.

When developing my new role as subject leader it was evident that storing and using resources to support the learning of science at our school was not to a standard that we would ideally like or indeed expect. It became apparent through teacher questionnaires that teachers were wary of using resources because of either not knowing where they were or in several cases not actually being aware of what we had in our science cupboards. I arranged an audit of all science resources, which included a whole school resources 'amnesty' so I could really gage a good understanding of what we had and as a result, what we needed. In addition, I asked teachers to keep an ongoing record of any barriers they faced in science due to lack of specific resources and discussed with them ways we could overcome these barriers. This led to ordering and restocking of several resources such as crocodile clips, compasses, pipettes etc. Since the audit all staff are aware of the science cupboards system with one cupboard for each year group, with clear signage detailing resources and topics covered in that year group. In addition, we have a new science cupboard for all to access the majority of 'generic' science materials. This too is clearly labelled and very easily accessible (Portfolio slide 12). Feedback from staff is extremely possible with a few teachers admitting they had no idea we had certain resources and how they are now and can definitely be used from now on to support teaching and learning. We maintain that were possible we use 'free' resources to support our learning. Our teachers and children can be seen collecting rocks, leaves and even worms for compost making from our school grounds. The impact is reducing cost on an ever tight school budget (Portfolio slide 12). Where possible we involve parents and ask for resources from home to be donated and also we request loans from outside agencies. One of our loans included a class set of microscopes from the Royal Microscopy Society. Children used these really effectively for the whole spring term which included British Science Week this impacted on children's engagement in science and exploration at zero cost (Portfolio slide 12). In addition, we have developed strong links with a local secondary school who are producing 'topic' boxes that we will, loan at the beginning of each new half term in Y5 and Y6. Again, this is of no cost to us, comes with its own CPD on how to best use it and provides fantastic support for learning due to how resources are specifically related to enhancing the topic.

C1: All pupils are actively engaged in a science enquiry; using a variety of enquiry strategies, independently making decisions, using evidence to answering their own questions, solving real problems, evaluating their work.

Children's curiosity is encouraged and valued. They ask questions and encounter challenging problems, and independently come up with ways to investigate them using their growing scientific skills. Differentiated activities of appropriate challenge are provided for all pupils offering extension and open-ended work for the most able, and support/guidance for the least. Children are given the opportunity to reflect on their work. They are encouraged to engage in relevant and motivating science at home. Pupil are encouraged to participate in school-based science initiatives.

We are working hard to make as much science learning as possible based around children's questions and curiosity. Feedback from children suggest they enjoy completing investigations where they decide what to investigate. In light of this we have been trialling giving children a topic and asking them to generate their own 'enquiry statement' which, whilst supported for ways they might explore this, work independently or collaboratively with others to investigate. In year six children were given the topic of 'lungs'. One common enquiry statement was "Do boys or girls have a greater lung capacity?" Children who wanted to explore this, discussed ways this could happen. They decided to investigate using balloons. They enjoyed leading their own work and investigating their ideas (portfolio slide 16). Due to working walls and displays in class, in addition to our new self-evaluation check list, (Portfolio slide 13) children are aware of the five scientific enquiry skills and look to these to consider ways in which they might investigate an enquiry statement. Feedback from one less able child showed how sometimes they may not know how to answer their question but enjoyed asking questions and with help can use the 'pink slips' to know which scientific enquiry skill might help them (Portfolio slide 13). This understanding has an impact on how children feel valued within the subject and know that they thoughts, opinions and curiosities are respected and important, thus laying foundations for meaningful learning. Science club is weekly and ongoing throughout the year. It is offered to lower and upper key stages on a rota basis. We engage in fun and 'wow' activities with scientific elements threaded through our discussions. Science club is proving extremely popular with a current waiting list (links to C3, portfolio slide 17) Moving forward I would like to train ambassadors in the upper school to lead sessions with support of TAs, so that more children can access the club. Half termly whole school science projects are issued and embraced by children and parents. Feedback from all involved indicate these are a crucial part of engagement and enjoyment in science at home and this impacts on making links to learning and developing a deeper understanding at school (Portfolio slide 7). In addition, I would like to complete a regular scrutiny on differentiating for most able learners and ensuring there are appropriate challenges and extensions in the activities they participate in to broaden and deepen understanding and further engage curiosities.

C2: The purpose of science assessment is well understood and shared by members of the school community. Assessment approaches are designed to fit those purposes

Teachers across the school build different assessment strategies in their science lessons and outcomes of these into their planning. The science subject leader is pro-active in introducing new strategies.

Teachers are aware of the expected levels of attainment for the pupils in their class and are able to make summative assessments confidently.

Science assessment is an area that is still developing in our school. Teacher's confidence has certainly grown in making both formative and summative assessments but are aware that more work is still to be done to fully understand what age-related looks like in topics together with displaying scientific enquiry skills and how the weighting of these, along with knowledge and understanding impacts on overall judgement when assessed. As a result of discussions and training from our science advisor from [redacted] we are all now more familiar with the recording of assessment. After discussions with the Head we purchased the assessment package for science and now use these with growing confidence to assess children every half term at the end of every topic area. To support our judgements we also use 'Assessment tasks' at the end of units and this supports the teaching in making sure judgments are accurate. An example of this is when Year 3 bone shaped dog biscuits to model the human body. This was a very good opportunity to support assessment and be part of ongoing conversations between children as they justified their choices and discussed their understanding (Portfolio slide 4). In addition, we use 'tracking sheets' to monitor use of working scientifically skills across a sample range of children throughout the school. The impact of this is that teachers have a greater understanding of how scientific enquiry skills are developing in children and can judge the impact of securing these (Portfolio slide 14). I developed the pink 'self-assessment' slip in response to recognising that children were often unsure about which skills they had used in their lessons. The slips are now used by each child at the end of every lesson and are an opportunity for children to display understanding on which principles they have met in that lesson and which scientific enquiry skills they have engaged with (portfolio slide 14) Teachers can use these to make judgements on whether or not the children are secure in this understanding thus informing assessment more. Moving forward I would like to adopt an online system for collecting data across the school. I believe this would be a more effective and efficient way of displaying and comparing data across year groups and over time.

D1: Science supports and links with other curriculum areas and contributes to maximising whole school initiatives while retaining its unique status

Through their planning, teachers have successfully identified appropriate links with other subject areas. Pupil work demonstrates the use of science as a context for work in core curriculum areas.

End of term year meetings of all SLT and teaching staff are a time where we discuss cross curricular learning at school and can plan in opportunities for cross-curricular links in each subject. I believe all teacher in our school contribute to making science part of the wider curriculum. Opportunities for cross curricular writing in literacy are explored, with children writing explanation, instruction texts and diary entries linked to their science topics (Portfolio slide 18). The link between science and PSHE and PE is also made clear, with an emphasis on the need for a healthy diet and lifestyle and the link between exercise and health. Links with maths are regularly made through the use of tables and graph construction, along with the use of averages and sampling methods (Portfolio slide 18). Moving forward I would like to work alongside staff to develop more opportunities for using ICT alongside science learning. We should support children in recognising the role of technology in Science through effective use of ICT and equipment in everyday science lessons.

D2: There are clear links to other schools and outside agencies/organisations/communities to enrich science teaching and learning

A programme of regular visits/visitors, outreach experiences and workshop activities are being developed for all classes to enhance specific science units/themes. Field work is carried out in the local area and sometimes, beyond it. Contact by pupils and teachers is made to other schools/community to enrich scientific understanding.

Over the course of the year there have been several outside agencies who have contributed to science learning within our school. Our range of visitors included Space Scientist [redacted] who led sessions on Space with Year 5 children during their Earth and Space topic. They used knowledge already gained in lessons to support a new investigation on 'Martian Soil' testing and investigating the properties of different soil samples to which one came from Mars (Portfolio slide 19). Children enjoyed this session and reported that it was fun because "we knew a bit about mars already when we did a planet study with [redacted] but we got to learn more with our science visitor" A 'lighting it up' workshop supported learning in Year 4s 'Electricity and Components' unit (Portfolio slide 19). The whole school have also had many visitors delivering assemblies which are science based despite not being relevant to all learning at that time. For example, Affinity Water's assembly created a huge amount of interest and stirred excitement and curiosity amongst children who experienced interactive activities which strived to demonstrate how much water is wasted in the western world and how each of us, regardless of age could conserve water (Portfolio slide 19). The feedback from this particular assembly was incredibly positive and children reported back to suggest they had turned their taps off whilst brushing their teeth last night! This shows me that workshops of this nature are not only fun but provide lots of learning points that children take home and build on. Recent links with a secondary school have proved to be a great way of preparing children for science as they approach KS3. Our year 5 and 6 children have visited the secondary school and were welcomed with a whole host of activities including 'wow' chemical reactions and dissecting a lamb's liver. Children from year 6 referred to class learning on 'The Circulatory System' and used learnt scientific vocabulary (veins and arteries etc.) to discuss the activity. A range of visitors such as these have a positive impact on science learning at our school. Visitors offer new, innovative ways of delivery knowledge in new areas and those currently studied. They provide children with an opportunity for deepening their understanding and furthering their interests. Moving forward I am planning to establish links with our local infant feeder school as links with secondary school have had a clear positive impact on all children. I have made contact with the science leader at this school and we are in discussions about a joint Y2/3 science club held during end of term holidays.

E: Science at your school

Please answer the following questions about your school:

1) What is your DfE number? (check with the school office)

DfE Number [redacted]

2) Please describe as best you can your school type (Primary, JMI, Inf, Special, Academy, etc)

Junior School

3) How many classes per year group?

Currently two classes per year group. Moving to three form entry in September 2017

4) How many cohorts/Year groups?

Four year groups (Year 3-6)

5) Do you have a nursery attached?

No nursery attached

6) Do you have a children's centre attached?

No

7) How would you describe the catchment/intake of children into your school?

Children predominantly white British from close catchment area. Number of children registered on school roll is very close to capacity (240) with 235 pupils (28-30 per class). Numbers entering new year 3 class as we move to three-form entry are slightly lower.

8) Have there been any particular developments/circumstances in the last three years that you feel you would like to alert the reviewer to?

Change of leadership and staff re-structure deployed by governing body in bid to accommodate budget restraints.

Acting Head Teacher during Summer term in absence of Head Teacher.

School moving to three-form entry.

Previously, no official subject leader of science (Head picked up subjects without a subject leader).

This is my first year being a subject leader and therefore leading science.

9) Looking back through this PSQM year, are there any specific science highlights you would look to headline?

There have been so many highlights over the last academic year as we have been working towards PSQM. One was the success of our parent-child workshop. Up to this point I had been trying extremely hard to promote science through lessons and home learning etc. This paid off when so many parents showed their support in an overwhelming event. In fact, the most successful event ever held at our school. As a fairly new teacher and completely new to science leadership this was a fantastic feeling to understand that all the hard work was worth it! Another highlight was when our chair Governor wrote me a letter (unexpectedly). She noted how much quality science was going on around the school. She spoke to children who were enthused about science. She showed thanks for working hard in the role as subject leader to promote a subject that has never had such a high profile. This was a highlight!

10) What do you feel the school's and your involvement in PSQM this year has done for science at your school?

I am extremely happy with past academic year. The PSQM award has really supported us in highlighting barriers to good science teaching and learning and how we might overcome them. It has helped to give us a focus and vision on what science looks like at [redacted] and where we want to go with it. We understand that this is an on-going journey and it doesn't end after the award. Governors, SLT, Teachers, Children and Parents agree that science is now valued at [redacted] where it may not have been so before. Children look forward to science that now appears to have more purpose thanks to clear vision through leadership and working towards the PSQM. Children (and now teachers too!) clearly enjoy science experiences – The whole year has been a highlight.

[redacted] are now proud of science teaching and learning in our school and my confidence as a subject leader has grown immensely during this process which in turn can only be a good thing for future of science at [redacted]

Appendix I - Sample interview schedule

Interview schedule - Danielle 3.4.17

Pre interview

I need: Banqueting paper and pens, notebook with instruction, interview schedule to make note on, biscuits and grapes, post-it notes

Check recording device is working. Check what time we need to finish.

Introduction

Note: date, time, location, who is present, interview being recorded

…………………………………………………………………………………………

What I want to find out	Question	Prompts	Notes
PSQM day 2 7th march	You were concerned about gathering evidence. You have now had day 2 PSQM training so how do you feel about gathering evidence now?		
Parent workshop (10th March)	The thing I'm most excited to hear about is your parent workshop How did it go? How many came?		

	Feed back from parents, SLT, children		
British Science Week	Next most exciting thing was BSW 13th to 17th March How was it?		
Resources audit	You planned to do your audit in half term. How did that go?		
Free CPD at science museum	Has that happened yet? I think one of your colleagues was going.		
RMS Microscopes	How successful was that?		
Pleased with how things were going last time	Last time you felt like you would make it to the summit. Storm is		

	passing; Still feel that way?		
"Feels like I should have all the answers" "I'm still no expert"	Do you still feel that way?		
Teachers were emailing you and asking questions	Increasing, decreasing/same?		
What else has happened?			
What else do you have planned?			
General prompts	Could I bring you back to the really interesting thing you were saying about ….. That's interesting; please can you tell me more/why/how? That hadn't occurred to me but I would like to know more so please can you explain it in a bit more detail?		
River of experience	**How does this make you feel now you are over half way through?**		

Say THANK YOU and try to arrange next date.

Appendix J - Section of transcribed interview

Interview with Danielle at Cherry Trees School

3.40 pm on Wednesday 3rd May in Danielle's classroom

Present: Clare Warren (C) and Danielle (D)

line no			Notes
55	C	Please tell me about the parent workshop 10th March?	
56	D	amazing probably the best thing we've ever done we it was really late to get started because out of the hall up here we had people queueing around the block there was 120 for a school of 235 children 120 parent turned up	
57	C	brilliant	
58	D	we had to move the workstations out more chairs in people were standing up it was amazing I had to cut down my talk presentation because I was aware that some of these parents had to wait 40 minutes just to get in they had to all sign in but it was packed fantastic and if I'd have known there would be so much interest I would have done more work stations but I didn't know ever we had 50 replies which amazed the Head because they only get a handful 8 or 9 that's the most people they have so initially I said I've only got I think it was about 30 is that doable and she said that's brilliant and we ended up with 120	
59	C	fantastic	
60	D	it’s the best workshop the school's ever seen and that comes from the Head and I was so happy and she came and rubbed my arm and she said whatever you’ve got I want to bottle it so that was a nice compliment	
61	C	well done	
62	D	so yes it was really successful lots of good feedback from the parents	
63	C	what kinds of things did they say?	
64	D	they said it's really nice to be able to come in and do something and get some ideas of what they could do at home with their children um I gave out some handouts the idea was that I'd give out the handouts and gather them back at the end but there was no gathering back because there were so many of them i left some handouts out you know websites and nice books and things so they could do kitchen cupboard science and things it was really nice really really good	
65	C	fantastic	
66	D	and we had the microscopes still so they could take a look at I was so and everyone was so … it was kind of a glory moment	
67	C	good well done you did you get any feedback from the kids on that	

68	D	the children loved the fact that their mums and dads were in since then I haven't done a pupils voice but it will form a part of my next pupil voice because so many of them were there and they liked the fact they could do things with mum and dad and they got to take things home that they made periscopes, rockets and all sorts a bit of D & T was in there they liked it from what I hear	
69	C	good that's fantastic isn't it and what about your British science week?	
70	D	aahh that was lovely really nice	
71	C	second best to the parents though	
72	D	I still like the parent workshop better um yeh it was really nice each teacher had a science activity they taught every day to a different class	
73	C	right	
74	D	in the afternoon so I had helicopter spinners quite a simple one but we adapted it quite a bit um yeh it was really nice excellent feedback from the children and teachers they loved science week they wanted it to be in the mornings as well as the afternoons I said you will give me a headache stop it	
75	C	laughs	
76	D	that's always really good what we planned on doing is some I think for the year 6s because they only joined in on the Friday because of the build up to SATs they only joined in in the paper flower competition on the Friday so I am trying to plan a special science day just for them once their SATs are over I'm thinking of CSI kind of thing but the time is tight and I want to be realistic	
77	C	I emailed you something somebody else had done one	
78	D	yeh you did I've got that so that's what I was thinking of it's just for that year group	
79	C	right	
80	D	I want it to be nice for them but I want to be realistic about the amount of work to do in the summer term because at the moment the thing …… is not allowing for much more and at the weekend I'm being a mum and it's a squeeze	
81	C	well it would be and your resources audit	
82	D	time literally just that and it's not an excuse it's a reason	
83	C	well I know you had it planned to do in your half term	
84	D	and yesterday for the first time ever [redacted] asked me to go in on the Governors meeting teaching and learning and asked me to speak about what we had been doing for the award um and in my notes I had put looking forward I need to do an audit we need to know what needs to be replaced	
85	C	well you need to do that for PSQM	
86	D	I know we need to do that this term but it needs to be done sooner rather than later but it's such a big task	
87	C	and it's not something you can do in an hour on a Friday morning	
88	D	definitely not no it's going to be a weekend job or an occasional day job but we do have a bank holiday coming up so I might come in on the bank holiday it's just the logistics of it where those cupboards are it's a walk through to the staff room	
89	C	you can't do it during the school day	

90	D	you can't do it while there's people here it's impossible to do while people are here so it has to after school and our caretaker is quite stringent you have to be out by half past 5 at the latest and by the time you get the children out and people start disappearing because of the through traffic you need the school to be closed really it's doable when it's open but as long as there's not too many people here because the cupboard is as wide as the walkway so you open the cupboard and you've blocked the walkway	
91	C	that's tricky then	
92	D	[redacted] next door says she will help me with it	
93	C	oh bless her	
94	D	which is lovely	
95	C	did you speak to the [redacted] grandmother	
96	D	yes we've got the £500	
97	C	what are you going to do with it?	
98	D	because of the success of the microscopes they were on plan they've gone back now the initial thought was thinking about a set of microscopes for the class for the school sorry but I know there are a few teachers who didn't use them and I'm not going to buy anything which isn't going to be used and I told nan not my nan I told nan that we are going to hold fire on what we will spend it on because I want to do a stock take first	
99	C	um huh	
100	D	and of course we have our science budget so I would really like it to be something special that £500 so see where the greatest need is because my normal science budget should be paying for normal science things	
101	C	yeah	
102	D	consumable you know	
103	C	and replacing your standard things	
104	D	we've got a whole bag of crocodile clips and things like that which say these do not work which one of my Year 4 teachers sorted out the other week	
105	C	which is helpful	
106	D	yes very helpful I wouldn't know I don't teach it so I wouldn't know um and if you've got part missing in the digestive system then if intestines or the bowels are missing then what's the point those kinds of things need replacing and even do they even use them anyway so it's one thing seeing what we've got and it's another thing knowing what you need unless you actually speak to each teacher what do you actually use	
107	C	yep	
108	D	um because I know when I looked in the cupboard the other day and saw a digestive system I know that year 5 have been doing that and have they got it out I very much doubt it from the amount of dust it had gathered.	
109	C	but they should	
110	D	mmm	

