Impact of Royal Society of Chemistry bursary-funded Primary Science Quality Mark on primary science teaching

University of Hertfordshire
School of Education

Research report

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Contents

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1 Executive Summary

1.1 Context and aims of the research

This small-scale research project was carried out to evaluate the impact of Royal Society of Chemistry (RSC) bursary-funded Primary Science Quality Mark (PSQM) on the teaching of science, and especially chemistry, in the primary schools involved in the PSQM scheme for the first time. Of particular interest were any changes in the attitudes of primary teachers and pupils towards science and chemistry as a result of this focus.

The aims of the PSQM award programme include: raising the profile of science in primary schools; providing schools with a framework and professional support for developing science leadership, teaching and learning; and celebrating excellence in primary science. Local networks (PSQM hubs), led by PSQM-trained experts in primary science, provide support for science for schools. Schools with bursary-funding from the RSC were initially working at bronze (introductory) level and were in an area of identified need with respect to access to primary science continuing professional development (CPD). Some schools submitted at silver level because they had exceeded the descriptors for each of the criteria for the award. The RSC also provided access to a developing primary website which has lesson materials, exemplar videos and online CPD modules.

The main aim of this research was to explore the impact of the scheme on attitudes and aspirations of pupils and teachers with respect to science and to provide evidence to inform future RSC policy decisions regarding bursary-funding for the PSQM scheme in new schools.

1.2 Methodology

This practice-focused research took an interpretive approach to understand the attitudes, behaviour and thinking of the participants. Data collection methods included: an email questionnaire; semi-structured telephone interviews; a focus group with science leaders; and a review of some of the data available on the PSQM portal.

1.3 Reasons for doing the PSQM

The science leaders revealed a number of reasons for choosing to do the PSQM including to raise the profile of science in their school; to learn together with colleagues from other schools and hub leaders who have primary science teaching expertise and for the professional development opportunity for them as a science leader.

1.4 The impact of doing the PSQM on primary science teaching

Science leaders were better equipped for their own teaching, as well as for leading others. The science leaders were aware of changes in how they were carrying out this role since starting the PSQM. They were more secure in their role and were working from key principles for science teaching in their school that had been developed through listening to the pupils.

The science leaders had developed a wider range of learning opportunities including learning outside, having science visitors and going on science-based trips. These strategies to engage pupils were being implemented in conjunction with a focus on child-led and

hands-on learning across the school. Pupils were being given more opportunity to ask their own questions and to work scientifically to answer their own questions and lead their own investigations. This had not been an easy transition for many of the science leaders or the teachers in their schools because the pupils were not used to working independently and some pupils did not do well at first. The teachers found it difficult letting go of controlling the investigative work.

There was substantial evidence of enrichment in teaching, learning and assessment, and also of more consistency in the quality of teaching primary science across the school.

1.5 The impact of doing the PSQM on attitudes to science

Science leaders' enjoyment and confidence in teaching science and their understanding of the role has grown. They take more risks, use more resources and are more motivated to prepare more deeply for their teaching and their role of leading others. They were excited by the fact that other teachers were being inspired to teach science in a more engaging way because of their leadership.

Many teachers were working harder and were more creative. They were feeling encouraged by the response of the pupils. They were talking more about science and were feeling more confident about using resources for teaching primary science. Some staff were finding it harder to embrace the changes.

One science leader reported that '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.'

There has been an increase in the pupils' motivation and enthusiasm for science since the schools have taken on doing the PSQM. The pupils are more engaged in science-focussed activities within and outside school. The pupils are more positive about science, use more scientific vocabulary and their understanding of science is improving. This is summed up well by some of the science leaders:

> 'The children were assigned a case that required them to use simple ideas about chromatography to identify a criminal. This idea was further developed in English written work and was enjoyed by all. The latest survey shows that solving scientific problems are now being enjoyed by all year groups.'

> '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.'

A highlight of the PSQM year was 'the excitement engendered by science visitors and trips. The children's learning has been greatly enhanced by these experiences. … Seeing Year 3 children on the beach…making the connection that the cliff behind them and the rocks under their feet were the same chalk that they had investigated in class was another great moment. Getting children learning outside.'

1.6 Resources for teaching primary science

The PSQM prompted an audit of all the resources for teaching primary science available in the schools. The responses varied between schools who felt they were well resourced and those who needed to increase their resources.

Considering the digital resources in particular, none of the participants in the focus group or interview had used any of the resources on the website in their lessons, but they agreed that they were very high quality resources. The difficulty was finding a way to apply them to what they wanted to teach. Only one science leader commented on the resources made available to them through the RSC website without being specifically prompted. They reported in their final submission that they had used the RSC resources in their school to enhance the teaching. Therefore it seems that these resources have made very little impact on primary science teaching within these schools mainly because the teachers could not see their relevance to the primary science topics.

The subject leaders identified how the RSC bursary had benefitted their school through funding resources, paying for speakers, and enabling the science leader to have supply cover to be able to attend PSQM hub meetings.

1.7 Future research

The research provides evidence that developing science leaders in school has a positive impact on attitudes to science. In future it would be interesting to see if there is a direct link to attainment in science at the end of primary school, and of further engagement and attainment in secondary school and beyond.

2 Research context and aims

2.1 The context

Attitudes that are developed in primary school can have a lasting impact on the future involvement of pupils with science in their secondary settings and beyond (Royal Society, 2010; CBI, 2015). Drawing on the work of the Economic and Social Research Council (2013), the Wellcome Trust emphasize that:

> 'It is therefore essential that all primary school pupils experience inspiring science that builds their understanding of the value and place of science in their lives. This will lay the bedrock for their future studies, enable them to make well-informed decisions in our increasingly hi-tech world and give them access to a wide range of rewarding careers.' (Wellcome Trust, 2014, p. 4)

The PSQM is an award programme with the following 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
- to use networks to provide local support for science for schools
- to assemble a rich database of current practice in primary science and make it accessible to the wider science education community.

