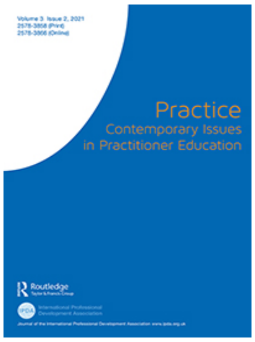

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'I have enjoyed teaching science more': changing the attitudes of primary teachers and pupils towards science

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ABSTRACT

This article explores issues with primary science, changing attitudes towards primary science and the interrelationship between attitudes and experiences. It examines findings from research that investigated the views and experiences of twelve science leaders undertaking a professional development programme designed to develop primary science pedagogy and leadership. Qualitative data collected using questionnaires, an interview, focus group, and programme submissions were analysed thematically and using keywords. The findings suggest changes in science leaders' and teachers' attitudes towards teaching science and of pupils towards learning science. By considering attitudinal change as a particular form of learning leading to the acquisition of 'personal knowledge' after Eraut, this article raises questions about individual and social construction of attitudinal knowledge. It also explores the way attitudes and experiences interrelate and how teachers' professional development might influence collective attitudinal knowledge across school communities and, in turn, enhance individual learning.

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Primary science; primary teachers; science education; primary education; attitudes

Introduction

This article examines findings from a qualitative research study involving twelve primary science teachers engaged in a professional development programme designed to develop science pedagogy and leadership in schools. It focuses on the attitudes of pupils and teachers to science, which is an important area of ongoing interest and research (e.g. Pell and Jarvis 2001, Jarvis and Pell 2004, van Aalderen-smeets *et al.* 2012, DeWitt *et al.* 2013, Savelsbergh *et al.* 2016, Huang *et al.* 2019). This article provides an original perspective by framing attitudes as a form of knowledge (Eraut 2004) and sharing insights and raising questions about attitudes in this context. It contextualises the study using literature relating to the learned nature of attitudes (Haney 1964, Jarvis 2012) and attitudes as an element of personal knowledge (Eraut 2004); teachers' influence on pupils' attitudes; attitudes towards science; and the association between attitudes and experiences. After describing the research study, the findings are analysed to explore how the science leaders refer to attitudes and report attitudinal change. The article provides implications for theory and practice in teacher education relating to attitudinal change as a form of

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learning; the tacit and explicit aspects of attitudinal knowledge; and its individual and social nature and development. The article also considers whether attitudinal knowledge can be developed and held collectively in schools, as Fischer and Nakakoji (1997) have found for work knowledge in other settings, possibly through a process of 'socialization' (Nonaka *et al.* 1996, p. 205), and if so, how this might, in turn, enhance individual learning.

Context

Attitudes and personal knowledge

According to Ajzen (1989, p. 241) 'An attitude is an individual's disposition to respond favourably or unfavourably to an object, person, institution, or event, or to any other discriminable aspect of the individual's world'. Behaviour reflecting an individual's attitude can be both verbal and nonverbal (Ajzen 1989). Attitudes are usually learned (Haney 1964); as Jarvis (2012, p. 190) explained: 'there are a number of totally different processes whereby knowledge, skill or attitude is acquired through the transformation of experience and each of these is seen as a learning process'. Eraut (2004, p. 264) situated attitudes as a component of 'personal knowledge', which 'includes not only personalized versions of public codified knowledge but also everyday knowledge of people and situations, know-how in the form of skills and practices, memories of episodes and events, self-knowledge, attitudes and emotions'. Such personal knowledge can be tacit or explicit and as learning and knowledge are contextualised questions arise about the individual or social nature of particular items of knowledge (Eraut 2000).

Collinson (2012) identified several sources of values and attitudes that are pertinent to professional development opportunities and school contexts. These sources include teachers, who can have an effect from childhood, and influences present in adulthood, such as 'intensive professional development, professional colleagues, reflection, prior careers, inquiry' (Collinson 2012, p. 326). School teachers and other educators can play an important role in influencing pupils' and students' attitudes. Osborne *et al.* (2003, p. 1070) reported that research evidence demonstrates 'that it is the teacher variables that are the most significant factor determining attitude, not curriculum variables'.

STEM education and issues with primary science

STEM (science, technology, engineering and mathematics) education is a focus of international interest and attention (e.g. Fitzgerald *et al.* 2020, Marginson *et al.* 2013, Lee *et al.* 2019). So too is the impetus to engage primary pupils in science (ALLEA Working Group Science Education 2012, Wellcome Trust 2014, Ofsted 2021) as it is whilst in primary school that many children decide whether or not they will study science post-16 or pursue a career in a STEM subject (Archer and Tomei 2013). In England, the drive for improvements in literacy and numeracy (CBI 2015) and the associated focus on school league tables have reduced the attention given to science. These factors, and the launch of the new national curriculum for science (Department for Education 2013), all contributed to a perceived need to increase the profile of primary science in England; as well as in other national settings (ALLEA Working Group Science Education 2012).

Research commissioned by the Wellcome Trust has identified several issues with teaching primary science in the UK. Leonardi *et al.* (2019, p. 43), for example, report 'a lack of time and resources to deliver science in the way they would like to' as two of the main barriers when they interviewed 50 staff, including head teachers and science leaders. A few of the interviewees discussed 'teachers' lack of interest in science as a key barrier and how the decrease in the perceived importance of science in schools has led to a lack of motivation'; 'teacher confidence' and 'a lack of subject knowledge' were also thought to influence science teaching in some schools (Leonardi *et al.* 2019, p. 44). These findings were consistent with responses to an earlier survey of 805 primary school teachers/ leaders carried out by the National Foundation for Educational Research (NFER) (Wellcome Trust – NFER 2016).