111	C	but perhaps they don’t know it's there	
112	D	mm it's still a big thing I need to do but I'm going to have to wait for the bank holiday	
113	C	bless your heart that makes me really sad that you give up your holiday so generally you felt the microscopes were successful and you can borrow them every year?	
114	D	and we really enjoyed them every class I've spoken to they wrote me little thank you notes they really enjoyed them Dear Miss sfosfuS thanks a million for getting us the microscopes it made us enjoy science even more it was fascinating to see the creatures up close the funny thing was watching and hearing other people and seeing their reactions to what they saw from [redacted] I don't really know [redacted] much that was a good example they put some on a poster for me but that one has obviously fallen off somewhere	Reading note from pupil
115	C	oh that’s really lovely oh great right you mentioned a little while ago governors that you got asked to go and present to them how did that go	
116	D	really well and also a governor link walk a link governor walk she came and did a learning walk she was really impressed she came and did a report she was mega impressed with what we've been doing and as a result she says we need a specific governor for science	
117	C	oh so she's not your science governor then?	
118	D	no she's the lead governor	
119	C	right	
120	D	and she was really impressed with what we are doing and she wants us to have a science lead governor	
121	C	are there ones for English and Maths?	
122	D	I don't think there are	
123	C	but if you are planning to work towards gold then that makes sense because it's showing that it's got an even higher profile	
124	D	so it's out there with the governors now last night I had to present to all the teaching and learning governors and I had a big long list of what the PSQM is what we're doing now and moving on what we're planning to do um and that went down a treat as far as I know I was allowed to leave early because I'm not a governor I'm just a lowly teacher so I left after my bit of spiel.	
125	C	you just said I'm just a lowly teacher after all this stuff do you feel like you're perhaps a bit less lowly than you were before you started	
126	D	I don’t know I mean everyone has got their things they're doing I did feel like the PSQM is more challenging than a lot of the other things going on I know that the PE teacher is doing an award in PE there's no paperwork nothing and so that does make me feel like why did I get the short straw why have I got to do it all but you know yeh so I say just a lowly teacher I am just a teacher who happens to have err subject a subject leader that is probably more high profile that the other foundation subjects and I made my bed by choosing it	
127	C	well you did offer didn’t you	
128	D	yeah right so now I'm lying in it I mustn't put a downer on it because I am enjoy it and I really like the fact that I can see so much change in this place because of what I'm doing saying and putting in place which is a really good feeling	

129	C	good	
130	D	tiring but good	
131	C	exactly	
132	C	so going back to your mountain you said you were definitely climbing how's the mountain looking now?	
133	D	slightly plateauing there's a slight plateau but we are still very high up does that make sense	
134	C	so that in you've climbed a long way?	
135	D	we're high up the mountain we've climbed a long way we're approaching the peak	
136	C	Ok getting to the summit	
137	D	we're on the last scramble this is wholly irrelevant when I was a child we went to Snowdonia and I always remember them saying you have this mountain and right near the top you have this bit called the scramble and all the rocks are loose and you it is very steep and you have this scramble right at the very peak and it took us a hell of a long time to get up that last little bit because it was dangerous and rocky and that feels exactly what it's like now that we've done so well we've put all of that hard grafting all that hard work and now is the pinnacle and to reach that peak at the top is like a scramble but we'll get there	
138	C	yeah	
139	D	I don't know why remembered that it just sprung to me	
140	C	yeah well that's interesting that you can make analogies and make links with other things that are nothing to do with science	
141	D	so even though I feel we are plateauing a little bit just coasting along as far as this goes more so because in school everything is happening we are coasting along but we are so high up it's ok to have a bit of a plateau and smooth out a little bit because it soon scrambling up again	
142	C	and is the storm still passing?	
143	D	storms passing it will have passed when I get three things done the cloud will have drifted away	
144	C	excellent good last time you said people other teachers were starting to email you and ask you question in the corridors and ..	
145	D	yes absolutely	
146	C	is that carrying on	
147	D	one in particular does that quite a bit others I've not given the chance to because I've been bombarding them quite a bit because I found some more of the BBC live lessons erm some terrific science stuff because I think year 5 are doing that and I've passed this lovely one a tree investigation on to year 5 she is running with it year 4 have done my investigations of the live lessons um electricity and circuits and they're really on board with doing it and actually we've got I think I told you last time about the little slips we're doing at the end of every lesson	
148	C	yeh because you were trialling them in year 4 and you were going to roll it out to everybody else	
149	D	I emailed it this morning and I've asked no I've told teachers these need to be done after every lesson because they are proving very worthwhile in year 4 and when I did a book look it's really quick to see and to understanding the children have of our principles and scientific enquiry so I've asked my TA to make me a big load of those so that should keep us going for a few lessons	
150	C	so who sticks those into books?	

151	D	they do	
152	C	excellent	
153	D	so they're at the point now where I say go and get your self-assessment sheet and they stick it in and they tick what's what	
154	C	and how consistent is what they're ticking?	
155	D	it's OK um sometimes they get a bit I had one boy that had said you showed us a power point on rocks so that's research isn't it and I suppose for them that is research so they are looking up something so I understood what he meant he justified it well but actually its not research you've not gone out to find out information so I let that one go and we have things like observing over time um which some children feel like that science lesson is an eternity and they haven't observed over time what do you mean I looked at it for five seconds and I explained that observing over time means a longer period of time you might come back to it tomorrow the next day and the next day and little tweaks like that but I've got to say what we tend to do when they stick these in we check as a class so what have we done today we was identifying and classifying rocks yesterday today we were fair testing so we were putting the same amount of water on each rock so we make it fair we just talk it through and it almost like they can't get it wrong but the principle one they do on their own they can never get it wrong because its what they believe they have met and if they didn't have team work and if they didn't believe science is fun then they shouldn't tick it	
156	C	yeah	
157	D	and if they tick all of those then brilliant	
158	C	Yep I expect they won't tick every one every week	
159	D	and there isn't an investigation every week and they're not going to be able to relate things to an outside school context every week some of it might be completely new so they can't tick it all every week	
160	C	good so basically what's coming up next is lots your audit and all your evidence really	
161	D	my logs evidence is the biggy	
162	C	and you've got your year 6 science day	
163	D	and at some point I did say that we might we have one term in each year group that's the same topic. Rocks and soils in year 3 lasts a whole term and animals including humans lasts a whole term and I think that's a bit long so I am thinking about adapting it so two or three weeks so the last two or three weeks is purely based on standalone investigation or scientific enquiry for any of these you have missed over the year so you know you have done everything so if you haven't done much observing over time you have got those couple of weeks anything it doesn't matter what the subject is anything	
164	C	plants that's a good observation over time	
165	D	and I think that sometimes the vocabulary I think the children get bored of it so I'm saying igneous, metamorphic and sedimentary I think they get bored with it they tire of it and I think it's nice to end that term doing something fizz, pop bang	
166	C	and if they've got any questions they've asked as they've gone along you could capture these questions and investigate those as well	
167	D	yes child -led investigations I'd like to do that I want to get this kind of stuff done first	
168	C	good are you happy to update your river of experience	

169	D	you know every time you come I put these grapes on my desk and we share them in class the children work for them if they've remember their capital letters and full stops they get a grape	
170	C	oh that's genius	
171	D	miss can I have one of your grapes no you cant	
172	C	do you want to come round this side?	
173	D	oh its my river isn't it right where were we I'm going to do this because its like a little … how many more times will you come	
174	C	about two it can always go round the corner if it needs to	
175	D	a little meander	
176	C	so that took is up to February so in March you'd put the things which were coming up	
177	D	useful that was also a bit frightening	indicating the PSQM training
178	C	in what way was that a bit frightening?	
179	D	because some people always seem so much more switched on although some people say that about me you know … this was a big smile excellent .. And then so was this (indicating parent workshop and science week)	
180	C	so do you want to perhaps represent March things somehow on there	
181	D	so lets have a look I'm rushing for time but I'm still using different coloured pens so we had governor walk	
182	C	yeah I'm glad you mentioned that because that wasn't in your coming up	
183	D	this is the good stuff so I'm going to come up here …… governors learning walk excellent report ….. We had our parent workshop ….. Big smiles … obviously we had British Science Week with lots of happy children … In April Year 6 sad face so special science day for them ….what else have we done … I''ve got the video coming up with [redacted] which is nice for the science ambassadors …..	
184	C	why do you think [redacted] asked you to do that?	
185	D	I think she's worked with the school before and I think we're quite local I'm pleased it's nice and I was pleased when I was asked to be one of your …	
186	C	victims?	
187	D	victims (laughs) yes we'll go with that … (inaudible) science ambassadors	
188	C	have you got to get permission for the children to be in it?	
189	D	yes I've got that um so here April … we're not in April we're in May	
190	C	yes	
191	D	but if I do April and here is May and here it all joins into a big ball of craziness	
192	C	Ok	
193	D	excellent things happening …. Except the paper based stuff it isn't that there isn't evidence of really good stuff going on it is just collating everything	
194	C	yes	

195	D	I will put capturing and collating and here in this whirlwind and here is my little mountain and here's the scramble	
196	C	you will need oxygen soon	
197	D	here's the scramble which takes a long time … we've come a long way … make sense?	
198	C	That makes sense to me	
199	D	You've got a picture this week as well … if I just write a little still no audit I think that’s' about it	
200	C	oh yes	
201	C	Thank you for your time that's lovely	
202	D	I forget what this looks like until I see it and I think oh yeh … did that and did that .. Second day training I will just put that on there very quickly… oh did I write that on there? Yes I did day two there yes it's on there	
203	D	there's something else I wanted to tell you but I can't remember it at the moment	
204	C	well tell me if you remember it next time	
205	D	well I'll have to remember it first I'm not that bright	
206	C	I think you are doing brilliantly I think you need to go	
207	D	I'm so sorry to cut you short	
208	C	no that's fine	
209		END OF INTERVIEW	

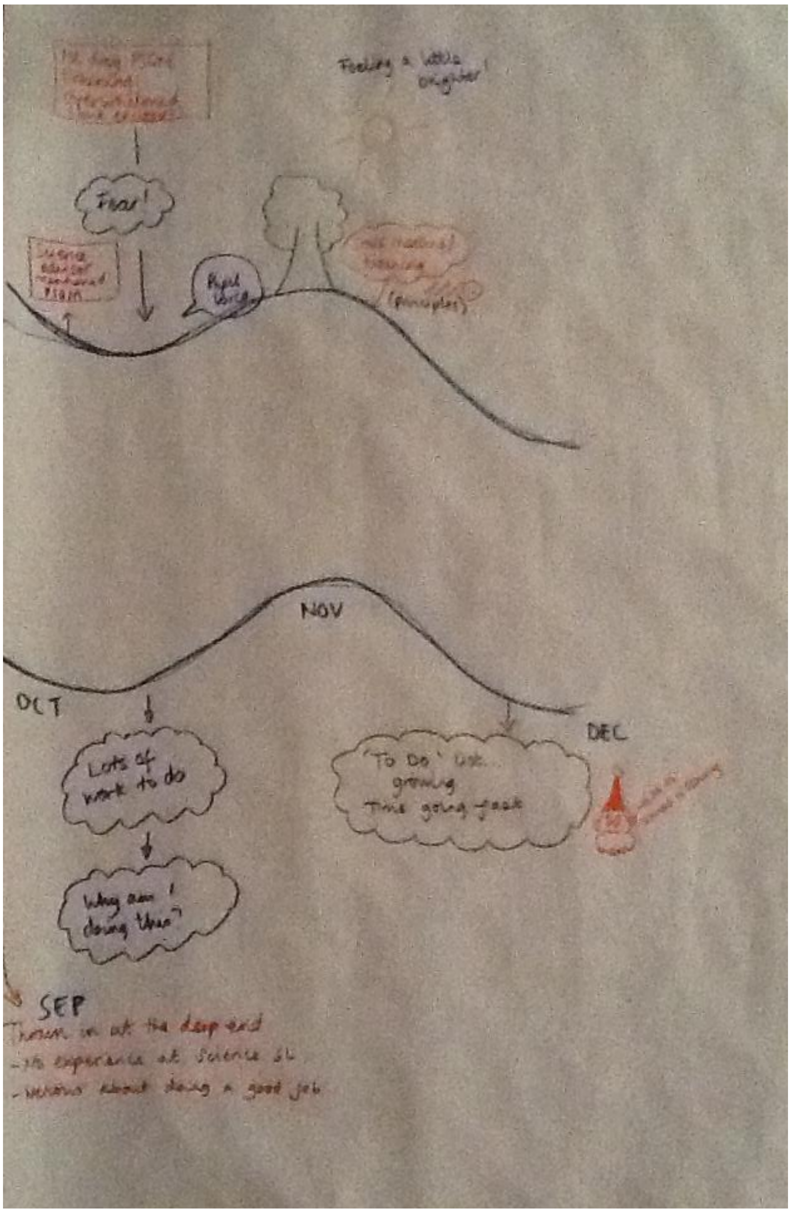
Appendix K: Code Book (1.2.18)

Name	Description
Agency	Any quote which shows agency of the SSL
Constraints	Any constraint which makes progress towards PSQM or other aspects of teaching (except budget and space)
Budget	Any comments about budget or ways in which budget imposes constraints
Space	Any comments about physical space, classroom layout etc which impedes developments
Negative emotions	Any mention of emotions which could generally be regarded as negative in this context
Positive emotions	Any mention of emotions which could generally be regarded as positive in this context
Home	Comments related to home life generally
Children (SSL)	Comments related to SSL's own children
Partner	Comments related to SSL's partner
Ofsted	Any mention of Ofsted
Other awards	Any mention of other award programmes related to other subject areas e.g. Artsmark
Other people	Other people not included in list below
Children (sch)	Comments related to children in school not covered below
Asking questions	Discussion of children asking their own questions
Engagement	Discussion of children being engaged, or interested in science
Enthusiasm	Discussion of children being enthusiastic or enjoying science
Understanding	Discussion of children developing science understanding
Colleagues	Comments about interactions with colleagues
Governors	Comments about interactions with governors, either in meetings, learning walks or in other ways
Head	Comments about formal and informal interactions with the Head Teacher
Hub leader	Comments about any meetings, discussions or on-line interactions with the hub leader
Parents	Comments about feedback/suggestion or engagement with parents
Personality	SSL's comments related to her own personality
PSQM	
Activities	Any mention of an activity which the SSL, other teachers, children, parents, governors have engaged related to science
Admin	Administrative activities related to creating documents and evidence required as part of the PSQM process

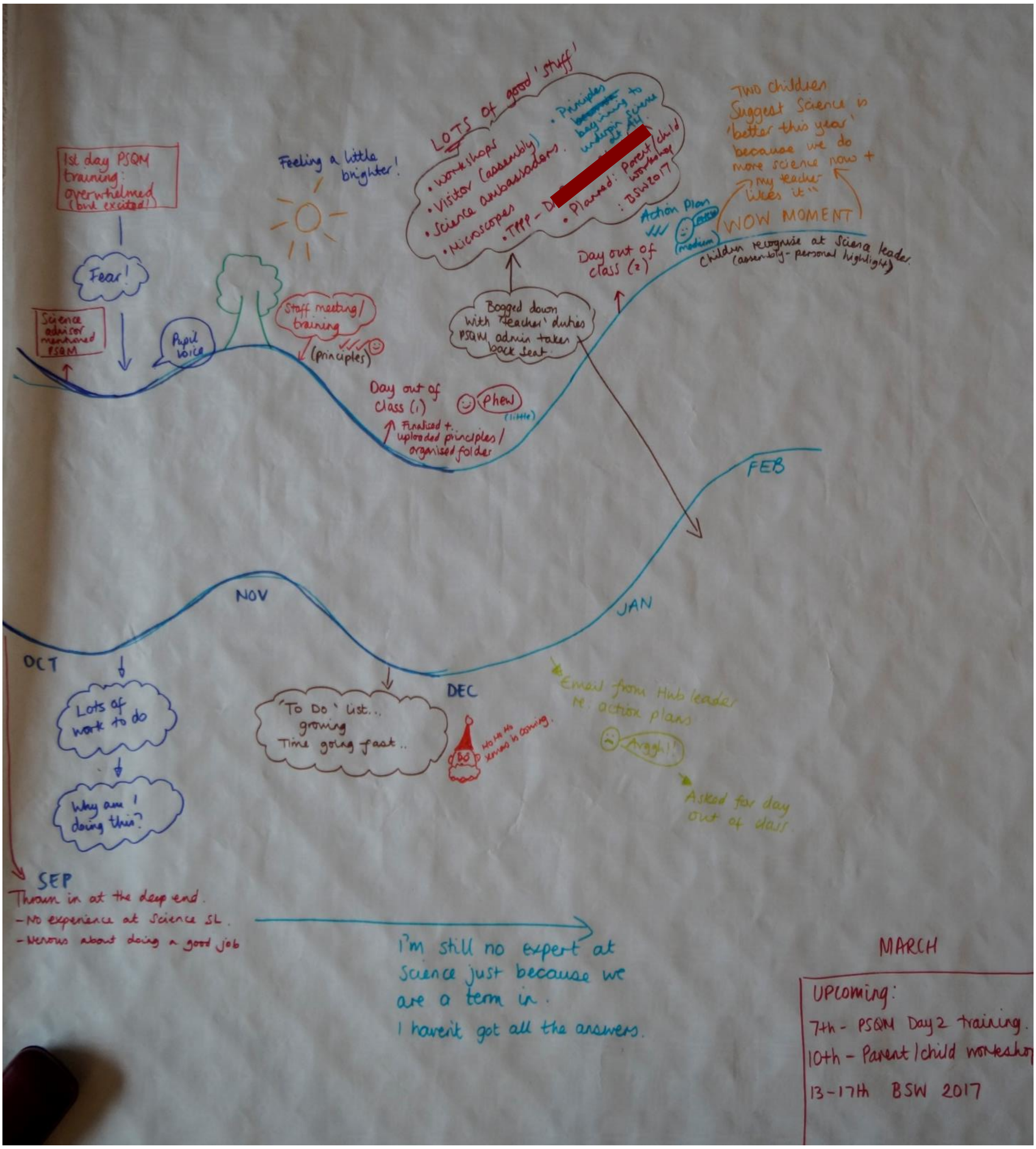
Name	Description
Benefits	Any positive comments about the benefits of working towards the PSQM
Bronze/silver/ gold	Any comment related to the level of the award.
Concerns	Any comment related to worries or concerns about taking part in the PSQM.
Future	any comments about what happens after PSQM
Staff meetings	Any mention of staff meetings
Training	Any mention of training attended by SSL or colleagues
Research participant	Any comment related to being a participant in my research
River of Experience	Any comment related rivers of experience
School improvement	Any comment related to improvements which are occurring in school
Career aspirations	Any mentions about future career aspirations or lack of aspiration
Commitment	Comments demonstrating commitment or dedication to work as a teacher
Experience	Teaching experience related comments
Hard work	Any mention of how hard the SSL is working either towards the PSQM or more generally in work as a teacher
Organisation	Comments related to being organised, either with PSQM activities and admin or more generally as a teacher
Pay	Comments about teachers' salaries and/or other benefits
Route to teaching	Explanation of route into teaching for the SSL
Subject leadership	Any comments about being a subject leader
Targets	Any comment about targets that the SSL has been set, either as part of performance management process or in any other context
Vocation	Comments about teaching as a vocation
Time	Comments about time (typically lack of)
SL time	References to time out of the classroom given to SSL either to work towards the PSQM or for other SSL responsibilities
Validation	Any comments made by others (or SSL herself) which is validation of the work she is doing towards the PSQM
Views on Science	Any view on science stated by SSL
Expertise	Any comments on science and science teaching expertise (or lack of it) related to herself. Or any comment which I judge shows expertise in science teaching and learning.
Profile	Any comments related to the profile of the SSL within the school or in the primary science community