Primary school science subject leaders apply to take part in the PSQM programme and are appointed to local PSQM hubs. These are led by PSQM-trained experts in primary science who support subject leaders through the year-long programme of professional development, school-based evaluation, action planning and implementation to develop all aspects of science teaching, learning and subject leadership. This culminates in subject leaders submitting a set of reflections and supporting evidence on practice in primary science in their school. The schools which have bursary-funding from the Royal Society of Chemistry (RSC) were selected because they were new to PSQM, were initially working at bronze (introductory) level and were in an area of identified need with respect to access to primary science continuing professional development (CPD). Some schools submitted at silver level because they had exceeded the descriptors for each of the criteria for the award.

Schools that are accepted for the bursary pay £150 of the application fee whilst the RSC pays the remaining £500 of the application fee and additionally provide £500 towards costs of cover for teachers to be freed for CPD. Additionally the RSC are providing access to a developing primary website (Learn Chemistry), which has primary focused resources and videos. A condition of funding was commitment to the evaluation process.

2.2 The aims

The main aim of this research was to explore the impact of the scheme on attitudes and aspirations of pupils and teachers with respect to science and to provide evidence to inform future RSC policy decisions regarding bursary-funding for the PSQM scheme in new schools. The results might also inform future direction of funding to strengthen primary science, for example, with respect to on-line resources and training.

3 Research team

The research was carried out by the following members of the research team at the School of Education, University of Hertfordshire (UH): Dr Liz White, Head of School Direct Routes into Teaching (Project Lead); Dr Claire Dickerson, Research Fellow; and Julia Mackintosh, Deputy Programme Tutor, School Direct Routes into Teaching.

4 Research methods

This practice-focused research took an interpretive approach to understand the attitudes, behaviour and thinking of the participants. Data collection methods included: an email questionnaire; semi-structured telephone interviews; a focus group with science leaders; and a review of some of the data available on the PSQM portal. In total, twelve science leaders participated in the research. The participants were 'conversational partners' in the research (Rubin and Rubin, 2005, p. 14).

4.1 Science leaders (Round 8): email questionnaire

Eight science leaders in the eight schools that registered for the RSC bursary-funded PSQM in May 2014 (Round 8) were sent a questionnaire with open-ended questions via email. Two leaders responded as a result of follow-up. The draft questionnaire was piloted with a hub leader and other colleagues and revised in the light of feedback.

The two science leaders who responded to the email questionnaire also contributed to the data available from the PSQM portal (Section 4.4).

4.2 Science leaders (Round 9): telephone interview

Three science leaders in three schools, representing hubs that enrolled for the RSC bursary-funded PSQM in September 2014 (Round 9) were invited to take part in a telephone interview. These schools were selected by hub leaders. One science leader responded to the invitation and took part in an interview, which was recorded digitally and partially transcribed. The interviewee was sent the relevant set of 'key points' so that they could add, remove or amend any of the text. In order to maintain confidentiality this data will be disseminated with the data from the focus group.

4.3 Science leaders (Round 9): focus group

The hub leader and the science leaders from three primary schools that registered for the RSC bursary-funded PSQM in September 2014 (Round 9) were invited to a focus group to share their experiences. A science leader from each of the three schools was willing to take part but at short notice one was unable to attend and was replaced by a second leader from one of the other schools. The participants were as follows:
Y3 teacher, new science leader (in role from Sept 2014) from school X.
Y5 teacher, experienced science leader from school Y.
Y4 teacher, new science leader (in role from Sept 2014) from school Y.

Others present during the interview as observers: the PSQM hub leader and a representative from RSC. The Year 5 teacher looked directly at the hub leader at the start of

the interview when she answered questions, but after the first 2/3 questions this did not happen. Having the hub leader and RSC representative in the room may have impacted on participants' answers.

4.4 Data available from the PSQM portal (Round 8)

Sections of the final submission documentation (Criteria C3 and Criteria E, questions 8-10) provided by the eight schools that registered for Round 8 were reviewed for indications of attitudes towards science and chemistry. Extracts of the submissions that were thought to suggest changes in attitudes of primary teachers and pupils towards science and chemistry were marked. Some of these extracts are included in the findings section. These sections of the final submission documentation (Table 1) were identified following a review of the range of documents submitted by one school.

Of the eight schools that registered for Round 8, six were working towards the silver level award and two were working towards the bronze level award.

Table 1 Criteria C3 and E

Criteria	Indicators
C3: Children enjoy their science experiences in school (Criteria C1 – C3 relate to 'Pupils and learning')	***Bronze level:*** When questioned, children in the science subject leader's class talk with enthusiasm about their current and past school science activities. Children's opinions are valued and responded to. ***Silver level:*** 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.
E (questions 8-10 all levels) (Criteria E questions 1-10 relate to 'Science at your school') *Section E includes the following advisory:* Material will become the copyright of the Primary Science Quality Mark, and may be used for publicity, research or internal development purposes. If used to publicise PSQM the school's permission will be sought and the school's name acknowledged. All data use for research or PSQM training and development will be anonymised.	Please answer the following questions about your school: 8) Have there been any particular developments/circumstances in the last three years that you feel you would like to alert the reviewer to? 9) Looking back through this PSQM year, are there any specific science highlights you would look to headline? 10) What do you feel the school's and your involvement in PSQM this year has done for science at your school?

As noted by Turner et al. (2013, p. 7) relating to data from the PSQM portal:

> 'The subject leaders are self-reporting to achieve a PSQM award. Professional and honest self-evaluation is expected, but the requirement to demonstrate that certain criteria were met might have influenced the content. Furthermore, the structure of the framework and the questions that the subject leaders responded to will have influenced their reflections.'

5 Research findings

The findings have been grouped into the following themes:
5.1 Reasons for doing the PSQM
5.2 The impact of doing the PSQM on primary science teaching
5.3 The impact of doing the PSQM on attitudes to science
5.4 Resources for teaching primary science

Some identifiers have been deleted from the findings presented in this section of the report and minimal editing has been carried out, if considered appropriate, including the correction of minor typographical errors in the data from the PSQM portal. In the report the quotations have been coded only according to whether they were collected via the email questionnaire; semi-structured telephone interview or focus group (code I/Q); or according to whether they formed part of the final submission documentation available from the PSQM portal (code S) in order to ensure confidentiality.