Attitudes towards science

According to the Royal Society (2010, p. 69) 'perhaps the chief reason for the importance of attitudes lies in their influence on choice about pursuing science and mathematics related studies'. Two main types of attitudes have been identified in relation to science education: '*scientific attitudes*' and '*attitudes towards science*' which include 'interest in science' (Gardner 1975, p. 1 original emphasis). Attitudes to science are 'the views and images young people develop about science as a result of influences and experiences in a variety of different situations' (Ramsden 1998, p. 128). Several authors have noted the complexity associated with defining attitudes towards science (e.g. Ramsden 1998, Osborne *et al.* 2003), which are discussed in this article.

The Royal Society (2010, p. 65) suggested that: 'In the context of science and mathematics they [attitudes] are made evident in the liking for, interest in and confidence in learning these subjects ... '. In the current study, these expressions of attitude (liking, interest and confidence), are used to explore attitudinal change together with components and expressions of attitudes identified by van Aalderen-smeets *et al.* (2012) and terms used by the research participants themselves such as enthusiasm and enjoyment. van Aalderen-Smeets *et al.* (2012, pp. 176–177) considered primary teachers' attitudes towards science and towards teaching science as a complex, multidimensional concept and devised a theoretical framework where attitude was composed of 'Cognitive Beliefs', 'Affective States' and 'Perceived Control', with 'behavior and behavioral intention as outcomes of attitude'. In terms of the ways attitudes are evidenced, as suggested by the Royal Society (2010, p. 65), it could be suggested that 'liking for' relates to the affective state; 'interest in' relates to cognitive beliefs; and 'confidence in' relates to perceived control in the framework developed by van Aalderen-smeets *et al.* (2012). In this article the emphasis is on teachers' attitudes to science teaching and pupils' attitudes to science and to learning science.

Several researchers have looked at the attitudes of primary pupils and teachers to science (e.g. Pell and Jarvis 2001, Jarvis and Pell 2004, van Aalderen-smeets *et al.* 2012, DeWitt *et al.* 2013). DeWitt *et al.* (2013) used a quantitative tool to explore associations between primary pupils' aspirations to a science career and attitudes, and reported that generally, pupils had positive attitudes to science; reported positive parental attitudes to science and held very positive views of scientists, but these attitudes were not translating directly into aspirations in science. This finding has implications for approaches designed to influence pupils' attitudes towards science with a view to encouraging them to engage in science careers.

Insights into pupils' views have also been obtained through open-ended questioning using questionnaires and focus groups (Chetcuti and Kioko 2012). Chetcuti and Kioko (2012, p. 1579) reported that girls in secondary schools in Kenya 'attributed a positive attitude towards science to whether they enjoyed their science lessons in school', citing the teacher and the pedagogic approach used as the most important reasons for their enjoyment. Denessen *et al.* (2015) investigated the relationship between primary teachers' enjoyment in teaching about science and pupils' attitudes towards science and reported that pupils' attitudes were affected by teachers' attitudes.

Jarvis and Pell (2004) explored changes in primary teachers' confidence, attitudes and cognition before and after a two year in-service programme and whether any changes influenced the attitudes and cognition of pupils. They concluded that the programme 'generally had positive outcomes with regard to teachers' confidence, self-perception of ability, attitudes to managing science in the classroom and science understanding' and reported that pupils' cognition and attitudes to science were influenced by their teachers (Jarvis and Pell 2004, p. 1806). However, the findings were complex and there were important differences between teachers, suggesting that individualised professional development approaches might be more effective (Jarvis and Pell 2004). More recently, van Aalderen-Smeets and Walma van der Molen (2015, p. 710) argued for focusing on teachers' attitudes in primary science professional development as a result of findings from a programme that 'had profound positive effects on primary teachers' professional attitude towards teaching science'. As a result of further empirical research, van Aalderen-smeets *et al.* (2017) suggested that it might be necessary to focus on attitudinal change in order to effect change in teachers' attitudes. Other large-scale studies have reported an influence of professional development on primary science teacher confidence (e.g. Harlen *et al.* 1995, Murphy *et al.* 2007).

Attitudes and experiences

Research on attitudes towards science generally stems from an aspiration to provide conditions in which pupils 'make sense of, and feel positive about, their experiences in science lessons' (Ramsden 1998 p. 132). The relationships between teachers' attitudes towards science and their experiences of science, pupils' attitudes and experiences in relation to science, and the way teachers' and pupils' attitudes and experiences interrelate, are complex. Leonardi *et al.* (2019, p. 42) note that a few of the interviewees in their study, head teachers, science leaders and teachers, acknowledged an association between 'their own positive experiences in school' and 'the extent to which they enjoy teaching the subject'. Similar links between experiences and attitudes have been found for mathematics where McAteer and Grinyer (2019) reported that primary teachers strongly associated their experiences of being taught mathematics with how confident and competent they felt in the subject. Whilst Jarvis (2012) explained the association between experience and attitude, as described earlier in this article, the Royal Society (2010, p. 59) drew attention to the relationship between children's attitudes to science education and their experiences suggesting that attitudes 'are often thought to be both a result of children's experiences and a factor in determining their willingness to engage in relevant activities'. This relationship might be visualised as an upward or downward iterative spiral, from experiences to attitudes and attitudes to experiences, affecting children's inclination to engage in science. Teachers can play an important part in influencing the nature of this spiral. For example, Frenzel *et al.* (2009) explored the association between mathematics teachers' enjoyment of teaching and students' enjoyment in class. These researchers demonstrated a positive relationship between teachers' enjoyment and students' enjoyment and suggested that enthusiasm was the mediating factor in the transfer of enjoyment experienced by mathematics teachers to their students (Frenzel *et al.* 2009). Whilst enjoyment might be considered to be an 'affective experience' enthusiasm is expressed through behaviour (Frenzel *et al.* 2009, p. 706).