Appendix L: Danielle's river of experience at the end of each interview

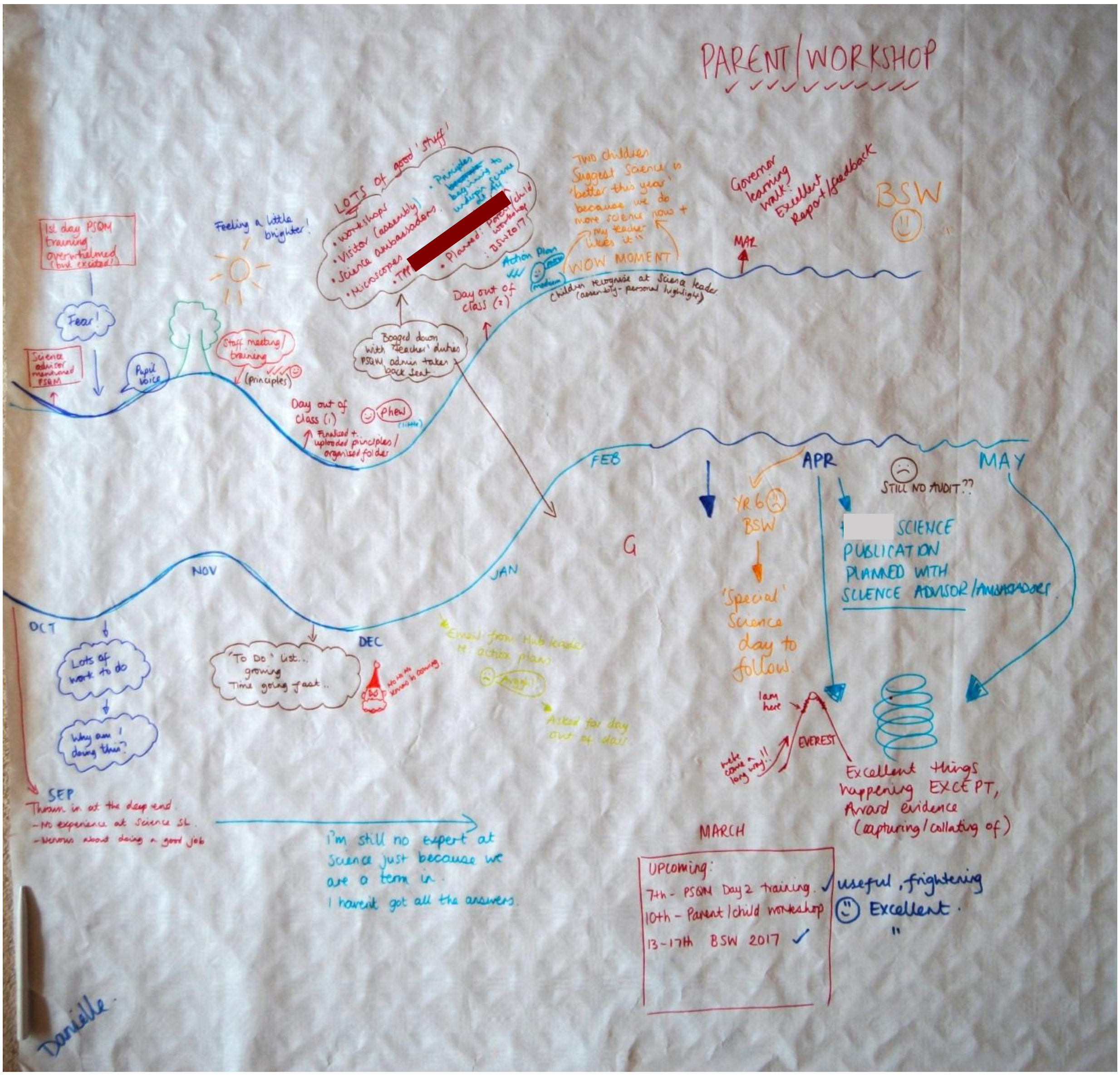
Danielle's river of experience 14.11.16



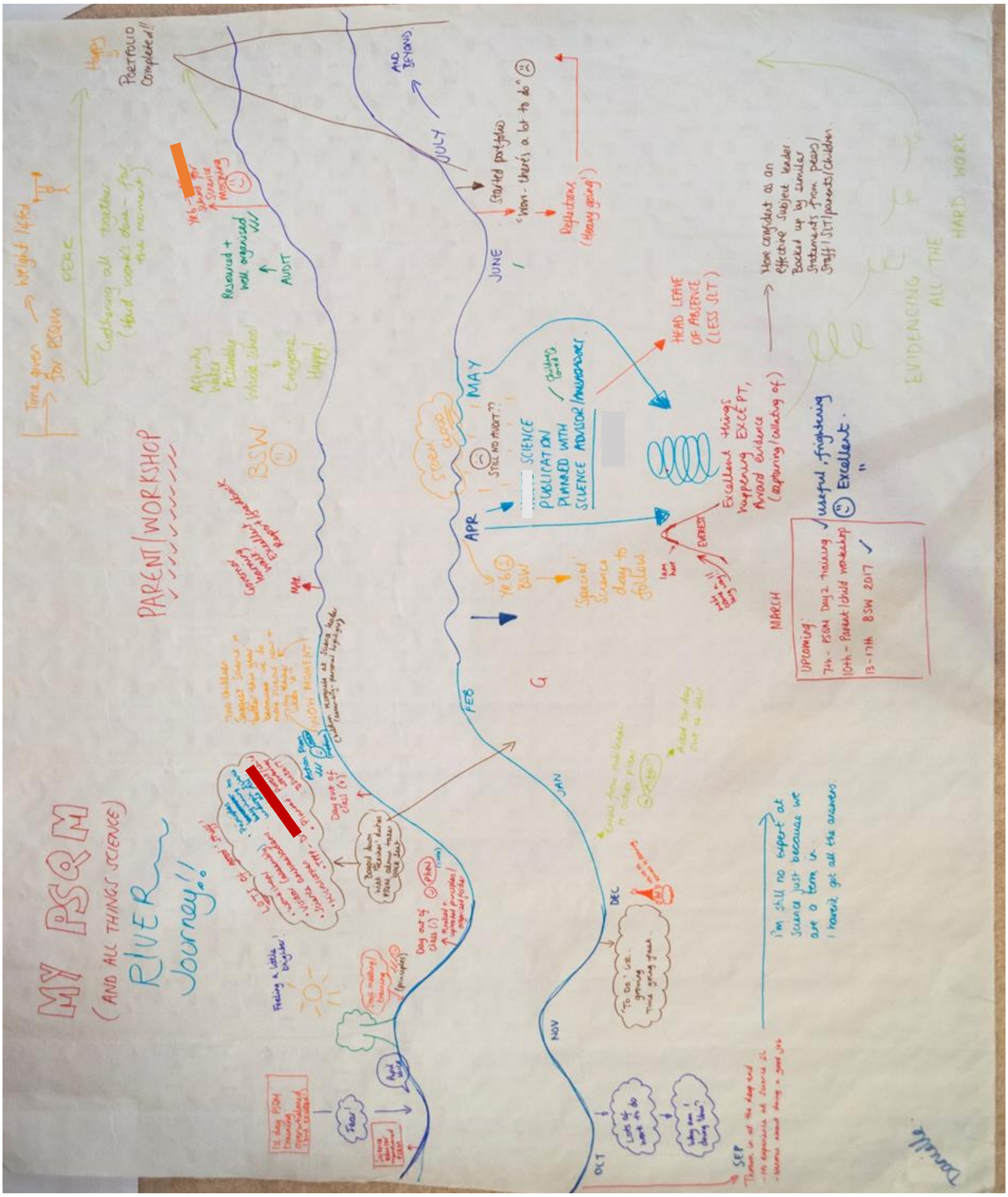
Danielle's river of experience 8.2.17



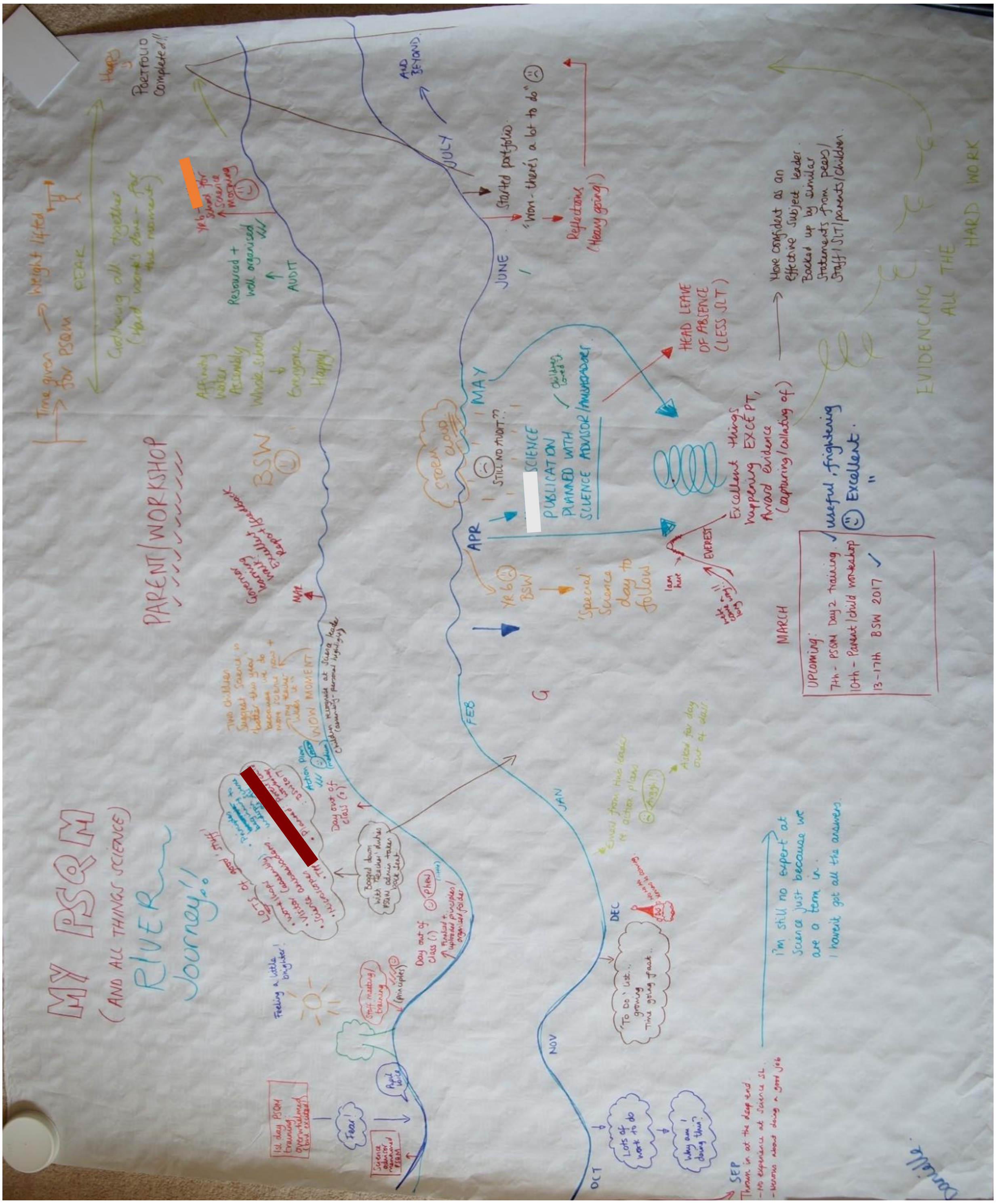
Danielle's river of experience 3.5.17



Danielle's river of experience 12.7.17

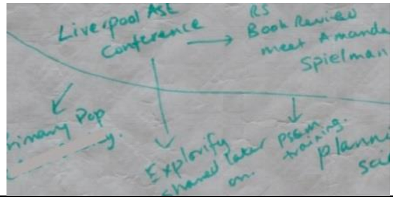


Danielle’s river of experience 17.1.18



Appendix M – Sample section of table used to analyse data

Communities of practice	**Claims and** links to other theory	**Participant Quotes** **Danielle, Mrs Jones, Mrs Collins, Alice Woods, Miss Dean, Mrs White, Mrs Peters, Miss W**
MASTERS AND MASTERY Can analyse CoP by considering location and organisation of mastery in the community (p123) P94 - "Mastery resides not in the master but in the organisation* of the community of practice of which the master is part." P94 - Decentering of master as pedagogue moves the focus of analysis away from teaching onto the intricate structuring of the communities' learning resources. P91 master-apprentice relationship "roles of masters are surprisingly variable across time and place" P94 – the authority of masters and their involvement with apprenticeship varies dramatically across CoP P92 "in shaping the relation of masters to apprentices, the issue of conferring legitimacy is more important than the issue of providing teaching"	Masters at different times may by HL, other primary science education experts (e.g. local science advisor), other SSLs, SSL in school becomes the master Mastery resides with PSQM framework and wider community of practice NOT with the HL SSLs focus on the action plans, science activities rather than the HL In hub HL is initially the master although others may share ideas and like to do this. In school SSL becomes the master although at times may defer to the HT. Authority of HLs varies across hubs Authority of SSLs within school varies across schools	Hub leaders get very few mentions – tends to happen only if I have asked about HL Mrs Jones arranged for two NQTs to attend an NQT science course and noted they both sought her advice about teaching science. One NQT was in her own year group so when attending the same meetings Mrs J had more opportunities to share ideas and suggestions. Staff meeting was arranged and run by maths SL (because Mrs J was not in school). each teacher did on-line science module related to the topic they would teach next term. Later teachers thanks Mrs J for this opportunity. "We had outdoor learning training from an external company to use our outdoor environment because we secured a bid to get funding to improve outdoor learning environment and then we had training on it." Mrs J was invited to speak at a local primary science conference explaining why she had chosen to do PSQM and what she had done so far. Over lunch she had spoken informally to other SSL to give them tips and "to try to get them to do PSQM."

P93 "opportunities for learning are, more often than not, given structure by work practices instead of by a strongly asymmetrical master-apprentice relations" P110 – acceptance by and interaction with acknowledged adept practitioners make learning legitimate of value from the point of view of the apprentices. Apprentice learners know there is a field of mature practice of what they are learning to do	Legitimacy conferred because the SSL chooses (or agrees) to work towards PSQM. Legitimacy of other teachers in school conferred because the school is aiming for PSQM. Some of my participants bemoaned the lack of opportunity to take part in further CPD. PSQM provides no subject specific CPD Structured work processes equate to the PSQM process In my experience HL/SSL relationships are not strongly asymmetrical. Acceptance by HLs and others in their hubs. Joining local networks, attending conferences Also, staff in school engage with SSLs which makes their learning legitimate – begin to seek advice from SSL; increased science chat. field of mature practice evident in self-assessment and action planning based on the framework. HL may provide role model and additional signposts. Field of mature practice may relate to developing primary science expertise or more general leadership expertise	During the year Mrs J became known to the chdn as SSL. "They will say, oh Miss I did this and Miss we did this and this. After I did the Principles launch they knew I was in charge of science, so the chdn are saying oh it's really good we did this experiment where we did this, this and this and I got a pot of gold for doing science work and they talk to me more independently. That isn't just through pupil voice; they come and speak to me in the playground or wherever." Mrs White too scared to ask HT to put science on SDP Miss Dean notes that some colleagues are not confident teaching science. The HT is supportive of her wish to reduce the amount of recording in science. Afternoon lesson became theme based with lower expectations about the amount of writing. "To have that mindset up in SLT it makes my job a lot easier to come in and say these are the things which we think are important, or the kids think are important, let's meet half way and do it, so I think I have been lucky." I asked about whether my visits had benefitted her. "I think you have made me think of the future a lot more than I would have done. So, the future of the subject and my future as well actually, as a leader, because something before which obviously I had said I am just a class teacher and that is what I want to be, but then with your kind of provoking question into what about down the line would like this, this, this. I think that has opened up a little bit more to me" Alice goes to ASE conference 
Communities or field of learning resources	What learning resources are access by SSLs?	Friend who is a secondary science teacher – Miss D was excited and asking questions of her friend and she believed this rubbed off on the children

Work practices	Devising Principles Writing action plan Implementing action plan Reflecting on actions	Mrs J was aware she needed to audit and reorganise resources. "That is quite a big thing as we had a mess in there, so I am going to be coming in for a day over the school holidays to do the entre school and sort it all out and make a big box like we did for year 4 and put electricity in it and then say this is staying in year 4 classrooms" In advance of reorganisation she produced lists of what was to go in each box and arranged time for herself and a TA to carry it out. Mrs J redesigned the school's science web page.
LEGITIMACY P92 "in shaping the relation of masters to apprentices, the issue of conferring legitimacy is more important than the issue of providing teaching" P111 "legitimate participation of a peripheral kind provides an immediate ground for self-evaluation. The sparsity of tests, praise or blame typical of apprenticeship follows from the apprentice's legitimacy as a participant." P100 – "The key to legitimate peripherality is access by newcomers to the CoP and all that membership entails. ACCESS AND TALK/LANGUAGE ALSO RELATE TO LEGITIMACY	Attending PSQM training gives SSLs legitimacy Key to PSQM is access to knowledge of how to write principles, framework, working towards an award, access to information from HL	**LEGITIMACY** "I think teachers are knowing it is high profile and it has given it that bit of importance." Forces you to do it PSQM gives you a platform "I think the fact that they know you are doing this whole process and they are being monitored quite rigorously, they have really stepped up and this term has been particularly good." Because of her experience and enthusiasm for science Mrs J asked to become SL for science even though she works 2 days per week Science was on the school improvement plan and she told the HT that PSQM would be good for the school, but she wanted a couple of terms as SSL to implement her own action plan before starting PSQM. "So, I think having an award gives you a better status in the school because actually if you are not going for anything then you are just doing it because it is that subject because you want to do it rather than the school is going to gain for altogether." "I would recommend it if you were a new subject leader going into the role because it forced me to do things that before not that I would find excuses, but it would be quite easy to find excuses of I cant do that because I have also got to teach year 6 and I have go this to do and that to do. So actually, there is an end date. You have got to get there, and you are going to have to do it somehow and I think it shows you it is possible to change the course of a subject in school and handle all of the other three thousand things you handle as a class teacher. It just means that you have got to ask for a bit of extra time and if you don't get it you

		have got to stand your ground and say I need it if you want this to happen for the school" "It has enabled me to have that platform to say you need to do it like this or let me show you another example." "So, it just gives you a bit of evidence or a bit of well actually this is coming from somewhere rather than me just plucking it out of my head because I had seen it in a class last year when I was training."
ACCESS Can analyse CoP in terms of problems of power, access and transparency. P100 – "The key to legitimate peripherality is access by newcomers to the CoP and all that membership entails. P110 – to be able to participate in a legitimately peripheral way entails that newcomers have broad access to arenas of mature practice P103 – depending on the organisation of access, legitimate peripherality can either promote or prevent legitimate participation.	PSQM gives SSLs access to HLs, local network, PSQM framework etc Few mentions of PSQM training during interviews. Most participants showed a desire for more opportunities to meet as a hub and network with other SSLs (without mentioning hub leader). HTs can support or constrain SSLs peripheral participation by allowing time out of class, providing budget for training. Colleagues also can provide affordances and constraints Broad access to mature practice through framework, HL, networks, websites, Organisation of access might include time out of class for PSQM or science t & l tasks, budget for new resources or CPD etc	Alice given time out of class to attend PSQM training At the start Mrs J was concerned that only working two days each week would be an issue so decided to share some of the responsibility with the maths SL. "We are both feeding each other with leadership knowledge on both the subjects and we have done team teaching together as well, so we plan the lesson and do half each and be critical friends and chat to each other. She does it with me in science and I do it with her in maths so that was really nice and you feel comfortable." Having science on the SDP was helpful, as was the SLT making cover available for her to observe lessons. The HT would also pay her to come in on her days off t d additional work. Also, teachers have one day out of class per term to plan together in year groups. Miss D concerned that because she had only just completed NQT year that there might be a backlash from colleagues. "Like she has only been here two years and she's telling us what to do." "because we teach so much RE it is easy to just sweep everything else under the rug. So, I think changing leadership around did help bring it out of that rut." She was concerned that she was not given release time to lead science, especially as she was working towards PSQM. She described it as "very tricky", "because we don't get any release time for subjects unless you are on the SLT" When it came to collating her evidence the school had closed for a few days because of snow which had given her additional time to compile her evidence.