5.1 Reasons for doing the PSQM

The science leaders revealed a number of reasons for choosing to do the PSQM including:

5.1.1 To raise the profile of science in their school

> 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.' (I/Q)

> 'We just felt that science had got a low profile since we've been so heavy on numeracy and literacy… no-one really spoke about it. All we really spoke about and had staff meetings about were maths and literacy.' (I/Q)

> '…introducing PSQM at the same time as the national curriculum [for science, new in 2013] meant that everyone had to start something new, so why not start with a bang!' (I/Q)

5.1.2 To learn together with colleagues from other schools and hub leaders

Being able to work collaboratively with other science leaders and with those with primary science teaching expertise was valued.

> 'There was also the opportunity to work with the Science advisor and other School Science Leaders, sharing ideas for best practice.' (I/Q)

‘I have enjoyed sharing good practice and expertise with colleagues from other schools.’ (I/Q)

5.1.3 The professional development opportunity for science leaders

‘In my first year as science coordinator I felt like I wasn’t ready, but in my second year, when I found out more about it, that it was just as much about developing me as developing the children, I thought it would make me a better coordinator.’ (I/Q)

‘…it would be really good to help develop me as a leader and to give me a vision for science, because I did feel taking on science by myself was quite a scary prospect. She [the last science leader] was a hard act to follow, so I think it was a good way of focusing in on science and giving me something, as well as the school to focus on.’ (I/Q)

5.2 The impact of doing the PSQM on primary science teaching

5.2.1 The science leaders were better equipped for their own teaching

Comments were made that related to subject knowledge *per se*, but more relating to pedagogy for teaching science.

‘I’ve got a degree in science so I don’t think my subject knowledge has changed but I think how I teach it has definitely changed…I don’t think my understanding of science has changed but I think my understanding of how children learn about science has changed.’ (I/Q)

‘Definitely improved my subject knowledge, some of the topics in Y5 and Y6 are difficult e.g. evolution, and from lesson observations we have highlighted to staff that you need to go away and study.’ (I/Q)

‘I now feel much clearer about what excellent science looks like. This makes it easier to plan engaging lessons.’ (I/Q)

‘I try to set [the children] a challenge and ask them what they have found out from this experience. I try to eliminate too much teacher talk, the talk now comes afterwards.’ (I/Q)

‘The principles are there to support it [science teaching]. So now, when I’m looking at books, when I’m looking at planning, when I’m looking at lessons, when I’m doing my own planning, I keep that in mind and I think that gives me a clear vision. It gives us forward motion - all together.’ (I/Q)

5.2.2 The science leaders were better equipped for leading others

The science leaders were aware of changes in how they were carrying out this role since starting the PSQM. They were more secure in their role.

‘Before, I was ticking the boxes, doing observations, but I didn’t really know what I was looking for. I was looking at books but I wasn’t really sure what I was looking for

as I was fairly new to the whole process. Now, because we have developed more of a school vision and with the additional CPD that I have had on top of PSQM, I have got a much better view of what it should look like in our school.' (I/Q)

'It [the way that I work with the staff] is more focused. Because we are working towards that same goal, we know what the main areas for improvement are e.g. child-led investigations. Before, I might have gone to CPD, brought it back, shared-out what I did with staff. But now I'm able to take what I get from other CPD, and then think about how that is going to fit-in to our school, so I can definitely be more strategic in terms of my knowledge and things that I pick-up.' (I/Q)

5.2.3 Development of key principles for science teaching

Listening to pupil-voice had provided the foundation for these principles.

'The involvement in the PSQM has given the school a clear vision for science. In developing key principles there is a strong commitment by the teaching staff and the pupils to ensure the science that takes place adheres to these principles. We have been able to look closely at the investigative science aspect of lessons and given children more autonomy in their learning.' (S)

'[The teachers] are clear on the school's principles for teaching science which grew out of pupil-voice activities. These principles include embedding science within topic work and making science hands-on and as child-led as possible. They are clear that children should be given opportunities to learn outside, have science visitors and go on science based trips.' (I/Q)

5.2.4 Pupils were being given more opportunity to ask their own questions

Different approaches were being used to enable pupils to ask their own scientific questions.

'The school has put a greater emphasis on the children asking their own questions' and 'children are encouraged to carry out their own investigations more.' (I/Q)

'Our teaching staff would sometimes include this [pupils asking their own questions] as an objective. However, we have implemented specific initiatives to encourage far more child-led learning, starting with the children's questions. One term each class was given a mystery object. These were the starting point for children generating questions and designing investigations to discover the answers. Our pupil voice exercise highlighted the children's desire to lead their own investigations.' (I/Q)

'It is science week this week and we have the broad theme of air travel. Every year group had their own type of air travel and came up with their own questions and every afternoon they had the opportunity to investigate them.' (I/Q)

'At the start of topics I used to do the 'What do you know and what do you want to find out?' But they don't really know what they want to find out until they have dipped their toes in. So now I do a lesson first and then I ask them if there is anything else they would like to know and they jot it down in their books. Then I try to cover this at some point or towards the end of a topic I ask what they still want to find out and we

go and investigate it. I make a point that if a child asks something that I don't know, that we write it on the board and come back to it.' (I/Q)

5.2.5 Pupils were being given more opportunity to lead their own investigations

From the starting point of pupils generating their own questions, there have been increased opportunities provided for pupils to work scientifically to answer their own questions through investigative work.