Research study

Primary Science Quality Mark

The Primary Science Quality Mark (PSQM) professional development programme has been implemented within the UK and in several other countries including the Netherlands, Germany, Cyprus, Singapore, Indonesia, Malaysia and the USA. In England, some primary schools have engaged their science leaders in the programme in order to address the reduced focus on science and to prepare for teaching the new national curriculum (Turner *et al.* 2013, White *et al.* 2015). During the programme schools are provided with a framework and professional support for developing science learning, teaching and leadership. Science leaders from participating schools are not science specialists but primary teachers who lead the development of science pedagogy in their school during the programme and are appointed to local PSQM networks or hubs. Hub leaders are PSQM-trained primary science experts who support the teacher-leaders through face-to-face activities and online mentoring during the year-long programme, which involves school-based evaluation, action planning and implementation (Turner *et al.* 2013). At the end of the programme the science leader submits reflections and supporting school-based evidence on practice in primary science in order to achieve an award. Professional development programmes for teachers, such as PSQM, are designed to lead to increased knowledge and skills and/or changes in attitudes and beliefs, changes in classroom practice, and improved learning outcomes for pupils (e.g. Guskey 2002, Desimone 2009). During the PSQM the science leaders are encouraged to become extended professionals who are committed to developing through the systematic questioning of their own teaching and testing theory in practice (Stenhouse 1975).

Aims, participants and data collection

This research study investigated the views and experiences of twelve science leaders in schools undertaking the PSQM programme. Rich contextualised qualitative data were collected and used to explore the impact of the programme, if any, on the science leaders' attitudes towards science and their perceptions of changes in the attitudes of teachers and pupils. These data were collected using a self-completion questionnaire, an interview and a focus group and from documents submitted for the PSQM award. This article focuses on data relevant to attitudes and attitudinal change, which are used to address the following research questions:

- How did the science leaders talk about attitudes? (What language or 'vocabulary' did they use?)
- Is there evidence for any changes in the attitudes of science leaders and teachers towards teaching science? If so, how did science leaders' and teachers' attitudes change?

- Is there evidence for any changes in the attitudes of primary pupils towards science or towards learning science? If so, how did pupils' attitudes change?
- What can we learn about: attitudinal change as a particular form of learning; the nature of attitudinal knowledge and its construction?

The data arose from listening to the meanings being constructed by twelve science leaders who worked in schools that started the PSQM during 2014 (cohorts 8 and 9) (Table 1). These twelve schools received a Royal Society of Chemistry bursary to enable them to engage in the programme.

Data were initially collected using a self-completion questionnaire, which included some open-ended questions (Table 2) that invited responses to 'permit one to understand the world as seen by the respondents' (Patton 2002, p. 21). The questionnaire was piloted to assess how the questions were interpreted within the context

Table 1. Data collection approach and number of participants.

Data collection approach	Number of participants	Cohort
Questionnaire	2	8
Interview	1	9
Focus group	3	9
PSQM submission documentation	8 (2 of these participants completed the questionnaire)	8

Table 2. Data collection approach and question areas relevant to attitudes towards science.

Questionnaire
Before you started working towards the PSQM:
QA. Did you enjoy teaching science topics?
QB. Did you feel confident to teach science topics?
QC. Did the children in your class enjoy science topics?
QA-QC included the response options: Yes, always; Yes, sometimes; No, hardly ever; No, never; Don't know; and: Please comment on whether or not this aspect has changed during the year, and if so how it has changed.
Can you give any examples of specific changes that you have noticed:
QD. in your own or your teachers' attitudes and thinking about science topics?
QE. in the children's attitudes and understanding about science topics?
Interview and focus group
QF. Were there any issues/attitudes that you wanted to change? (Following: Why did you choose to do the PSQM in your school?)
QG. Do you think your attitudes to science have changed since you have been doing the PSQM in your classroom? If so how? (e.g. enjoyment, confidence, engagement)
QH; QK. Have you seen a change in the attitudes of the children? If so, can you give me an example? Context: QH. participant's own teaching; QK. across the school
QJ. Do you think teachers' attitudes to science have changed since you have been doing the PSQM across the school? If so, how? (e.g. enjoyment, confidence, engagement)

of the complete instrument (McColl *et al.* 2001) and the final version was sent by email to eight science leaders. Two of the science leaders responded and their responses were reviewed to inform the subsequent data collection activities. The eight science leaders invited to complete the questionnaire contributed to the research through documentation submitted for the PSQM award. One science leader undertook a telephone interview, and three science leaders in one hub engaged in a focus group. The interview and focus group provided opportunities for 'probing or extending' the participants' responses; such opportunities were not available when collecting data using the self-completion questionnaire (Patton 2002, p. 21). The questions used for the questionnaire, interview and focus group were designed to explore aspects of teaching, learning and leading science. Those question areas most relevant to attitudes towards science are shown in Table 2. Responses to other questions are also included where these contribute to the discussion of attitudes and attitudinal change.

Data from the award submission documentation were provided as evidence for criterion C3 (Children enjoy their science experiences in school), and from responses to questions about general or science-related issues within the school that the science leader wanted to report; and to the question 'What do you feel the school's and your involvement in PSQM this year has done for science at your school?'

Ethical approval for the study was obtained from the relevant University of Hertfordshire Ethics Committee. Participants were informed that their engagement, or otherwise, in the research would not have any influence on their involvement with the PSQM and that confidentiality would be maintained if data were disseminated. Members of the research team were independent of the PSQM programme. An interpretive research approach was used, characterised by specific interest in the participants as individuals and a desire to understand the subjective world of their experiences and how they interpreted them (Cohen *et al.* 2007). The interview and focus group were designed to benefit all involved (Cohen *et al.* 2007) and the science leaders were viewed as 'conversational partners' (Rubin and Rubin 2005, p. 14). They were self-reporting regarding their own attitudes and experiences and also reported their perceptions and observations of any changes in the attitudes and behaviour of colleagues, pupils and others within their school communities. The questions were open-ended, designed to generate in-depth data. The openness of the questions and the intention to build a mutually safe and supportive environment gave respondents some power over what was discussed and understanding was constructed with the researcher through the process. The desire was that the science leaders would benefit through having an interested person with whom to reflect on experience and practice.