		"I have really enjoyed shadowing the old subject leader because … if anything it opened my eyes to what could be done with subjects after the other teacher had led it … I realised that change is good sometimes and sometimes we need to amp things up a bit, so that was nice because … I had seen what I liked and what I didn't like, and I had a really clear head of what I wanted." During her appraisal she raised this with the HT and he agreed to release time. Gaining colleagues support was a potential issue which she identified. "I know what I am like when other subjects want me to do something and then you have three thousand things to do, how do you know that your subject is top of someone's priority list?" so she needed to be "checking up and making sure" "However you can tell because when I go to visit classes when they are doing science days and mornings you can see that the kids are exploring and they have got lots of questions which tells me that the teacher's thought must have been on the right track but it is just making sure you keep on top of that." "I have been lucky to be in a school where people do get on with each other and listen and support each other. That has been really useful as well but that doesn't mean that it gets any easier to raise you voice in the first place because it would be very easy to go with the flow rather than saying we should maybe do it this way. Yes conversation. I think that is nice and reassuring that teachers are coming to me and saying what do you think about this?"
TALK/LANGUAGE P109 For a newcomer then to learn from talk as a substitute for LPP; it is to learn to talk as a key to LPP. P105 – issues about language, … , may well have more to do with legitimacy of participation and with access to peripherality than they do with	Examples of SSLs talking as primary science experts	At the start described science teaching and learning as, "I just thought there were lots of elements that have been good, teachers are good; children seem to enjoy it. She noted, "It is a core subject" but thought it was disjointed before she took over as SSL but was already becoming more cohesive because of her initial actions. Over time she hoped teachers would become more enthusiastic and confident which would lead to improvements in the chdn's work.

knowledge transmission. Indeed, as Jordan (1989) argues, learning how to become a legitimate participant in a community involves learning how to talk (and be silent). P107 – didactic instruction creates unintended practices. The conflict stems from the fact there is a difference between talking about practice from outside and talking within it. *(Links to teaching and learning above)* P108 – apprenticeship learning is supported by conversations and stories about problematic and difficult cases. Jordan (1989) stories play a major role in decision making. "These stories then are packages of situated knowledge" (p935)	Through self-evaluation and principles activity SSLs begin to learn how **to** talk. Repeating within school may reinforce. Engaging with websites, CPD, visitors, visits, HL may all increase understanding of primary science teacher discourse My participants are talking about the practice of themselves and their colleagues rather than talking about the practice from the outside. Sharing stories within the hub – little evidence apart from saying they want more opportunities to get together with hubs. Are the stories my participants tell "packages of situated knowledge" (*I think they are.)*	She thought pupils loved science but thought it was unlikely they would be able to recall what they had done. She hoped to make science more meaningful and memorable and to inspire them to engage in science activities at home. She hoped the quality of their work would improve and put emphasis on improving their skills in addition to their knowledge. When I asked how she would know science t & I was improving she told me she hoped to see "the quality of work in the books and seeing observations and teachers using more skills based and vocabulary and writing, displays and trying to include a hands-on table." 2nd interview she mentioned key vocabulary is now displayed on noticeboards and she knew staff were making greater use of word banks for SEND children and those who struggled to write. Also a few display tables had now appeared in classes which she was pleased with. When speaking about the worm lesson I asked what she was particularly pleased with and she replied that "children were in charge of their own learning." "what is really nice is one of the safe places, safe places I sound mental, safe places for me is the HT's office where I feel, it's a nice idea so what do you think? So, it is nice because he will say I hate it, or he will say no that is really good, we will do it with every subject which is what happened when I went and approached him with this before I then said in a staff meeting." E.g. Alice's view that formative assessment is ad hoc, and "I think we need to do some working scientifically training" Staff meetings Alice decides to meet each teacher individually

Appendix N - Letter from ethics committee approving pilot study

University of Hertfordshire UH

SOCIAL SCIENCES, ARTS AND HUMANITIES ECDA

ETHICS APPROVAL NOTIFICATION

TO	Clare Warren
CC	Dr Diane M Duncan
FROM	Dr Timothy H Parke, Social Sciences, Arts and Humanities ECDA Chairman
DATE	18/10/16

Protocol number: cEDU/PGR/UH/02689

Title of study: Primary Science Subject leaders: The stories they live by.
A study of the impact of the PSQM programme on teacher identity and agency

Your application for ethics approval has been accepted and approved with the following conditions by the ECDA for your School.

Approval Conditions:

The supervisor must see and approve the interview schedule/themes prior to recruitment and data collection.

This approval is valid:

From: 18/10/16

To: 30/09/17

Please note:

Your application has been conditionally approved. You must ensure that you comply with the conditions noted above as you undertake your research. You are required to complete and submit an EC7 Protocol Monitoring Form once this study is complete. Available via the Ethics Approval StudyNet Site via the 'Making an Application' page http://www.studynet2.herts.ac.uk/ptl/common/ethics.nsf/Homepage?ReadForm

Failure to comply with the conditions will be considered a breach of protocol and may result in disciplinary action which could include academic penalties. Additional documentation requested as a condition of this approval protocol may be submitted via your supervisor to the Ethics Clerks as it becomes available. All documentation relating to this study, including the information/documents noted in the conditions above, must be available for your supervisor at the time of submitting your work so that they are able to confirm that you have complied with this protocol.

Approval applies specifically to the research study/methodology and timings as detailed in your Form EC1. Should you amend any aspect of your research, or wish to apply for an extension to your study, you will need your supervisor's approval and must complete and submit form EC2. In cases where the amendments to the original study are deemed to be substantial, a new Form EC1 may need to be completed prior to the study being undertaken.

Should adverse circumstances arise during this study such as physical reaction/harm, mental/emotional harm, intrusion of privacy or breach of confidentiality this must be reported to the approving Committee immediately. Failure to report adverse circumstance/s would be considered misconduct.

Ensure you quote the UH protocol number and the name of the approving Committee on all paperwork, including recruitment advertisements/online requests, for this study.

Students must include this Approval Notification with their submission.

Appendix O - Pilot study consent form

UNIVERSITY OF HERTFORDSHIRE
ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS
('ETHICS COMMITTEE')

FORM EC3 CONSENT FORM FOR STUDIES INVOLVING HUMAN PARTICIPANTS.

I, the undersigned *[please give your name here*, *in BLOCK CAPITALS]*

……………………………………………………………………………………………………….…
of *[please give contact details here, sufficient to enable the investigator to get in touch with you, such as a postal or email address]*

…..……
hereby freely agree to take part in the study entitled:

Primary Science Subject Leaders: The stories they live by.
A study on the impact of the PSQM programme on teacher identity and agency

(UH Protocol number: cEDU/PGR/UH/02689)

1 I confirm that I have been given a Participant Information Sheet (a copy of which is attached to this form) giving particulars of the study, including its aim(s), methods and design, the names and contact details of key people and, as appropriate, the risks and potential benefits, how the information collected will be stored and for how long, and any plans for follow-up studies that might involve further approaches to participants. I have also been informed of how my personal information on this form will be stored and for how long. I have been given details of my involvement in the study. I have been told that in the event of any significant change to the aim(s) or design of the study I will be informed, and asked to renew my consent to participate in it.

2 I have been assured that I may withdraw from the study at any time without disadvantage or having to give a reason.

3 In giving my consent to participate in this study, I understand that voice-recording will take place and I have been informed of how/whether this recording will be transmitted/displayed.

4 I have been told how information relating to me (data obtained in the course of the study, and data provided by me about myself) will be handled: how it will be kept secure, who will have access to it, and how it will or may be used.

5 I understand that if there is any revelation of unlawful activity or any indication of non-medical circumstances that would or has put others at risk, the University may refer the matter to the appropriate authorities.

6 I have been told that I may at some time in the future be contacted again in connection with this or another study.

Signature of participant……………………………………………….Date………………………..

Signature of (principal) investigator………………………………….Date………………………..

Name of (principal) investigator: CLARE WARREN

Appendix P – Pilot study participant information sheet

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS (‘ETHICS COMMITTEE’)

FORM EC6: PARTICIPANT INFORMATION SHEET

1 **Title of study**

Primary Science Subject Leaders: The stories they live by.
A study of the impact of the PSQM programme on teacher identity and agency.

2 **Introduction**

You are being invited to take part in a study. Before you decide whether to do so, it is important that you understand the research that is being done and what your involvement will include. Please take the time to read the following information carefully and discuss it with others if you wish. Do not hesitate to ask me anything that is not clear or for any further information you would like to help you make your decision. Please do take your time to decide whether or not you wish to take part. The University’s regulations governing the conduct of studies involving human participants can be accessed via this link:

http://sitem.herts.ac.uk/secreg/upr/RE01.htm

Thank you for reading this.

3 **What is the purpose of this study?**

This pilot study aims to inform the data collection and data analysis of the main study. The purpose of the main study is to answer three research questions:

1. Is science subject leader identity changed during the PSQM year and if so, how, and in what ways?
2. Is science subject leader agency changed during the PSQM year and if so, how, and in what ways?
   (Agency is the capacity of people to act purposefully and reflectively in their world)
3. If there are changes to science subject leader identity and agency, which contextual features have influenced this change?

I will write up the results of the study as part of my PhD thesis.

4 **Do I have to take part?**

It is completely up to you whether or not you decide to take part in this study. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to join the study does not mean that you have to complete it. You are free to withdraw at any stage without giving a reason. A decision to withdraw at any time, or a decision not to take part at all, will not affect any treatment/care that you may receive (should this be relevant).

5 **Are there any age or other restrictions that may prevent me from participating?**

As long as you are performing the role of science subject leader in a school working towards the PSQM award in round 13 you are eligible to participate.

6 **How long will my part in the study take?**

If you decide to take part in this study, you will be involved from October 2016 until September 2017.

7 **What will happen to me if I take part?**

The first thing to happen will be to arrange a date at which I can visit you at your school to carry out an initial interview about the story of your PSQM year. In the first interview you will be asked to tell the story of how you became science subject leader and how you come to be participating in the PSQM programme. The interview will be open-ended but I expect it to take about an hour. In subsequent interviews (one each half term) the story will continue and you will be asked to validate and contribute to the data analysis.

8 **What are the possible disadvantages, risks or side effects of taking part?**

I am not aware of any disadvantages, risks or side-effects of participating.

9 **What are the possible benefits of taking part?**

In similar studies some participants have found that the process of self-narration can enable teachers to reflect on their thinking. I will also ask for your assistance in critically reviewing my interpretations which you may find an interesting and informative process.

10 **How will my taking part in this study be kept confidential?**

As you take part in the study you will be known by a pseudonym, as will your school. In all recorded interviews you will be referred to by your pseudonym and your name will not appear on any other documents apart from the Consent Form (EC3). Any information produced using the data will be written or presented in such a way that your confidentiality is protected.

11 **Audio material**

Interviews will be recorded but throughout you will be known by your pseudonym. Audio materials will be transcribed and all electronic files will be saved on a password protected laptop and backed up on a password protected external storage device.

12 **What will happen to the data collected within this study?**

This study is a pilot study which will inform the data collection and data analysis methods used in the main study which will begin in March 2017.

12.1 The data collected will be stored electronically, in a password-protected environment, for 36 months, after which time it will be destroyed under secure conditions;

12.2 The data will be anonymised at the time it is collected.

13 **Will the data be required for use in further studies?**

13.1 The data will not be used in any further studies

14 **Who has reviewed this study?**

This study has been reviewed by:

14.1 The University of Hertfordshire Social Sciences, Arts and Humanities Ethics Committee with Delegated Authority

The UH protocol number is cEDU/PGR/UH/02689

15 **Factors that might put others at risk**

Please note that if, during the study, any medical conditions or non-medical circumstances such as unlawful activity become apparent that might or had put others at risk, the University may refer the matter to the appropriate authorities.

16 **Who can I contact if I have any questions?**

If you would like further information or would like to discuss any details personally, please get in touch with me by email at c.warren4@herts.ac.uk or ring me on 0790 535 2636

Although we hope it is not the case, if you have any complaints or concerns about any aspect of the way you have been approached or treated during the course of this study, please write to the University's Secretary and Registrar.

Thank you very much for reading this information and giving consideration to taking part in this study.

Appendix Q - Letter from ethics committee approving main study

University of Hertfordshire UH

SOCIAL SCIENCES, ARTS AND HUMANITIES ECDA

ETHICS APPROVAL NOTIFICATION

TO	Clare Warren
CC	Dr Diane M Duncan
FROM	Dr Timothy H Parke, Social Sciences, Arts and Humanities
DATE	29/03/17

Protocol number: **cEDU/PGR/UH/02951**

Title of study: Primary Science Subject leaders: The stories they live by. A study of the impact of the PSQM programme on teacher identity and agency

Your application for ethics approval has been accepted and approved with the following conditions by the ECDA for your School and includes work undertaken for this study by the named additional workers below:

Approval Conditions:

The supervisor must see and approve both the questionnaire and the interview schedules, prior to recruitment and data collection.

This approval is valid:

From: 29/03/17

To: 30/09/18

Additional workers: no additional workers named

Please note:

Your application has been conditionally approved. You must ensure that you comply with the conditions noted above as you undertake your research. You are required to complete and submit an EC7 Protocol Monitoring Form once this study is complete. Available via the Ethics Approval StudyNet Site via the 'Making an Application' page http://www.studynet2.herts.ac.uk/ptl/common/ethics.nsf/Homepage?ReadForm

Failure to comply with the conditions will be considered a breach of protocol and may result in disciplinary action which could include academic penalties. Additional documentation requested as a condition of this approval protocol may be submitted via your supervisor to the Ethics Clerks as it becomes available. All documentation relating to this study, including the information/documents noted in the conditions above, must be available for your supervisor at the time of submitting your work so that they are able to confirm that you have complied with this protocol.

Approval applies specifically to the research study/methodology and timings as detailed in your Form EC1. Should you amend any aspect of your research, or wish to apply for an extension to your study, you will need your supervisor's approval and must complete and submit form EC2. In cases where the amendments to the original study are deemed to be substantial, a new Form EC1 may need to be completed prior to the study being undertaken.

Should adverse circumstances arise during this study such as physical reaction/harm, mental/emotional harm, intrusion of privacy or breach of confidentiality this must be reported to the approving Committee immediately. Failure to report adverse circumstance/s would be considered misconduct.

Ensure you quote the UH protocol number and the name of the approving Committee on all paperwork, including recruitment advertisements/online requests, for this study.

Students must include this Approval Notification with their submission.

Appendix R – Main study consent form

UNIVERSITY OF HERTFORDSHIRE
ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS
('ETHICS COMMITTEE')

FORM EC3
CONSENT FORM FOR STUDIES INVOLVING HUMAN PARTICIPANTS.

I, the undersigned *[please give your name here*, *in BLOCK CAPITALS]*

………..…
of *[please give contact details here, sufficient to enable the investigator to get in touch with you, such as a postal or email address]*

…..………
hereby freely agree to take part in the study entitled:

Primary Science Subject Leaders: The stories they live by.
A study on the impact of the PSQM programme on teacher identity and agency

(UH Protocol number: cEDU/PGR/UH/02951)

1 I confirm that I have been given a Participant Information Sheet (a copy of which is attached to this form) giving particulars of the study, including its aim(s), methods and design, the names and contact details of key people and, as appropriate, the risks and potential benefits, how the information collected will be stored and for how long, and any plans for follow-up studies that might involve further approaches to participants. I have also been informed of how my personal information on this form will be stored and for how long. I have been given details of my involvement in the study. I have been told that in the event of any significant change to the aim(s) or design of the study I will be informed, and asked to renew my consent to participate in it.

2 I have been assured that I may withdraw from the study at any time without disadvantage or having to give a reason.

3 In giving my consent to participate in this study, I understand that voice-recording will take place and I have been informed of how/whether this recording will be transmitted/displayed.

4 I have been told how information relating to me (data obtained in the course of the study, and data provided by me about myself) will be handled: how it will be kept secure, who will have access to it, and how it will or may be used.

5 I understand that if there is any revelation of unlawful activity or any indication of non-medical circumstances that would or has put others at risk, the University may refer the matter to the appropriate authorities.

6 I have been told that I may at some time in the future be contacted again in connection with this or another study.

Signature of participant……………………………………………………Date…………………………

Signature of (principal) investigator……………………………………Date…………………………

Name of (principal) investigator: CLARE WARREN

Appendix S – Main study participant information sheet

UNIVERSITY OF HERTFORDSHIRE

ETHICS COMMITTEE FOR STUDIES INVOLVING THE USE OF HUMAN PARTICIPANTS (‘ETHICS COMMITTEE’)

FORM EC6: PARTICIPANT INFORMATION SHEET

1 **Title of study**

Primary Science Subject Leaders: The stories they live by.
A study of the impact of the PSQM programme on teacher identity and agency.

2 **Introduction**

You are being invited to take part in a study. Before you decide whether to do so, it is important that you understand the research that is being done and what your involvement will include. Please take the time to read the following information carefully and discuss it with others if you wish. Do not hesitate to ask me anything that is not clear or for any further information you would like to help you make your decision. Please do take your time to decide whether or not you wish to take part. The University's regulations governing the conduct of studies involving human participants can be accessed via this link:

http://sitem.herts.ac.uk/secreg/upr/RE01.htm

Thank you for reading this.