> 'I allow children to suggest things that they would like to investigate, I have a science investigation box.' (I/Q)

> 'Child-led investigations - from talking to the children that is something that they wanted, more control, to be able to investigate their own ideas. When you are teaching that is quite scary to do, because you want to provide more structure and control. But there is much more of that [child led investigations] throughout the school now.' (I/Q)

> 'In a lesson on magnets the children had to test the strength of different magnets. They had to devise their own investigation, collect their resources, find out the answer and then report back. We then compared investigations to see which was the most accurate and that was very informative for me. I could see that they were far more capable that I had thought.' (I/Q)

5.2.6 The schools had developed a wider range of learning opportunities

Schools were using outside learning, having science visitors and going on science-based trips. These strategies to engage pupils were being implemented in conjunction with a focus on child-led and hands-on learning across the school.

> 'This time I am doing separating materials, doing solids, liquids and gases, so in hindsight the way that I'm going to teach it is different to the way I would have taught it in the past by just putting the materials out there for the children to devise their own experiments. In the past I would have given a question such as 'how can we make water evaporate faster?' but I will say something like 'what effects evaporation?' Getting them to think of their own questions.' (I/Q)

> '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.' (I/Q)

> There are 'more child-led investigations, because they are starting to know about the different types of inquiry, that has started to be embedded within teaching. So children are starting to be able to identify which line of inquiry for a particular investigation. And taking more risks.' (I/Q)

> 'We have seen different ways of things being taught, different contexts and scenarios. In Y6 they were doing selective breeding, in the style of a debate, the teacher spoke to us and said if it hadn't been for this [PSQM] she wouldn't have

known where to go with it. We observed it, all the children understood, they knew what they should be doing. It was really good.' (I/Q)

'... in KS1, and in KS2, we saw really nice contextualised learning e.g. stories that support the lessons: The cat wants to go to sleep, which materials should we use for its box? Which is darkest? The children had to test the materials.' (I/Q)

5.2.7 The transition to pupil-led learning had not been easy for many teachers

Pupils were not used to working independently and some pupils did not do well. The teachers found it difficult letting go of controlling the investigative work.

'It is important to have the prior skills and to be able to work independently as well as being able to think for themselves. Thinking skills are an issue in our school, so we are trying to focus on this. It takes a lot of practice, getting the children to take risks.' (I/Q)

'I think this is an area for us to work on. We still have quite a long way to go with that. I am finding in Y5 that as it is fairly early days, the children have not had all of this all the way through school. In my class we looked at 'What is the best material for a mountaineer's jacket?' We used hot potatoes and wrapped them up to see how the temperature dropped but they lacked skills that I thought they might have. They are an able year group, so I think this is because [the focus on] independence in science hasn't been there all the way through school. So I still have to feed a lot to them, so it is something that we have to continue to build.' 'Although they didn't all do well, working like this enabled pupils to take first steps in planning an inquiry e.g. using a thermometer and testing different things. They did get something from it. If I had just given them a worksheet and told them to complete it, then they really would have got nothing from this investigation.' (I/Q)

'… I looked at how to transport an egg from a space to the ground without breaking. I found that some children just wanted to wrap it up in all of the materials that they had, others thought more deeply about it. So it is a bit of a mix.' (I/Q)

'The children are so used to teachers standing there and confirming everything that they do and guiding what they do, that they find it difficult.' (I/Q)

'It is knowing when to intervene. Sometimes it is OK for the children to make an error, but sometimes you have to intervene, otherwise they learn nothing from the activity.' (I/Q)

'It is hard when you have a range of abilities. Some are quite able, some aren't and it is a minefield, trying to identify children's strengths and weaknesses in this area. They might be brilliant at the subject knowledge, but not good at this [working scientifically] and it is very difficult to assess this and group children accordingly.' (I/Q)

'… making it more child-led rather than giving them questions to investigate, it is getting them to devise their own questions. Initially it seemed quite hard; I was

struggling to get them to be able to think of their own questions. Now they seem to be a lot more able and willing and are using the correct vocabulary and having the right approach. I think it worked very well because last term the topic was forces, which is very, very investigative and very investigation-led and every week it was an experiment …' (I/Q)

'The challenge is standing back and not being in control. I think as teachers we like to make sure everything is done in an organised approach.' (I/Q)

5.2.8 More cross-school consistency in the quality of teaching primary science

The key principles for teaching science supported cross-school consistency. There was increased clarity and confidence in what good science teaching looked like in the school.

'We [the teachers] were all doing completely different things and had a different take on science and how to do it. Now, because we have led a couple of staff meetings based on what we have done here [PSQM training] we are all going down the same route. There is more consistency.' The inconsistent approach was seen as a barrier to effective teaching 'especially when you have NQTs and a high turnover of staff. They can now fit-in with our vision. That definitely helps.' 'Also [before PSQM] we didn't have a clear vision of what good science teaching should be across the school.' (I/Q)

'In the past I would do a staff meeting based on some CPD that I have had, but it wasn't as direct as it is now. Now I say 'This is what I did, this is how it will fit-in with our principles of child-led investigation, you could do this, this and this'. So it's rubbing off. There's better leadership. Now we are following it up. Before I would say 'You could do this… This is a nice idea to try…' Now I say 'You could do this, this is what we see as best practice' and then when we give feedback [after lesson observations] we can say 'That was really nice' or 'Perhaps next time you could put that in a context' because we are following it through now.' (I/Q)

5.2.9 Enrichment in teaching, learning and assessment in primary science

There was substantial evidence for enrichment across all areas of primary science teaching, learning and assessment.