Data management and analysis

The completed questionnaires were submitted by email and the interview and focus group session were recorded and transcribed. Although the sample size was small, the data were rich and as Patton (2002, p. 46) asserted 'While one cannot generalize from single cases or very small samples, one can learn from them – and learn a great deal, often opening up new territory for further research . . .'.

Table 3. An example of data within each theme.

Theme 1: The impact of doing the PSQM on attitudes to science
'the clear growth in confidence of the staff when leading investigations has directly lead to the growth of enjoyment of the pupils and to higher levels of attainment, especially with higher ability pupils'. (School A)
Theme 2: The impact of doing the PSQM on primary science teaching
'on our learning walks we are seeing that in the lower year groups that children are starting to be able to plan their own investigations. So hopefully as time goes on we will see children coming through that are capable of planning their own investigations'. (Jessica)
Theme 3: Reasons for doing the PSQM
The PSQM provided: 'an opportunity to celebrate all the things we were already doing well but it gave us an extra incentive to make science teaching and learning in the school even better. It has been wonderful to see the children so enthused'. (Eddie)
Theme 4: Resources for teaching primary science
'we bought a full-size skeleton and I went to observe a student's lesson all about bones and I hoped he might use it. At the end of the lesson he wheeled it out and I thought "Yeah!" and the children all gasped, they were mesmerised by it'. (Riah)

The research lead categorised the data into four themes derived from the overall research aim (Table 3): the impact of doing the PSQM on attitudes to science; the impact of doing the PSQM on primary science teaching; reasons for doing the PSQM; and resources for teaching primary science (White *et al.* 2015). Data within the first theme, explained below, are used to address the research questions in this article; data in the remaining themes contextualise these findings. Pseudonyms are used for participants in the focus group and interview (Sam, Jessica, Nilgun and Riah) and for questionnaire respondents (Eddie and Alex). Data obtained from the PSQM submission documentation are denoted alphabetically (School A – School H). Care was taken when interpreting these submission data because the science leaders were reporting in order to achieve an award, which together with the nature of the framework and the questions might have influenced their responses (Turner *et al.* 2013).

Theme 1: The impact of doing the PSQM on attitudes to science

Using the three aspects of attitude proposed by the Royal Society (2010, p. 65) evidence was sought for pupils having a 'liking for, interest in and confidence in learning' about science. Evidence was also sought for these three aspects of attitude in relation to teachers teaching and leading science. Themed data were complemented by findings identified by searching for key words, which were presented in context (Ryan and Bernard 2003). The key words comprised: expressions of attitudes proposed by the Royal Society (2010), like, interest and confidence; the antithesis of these expressions; and the affective aspects, enjoyment and anxiety, proposed by van Aalderen-smeets *et al.* (2012). These terms were identified through electronic searching of the complete dataset (e.g. 'confiden' to identify confidence, self-confidence, confident, confidently, no confidence/lack of confidence, no/lack of self-confidence, not confident, not confidently). As expected, there was overlap in findings identified from the data theming and the key word search. Some examples of findings are presented in Table 3. In addition, some terms the participants used in response to questioning about attitudes were identified to illustrate the science leaders' vocabulary of attitudes and their perceptions of the way attitudes are exemplified.

Findings and discussion

This section illustrates how the science leaders spoke about attitudes and then critiques evidence for attitudinal changes, and the nature of any changes, focusing on selected issues each time. The interrelationship between the science leaders, teachers and pupils leads to some overlap between the findings presented in different sub-sections. Here, 'changes' are seen within the scope of the impact of the PSQM programme, where 'impact is defined as an effect on, change or benefit to … ' (HEFCE 2011/2012 p. 48). The emphasis is not on this particular programme but on using the findings to attend to: attitudinal change as a form of learning leading to the creation of personal knowledge (Eraut 2004); individual and social construction of attitudinal knowledge; and how teachers' professional development might influence collective attitudinal knowledge across school communities and, in turn, enhance individual learning. Attention is also given to the association between teachers' and pupils' attitudes towards science and their experiences of science.

The science leaders' vocabulary of attitudes

The key word search revealed that the science leaders' responses included the terms *like, confidence* and *enjoy* proposed by the Royal Society (2010) and van Aalderen-smeets *et al*. (2012) in ways that suggest attitudes towards science and towards learning and teaching science. For example, pupils '*liked* the idea of taking part in lessons that used science experiments' (School F); 'the clear growth in *confidence* of the staff when leading investigations' (School A); and there was '*enjoyment* of science across the school' (School G). The terms *interest* and *anxiety* were not identified. Science leaders also referred to *engagement*, a term given, together with enjoyment and confidence, as an example of attitude in some questions (Table 2); for example, Jessica referred to pupils being 'more *engaged* when they are in the lessons'.

The participants also used other terms to discuss attitudes. They described attitudes as being *positive*: 'Children have a very *positive* attitude to science' (Alex); and referred to *enthusiasm*, a term used in some PSQM criteria: 'The teachers are encouraged by the children's levels of engagement and *enthusiasm*' (Eddie). When questioned about attitudes the science leaders reported behaviours, such as discussing and sharing ideas: 'I think people are a lot more positive about it and are talking about it more in the staff room, sharing ideas that I never really heard people sharing before' (Sam). Responding to a question about attitudes and thinking, Alex reported: 'Teachers in the school have worked hard to link science topics to their learning journeys and they have put much more effort into making the children's learning "hands on"'.