3 **What is the purpose of this study?**

The purpose of this study is to answer three research questions:

4. Is science subject leader identity changed during the PSQM year and if so, how, and in what ways?
5. Is science subject leader agency changed during the PSQM year and if so, how, and in what ways?
   (Agency is the capacity of people to act purposefully and reflectively in their world)
6. If there are changes to science subject leader identity and agency, which contextual features have influenced this change?

I will write up the results of the study as part of my PhD thesis.

4 **Do I have to take part?**

It is completely up to you whether or not you decide to take part in this study. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. Agreeing to join the study does not mean that you have to complete it. You are free to withdraw at any stage without giving a reason. A decision to withdraw at any time, or a decision not to take part at all, will not affect any treatment/care that you may receive (should this be relevant).

5 **Are there any age or other restrictions that may prevent me from participating?**

As long as you are performing the role of science subject leader in a school working towards the PSQM award in round 14 you are eligible to participate.

6 **How long will my part in the study take?**

If you decide to take part in this study, you will be involved from March 2017 until May 2018.

7 **What will happen to me if I take part?**

The first thing to happen will be to arrange a date at which I can visit you at your school to carry out an initial interview about the story of your PSQM year. In the first interview you will be asked to tell the story of how you became science subject leader and how you come to be participating in the PSQM programme. The interview will be open-ended but I expect it to take about an hour. In subsequent interviews (one each half term) the story will continue and you will be asked to validate and contribute to the data analysis.

8 **What are the possible disadvantages, risks or side effects of taking part?**

I am not aware of any disadvantages, risks or side-effects of participating.

9 **What are the possible benefits of taking part?**

In similar studies some participants have found that the process of self-narration can enable teachers to reflect on their thinking. I will also ask for your assistance in critically reviewing my interpretations which you may find an interesting and informative process.

10 **How will my taking part in this study be kept confidential?**

As you take part in the study you will be known by a pseudonym, as will your school. In all recorded interviews you will be referred to by your pseudonym and your name will not appear on any other documents apart from the Consent Form (EC3). Any information produced using the data will be written or presented in such a way that your confidentiality is protected.

11 **Audio material**

Interviews will be recorded but throughout you will be known by your pseudonym. Audio materials will be transcribed and all electronic files will be saved on a password protected laptop and backed up on a password protected external storage device.

12 **What will happen to the data collected within this study?**

12.1 The data collected will be stored electronically, in a password-protected environment, for 36 months, after which time it will be destroyed under secure conditions;

12.2 The data will be anonymised at the time it is collected.

13 **Will the data be required for use in further studies?**

13.1 The data will not be used in any further studies

14 **Who has reviewed this study?**

This study has been reviewed by:

14.1 The University of Hertfordshire Social Sciences, Arts and Humanities Ethics Committee with Delegated Authority

The UH protocol number is <*enter*>

15 **Factors that might put others at risk**

Please note that if, during the study, any medical conditions or non-medical circumstances such as unlawful activity become apparent that might or had put others at risk, the University may refer the matter to the appropriate authorities.

16 **Who can I contact if I have any questions?**

If you would like further information or would like to discuss any details personally, please get in touch with me by email at c.warren4@herts.ac.uk or ring me on 0790 535 2636

Although we hope it is not the case, if you have any complaints or concerns about any aspect of the way you have been approached or treated during the course of this study, please write to the University's Secretary and Registrar.

Thank you very much for reading this information and giving consideration to taking part in this study.

Appendix T - Letter from ethics committee approving amendments to main study

University of Hertfordshire UH

SOCIAL SCIENCES, ARTS AND HUMANITIES ECDA

ETHICS APPROVAL NOTIFICATION

TO	Clare Warren
CC	Dr Diane Duncan
FROM	Dr Timothy H Parke, Social Sciences, Arts and Humanities ECDA Chairman
DATE	01/06/18

Protocol number: **cEDU/PGR/UH/02951(1)**

Title of study: Primary Science Subject leaders: The stories they live by.
A study of the impact of the PSQM programme on teacher identity and agency

Your application to modify and extend the existing protocol as detailed below has been accepted and approved by the ECDA for your School and includes work undertaken for this study by the named additional workers below:

Modification: As described on the EC2

This approval is valid:

From: 01/06/18

To: 30/09/18

Additional workers: **no additional workers named**

Please note:

If your research involves invasive procedures you are required to complete and submit an EC7 Protocol Monitoring Form, and your completed consent paperwork to this ECDA once your study is complete. You are also required to complete and submit an EC7 Protocol Monitoring Form if you are a member of staff. This form is available via the Ethics Approval StudyNet Site via the 'Application Forms' page http://www.studynet1.herts.ac.uk/ptl/common/ethics.nsf/Teaching+Documents?Openview&count=9999&restricttocategory=Application+Forms

Any conditions relating to the original protocol approval remain and must be complied with.

Any necessary permissions for the use of premises/location and accessing participants for your study must be obtained in writing prior to any data collection commencing. Failure to obtain adequate permissions may be considered a breach of this protocol.

Approval applies specifically to the research study/methodology and timings as detailed in your Form EC1/EC1A or as detailed in the EC2 request. Should you amend any further aspect of your research, or wish to apply for an extension to your study, you will need your supervisor's approval (if you are a student) and must complete and submit a further EC2 request. In cases where the amendments to the original study are deemed to be substantial, a new Form EC1A may need to be completed prior to the study being undertaken.

Should adverse circumstances arise during this study such as physical reaction/harm, mental/emotional harm, intrusion of privacy or breach of confidentiality this must be reported to the approving Committee immediately. Failure to report adverse circumstance/s would be considered misconduct.

Ensure you quote the UH protocol number and the name of the approving Committee on all paperwork, including recruitment advertisements/online requests, for this study.

Students must include this Approval Notification with their submission.

Appendix U – Participants' short stories and rivers of experience

Alice Wood's Story

Alice worked as an Analytical Chemist until she started a family. Once the children went to school, she started work as a learning support assistant. Having completed an HLTA course, she then provided PPA cover and taught science to the year 3/4 class. Alice was in two minds about training as a teacher. She enjoyed teaching primary pupils but found the financial incentives to train as a secondary science teacher attractive. "Work-life balance is a real problem for teachers and, as a single parent, it might be an issue." "I've got this year to be thinking … which direction to go?"

Alice worked in a small rural school with mixed age classes, leading to staff taking on several roles and working very hard. Alice believed staff were valued for their strengths, not whether they were a TA, or teacher. Numbers of pupil premium and EAL children are well below the national average, but the number of SEND children is slightly above.

Having assisted the previous science leader until her retirement, Alice took over, keen to continue promoting science. She thought PSQM was a good way to achieve this and her Head teacher agreed. Her Head teacher is someone who says, "if you have an idea, … get on with it." Ofsted's designation of science as an improvement area had raised the profile recently, but Alice desired further improvements.

Alice is passionate about science. "I am mostly a TA, but … science is what really gets me. I love it." She felt practical approaches to science teaching were important. "It's all about children having memorable experiences." Children should aspire to do, "all sorts of things" and Alice believes many could find employment with the numerous local STEM employers. She wished to dispel science stereotypes. "There can be a perception that you have to be unusually brainy or something to do science."

To create science **principles**, Alice consulted teachers, children, parents and governors. Child-friendly, adult, and pictorial versions of the **principles** were created for display in classes. Alice devised a tick sheet to record which **principles** could be followed in lessons, but her view of the **principles** changed over time. "I thought this is an exercise to show that we can produce something, collaborate … later you realise … we do things this way because we want this to happen."

The PSQM framework helped Alice develop science teaching and learning. "The targets of the criteria are good because … when you read all the criteria you think … we could do that to improve." Her **action plan** was based on the criteria, but she was flexible when opportunities arose. PQSM was helpful in accessing opportunities in the broad primary science community of practice. "When you mention PSQM they are like, oh yes, we will support that." However, Alice expressed frustration with PSQM because of the difficulty gaining a refund of overpaid fees. Until this issue was resolved there were no funds for CPD.

Alice arranged many activities to enhance science - British Science Week, CREST awards, judging the Royal Society children's book prize, Great Science Share, visitors from industry, visits, the Polar Explorer Project, a transition project, and a science themed world book day. "The children all know me as the science person; they say, I did this at the weekend." Alice wrote regular blogs about science events and thought this was helpful when compiling PSQM evidence.

Because of the school's focus on vocabulary and reasoning skills, Alice registered for Explorify[10]: "It's quick and easy and you can do it as a lesson starter. The children really enjoy it." Alice was designated an Explorify Pioneer by Wellcome. She shared the BBC Terrific Scientific lessons with colleagues, and they received a BBC School of Excellence certificate. Alice provided CPD to colleagues on working scientifically

[10] https://explorify.wellcome.ac.uk/

and developed science assessment practices. She supported teachers individually, attended local science network meetings and undertook an on-line STEM learning course with a couple of colleagues.

The teaching and learning of science improved over the year. "I think we are teaching things in more adventurous ways, being bolder about trying new things … linking it to our topic as much as possible." She felt there was a practical element in most science lessons now, with science enquiry increasingly evident in books. She was therefore frustrated when the Ofsted inspector did not interview her during their visit, and science was not mentioned in their report. "Oh ok, well at least it is nothing negative, but after all that work." She outlined the advantages of working towards a PSQM.

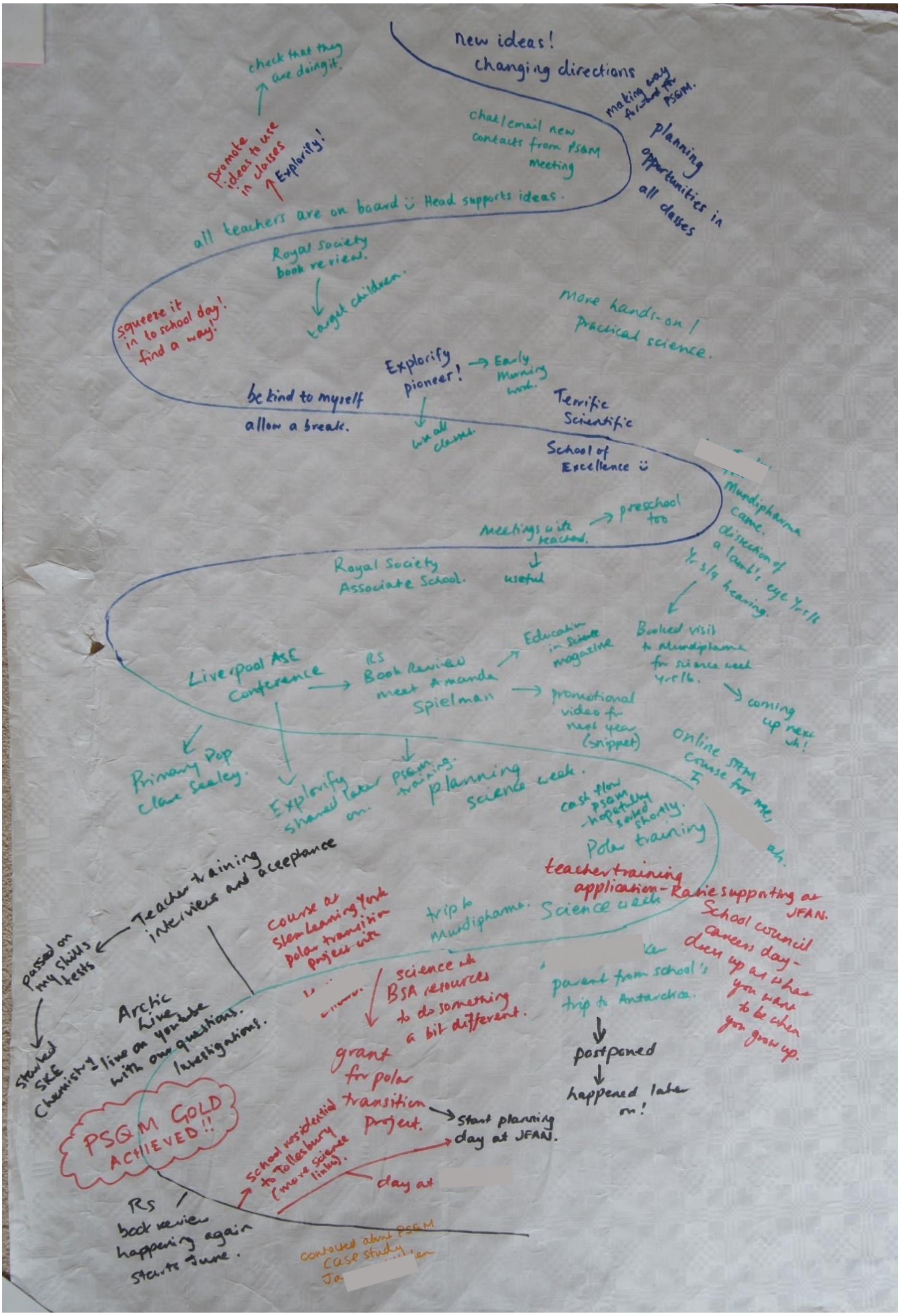
> If we reach to do the best in everything then we potentially might get this lovely shiny award. So, you push to always do something a bit different, find things out that you wouldn't normally do. PSQM helps you reflect on what you are doing and why you are doing it … I have not got the teaching background … so that has helped me understand why you are doing things … it is a good process to evaluate the whole, where you are at and where you want to be and what you achieve and children are definitely seeing it raises profile for science so that is good … There have been more people saying, this is interesting what can we do; what can we offer? So that is nice.

Alice regarded PSQM gold as a challenging and described writing **reflections** as "a long slog". She viewed the compilation of the PSQM evidence as an iterative process with **reflections** and the **portfolio** interacting. "They feed off each other… It keeps changing all the time."

Having successfully achieved PSQM gold, Alice left to train as a secondary science teacher.

> I think, it might have affected my confidence to put forward for teaching training. I've gone through a process where I think I can do this and maybe I can do the next thing for my career. There are steps that might seem like a big hurdle but if you do a lot of little steps.

She thought improvements in science teaching and learning would be sustained because her colleagues were, "quite into science anyway", but it would be necessary for the new science leader to, "encourage and coax" staff to maintain high standards.


new ideas!
changing directions
making way forward for PSQM.
planning opportunities in all classes
check that they are doing it.
Promote ideas to use in classes
Explorify!
chat/email new contacts from PSQM meeting
all teachers are on board :) Head supports ideas.
Royal Society book review.
target children.
squeeze it in to school day! find a way!
More hands-on / practical science.
Explorify pioneer! → Early Morning work.
be kind to myself
allow a break.
Terrific Scientific
School of Excellence :)
Mundipharma came.
dissection of a lamb's eye
Meetings with teachers. → preschool too
Royal Society Associate School.
useful
Liverpool ASE Conference
RS Book Review meet Amanda Spielman
Education in Science magazine
promotional video for next year (snippet)
Booked visit to Mundipharma for science week
coming up next wk!
Primary Pop Clare Seeley.
Explorify shared later on.
PSQM training.
planning science week.
Online STEM course for me.
cash flow PSQM hopefully sorted shortly.
Polar training
Teacher training interviews and acceptance
passed on my skills tests
teacher training application
School council careers day
course at STEM Learning York polar transition project
trip to Mundipharma.
Science week
science with BSA resources to do something a bit different.
parent from school's trip to Antarctica.
postponed
happened later on!
Arctic Live
live on youtube with our questions.
investigations.
started SKE Chemistry
grant for polar transition project.
Start planning day at JFAN.
PSQM GOLD ACHIEVED!!
School residential to Tollesbury (more science links).
RS book review happening again starts June.
contacted about PSQM case study

Danielle's Story

When her youngest child started nursery, Danielle registered for a Higher Education diploma; the first step in her long-held ambition to become a teacher. After achieving the diploma, along with English, mathematics and science GCSEs, she attended university, graduating as a qualified teacher. When I met her, Danielle had worked at the two form entry Cherry Trees Junior School for three years. The school, situated in a large, growing town, had above national average levels of deprivation and SEND pupils.

After her NQT year, Danielle became history and geography subject leader, but wished to have greater impact with a higher profile subject. The head teacher was delighted when Danielle offered to become science subject leader. "She literally handed me the books there and then." Science excited Danielle because she could engage pupils with hands-on activities and she wanted to share her enthusiasm with children and colleagues, while maintaining her strongly held view, "I am not a scientist".

The science adviser recommended PSQM and Danielle persuaded her head teacher gaining a PSQM would help prepare the school for future Ofsted visits. Before starting as subject leader, Danielle set an overwhelmingly popular summer holiday home learning task. This early success caused her to reflect, "I want this all the time."

Science was a highlight of Danielle's week, but colleagues often left it to supply teachers or neglected it during timetable disruptions. The science cupboard's disorganised, dusty and broken resources reinforced Danielle's view that too little practical science was happening. She hoped PSQM would improve her colleagues' views of science, and she would have funds to buy new resources.

At the start of her river of experience Danielle wrote, "Thrown in at the deep end – no experience as science subject leader – nervous about doing a good job", and prior to the training she thought PSQM bronze would be achievable. However, in discussion with her hub leader, she decided to aim for silver.

Having gathered suggestions from staff and pupils about the attributes of good science learning, Danielle convened a staff meeting to create the **principles**. Her colleagues found the task of prioritising the ideas engaging and Danielle noted significant agreement with her own views.

Danielle ensured the **principles** were displayed in every classroom, conducted an assembly explaining them to pupils, and piloted sticking a **principles** sheet in pupils' books so children ticked which applied during lessons. This was implemented across the school. They were also used as a focus for monitoring activities. "I want to thread them into everything because they are underpinning what science is about in our school."

Danielle instigated many science related activities for pupils, including 'Scientist of the Week', 'Name the Skeleton', science week, and other national initiatives. A science board displayed the photos of two pupil Science Ambassadors from each class. At a parent and child workshop the Science Ambassadors were trained to discuss the science activities on display. Danielle stated, "It's the best workshop the school's ever seen and that comes from the head and I was so happy, and she came and rubbed my arm and she said whatever you've got I want to bottle it. So that was a nice compliment." Parents and children were also delighted, and Danielle described it as "a glory moment." The following year, so many children applied to become Science Ambassadors, that interviews were conducted.

Her achievements were also acknowledged by the Chair of Governors who was "mega-impressed". during a learning walk. The deputy head also noted, during Danielle's performance review, the rising profile and improving quality of science.