'We have introduced floorbooks, which all the teachers have been quite happy about, which potentially reduces marking, and it's just photos and the children's comments and maybe photo's about how the children have recorded their findings or the conclusion or something like that rather than going through doing aim, equipment, method, results.' (I/Q)

'Teachers are clear on how to meet the new curriculum objectives and assess against them.' (I/Q)

'Our dialogue and marking really helps the children to feel as though they are being responded to and that what they are doing is valued. SMSC (Spiritual, moral, social and cultural development) is evident in all classes which enables children to be

confident to ask questions and find things out for themselves. This in turn allows children to take control of their own learning.' (S)

'We have had lots more links to maths as well. We found out that science was just [using] bar charts but we are finding much more inventive ways of linking to maths, using pulse rate and ordering decimals, that kind of thing.' (I/Q)

'Children spoke about how they loved begin forensic scientists to solve the 'disappearance' in year 6, and key 1 pupils were full of information about the Zoolab creatures that visited them. Each year group was able to give specific examples of investigations that had taken place in their current science unit and many discussed either trips out or visitors that made science seem real for them.' (S)

'[Children] felt that they had more control over the direction investigations took, with 60% of children commenting that that is the aspect they liked about science – planning and carrying out investigations for themselves. Only 20% of children mentioned the recording aspect of science negatively and one of the other children responded that they liked it when one member of the team was given the job of photographing the experiment to produce evidence of what they found out when looking at dissolving in year 6. A twilight is planned in for the summer term on alternative ways of recording in science.' (S)

'Being involved in the RSPB Big Schools Bird Watch created a real buzz around the school and allowed children to become experts in identifying species of birds. The forensic Friday lessons in year 6 had a similar effect and children were keen to learn more about the role of forensic science in modern day police investigations. The development of a science club during golden time has seen children really excited about science and keen to take their learning home to continue experimenting and sharing what they have learnt with their parents.' (S)

'During PSQM stronger links have been made with a local secondary school which has helped cater for the needs of more able scientists in year 6.' (S)

5.3 The impact of doing the PSQM on attitudes to science

5.3.1 Science leaders' attitudes to teaching science

Science leaders' enjoyment and confidence in teaching has grown. They take more risks, use more resources and are more motivated to prepare more deeply for their teaching.

'I have enjoyed teaching science more since working towards the PSQM as I am thinking more about my teaching...' (I/Q)

'My class love science. It has become a favourite lesson for us all.' (I/Q)

'It's a lot of work. It's all been really positive...' (I/Q)

‘I am far more critical of my own teaching, I want it to be as good as it can be. It has made me look further for materials, resources and ideas.’ (I/Q)

‘I have tried to find ways to make my lessons more engaging and rather than me talking for half an hour, I try to let the children be more involved.’ (I/Q)

‘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 I successful learning looks like.’ (I/Q)

‘I take more risks. I have been in Y3 for a few years and I was becoming complacent with the way that I was teaching science. With the new national curriculum and the PSQM I take more risks, I use more resources. The PSQM has given me something to focus on. Using the principles and talking to the children, I have a much clearer vision of what they want within a science lesson, so I try to adhere to that rather than what I have been used to doing.’ (I/Q)

In terms of science topics, one science leader commented:

‘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.’ (I/Q)

5.3.2 Science leaders’ attitudes to leading primary science

Science leaders’ enjoyment and confidence in leading science within their school has grown. Their leadership is more flexible, guided by a clear shared vision for primary science within the school. They were excited by the fact that other teachers were being inspired to teach science in a more engaging way because of their leadership. They were motivated because of the outcomes on pupil attitudes.

‘Initially, I was just down in name [as science leader] and didn’t think there would be that much to do apart from just keep on top of resources and an occasional book trawl or something like that but we have really upped the profile so it’s been really good. Going round looking at displays, that’s been a big thing… That’s been another change I think.’ (I/Q)

‘We have tried to help the staff to be more creative, so it’s trying to share a range of resources with the staff. We are not as rigid as we were.’ (I/Q)

‘For me the motivation comes from the fact that I am leading by example. You are the one that staff are going to come to, so you feel that you have to know things, or at least be willing to go and find out.’ (I/Q)

‘I have developed professionally. I’m more confident, I’m more willing to lead staff meetings and drive things forward. I do learning walks, observe lessons, book scrutinies, which is something that I have never done before.’ (I/Q)

‘I think [I am more confident] because I have a clear vision. I feel that the staff are on-

board because they also see that vision. It is empowering because it feels like I'm not on my own. There are other people with you, working towards the same goal. 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. It has taken a good six months, but slowly, through children's comments, you start to feel like I am actually making a difference.' (I/Q)

5.3.3 Teachers' attitudes

Many teachers were working harder and were more creative. They were feeling encouraged by the response of the pupils. They were talking more about science and were feeling more confident about using resources for teaching primary science. Some staff were finding it harder to embrace the changes.

> 'Teachers in the school have worked hard' and 'they have put much more effort in…' (I/Q)

> 'The teachers are encouraged by the children's levels of engagement and enthusiasm.' (I/Q)

In one school, before they started the PSQM:

> '…everybody was teaching it [science] and was quite happy about it, it was just that no-one really spoke about it'. (I/Q)

At the end of the PSQM year the science leader thought that:

> '…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. Before we were always talking about numeracy and literacy.' (I/Q)

> 'They [other staff] feel more confident using them [resources]. They know what is there and that it is relevant to what they are doing.' (I/Q)

> 'We have started to use things like data loggers and ramps, that we had before, but never used. The staff are now more willing to go away and make things. One of the teachers went away and made a frozen hand to look at melting.' (I/Q)

> 'In science week this week I went in to pick up some resources and the cupboard was empty! That is the first time that I have ever seen that cupboard empty, which is great.' (I/Q)

> '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.' (I/Q)

> '…there is no reason why it [the positive changes] can't continue with the remaining

year groups. I think people are much more willing to do things and they have embraced it. Because it echoes where we are going with maths at the moment, in terms of child-led, so a lot of it has come from maths, we have been able to piggy-back on that. We can say 'Look, it's very similar' and so the two subjects have married together really nicely. So that has fed into what we are doing too.' (I/Q)

'…the clear growth in confidence of the staff when leading investigations has directly led to the growth of enjoyment of the pupils and to higher levels of attainment, especially with higher ability pupils.' (S)

5.3.4 Pupils' motivation and enthusiasm for science

There has been an increase in the pupils' motivation and enthusiasm for science since the schools have taken on doing the PSQM.