There were fewer references to confidence in relation to pupils than teachers and apart from one reference to the enthusiasm of teachers and pupils, science leaders used the terms enthusiasm, enthusiastic and enthuse exclusively when referring to pupils, possibly influenced by the wording of the PSQM criteria.

The science leaders' and teachers' attitudes towards teaching science

Several science leaders' accounts suggest that their attitudes to teaching science had changed or were changing. Alex reflected 'I have enjoyed teaching science more since working towards the PSQM as I am thinking more about my teaching . . . ', illustrating the relationship between attitude (enjoyment) and other aspects of personal knowledge, 'the cognitive resources' (Eraut 2000, p. 130) required for thinking about teaching. When asked whether they thought their attitudes to science had changed (Table 2 QG), the focus group participants also described changes in their teaching. Riah asserted 'I am far more critical of my own teaching, I want it to be as good as it can be'; Jessica explained 'I have tried to find ways to make my lessons more engaging . . . I try to let the children be more involved'; and Nilgun reflected 'I take more risks, I use more resources'. Risk taking is supported by 'A confident, safe, collaborative, democratic, and supportive environment . . . ' (Iredale *et al.* 2013, p. 201). Here, Nilgun's response to questioning about the attitudes of other teachers implied she saw risk-taking as evidence of confidence in teaching: 'they seem more confident, they are taking risks'. She also referred to 'getting the children to take risks'. Spillane (2000) reported an association between confidence and risk-taking in his exploration of a school teacher's pedagogical experience in two subject areas. In higher education too, Sadler (2013) identified a link between a teacher's confidence, taking risks and perception of their knowledge of content and pedagogy where content knowledge tended to be more important. He noted that 'The main influence of this greater level of confidence upon development was that it was often described in conjunction with taking risks and trying out new ways of teaching' (Sadler 2013, pp. 163–164).

Confidence is a complex construct; student teachers identified that it is composed of 'cognitive, emotional (affective), and performance components' (Norman and Hyland 2003, p. 266). Eddie attributed an increase in confidence to teach science topics to having more ideas and greater understanding about 'successful learning':

> 'I felt fairly confident but the experience has certainly increased my confidence. I have a much bigger bank of ideas and greater clarity of what successful learning looks like' (Eddie - Table 2 QB).

Whilst Norman and Hyland's (2003) description of confidence includes a cognitive component, implied in Eddie's response, it also includes a performance element, which associates confidence and action. Thus, teacher confidence could be seen to have implications for pedagogic change, as Nilgun reflects below in response to a question about changes in understanding of science and science topics. Here, Nilgun illustrates a finding from Spillane's (2000, p. 326, 327) study of a teacher engaged in teaching mathematics and literacy, in which he observed that her confidence in literacy 'meant that she adopted a reflective stance, actively constructing and reconstructing ideas about teaching' in contrast to mathematics in which 'her stance was more passive as she struggled to memorize "experts'" remedies'. This suggests she could draw on a greater resource of personal knowledge in one subject area; her 'capabilities-what [she] can do-and the understandings that inform them' (Eraut 2007, p. 406).

> 'I am more motivated to go away and look at things more deeply, learning on the way, with the children. [Interviewer - why do you think you are more motivated to do this?] I have a clearer vision, I am more confident and willing to take risks [with my teaching] which is exciting because before, I was stuck in a rut.' (Nilgun).

Nilgun explains that she is motivated through seeing a positive impact on children's attitudes to science: 'It is all about the children; when you see the impact on the children, it's motivating because you feel like it is actually starting to work'. Nilgun's emphasis on confidence and risk-taking raises questions about the nature and value of components of personal knowledge. For example, might the value of tacit knowledge relating to routinisation that is lost during the change process (Eraut 2004) be offset in some situations by particular forms of attitudinal knowledge, expressed here as confidence? Whilst Nilgun's confidence seems to precede risk-taking in teaching, Loughran *et al.* (2012) identify challenges as teachers and pupils move from a position of confidence, familiarity and routine and are engaged together as learners in pedagogic change. They need to 'unlearn' prior practice, losing the support of the tacit knowledge that accompanied it (Eraut 2004), and enter 'a riskier situation characterised by uncertainty and a heightened consciousness of learning about practice' (Loughran *et al.* 2012, p. 5). Thus, as expected, in this study changing practice was not without challenge. Sam reflected that initially 'I was really struggling to get them [children] to be able to think of their own question' and Nilgun reports from observing practice across her school.

> 'Some staff are more willing to go on that journey and have a go. And some staff lack confidence. There is so much change [new National Curriculum] going on that they find it hard to grasp with everything else that they have to do. It is evident when you go on your learning walks that that some staff are willing to embrace it. There are more child-led investigations, they seem more confident, they are taking risks. They are allowing the children to have more control. Other staff stick to what they know best. And it's trying to move them all, slowly.' (Nilgun – Table 2 QJ)

The pupils' attitudes towards science and towards learning science

Whilst a 'positive attitude towards science' might represent different values including passivity or challenge (Alsop and Watts 2003, p. 1045), in the following examples, the science leaders seem to associate it with challenge. Alex links pupils' active involvement in developing science experiments with attitudinal change and greater understanding of 'scientific concepts' and Riah illustrates her assertion that the pupils are responding positively to science with engagement in science and using relevant vocabulary.