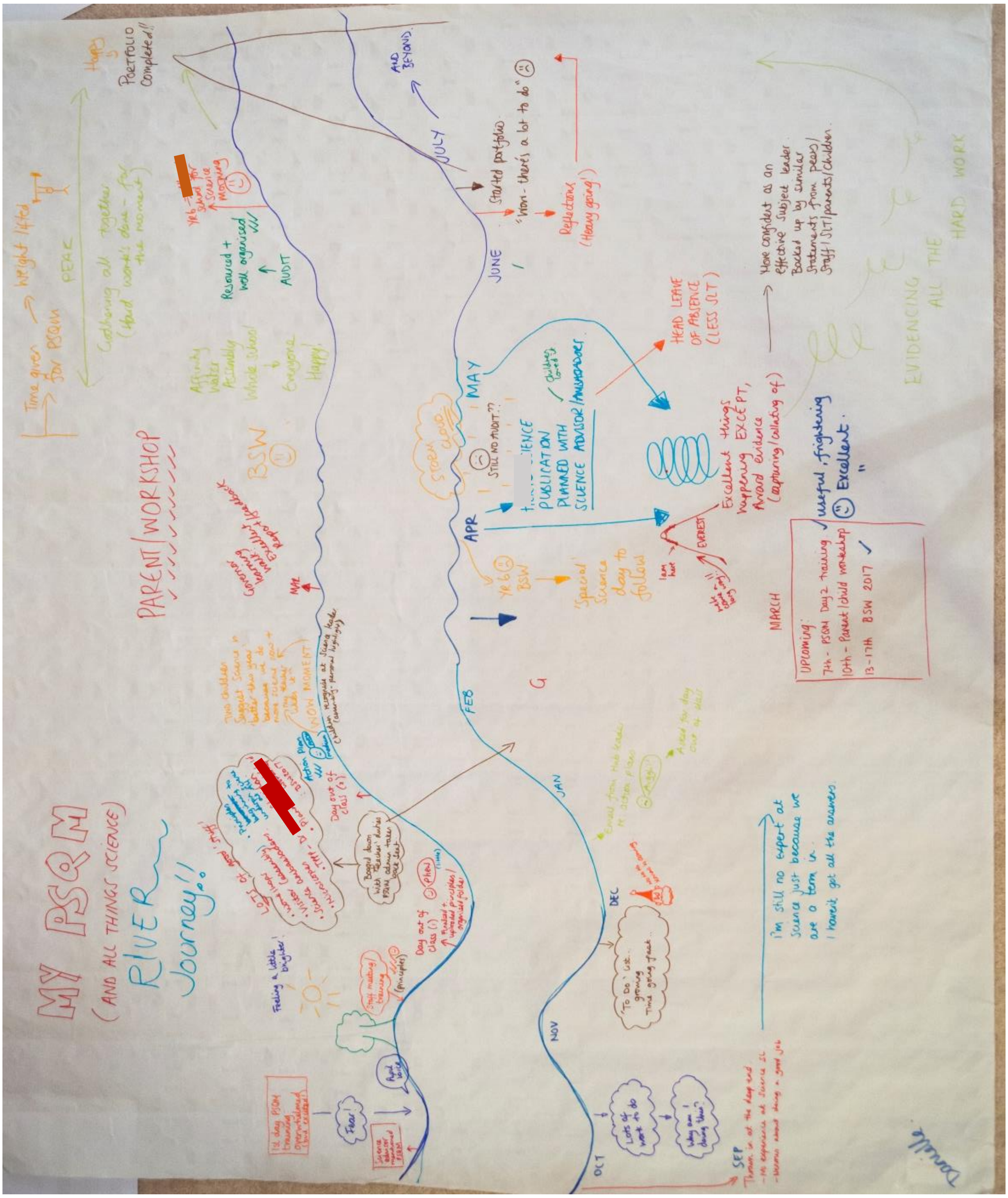
Towards the end of the year Danielle reflected on her successes. "Excellent things are happening, except the paper-based stuff." Collating PSQM evidence caused Danielle some anxiety. "We should have had the **subject leader log**, the **CPD log** and the **events log** and none of those are finished which obviously set a bit of a panic." She likened PSQM to mountain climbing and described it as a "lone journey", yet she acknowledged, "When I have wanted people's support, they have been there, but it was ultimately my journey." Danielle also mentioned she and other science leaders in her hub could have offered more mutual support, "but there is only so much time, isn't there?"

Danielle reflected on her previous ineffective leadership of history and geography, "I did nothing." She now believed she was an effective subject leader. "I feel like I have come a long way which is nice." She felt her colleague's attitudes to science had changed. "They are trying new ways to do stuff." "Science isn't getting missed because we have singing to do." The children told her their teachers now liked science more, but she felt they were just more confident.

She attributed the positive changes to PSQM because, "It is like a platform to stand on with your megaphone, because on the ground level you don't get heard so much." "Every little area of science teaching and learning is tapped into … the teaching and learning bit, your assessment bit … and everything in the four different areas and then you have all the criteria within those four areas … it focuses on so much. That's what helps raise the profile." Comparing PSQM to other awards, "It is making us reflect on what science we do … looking at ways to make it better, so it's not just a case of ticking boxes and nodding in the right places. It's proactive."

Danielle was successful in gaining PSQM silver and continues to raise the profile and quality of science, has several activities planned for next year and mentions the possibility of "going for gold". Some months after my final interview, Danielle emailed informing me she had started the NPQML and would be the senior of the two year five teachers, supporting an NQT colleague.

Danielle's river of experience



Mrs Collins' Story

As a child, Mrs Collins wanted to become a marine biologist or zoologist, but work experience in a special school changed her vocation. After biology, psychology and health and social care A levels, she trained as a primary teacher with a science specialism. Her dissertation about enquiry-based science had lasting impact. Her river of experience began with a shoreline showing the experiences which led to her passion for science.

After four years teaching elsewhere, Mrs Collins joined St Luke's School, as subject leader for French – "not my strength." Observing her teaching science, the head announced, "You've got to be subject leader for science". When the humanities subject leader departed, Mrs Collins also took on this role and attended a middle leadership course, hoping it might lead to a phase leadership role. The head asked her to consider working towards a PSQM and she agreed.

St. Luke's, a one form entry primary, in a large town close to London, had 40% of pupils on pupil premium, well above national averages, EAL pupils just above and SEND pupils below. Mrs Collins said the school was like a family, with some of the staff having attended as children.

Initially, Mrs Collins felt some colleagues disliked science which was rubbing off on the children. "Some year groups did science in one big block and then nothing for the rest of the year. So, where do you show the progress?" Some children were not experiencing practical work. Some topics were taught in wrong year groups, leading to duplication or incomplete curriculum coverage. To address this Mrs Collins rewrote the science curriculum. After book scrutinies, learning walks and lesson observations she determined science, "was the one core subject which gets forgotten." "Some staff here find science a bit of a scary subject to teach because they are not confident in their own subject knowledge."

Mrs Collins asked her class to draw a scientist and most drew a man, so she worked to increase awareness of female scientists. Aware that, in the catchment area, children's aspirations were low, she also worked to raise aspirations.

To raise the profile of science, Mrs Collins organised, a science week where children could be "immersed and drowning in science enquiry", a 'scientist of the term' competition, a science club, science news on Newsround[11] during breakfast club, and scientist visitors. She led science staff meetings, invited colleagues to observe her teach science, provided planning support to NQTs, and hosted science enquiry CPD for, "the very young staff". In an assembly, Mrs Collins asked children to complete the sentence, 'Science is good when …', inviting teachers to do the same. The schools' **principles** were created from their answers. She ran a competition to design a mascot, for display in classrooms alongside the **principles.**

During the year Mrs Collins noted improvements in science teaching and learning. "I know science is being taught around the school … and I know the resources are being used. I know they are enjoying it. I know science is plodding along without me interfering too much which is good. It means I have set it up well." There was evidence of more hands-on science in children's books and fewer lessons where teachers did a demonstration. Speaking to children, she discovered science was, "A lot more practical led, and more informal chats in the staff room of, 'wow this worked really well'."

Staffing issues within the school restricted the changes she was able embed. "We have got a lot of staff movement due to visas." "Out of four SLT, three were on maternity leave". "It was just one of those things of it all happening at once."

[11] BBC TV children's news programme

Mrs Collins said PSQM had made her think and improved her ability to question. "What else can I do that is going to make my science teaching better … that I can pass on to … colleagues?" "The PSQM … is actually pushing me in the right direction to think, what do I need to ask that is actually going to make a difference to improve the subject?"

At the start she believed a passion for science was important, but later likened subject leadership to a cake mixture.

> I think one of the key ingredients is being passionate, knowledge or subject knowledge is another ingredient and … pedagogy is your third element for your cake mixture for your perfect subject leader; the knowledge; the passion and the understanding how children learn.

During the year, Mrs Collins experienced two exceptionally stressful times. On the first occasion she drew herself drowning in her river of experience, and on the second, she was swept down the river out of control. Her second crisis was, "Probably the most stressed I have been in my life." "To the point I was going home in tears. I was just crying because I was tired." This time of stress coincided with Mrs Collins going for interviews. She also blamed broad societal issues. "I could name 15 out of my class of 28 that I would say are going to end up with mental health issues … I am genuinely quite scared that some of these kids are going off to high school because I don't think they are going to cope."

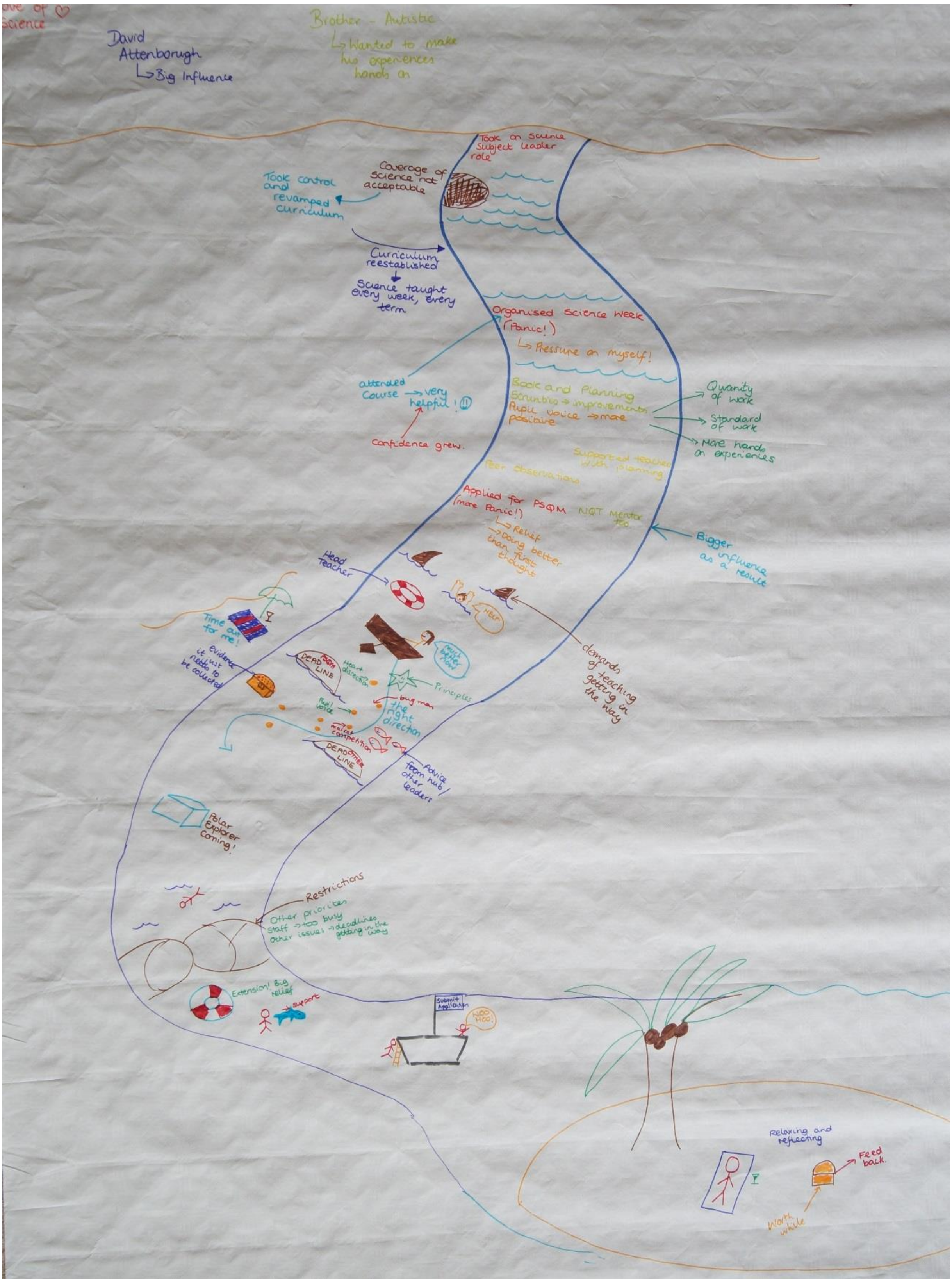
Time off sick and other pressures led Mrs Collins to apply for an extension to the PSQM submission deadline. Although she was granted an extra month, she completed and submitted her evidence within two weeks.

Mrs Collins and her head teacher were thrilled to be awarded PSQM silver. It was announced in a newsletter. "My friends were like well-done, good for you. But others made no comments which I thought was a bit odd. It was sort of just skimmed over".

Mrs Collins was leaving to become assistant head teacher in another school and, hopefully, science leader. She was concerned that high standards of science teaching would not be maintained when she departed. "When I pass onto the next subject leader and I am going to go, 'right there you go. Keep it up'."

Referring to her river of experience, she explained the importance of the PSQM feedback. "We had so much hardship here that actually this was such an accomplishment. I had gone through all the sharks. I had gone through the restrictions, but I still got to my island. I still got to what I was looking for despite all of this going on, … my pot of treasure is my feedback … That is probably a bigger treasure than the evidence." "This was so much worthwhile for me as an individual, but also for the subject here, that this actually is worth that whole journey."

Mrs Collins' river of experience



Miss Dean's Story

Miss Dean always wanted to become a teacher. Following a Drama degree, she trained and qualified with Teach First. Working with children in a deprived area appealed because she came from "not such a fantastic area". She trained in a Roman Catholic city school with 45% EAL pupils, almost double the national average, yet below average SEND and pupil premium numbers. Miss Dean was happy there, describing it as "a cosy community".

While training she initially shared a year 5 class but was then given sole responsibility. She continued teaching year 5 during her NQT year. When we met, Miss Dean was about to become the year 6 teacher and science leader. She was interested in science leadership because she recalled a, "really good primary teacher … who fuelled my interest in science." Eventually, she hoped to lead English, "but not so soon as it is a huge thing." She recognised Teach First trainees often moved quickly into senior leadership, but thought, "I don't want to rush it because I think the classroom experience is really important."

Before becoming subject leader for mathematics, the previous science leader had registered the school for PSQM, so they both attended the first PSQM training session which Miss Dean described as "a nice transition".

With RE timetabled for three hours weekly, Miss Dean thought, "science gets a bit drummed out", so introduced science days to supplement weekly science lessons. One science day had, "different components for experiments" for children to select displayed on tables. Children investigated their chosen materials and presented findings to parents and governors during a science fair. They did no writing, and "absolutely loved it."

The timetable was only one barrier to consistently good science teaching and learning. Miss Dean found teaching inconsistent. Some teachers used worksheets while others used photographs with written notes. She preferred the latter approach because, "a picture speaks a thousand words." Staff discussions were informative. "We had a lot of 'this is what we have done in the past', not a lot of 'this is what we will do in the future', which is why I think the subject had become a bit stale." She described the science equipment as, "all over the place. You could not find anything; sets weren't together … people avoided it." Miss Dean and a colleague reorganised the resources into labelled boxes. Some, like digital microscopes and data-loggers, were not used because colleagues did not know how. She needed to learn herself before she could train colleagues.

The **principles** became a focus for improving science teaching and learning. Teachers and children developed their own sets of **principles** which included similar ideas, and the children's were adopted.

Miss Dean aimed to provide all children with memorable experiences. A booklet of activities was sent home as optional home learning over the Christmas holiday. "There wasn't any writing, it was just, 'get your mum or dad to take a picture and email it to me.' Which went down really well." For her own class she purchased Love to Investigate boxes[12] which required problem solving and active learning. In one activity, children researched how messages were sent during World War II, then used electrical equipment to send their own messages. In another, children researched the eye, then Miss Dean dissected an eye in front of them. "They were telling me what they were seeing, and telling me what I was cutting, and when they could see the lens … that was really good, and they loved that."

For her own professional development Miss Dean attended science network meetings, local CPD opportunities, and a Conference at the National STEM Centre. She made colleagues aware of the Reach

[12] Available from Cornerstones Education.

Out on-line CPD modules. "They emailed back saying … it is perfect for a quick brush up." She believed these modules increased her colleagues' confidence.

Being relatively new, Miss Dean was concerned how advice she offered might be received by more experienced colleagues, so rather than observing, she planned and delivered lessons alongside colleagues. She did not want children writing formal reports so, on science day, was pleased to see children were not sitting at desks writing. She also described an investigative mathematics lesson which resulted from her changing views about good pedagogy.

From her year 6 class she appointed three Science Ambassadors to visit science lessons in other classes, talk to the children, take photographs, interview teachers and type up their findings. They had clipboards, badges and lab coats so they were identifiable. They also planned a whole school science day. "They did a stunning job organising it." Miss Dean regarded the creation of the Science Ambassador role as a success and planned to recruit for next year.

Miss Dean was happy to observe science teaching and learning had changed for the better. "Teachers are doing everything that I have asked ... letting the children have a bit more freedom. The children are making decisions for themselves, whether it be how to investigate something, or make up their own questions." She gave examples of lessons where children were, "in charge of their own learning", and, "There was absolutely no writing … they are actually following it up in an English lesson … Everyone was having a great time and the children were so enthusiastic. … It was such a good lesson because all the **principles** were being followed."