'…when I said it was science they all groaned. We don't get that any more. They say 'Yes!' The general feedback is much more positive from the children.' (I/Q)

'It has been wonderful to see the children so enthused.' (I/Q)

'The children are excited for science lessons, they want to know when the next one is. They are enjoying it and they are more engaged when they are in the lessons.' (I/Q)

'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 anymore.' (I/Q)

'It's really nice to see the children who were not excited by science more engaged. It is the whole class now, not just individual children who had a flair for science.' (I/Q)

'A pupil voice focus group …. has been carried out … and the children spoke with enthusiasm about scientific activities and how they think their learning has benefitted. In the children's own follow up work to scientific experiences and investigational work, they have shown enthusiasm for the activity and the subject. When writing comments on their reports to go home, teachers mentioned the children's enthusiasm for practical science experiments and development of skills and understanding.' (S)

'The enjoyment of science across the school is evident whenever you walk into a science lesson, children are always engaged in their learning and completely on task. This can be seen in our lesson observations, learning walks and pupil voice evidence. During our Ofsted inspection in [date] the inspector commented that 'Our learning is full of joy' which is evident from reception to year six across all subjects.' (S)

5.3.5 Pupils' scientific engagement within and outside the school

Pupils are continuing their science interest beyond the classroom through informal and structured opportunities:

'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. At the start of the year a few children said that there was too much teacher talk, now the situation has changed. They are much more enthusiastic, their comments show that they are looking forward to science and they go off and do their own science at home. Which is lovely.' (I/Q)

'Children take more pride in their science work because of their improved attitudes and there are more head teachers awards given for science giving science more recognition. Children are keen to take on science roles and give their opinions on science to help improve their lessons this is particularly evident in the older year groups such as year five and six. Children look forward to the change in the termly display in the corridor and interact with this asking and answering questions. The increased visibility of science around the school has encouraged further children to discuss and want to share their science learning with others.' (S)

'In Y6 they were looking at buzzers and created a game like 'Operation', they were so enthusiastic because the teacher was more willing to take risks. They feel like they are allowed to take risks. There doesn't have to be a write-up, where 'it has to be like this'. I have said to them that this is fine. So this has empowered them to do this.' (I/Q)

Highlights of the PSQM year were:

'The excitement engendered by science visitors and trips. The children's learning has been greatly enhanced by these experiences. It was a pleasure to witness the wonder and excitement on the faces of Year 1 children when animals (including a chicken) arrived in their classrooms. Seeing Year 3 children on the beach…making the connection that the cliff behind them and the rocks under their feet were the same chalk that they had investigated in class was another great moment. Getting children learning outside. The gardening programme, in particular, has been a great hit with the children. Their fascination with the plants and mini beasts they encountered and the pride they took in their work to improve their school grounds was wonderful.' (S)

'As Subject Leader I was particularly proud of the Science Assembly performed by my own Year 3 class. The children shared their Science learning on magnets, plants and rocks using songs, poetry and acting. They showed video footage of the pupil interviews they had conducted. One child acted as technician dealing with the power point presentation, accompanying music and video. This event combined their learning in Science, Literacy, Drama and ICT. However it particularly showcased Science. They enthused their audience, both children and parents; teaching them some great Science facts. There was so much great audience feedback, including several comments of, 'The best class assembly ever!' (S)

'The children I worked with enjoyed their science before. However science is now more embedded within topic work and therefore more purposeful. In response to the pupil voice exercise we have all classes have had a science visitor or trip. All children

have been conducting 'hands-on' investigations. So engagement and enthusiasm is at a high. This has been evidenced in pupil led science interviews.' (I/Q)

'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.' (I/Q)

'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.' (I/Q)

Listening to the pupils' voice prompted one school to focus on developing the use of the school grounds, which has led to more positive attitudes to science:

'The children, although they liked it [science], they wanted to be a lot more outdoors, they wanted it to be more fun, they wanted to do it more often'. Now 'people are using the outdoor environment a bit more. They are focusing on at least one investigation per half-term per topic. Quite often we'd find people didn't get the equipment out… but now people are making sure they focus on it.' 'When we did the same interview at the end of the autumn term we found that they were a lot happier with it.' (I/Q)

'…the children were assigned a case that required them to use simple ideas about chromatography to identify a criminal. This idea was further developed in English written work and was enjoyed by all. The latest survey shows that solving scientific problems are now being enjoyed by all year groups.' (S)

'One of the least popular areas of science learning was plant science. Since this survey teachers have made much more use of the pond and other areas around school to develop children's understanding about plants and how they fit into the local food webs. Pupil enjoyment of plant science has increased significantly in the later survey.' (S)

Two science leaders felt that the most important principle for their school was:

'Children are enthused by science and lessons inspire their curiosity'. '… we are in quite a challenging environment, we need to make science real life, worthwhile and to show them where the subject can take them. Also, when you have lessons that are making them think you don't need to worry about their behaviour. It all comes through their learning.' (I/Q)

5.3.6 Pupils' awareness and understanding of science is improving

The pupils are more positive about science, use more scientific vocabulary and their understanding of science is developing.

'They [the children] are using a lot more technical vocabulary and being a lot more positive about it. I think just because we as teachers didn't speak about science as much as we do now the children didn't speak as much about science.' (I/Q)

‘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.’ (I/Q)

‘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.’ (I/Q)

‘I was collared on the playground by a parent saying ‘Did you know there is an eclipse on Friday?’ So they know we are the people to speak to about science and they want to make sure that their children were involved in that process. We have never had that before.’ (I/Q)

‘…children are much more motivated they are more willing go out of their way to find things out e.g. get out science library books. So their understanding of science is slowly, but surely, improving.’ (I/Q)

‘We have a whole-school display where we share work, which was suggested by PSQM. It is near the dinner hall and I have seen even really tiny children looking at the pictures to see what is going on. It has raised the profile of science.’ (I/Q)

5.4 Resources for teaching primary science

The PSQM prompted an audit of resources for teaching primary science available in the schools. The responses varied between schools who felt they were well resourced and those who needed to increase their resources.