> 'Children have a very positive attitude to science. The School Science Fair had a huge impact on the children's attitude to science and they enjoyed devising their own experiments for the fair. The children really enjoy "hands on" science and this approach has helped them to understand scientific concepts more clearly' (Alex - Table 2 QE)

> 'There is a more positive response to science. I rarely see anyone reluctant to do science, it's not part of the ethos of the school any more . . . I found from our learning walks over the past year that children are able to talk about science in a more developed way. They are using the vocabulary that they should be using. And they want to do better. They want to use the vocabulary and understand things more deeply' (Riah – Table 2 QH)

The science leaders referred to pupils' enthusiasm in response to questioning about perceived changes in pupils' attitudes. According to Alsop and Watts (2003, p. 1043), 'feelings of enthusiasm, confidence and zeal are equally powerful motivators, so that learners are swept up in a flow of eagerness to learn'. Here, Eddie and Nilgun explain that children have responded enthusiastically to learning activities both inside and outside the classroom and are engaging in science activities at home. Assuming that enthusiastic behaviour by pupils reflects their enjoyment of science, as suggested for teachers (Frenzel *et al.* 2009), these teachers are implying that pupils are enjoying their experiences of science. If the relationship between enthusiasm and enjoyment is not only from teacher to pupil (Frenzel *et al.* 2009) but two-way, pupils' enthusiasm could increase teachers' enjoyment of teaching. Thus, whilst a teacher's role in influencing pupils' attitudes is highlighted (e.g. Osborne *et al.* 2003), these data illustrate reciprocal influences on attitudes within school communities. For example, Nilgun's reference to attitudinal change arising through seeing a positive impact on pupils' attitudes, cited earlier; Eddie's report 'The teachers are encouraged by the children's levels of engagement and enthusiasm'; and reports of parents referring to science.

> 'There is a buzz about science in the school. The children are engaged, enthusiastic and able to share their learning. With so much great teaching and learning combined with many out of class initiatives (gardening, bird watching, photography, science club, Rangers, child led science assemblies and science awards) we have been able to turn children on to science.' (Eddie – Table 2 QE)

> '. . . The children in my class are much more enthusiastic. I have a lot more children coming in saying that they have done science or research at home, they have found out things or asked other people about how things worked . . . ' (Nilgun – Table 2 QH)

> 'I find children talking about science a lot more in the playground. Also, parents are coming in. We have just had parents evening and a lot of the teachers were saying that the parents said that the children are now really enthusiastic about science. That hasn't happened before.' (Nilgun – Table 2 QK)

Attitudinal change as a form of learning; the nature of attitudinal knowledge and its construction: Implications for theory and practice

Research on attitudes and attitudinal change is inherently complex. Attitudes are integral to a context (Osborne *et al.* 2003) and focusing on attitudes might influence participants' perceptions and recall. However, the participants' assertions of attitudinal change are consistent with earlier findings from interviews with staff in schools that engaged in PSQM, which 'confirmed the improvements in teachers' confidence and ability to teach science, with a consequent positive impact not only on pupils' performance but also on their engagement and enjoyment' (Ofsted 2011, p. 50). In the current study, positive reports of attitudinal and behavioural change are counterbalanced by reflections such as 'Other staff stick to what they know best', illustrating the reality of practice and a longitudinal study would be of value in assessing the sustainability of any changes.

Despite challenges associated with research on attitudes, exploring attitudinal change from the science leaders' perspective provides an opportunity to reflect on developing and changing attitudes as a particular form of learning. This opens up ways of considering the nature and construction of attitudes that are different from those usually addressed in literature on teachers' and pupils' attitudes towards science. The contextualised nature of learning and knowledge leads to questions about the individual or social nature of particular items of knowledge (Eraut 2000), including 'attitudinal knowledge'. In schools, individuals' attitudes contribute to organisational culture as they are shaped by and revealed through activities, interactions and shared experiences. Based on understandings of the way experiences, attitudes and inclination to engage in science activities interrelate (Royal Society 2010), described earlier as an upward or downward iterative spiral, this interrelationship might be visualised in this way for members of staff and pupils on both individual and organisational levels. Attitudes towards different subjects, pedagogic approaches, individuals, groups and other aspects of school life are made evident in how curriculum areas are prioritised in the timetable and through the endorsement of professional learning opportunities. Engaging in PSQM, for example, implies a school's decision-makers have favourable attitudes towards science and signals support for the science leader's participation.

Professional development programmes, and schools themselves, provide opportunities for teachers and pupils to engage in both 'formal learning' and 'informal learning', which 'recognizes the social significance of learning from other people' and 'draws attention to the learning that takes place in the spaces surrounding activities and events with a more overt formal purpose' (Eraut 2004, p. 247). These spaces, together with the more formal shared interactions and experiences, could provide opportunities for 'attitudinal learning'; learning leading to attitudinal acquisition, creation or change through reflecting on explicit attitudes, surfacing tacit attitudes and developing individual and shared, collective attitudinal knowledge. Whereas teachers' attitudes towards teaching and pupils' attitudes towards learning attend to different foci in each curriculum area, the area itself provides a shared attitudinal focus across and beyond the school community, including parents, in this example. Might this provide a useful context for focusing on developing collective attitudinal knowledge? In this setting such 'collective knowledge' might be seen 'as knowledge shared by a group of individuals' (Hecker 2012, p. 426). If so, how might the underlying attitudinal knowledge be developed, held and maintained in schools? In project settings, Nonaka *et al.* (1996, p. 205) describe a process of 'socialization' that could also apply to schools. It is seen as a way 'of creating common tacit knowledge through shared experiences' initiated through developing 'a "field" of interaction, where individuals share experiences at the same time and space, thereby creating common unarticulated beliefs or embodied skills' (Nonaka *et al.* 1996, p. 205). Such a process might have implications for understanding the impact of PSQM. Whereas the importance of professional development being sustained and collaborative is well known (e.g. Cordingley *et al.* 2003), the nature of PSQM, which involves whole school processes of evaluation and development, could make an important contribution towards developing knowledge that is collective. Some responses in this study suggest collective attitudes towards science, for example, 'I rarely see anyone reluctant to do science, it's not part of the ethos of the school any more' and 'There is a buzz about science in the school. The children are engaged, enthusiastic and able to share their learning'. These, together with other findings from this study suggest that teachers' professional development can influence the development of collective, shared attitudinal knowledge across a school community. Engaging members of that community in attitudinal learning provides a mechanism through which each member can effect attitudinal change in themselves and others and contribute towards collective attitudinal knowledge. In addition, they can be instrumental in the creation of other forms of knowledge through motivating pupils to engage in what Alsop and Watts (2003, p. 1043) describe as 'a flow of eagerness to learn'.