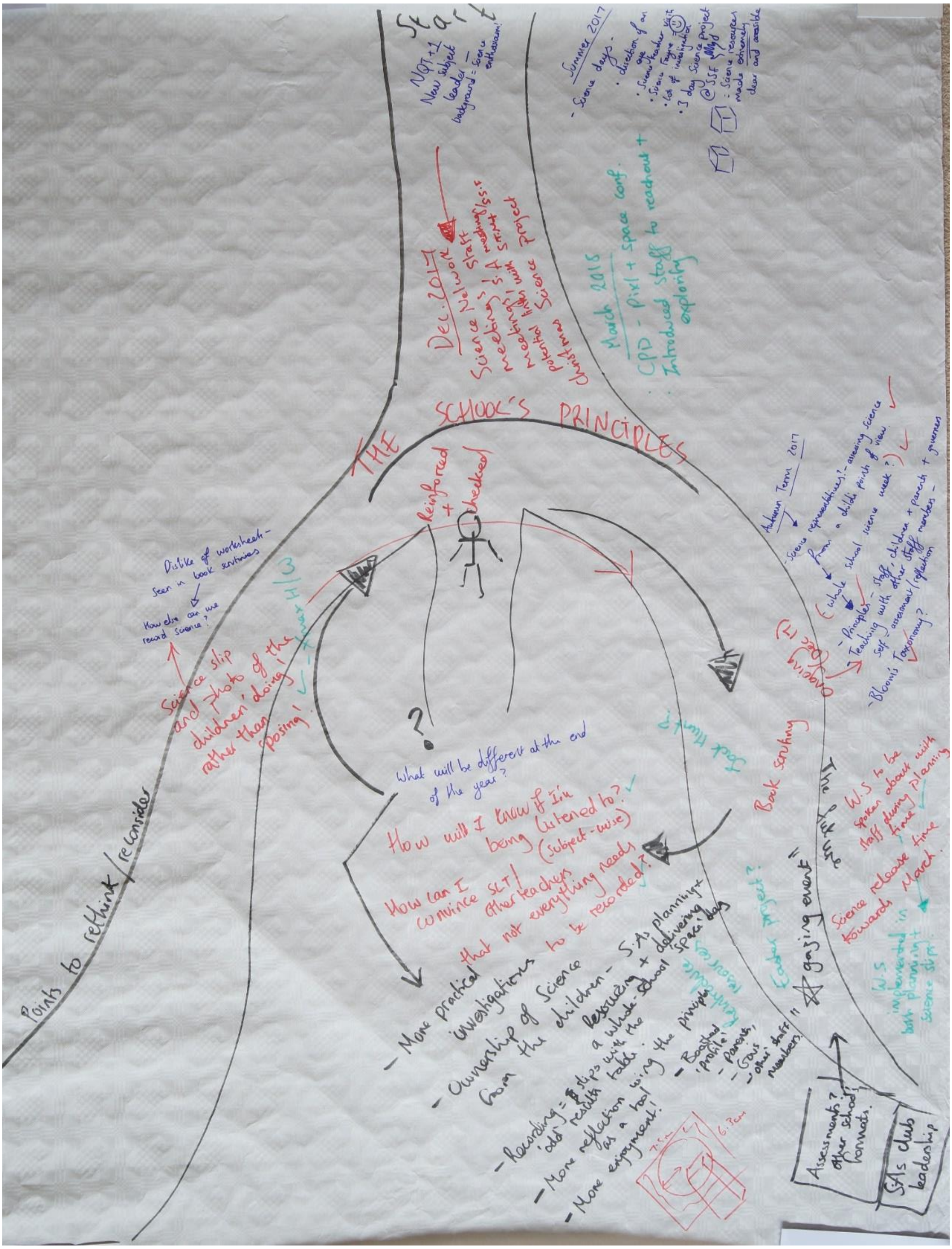
Miss Dean's view was confirmed in the school's Ofsted report. Inspectors were impressed by the, "high-quality of science work on display following recent science based thematic lessons." "It is nice as well, as it is not just the profile within the school, it is the parents and the governors and the outside team as well."

The school's small size and supportive ethos enabled Miss Dean to make a difference. "I think it is the environment to thrive as a new subject leader." "We are naturally helpful and cooperative with one another." Completing the PSQM evidence was time consuming so she asked the head for time out of class. "If you don't get it you have to stand your ground a little bit and say I need it if you want this to happen for the school."

When they achieved PSQM silver, the delighted head teacher walked onto the playing field where Miss Dean was with her class. "He was very keen to come and tell me." Upon announcing the result in their staff meeting, colleagues gave her a round of applause.

At our final meeting, Miss Dean hoped to continue leading science and had plans for the following year, including developing assessment. Staff turnover was low, and she was keen to "keep it up."

Miss Dean's river of experience



Mrs Jones' Story

After completing her master's degree, working in media, and presenting science events for children, Mrs Jones thought she might enjoy teaching. She found work as a teaching assistant, confirming her desire, and completed her PGCE in 2011.

Initially she was humanities leader, but on becoming part-time no longer led a subject. However, because of her experience, enthusiasm and support for colleagues, she was asked to lead science. She aspired to become a middle leader, and eventually a deputy head. When we met, Mrs Jones shared responsibility for a year four class in a three-form entry junior school whose pupil premium and EAL numbers were below the national average and SEND around average.

The local science advisor told her about PSQM and as science was on the school improvement plan, Mrs Jones proposed working towards a PSQM, but wanted two terms to implement her own action plan first.

At the start Mrs Jones described science in school. "Lots of elements that have been good; teachers are good; children seem to enjoy it." However, she hoped to make science more meaningful and memorable, with high-quality lessons emphasising investigative skills, inspiring children to engage in science at home.

Working part-time made PSQM challenging so Mrs Jones asked the mathematics leader to assist and attend the PSQM training with her. "We discuss everything together. She's not doing loads, but she is helping me out when I'm not in, and I am bouncing ideas off her." Her river of experience reflected the importance of this relationship, recording this immediately under 'Start of PSQM'.

Mrs Jones launched her PSQM year with a science week which both teachers and children loved. To maintain momentum, each term she planned, "a whizz bang science day" to boost questioning skills and cover any gaps in the curriculum. She enriched the curriculum with a range of visits, visitors, and extra-curricular clubs.

Children's ideas were incorporated in the **principles** and each class ran a competition to design a unique **principles** poster. Based on a pupil voice activity, Mrs Jones found most children were aware of the **principles** and some children had recorded which **principles** applied in lessons. Launching the **principles** changed children's perceptions of her. "They knew I was in charge of science, so the children are saying, oh, it's really good, we did this experiment where we did this, … and they talk to me more independently."

Mrs Jones needed to audit the resources. "We had a mess there so I am going to be coming in for a day over the school holiday to do the entire school and sort it all out and make a big box like we did for year four, and put electricity in it, and then say this is staying in year four classrooms."

Activities to develop colleagues' science teaching were initiated, including CPD and other support. Her school hosted twilight training on child-led enquiry funded by the Royal Society of Chemistry, attended by science leaders from other PSQM schools. She shared the content with colleagues and the next science day they trialled this child-led approach. CPD on teaching science outside, resulted in more outdoor learning. Mrs Jones redesigned the lesson plan format to record skills, vocabulary and resources, thus improving planning quality.

Mrs Jones believed colleagues were gaining confidence to take risks, letting children ask questions, and showing real progression in books. Fewer worksheets and more photographs were apparent in books, which also showed drama, posters or news reports. Key vocabulary was displayed, and staff made greater use of word banks. Display tables appeared in some classes. Mrs Jones' colleagues confirmed their growing confidence. "Before I started, I didn't know how to teach scientific skills, and I didn't know how to assess, and now through your training, and Reach Out CPD, and your inset days, I now feel confident to assess."

The children became able to 'work scientifically', enquire and analyse. "Every year group gave something that they had done ... they are more vocal, and they can explain." Her summary of improvements was positive.

PSQM was credited for improvements to science teaching and learning. Without PSQM, "I would have probably had half the ideas and achieved half the amount." However, she was critical of one aspect. "I really don't like the website."

She felt "very lucky" to have helpful colleagues. However, when it came to collecting evidence, she would have appreciated more support. "It is hard, and everyone is busy, and you try not to annoy them … Yes, that was the hardest part, to get people to reply and give me the right evidence."

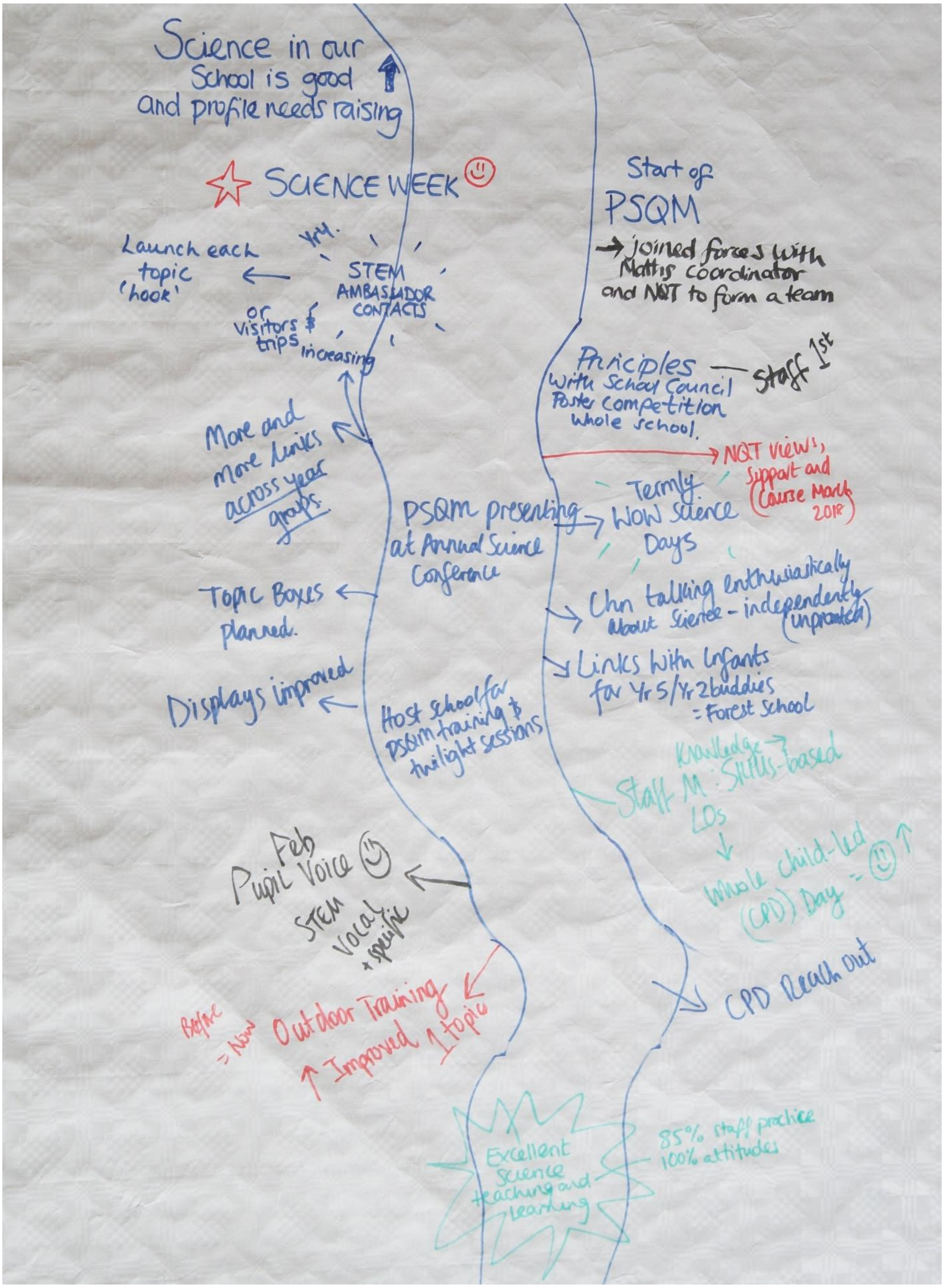
As PSQM neared completion, Mrs Jones carried on developing science. "I know it is going to continue even when finished because it is all in place and everyone is enthusiastic about it, so it is really, really good." She provided a comprehensive list of activities for the following year. "We don't do enough team teaching. So that is one of my aims … without PSQM I wouldn't have thought about it."

During my final visit Mrs Jones announced her promotion to phase leader and head of English. PSQM supported her in developing skills that helped her succeed against three other internal candidates. During the interview she presented, 'Explain your subject leadership experience and its impact across the whole school'. "So, I was like I am not worried about that."

After submitting her PSQM evidence she presented her **portfolio** to colleagues and their reaction was, "Wow, goodness, so pleased to see it on the screen." She also presented her **portfolio** to governors who said, "Incredible. You have definitely raised the profile." "Science was removed from the development plan, … so I really impressed them."

Staff and governors congratulated Mrs Jones on gaining PSQM silver. She felt "really pleased", recalling a review comment saying Mrs Jones, "is an effective subject leader, and she has implemented all of these changes. It has clearly had a big impact across the school. Like everything you hoped for; that you are striving for the whole time." "There wasn't anything surprising, it was just nice to hear someone's objective comment on it." Her closing thoughts on PSQM were, "I think it's great. It's been amazing, and I hope that after three years we can go for the silver again, or maybe even gold."

Mrs Jones' river of experience



Mrs Peters' Story

Before starting a family, Mrs Peters worked in a bank. Later, she volunteered at her children's school, training as a nursery nurse. Qualifications as a TA and HLTA led her to a teaching degree. When we met, Mrs Peters had taught for eight years, all at St George's, a two-form entry lower school, in an affluent area, with mostly white British pupils, and SEND and pupil premium children numbers below national averages.

One year after qualifying, Mrs Peters became SENCO and joined the SLT, but stepped down later because, "I wasn't doing what I enjoy; that is teaching." She became a year two teacher and science subject leader, initially "very timid", about her first subject leadership role.

Mrs Peters was the only participant renewing a PSQM (silver). Last time, she became science subject leader part-way through the PSQM year. It was "a bit of a shock" but "a great learning opportunity" given her lack of confidence to teach science. Her first PSQM experience improved her confidence, opened her mind to science around her and was, "very beneficial in the first year [as science leader]."

Mrs Peters aimed for PSQM gold because, "I know I have the time to put into it without juggling every other ball going." However, her role as class teacher took precedence. "My class comes first. I have them all day, every day and I teach all of the subjects." Describing her class as "difficult", she wanted to minimise release time because their behaviour deteriorated in her absence.

Describing science at the start, Mrs Peters thought it could be more exciting. She wanted to give, "everybody that confidence to step outside their own boundaries and give it a go". Mrs Peters was keen to use science as a context for the school's focus on developing thinking and reasoning. She and her colleagues decided to improve their existing **principles** employing different phrasing, "At our school we do", and "At our school we are", which increased ownership of the **principles.**

She regarded PSQM training sessions as good opportunities to share ideas, network and make connections but regretted there were not more opportunities to meet. When her hub leader returned the draft **action plan** it became apparent from the comments that Mrs Peters had misunderstood the requirements for PSQM gold. "That knocked my confidence quite a lot and I thought I have not got time to rectify this." Discussing how to reframe her actions helped her. She wanted to achieve gold, but worried how she would do it all. Her perspective changed to focus on, "three big things really … the [nursery school], the PSQM, Junior Park Rangers."

An annual science week, was replaced by half-termly science days to, "give the children ownership of it to find out what they want to find out … and time … to develop their own thinking." During the first science day Mrs Peters interviewed pupils, "to capture the excitement". The head ordered books for children to record science day learning as evidence of progression.

Mrs Peters persuaded the PTA to fund some science equipment and events, parents helped rejuvenate the school's science garden and pond, Friends of the Earth helped enhance the outdoor environment and science visitors ran sessions for classes. Eight Junior Park Rangers were appointed, with a squad of helpers, to run competitions and lead assemblies about the outside area. One aim was to join with another school and take on a local project. "We have a brook at the back of our school which is quite untidy, and we were going to tidy up that brook."

Mrs Peters was delighted with colleagues' responses to pupils' questions. "They've remembered what the children said, how they wanted to develop the experiment … so they did do it." She noticed teachers' increasing confidence to try new activities, highlighting the need for certain resources. "People have managed to step outside the box a little bit and try and use things like … data loggers." For the final half-term's science day, she wanted an assessment to bring it all together, giving children freedom to explore. Such initiatives changed practices. "Staff have said how it is much more easy to see the them working scientifically through more open-ended tasks, which is what I've been saying, but it's having the confidence to do it."

The venture to introduce the local nursery school to Forest Schools met with a negative response. Mrs Peters' head explained the nursery had other issues, "It's not to do with what we are doing". A programme was developed where the Forest School lead would host a group of nursery children in the school grounds. "She did all the planning and evaluation for them". However, nursery staffing changes meant the initiative failed to progress as planned. "They are coming into school a lot more regularly of the back of my science, but not for science specifically, not for the Forest School, but they have been coming in for different events."

Such incidents knocked Mrs Peters confidence, but opened her mind in other ways. "I am forever looking for more interesting ways to present things and more interesting ways to do things and to try and engage the children more." During her performance management meeting the head teacher thanked Mrs Peters, recognising how far science had come … especially science days and how the children were engaging with reasoning skills." Yet, Mrs Peters was not complacent. "I am not saying we are there yet, because we have still got work to do, and can still develop these children, and make the thinking even deeper … to find ways of really increasing their learning."

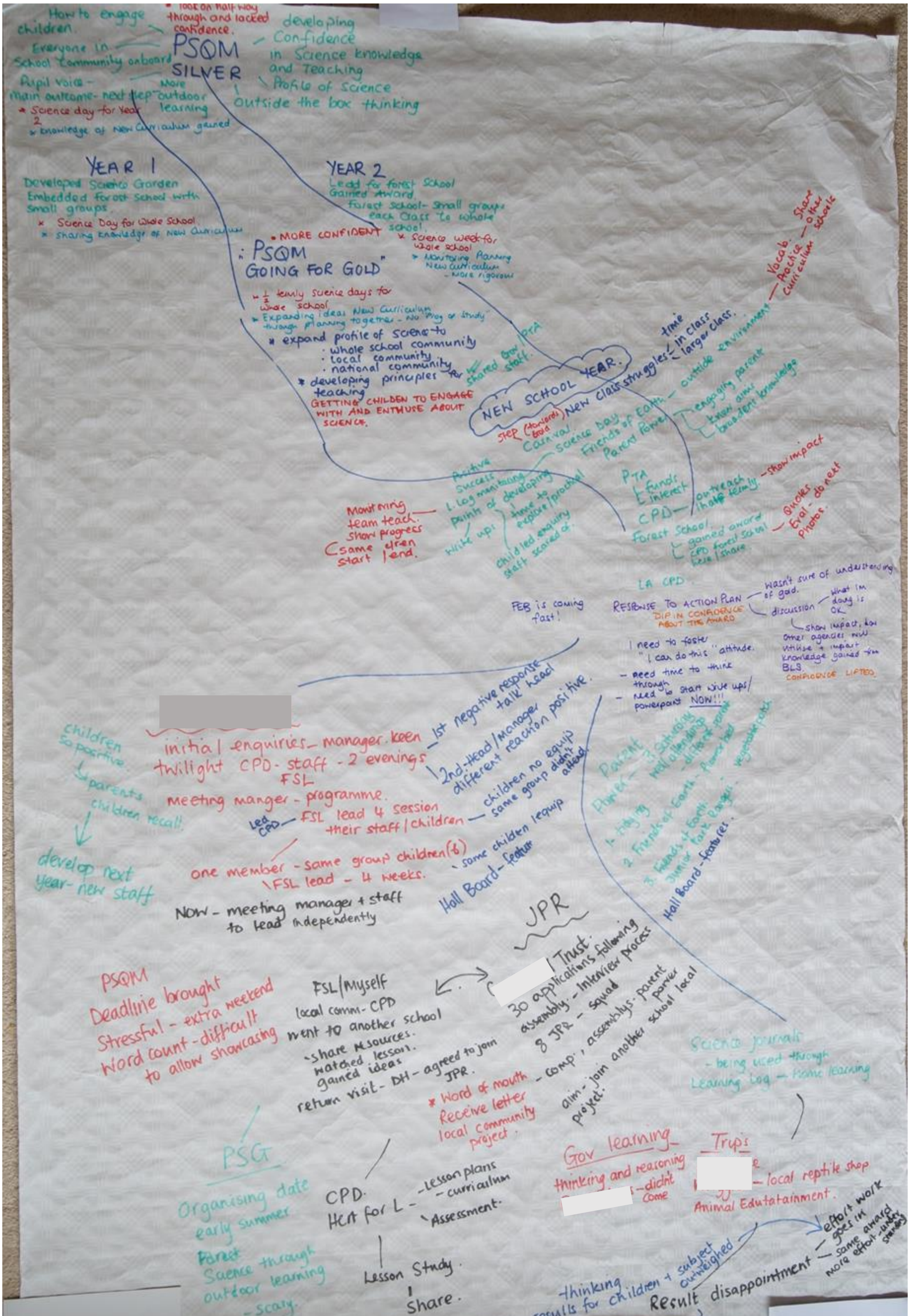
By the end of the year she believed children were developing their own thinking. "They are not just accepting that everything you tell them is right, which is great. How often do they get to do that especially in year two?"