‘Because we have a clear vision now, we know what type of resources we want. When I first started as a science coordinator, I went into the science cupboard and I just shut the door and walked out – there was so much rubbish in there! Now we feel we have a better grip on [science in] the whole school, we know what people need, we have asked the staff what they want, they have told us what they would like. In our role as leaders we listen to what people need and can get rid of stuff that is no use.’ (I/Q)

‘Our resources have not really changed as we were in the fortunate position to have a great range already. I am now much more aware of the resources that are required throughout the school.’ (I/Q)

‘We did a big audit of the resources and threw away a lot of really old things and found a lot of things that we didn’t know we had… no, we haven’t looked into a scheme or anything like that. No, I think resources are pretty okay and everyone is quite *au fait* with the resources.’ (I/Q)

‘There was a lack of resources that correlated to the new national curriculum e.g. data loggers. Through doing PSQM, because we were trying to raise the profile of science, there has been more of a budget for resources.’ (I/Q)

‘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.’ (I/Q)

5.4.1 The contribution of the RSC on-line resources

None of the participants in the focus group or interview had used any of the resources on the website in their lessons. But they agreed that they were very high quality resources. The difficulty was finding a way to apply them to what they wanted to teach. Only one science leader commented on the resources made available to them through the RSC website without being specifically prompted. They reported that they had used the RSC resources in their school to enhance the teaching. Therefore it seems that these resources have made very little impact on primary science teaching within these schools mainly because the teachers could not see their relevance to the primary science topics.

‘The use of the Royal Society for Chemistry resources has enhanced the teaching and provided children with opportunities for problem solving, often linked to their learning journeys.’ (S)

‘I’ve had a look at some [of the RSC resources on-line] and some of the ones to do with gases I recommended to my year 5 colleague. I haven’t used any personally for my teaching although there might have been some video links that I might have used. You use so many online things… I couldn’t give you a specific example now.’ (I/Q)

‘I tried my best! I spent hours searching, but I couldn’t find anything that was relevant to the units that we were doing. I found the site quite difficult to navigate - but it is very inspirational. I watched quite a few of the videos and shared them with staff and they were very willing to use them but across the board they said that they couldn’t find anything that would link with what they were doing in class.’ (I/Q)

‘The website is very difficult to use. Once you have found your section, you’re fine, because it is all there. But then I found that when I have been using the Snap Science [purchased teaching framework and resources], it is hard to marry the videos [on the website] with the Snap Science.’ (I/Q)

‘When we showed the staff everyone thought that it was really good. I really like being shown how to do things, so that aspect was very good. We gave out links to [to the videos] to staff, but without the links it was very hard to find things on the website.’ (I/Q)

‘There are things on the videos that don’t necessarily link to the units, so the videos were really good for science week. As the new national curriculum states, there is the opportunity to go over and above the national curriculum, so science week was an ideal opportunity to do this.’ (I/Q)

‘… it is a real shame about the RSC resources as I was really keen to use them. If it was set out by year groups or by topics, then it would be a lot easier to use. They would be really useful resources to have.’ (I/Q)

5.4.2 The contribution of the RSC bursary

The subject leaders identified how the RSC bursary has benefitted their school through funding resources, paying for speakers and enabling the science leader to have supply cover to be able to attend PSQM hub meetings.

> 'From staff meetings, I have asked colleagues in my school which science resources they have found the most useful. This has highlighted the need for good quality film clips. I have used some of the bursary money to address this issue.' (I/Q)

> '…it has really helped us to buy things. It has really helped us to buy things that we wouldn't have bought without the bursary e.g. resources and getting speakers in.' (I/Q)

> 'We haven't spent a lot of money on resources, we have spent more on experiences for the children e.g. speakers to come in and one year group went on a trip. Because I don't think you have to spend a lot on resources to make science good.' (I/Q)

One science leader felt that their school might not have done the PSQM without the bursary:

> 'because there have been a lot of times when I have had to have supply teachers [in] and things like that.' (I/Q)

> 'I think we would have done this year [whether or not there had been a bursary]. But due to budget cuts in these uncertain times I couldn't say for definite.' (I/Q)

6 Discussion of key findings and implications for practice

There is a current lack of focus on primary science teaching in schools in England because of the drive for improvements in literacy and numeracy and the associated focus on the league tables for schools (Turner et al., 2013). This recent continued lack of focus on primary science, together with the launch of a new national curriculum for science (Department for Education, 2013), has produced a recognition of the need for primary science to have a higher profile (CBI, 2015). This was highlighted by some of the participants in this research project who chose to do the PSQM to raise the profile and quality of science teaching and learning in their schools. The schools that were selected to be involved in this pilot project with RSC-bursary funding had not previously focussed on science. The science leaders who were involved in the research were keen to do the PSQM because of the professional development it would provide for their role and the opportunities they would have to work collaboratively with other science leaders.

PSQM programme impact

The findings suggest that the positive impact of the PSQM programme includes:

- *Developing science leaders in their leadership role*. There was a lot of evidence for changes in the way that science leaders were carrying out their role, both what they were doing and how they were doing it. They were enthusiastic and leading through example; becoming more secure in their identity as a leader and more articulate about their expectations. They were actively monitoring and encouraging feedback

through a variety of methods in order to be able to evaluate the engagement of the pupils with science (across the school, in the case of those going for the silver award). This is in line with a previous report on the PSQM, which states that:

> 'Training and professional development are at the heart of PSQM. Many schools have experienced a change in CPD culture as a result.' (Ponchaud, 2011, p. 1)

- *Developing a constructivist approach to learning science*. Constructivist approaches, including inquiry-based learning, hands-on approaches, child-led questioning and investigations, has had a significant impact on the pedagogy of the science leaders and the teachers in their schools. According to Harlen:

  > 'The concept of inquiry-based pedagogy is by no means new but it has been promoted actively in science and mathematics education in recent years because of its potential to lead to the understanding, competences and attitudes that are needed by everyone in increasingly technology based societies' (Harlen, 2013, p. 10)

  The transition to pupil-led learning was challenging for some teachers.