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References

Ajzen, I., 1989. Attitude structure and behavior. *In*: A.R. Pratkanis, S.J. Breckler, and A. G. Greenwald, Eds. *Attitude structure and function*. Hillsdale: Erlbaum, 241–274.

ALLEA Working Group Science Education. 2012. A renewal of science education in Europe. *Views and actions of national academies*. Amsterdam: ALLEA. https://www.interacademies.org/sites/default/files/publication/report_allea_2012_science_education_in_europel.pdf

Alsop, S. and Watts, M., 2003. Science education and affect. *International Journal of Science Education*, 25 (9), 1043–1047. doi:10.1080/0950069032000052180

Archer, L. and Tomei, A., 2013. *'What influences participation in science and mathematics?': a briefing paper from the Targeted Initiative on Science and Mathematics Education (TISME)*. London: King's College London. https://kclpure.kcl.ac.uk/portal/files/64435093/TISME_briefing_paper_March_2013.pdf

CBI, 2015. *Tomorrow's World – inspiring primary scientists*. http://www.cbi.org.uk/tomorrows-world/assets/download.pdf. Sponsored by Brunel University London.

Chetcuti, D.A. and Kioko, B., 2012. Girls' attitudes towards science in Kenya. *International Journal of Science Education*, 34 (10), 1571–1589. doi:10.1080/09500693.2012.665196

Cohen, L., Manion, L., and Morrison, K., 2007. *Research Methods in Education*. 6th. London: Routledge.

Collinson, V., 2012. Sources of teachers' values and attitudes. *Teacher development*, 16 (3), 321–344. doi:10.1080/13664530.2012.688675

Cordingley, P., *et al*. 2003. The impact of collaborative CPD on classroom teaching and learning. *Research Evidence in Education Library*. Version 1.1. EPPI-Centre, Social Science Research Unit, Institute of Education. http://eppi.ioe.ac.uk/cms/Portals/0/PDF%20reviews%20and%20summaries/CPD_rv1.pdf?ver=2006-02-27-231004-323

Denessen, E., *et al*., 2015. The Relationship between Primary School Teacher and Student Attitudes towards Science and Technology. *Education Research International*, 1–7. doi:10.1155/2015/534690

Department for Education, 2013. *National curriculum: primary curriculum. DFE-00178-2013*. https://www.gov.uk/government/publications/national-curriculum-in-england-primary-curriculum. Department for Education.

Desimone, L.M., 2009. Improving impact studies of teachers' professional development: toward better conceptualizations and measures. *Educational Researcher*, 38 (3), 181–199. doi:10.3102/0013189X08331140

DeWitt, J., *et al*. 2013. Young children's aspirations in science: the unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, 35 (6), 1037–1063. doi:10.1080/09500693.2011.608197

Eraut, M., 2000. Non-formal learning and tacit knowledge in professional work. *British Journal of Educational Psychology*, 70, 113–136. doi:10.1348/000709900158001

Eraut, M., 2004. Informal learning in the workplace. *Studies in Continuing Education*, 26 (2), 247–273. doi:10.1080/158037042000225245

Eraut, M., 2007. Learning from Other people in the workplace. *Oxford review of education*, 33 (4), 403–422. doi:10.1080/03054980701425706

Fischer, G. and Nakakoji, K., 1997. Computational environments supporting creativity in the context of lifelong learning and design. *Knowledge based systems*, 10 (1), 21–28. doi:10.1016/S0950-7051(97)00010-5

Fitzgerald, A., Haeusler, C., and Pfeiffer, L., Eds. *2020. STEM education in primary classrooms: unravelling contemporary approaches in Australia and New Zealand.*1st. Abingdon: Routledge.

Frenzel, A.C., *et al*. 2009. Emotional transmission in the classroom: exploring the relationship between teacher and student enjoyment. *Journal of educational psychology*, 101 (3), 705–716. doi:10.1037/a0014695

Gardner, P.L., 1975. Attitudes to science: a review. *Studies in science education*, 2 (1), 1–41. doi:10.1080/03057267508559818

Guskey, T.R., 2002. Professional development and teacher change. *Teachers and teaching*, 8 (3), 381–391. doi:10.1080/135406002100000512

Haney, R.E., 1964. The Development of scientific attitudes. *The Science Teacher*, 31 (8), 33–35.

Harlen, W., Holroyd, C., and Byrne, M., 1995. *Confidence and understanding in teaching science and technology in primary schools*. Edinburgh: Scottish Council for Research in Education.

Hecker, A., 2012. Knowledge Beyond the Individual? Making sense of a notion of collective knowledge in organization theory. *Organization Studies*, 33 (3), 423–445. doi:10.1177/0170840611433995

HEFCE (Higher Education Funding Council for England)., 2011/2012. *Assessment framework and guidance on submissions*. [REF 02.2011] http://www.ref.ac.uk/2014/media/ref/content/pub/assessmentframeworkandguidanceonsubmissions/GOS%20including%20addendum.pdf .

Huang, L., *et al*., 2019. Constructs evaluation of student attitudes towards science. *EURASIA Journal of Mathematics, Science and Technology Education*, 15 (12), em1792.

Iredale, A., *et al*. 2013. Confidence, risk, and the journey into praxis: work-based learning and teacher development. *Journal of Education for Teaching*, 39 (2), 197–208. doi:10.1080/02607476.2013.765192

Jarvis, P., 2012. *Adult learning in the social context*. London: Routledge.