Science subject leaders in Mrs Peters' hub were asked to submit draft evidence one month early, which became stressful because she had already planned her timeline. "I found I was working a lot of weekends in February which I would not normally do as I have quite a good work life balance." In the final weeks a different hub leader supported her. "On the support of **reflections**, I felt I got far more last time … I think I got one response back which told me how to change one **reflection**, which I did, and then I went through the others, … but I felt perhaps the support wasn't quite there because you were swapping people."

The PSQM review resulted in PSQM silver rather than gold. Mrs Peters was very disappointed with the result, returning to this several times. She felt her previous and new submissions, "were poles apart." "I think it might be my **reflections** that let me down." In reducing the word count to 300 she had, "Perhaps cut it back too much and then it didn't make sense to really sell what I had done." Despite her disappointment, "just think about … the difference you have made to the children and that is what I am going with really. I think I can unpick it until the cows come home, can't I?" While maintaining PSQM gives a good framework to work towards, she now wished to hand science over to a new leader, her disappointment instrumental in this decision.

An opportunity for a new challenge arose. Following a suggestion from a colleague, and with the support of her head teacher, Mrs Peters applied to work with schools across the county, moderating teacher judgements. She found it daunting and was nervous but concluded, "I have really enjoyed it … Yes, it is so useful, such good professional development. It really is; so, I will be doing that next year."

Mrs Peters' river of experience



Miss W's Story

"I always wanted to be a teacher." Following A levels in chemistry, mathematics and English, Miss W completed a degree in education in 2006. She worked in several schools, later experiencing middle leadership roles. When we met, she was an SLT member, KS2 leader and subject leader for science and computing.

Despite promotion to acting deputy head teacher during the PSQM year, she maintained she had no desire to become a head teacher. "I came into this job because I wanted to spend time with the kids ... I love the banter and my little STEM club - they have been counting the days this week; it's so cute. I would miss that." Promotion meant more time out of class, but she continued to teach her class science.

Her one form entry primary school has above average measures of deprivation and had never been graded by Ofsted as 'good' or better. Ofsted inspected just after she joined and she was honest, saying science was not good enough. A pupil voice activity reinforced her view. "Science is pretty rubbish and teachers do all the science. We watch a video or a PowerPoint and then we do a worksheet. It's not very interesting. I'd love to do real science; I'd love to go outside; I'd love to do experiments." Miss W was proud Ofsted graded the school 'good', but the report designated science as a key action. "The head teacher said to me, 'you are staying subject leader'. It became a passion for me." Based on a positive experience elsewhere, she persuaded the head they should do PSQM.

Ofsted findings supported Miss W's planned changes. "It very much helped ... we didn't have any choice but to improve science … It gives you more clout." Monitoring revealed insufficient science was taught in some classes, and quality was variable. External training was provided on science enquiry and recording, with further training by Miss W on working scientifically. "It forced people to work in a more enquiry-based way." To develop their skills, she observed colleagues teaching science. "When we do lesson observations here it is a very positive thing." She invited teachers to observe her teach science to their classes, modelling the approaches she promoted.

She implemented a new curriculum and described it as, "very science heavy". "It gave teachers a starting point. They were still busy embedding English and maths." "That was really effective because it just got people doing it." She implemented a new assessment system, developed with the maths and English leaders, and asked colleagues to use the model she used to mark science books. Miss W organised a science week, which proved very popular and gained the support of three colleagues to run a STEM club. Children were invited to indicate their interest in a STEM club, "and it was 90% of the school." She ordered science equipment which children requested for breaktimes and lunchtimes. The children designed **principles** mascots and posters for classroom displays.

As teachers adopted more hands-on science teaching approaches they began to let Miss W know when the resources were insufficient. Their changing practice led to briefer recording of children's work, increasing time for practical work. "I think teachers enjoy it more and therefore do it more."

Miss W summarised the improvements. "We are changing perceptions for adults as well as children … I am seeing them [her colleagues] buzzing when they talk about science … it's such a difference. We have displays in every classroom. Lots of homework is linked to science ... The profile has been raised through the activities." "Everybody thinks differently about science now… It was a thing to be dreaded … The kids know what it's like to have fun lessons … so why go back?" Miss W reported a pupil voice activity just before PSQM submission. "It was very positive; every child could tell me a science lesson they enjoyed, and some of the scientific language ... used is really impressive."

Time pressures escalated as Miss W approached the PSQM submission deadline.

> The trouble is that I am Acting Deputy, so I have got a lot of that stuff to do as well. My supervisor at Uni for my masters will say to me, … 'you need to get me some writing', and I think yes but my PSQM deadline is before that. This is March and I am getting married … so, it's just kind of too much. I distinctly remember saying to my other half that I was stressed … I am only doing everything at 70% and that makes me feel uncomfortable. I would not recommend to anybody to do all the things I did at once. It is stressful.

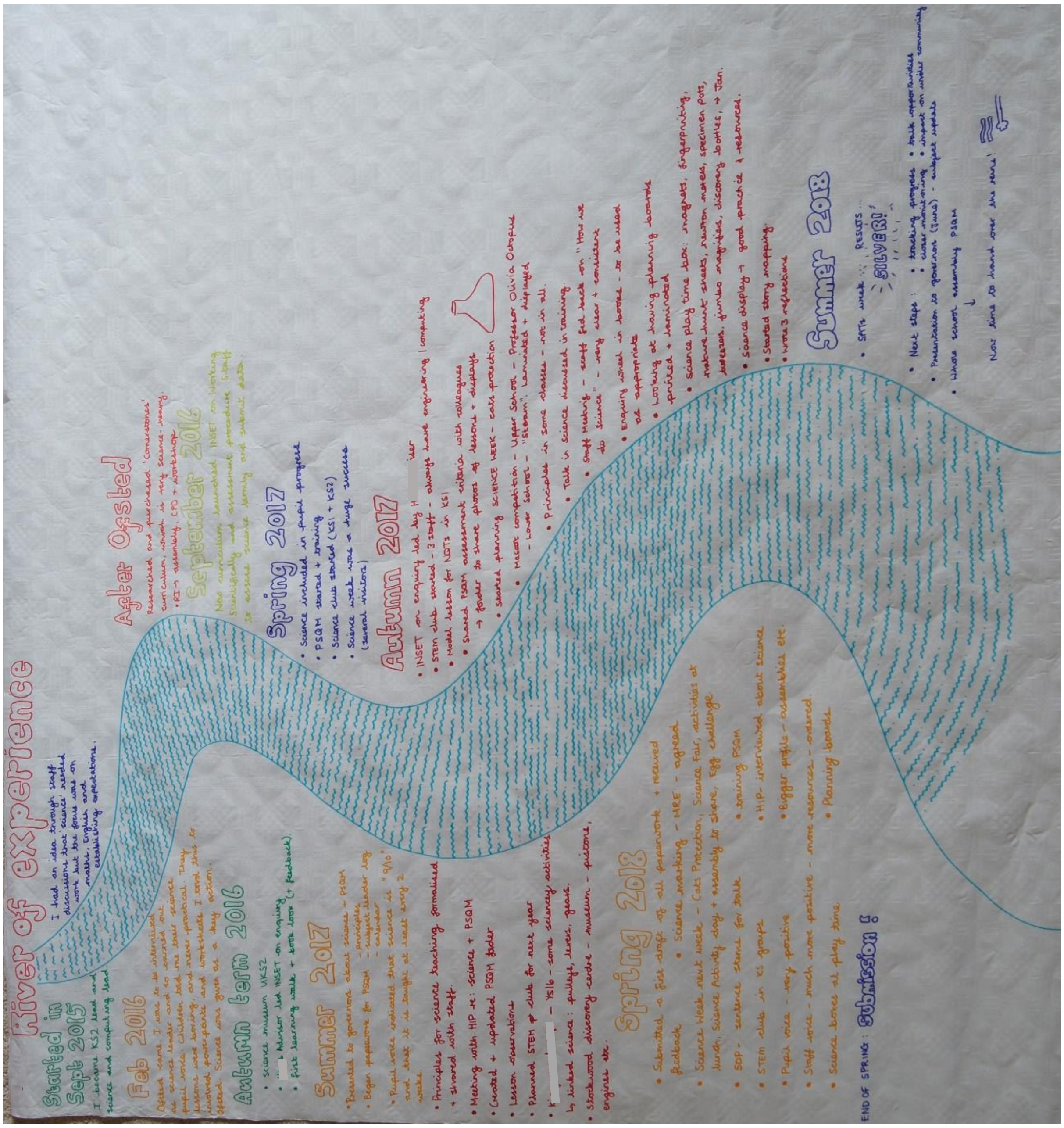
To relieve stress, she asked colleagues to help collect PSQM evidence, using two snow-closure days to collate it. "I don't regret it because it's been a heck of a two years … and to get through it and be nearly there is nice."

Despite the stress, Miss W acknowledged the combination of a master's and PSQM had improved her leadership skills. She developed relationships and a collaborative culture where teachers increasingly communicated with her, although this was harder as an SLT member. "I am not sure PSQM changed the way I teach but it has changed the way I interact with my colleagues."

Unprompted Miss W told me, "I would do PSQM again." She shared her positive experience of PSQM more widely. "I'm on the Facebook group for primary science coordinators … answers I give are to do with PSQM, simply because … it is a very clear framework of how to improve, rather than do it on your own."

Miss W put a notice in the staffroom when PSQM silver was confirmed and provided treats to thank her colleagues. "The annoying thing is people seem to think we've been downgraded from gold." The head asked if she would hand over science and develop reading instead. "I absolutely would … I would be fine with that. I don't think it is my baby. I had a big job to do but it is mostly done."

Miss W's river of experience



Mrs White's Story

Mrs White started teaching in 1992. When I met her, she worked in a one-form entry school, situated in an affluent village with pupil premium, EAL and SEND percentages below the national average. In the past she had been subject leader for PE, PHSE, history and geography. She was asked to take on the science leader role, "although it is not my sort of subject, as English is more my subject", "I was quite happy to do science", because, having no science background, she saw it as a bit of a challenge. We met during her second year as science leader. She was also responsible for SRE and trainee teachers. Mrs White had no aspiration to join the senior leadership team because, if she did, she would never see her husband, a head teacher.

A colleague suggested PSQM, "is a really good thing to get you into science … It would be good for your professional development." She visited the PSQM website and thought about it. "I took the first year to settle in and then went for it February."

Mrs White recognised other priorities pushed science down the agenda. "I think we have to keep the profile of science up quite high because I think there is a danger of it being … overshadowed by English and maths." However, she perceived her class teacher role as more important than science leadership. "I have other subjects that I need to teach, so I need to do my planning, do my marking, and do everything else associated with the class before I can do anything to do with science."

A pupil voice activity showed children, "really enjoy science, and like doing practical work but they don't like doing the writing." She concluded practical science happened infrequently when she audited science resources. "That made me think, what we have been doing practically?" The children's books revealed lots of writing. "Children always seemed to be doing the same sort of thing." As a result of her findings, colleagues agreed to encourage the children to ask more questions and, "to have at least one child-led investigation … per half term".

Mrs White was disappointed how few colleagues completed 'Science is good when ….' cards prior to the **principles** staff meeting. However, **principles** were agreed, printed and distributed to staff for display. She intended to refer to these when planning for team teaching because she wanted the focus to be on children asking their own questions (one of the **principles**).

Before the second interview, Mrs White had considered what she wanted to draw on her river of experience. "I am going to do, bars as if they are like jail." "I have chosen black." I asked her to expand. She was worried and felt guilty about not doing enough. "I don't feel I have done a great deal since the last time we met. I feel ... there is a barrier." "I know there are things on the **action plan** I could have done. Mrs White admitted she felt under pressure and wished there was no deadline. She said there was so much to do in teaching; finding time was difficult but she would have to prioritise. She mentioned marking policy changes and hoped this would free up time.

Mrs White reflected that early on she had been working on PSQM alone. I asked when she managed to involve others. "I had to update everybody in a staff meeting. We did the **principles** of science so that sort of involved everybody." There were quite a few staff meetings in the spring term which gave Mrs White the confidence to speak up and lead. When asked how it gave her the confidence she replied, "Because I had to speak to them!"

PSQM training also helped. Mrs White found being with other science leaders reassuring, talking to each other, especially about what they were finding difficult. The hub leader giving examples of things they needed to do really helped her to understand what the product was going to be. I asked what else the hub leader could have done. "I think more regular meetings would've helped me."

During the third interview Mrs White used the red pen, "to do a sun because it feels like I can see the light." She had raised the profile of science by organising numerous activities. For the science day she invited parents to help but was disappointed when only three responded. A previous science day led to, "a lot more parental involvement." A visitor from a pharmaceutical company made ice cream in a bag with the children. Another company provided an after-school science club. By the end of the year she had successfully raised the profile of science, listing displays, home learning tasks, science on staff meeting agendas, a science kit for minibeast spotting at break time, and plans for next year's science day as evidence.

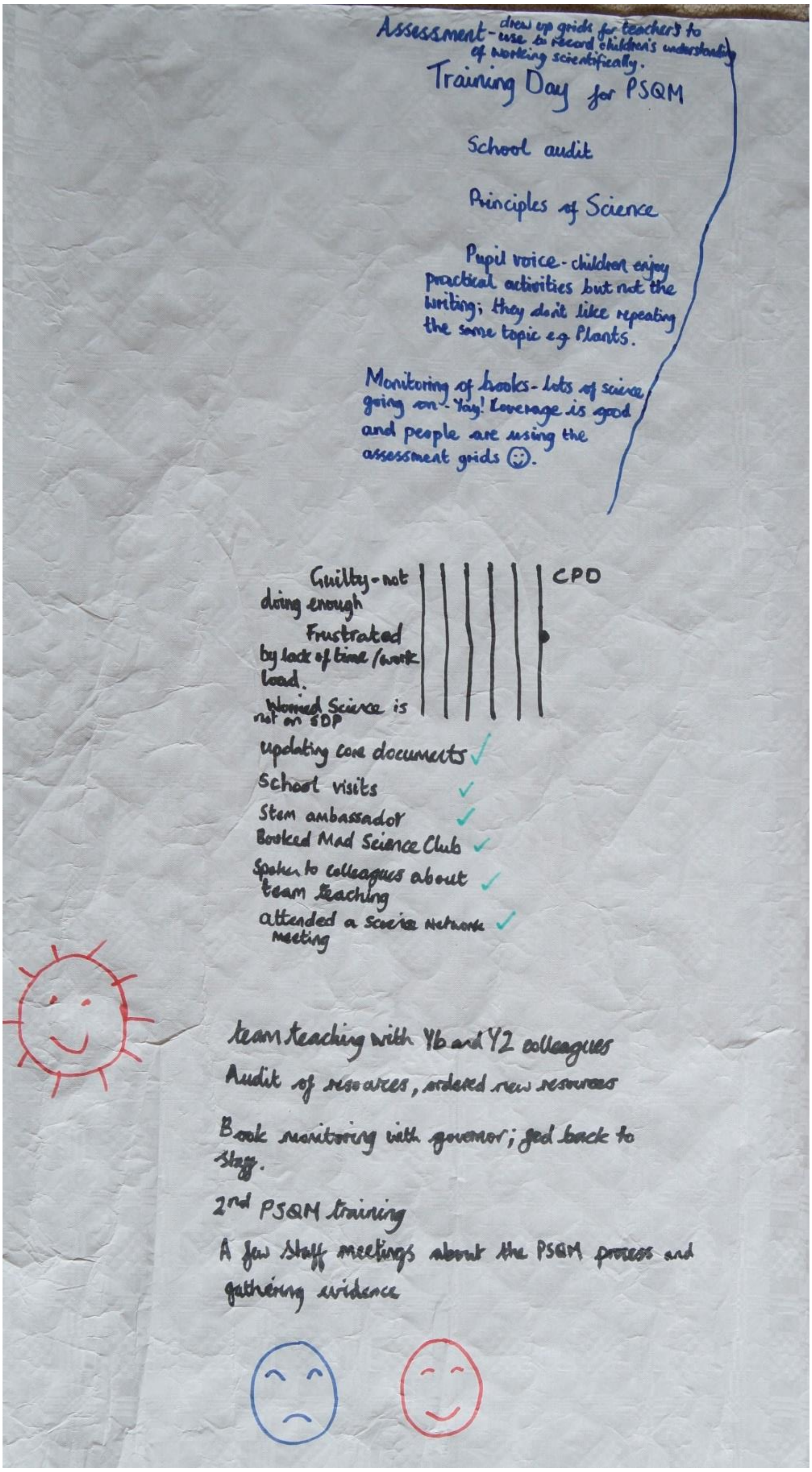
For her own development she attended local network meetings and accessed Reach Out on-line CPD on 'sound' which was "so quick and easy." She also started an on-line Future Learn course but writing PSQM **reflections**, "took over all her spare time", so she did not complete it.

I asked Mrs White how PSQM had changed her science teaching. "I'm trying to give the children more choice, more decisions rather than me saying right this is how we are going to do it today." I asked if colleagues' behaviour had changed. "They talk about what they are doing in science a lot more."

Children in her class wrote comments on their end of year reports. "They were talking about all the different things they enjoyed during the year. So many of them were science related; it's really good they remembered all the different things we've done."

Mrs White announced she was leaving at the end of the year to teach elsewhere. "I think doing the PSQM also gave me the confidence to apply for jobs because … it has been 12 years since my last interview." "I felt as if in doing this I had something really positive to talk about in an interview. It might sound really stupid." During the interview she talked about PSQM and hoped she might lead science at her new school. "Yes, I wouldn't mind doing science again and they have got a pond there."

The email from PSQM requested further evidence. "It was so disappointing to see that they couldn't award silver and it was a bit gut-wrenching because you put all that effort and hard work into it." On reflection she felt the comments were fair. The head teacher arranged an emergency staff meeting so colleagues could provide the necessary additional evidence. "It was really helpful, and everyone was involved in it." After submitting additional evidence, the school received PSQM silver.


Assessment - drew up grids for teachers to use to record children's understanding of working scientifically.
Training Day for PSQM
School audit
Principles of Science
Pupil voice - children enjoy practical activities but not the writing; they don't like repeating the same topic eg Plants.
Monitoring of books - lots of science going on - Yay! Coverage is good and people are using the assessment grids
Guilty - not doing enough
Frustrated by lack of time / work load.
Worried Science is not on SDP
CPD
updating core documents
School visits
Stem ambassador
Booked Mad Science Club
Spoken to colleagues about team teaching
attended a Science Network meeting
team teaching with Y6 and Y2 colleagues
Audit of resources, ordered new resources
Book monitoring with governor; fed back to staff.
2nd PSQM training
A few staff meetings about the PSQM process and gathering evidence