Jarvis, T. and Pell, A., 2004. Primary teachers' changing attitudes and cognition during a two-year science in-service programme and their effect on pupils. *International Journal of Science Education*, 26 (14), 1787–1811. doi:10.1080/0950069042000243763

Lee, M., Chai, C.S., and Hong, H., 2019. STEM education in Asia Pacific: challenges and Development. *The Asia-Pacific Education Researcher*, 28 (1), 1–4. doi:10.1007/s40299-018-0424-z

Leonardi, S., *et al*., 2019. *Understanding the 'state of the nation' report of UK primary science education*. Wellcome Trust. https://wellcome.ac.uk/sites/default/files/understanding-state-of-the-nation-report-of-uk-primary-science-education.pdf

Loughran, J., Berry, A., and Mulhall, P., 2012. *Understanding and developing science teachers' pedagogical content knowledge* 2nd . Rotterdam: Sense.

Marginson, S., *et al*., 2013. *STEM: country comparisons: international comparisons of science, technology, engineering and mathematics (STEM) education. Final report*. Australian Council of Learned Academies, Melbourne, Vic. http://hdl.handle.net/10536/DRO/DU:30059041

McAteer, M. and Grinyer, V., 2019. Changing attitudes to mathematics in primary school teachers in England. *PRACTICE*, 1 (2), 133–150. doi:10.1080/25783858.2019.1659632

McColl, E., *et al*., 2001. Design and use of questionnaires: a review of best practice applicable to surveys of health service staff and patients. *Health Technol Assess*, 5 (31), 1–256.

Murphy, C., Neil, P., and Beggs, J., 2007. Primary science teacher confidence revisited: ten years on. *Educational Research*, 49 (4), 415–430.

Nonaka, I., Umemoto, K., and Senoo, D., 1996. From information processing to knowledge creation: a paradigm shift in business management. *Technology in Society*, 18 (2), 203–218.

Norman, M. and Hyland, T., 2003. The role of confidence in lifelong learning. *Educational Studies*, 29 (2–3), 261–272.

Ofsted, 2011. *Successful science. An evaluation of science education in England 2007 2010* No. 100034 . Manchester: Ofsted. 2010 .

Ofsted, 2021. Research review series: science. https://www.gov.uk/government/publications/research-review-series-science/research-review-series-science

Osborne, J., Simon, S., and Collins, S., 2003. Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education*, 25 (9), 1049–1079.

Patton, M.Q., 2002. *Qualitative research and evaluation methods*. 3rd. Thousand Oaks, CA: Sage.

Pell, T. and Jarvis, T., 2001. Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, 23 (8), 847–862.

Ramsden, J.M., 1998. Mission impossible?: can anything be done about attitudes to science? *International Journal of Science Education*, 20 (2), 125–137.

Royal Society., 2010. *Science and mathematics education, 5-14. A 'state of the nation' report*. https://royalsociety.org/topics-policy/projects/state-of-nation/5-14/

Rubin, H. and Rubin, I., 2005. *Qualitative interviewing, the art of hearing data*. 2nd. Thousand Oaks, CA: Sage.

Ryan, G.W. and Bernard, H.R., 2003. Techniques to identify themes. *Field Methods*, 15, 85–109.

Sadler, I., 2013. The role of self-confidence in learning to teach in higher education. *Innovations in Education and Teaching International*, 50 (2), 157–166.

Savelsbergh, E.R., *et al*. 2016. Effects of innovative science and mathematics teaching on student attitudes and achievement: a meta-analytic study. *Educational Research Review*, 19, 158–172.

Spillane, J.P., 2000. A Fifth-Grade teacher's reconstruction of mathematics and literacy teaching: exploring interactions among identity, learning, and subject matter. *The Elementary School Journal*, 100 (4), 307–330.

Stenhouse, L., 1975. *An introduction to curriculum research and development*. London: Heineman.

Turner, J., *et al.*, 2013. *Primary science quality mark: learning from good practice in primary science*. Wellcome Trust. http://www.psqm.org.uk/__data/assets/pdf_file/0010/96283/PE-5751_Primary-science-quality-report-cover-PUBLISHED-VERSION-050613.pdf

van Aalderen-smeets, S.I., *et al.*, 2017. Primary teachers conducting inquiry projects: effects on attitudes towards teaching science and conducting inquiry. *International Journal of Science Education*, 39 (2), 238–256.

van Aalderen-smeets, S.I. and Walma van der Molen, J.H., 2015. Improving primary teachers' attitudes toward science by attitude-focused professional development. *Journal of Research in Science Teaching*, 52 (5), 710–734.

van Aalderen-smeets, S.I., Walma van der Molen, J.H., and Asma, L.T.F., 2012. Primary teachers' attitudes toward science: a new theoretical framework. *Science Education*, 96 (1), 158–182.

Wellcome Trust, 2014. *Primary Science: is it missing out? Recommendations for reviving primary science*. London: Wellcome Trust. https://wellcome.ac.uk/sites/default/files/primary-science-is-it-missing-out-wellcome-sep14.pdf

Wellcome Trust – NFER, 2016. *Wellcome Trust - NFER Teacher Voice Omnibus Survey Data*. London: Wellcome Trust. https://wellcome.ac.uk/sites/default/files/nfer-teacher-voice-omnibus-survey-data-apr16.pdf

White, E., Dickerson, C., and Mackintosh, J., 2015. *Impact of Royal Society of Chemistry bursary-funded Primary Science Quality Mark on primary science teaching*. Hatfield: University of Hertfordshire. http://vuh-la-risprt.herts.ac.uk/portal/en/publications/impact-of-royal-society-of-chemistry-bursaryfunded-primary-science-quality-mark-on-primary-science-teaching(2e8f6faf-006c-4c93-aaf7-40e03457b437)/export.html