- *Changed science teaching practices across the school*. In 1985 Guskey suggested that teachers did not change their practice as a result of embracing new attitudes and beliefs, but rather a sustained change in practice came from experimenting with a possible change first, then through seeing an impact on pupil learning there is a change in the attitudes and beliefs of the teacher. This research project provides strong evidence that this is the case. The science leaders were motivated about sustaining changes to their science teaching and leading because they could see a positive impact on the children's attitudes to science, for example:

  > '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. It has taken a good six months, but slowly, through children's comments, you start to feel like I am actually making a difference.'

  The findings suggest that teachers' confidence and risk taking had increased.

- *A more consistent approach to science teaching across the school*. This was supported through the development of key principles for teaching science which had arisen through listening to pupil-voice. These key principles have also raised the confidence of the science leaders to carry out their role. A wider range of science learning opportunities were being provided through the use of resources, visitors, the outside environment and visits.

- *Developing more flexible and innovative approaches to assessment strategies.* Harlen suggests that it is important that we give more attention to developing alternative approaches to assessing inquiry-based learning, as 'it is difficult to provide valid measures of the outcomes of inquiry using conventional tests' (Harlen, 2013, p. 32).

- *Teachers and pupils talking about science more*. Pupils were more engaged and were continuing their science interests beyond the classroom.

- *More pupil enjoyment of science*. This is in line with the findings of the Wellcome Trust that:

    '…where science has a good profile within the school as a result of dedicated leadership, and where staff are expected to teach exciting, investigative science with access to high-quality science expertise, children are likely to enjoy learning the subject.' (Wellcome Trust, 2013, p. 3)

  Attitudes to science have been evaluated through self-reporting of the science leaders and through their observation and monitoring of the engagement of teachers and pupils. Although there may be some doubt in self-reported attitudes the observation of behaviours indicating dispositions is thought to be more reliable (Royal Society, 2010). The Royal Society report on science and mathematics education 5-14 noted 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.' (Royal Society, 2010, p. 65)

  The science leaders were able to observe teaching, displays, scrutinise pupil work, listen to feedback from pupil panels and from their colleagues. They also observed informal interactions relating to the profile of science in their school. Science leaders reported attitudes, in terms of interest and liking, associated with specific science topics as well as a generalised sense of engagement, for example:

    'My class love science. It has become a favourite lesson for us all.'

  They also reported increased teacher confidence and pupil attainment:

    'the clear growth in confidence of the staff when leading investigations has directly led to the growth of enjoyment of the pupils and to higher levels of attainment, especially with higher ability pupils.'

  The correlation between attitudes and attainment cannot be taken as indicating cause and effect. It is possible that positive attitudes could lead to more effort and therefore higher attainment, although attitudes to science do not always seem to be strongly associated with attainment (European Commission, 2007; Royal Society, 2010). Attitudes include the dispositions of 'interest, liking and confidence in being able to succeed. These are dispositions that are likely to affect decisions about future involvement in science' (Royal Society, 2010, p. 68).

RSC contribution

There were diverse funding needs for raising the profile of science in the schools, with some schools enhancing their resources and others investing in science visitors and visits. The RSC-funding was probably not significant in schools choosing to do the PSQM, however it did enhance the provision in the schools, enabling them to advance their vision for science teaching and learning.

The quality of the on-line RSC resources was recognised, however the teachers' comments suggest that the website could be reviewed by practising primary science teachers in order for the resources to be flagged up in a way that helped them to match the resources to the topics that they were teaching.

This research advances our understanding of the attitudes of primary teachers and pupils towards science. In primary schools science is taught through national curriculum topics, so the teaching of biology, chemistry and physics is not explicitly separated in the classroom. The segregation of science into constituent disciplines is not a priority in primary science. Therefore evidence distinguishing attitudes towards chemistry in particular is not easy to obtain. However within the responses of the participants we identified seven references to topics that could be classified as more chemistry-focussed, eight references to topics that were more biology-focussed and eight references to physics–focussed topics. Examples are where the science leaders commented positively on teaching the rock cycle through a trip to the beach and the separation of substances by chromatography through a forensics project:

> 'Seeing Year 3 children on the beach…making the connection that the cliff behind them and the rocks under their feet were the same chalk that they had investigated in class was another great moment.'

> 'The children were assigned a case that required them to use simple ideas about chromatography to identify a criminal. This idea was further developed in English written work and was enjoyed by all.'

The range of chemistry-focussed topics commented on was very narrow compared to the range of biology- and physics-focussed topics. This could be because the participants in the research were more actively involved in specific year groups which may not have been teaching a range of topics that were chemistry-focussed.

This research was designed to provide evidence to inform future RSC policy decisions regarding bursary funding for the PSQM scheme in new schools. The results could also inform the direction of future funding to strengthen primary science, especially chemistry, for example with respect to on-line resources and training.

Future Research

A future area of research that would be interesting to explore could be the link between doing the PSQM and attainment in primary science at the end of KS2 which would also provide evidence for the impact of inquiry-based learning on attainment. This has also been highlighted by Harlen:

> 'Despite the strong arguments in favour of inquiry-based science education it appears that clear and convincing quantitative evidence of the promised impact on students' measured learning is sparse, even though there is anecdotal evidence that students enjoy and are engaged by inquiry-based activities' (Harlen, 2013, p. 22)

The current research provides underpinning evidence for the PSQM programme, suggesting that it is raising the profile and quality of primary science across the schools sampled. Some of the participants were identifying that pupils were more engaged in scientific activities both

within school and beyond school. Parents were also becoming more involved with the science teaching in school.

A further area of research would be a longitudinal study exploring the link between doing the PSQM and engagement and attainment in secondary school and beyond. This could provide evidence of an impact beyond the primary setting. The need for well-informed citizens who are able to make judgments about current issues based on a good understanding of science is vital to the future of the UK and beyond (Wellcome Trust, 2014). As is the need for an interest in science to meet future demand in the workplace:

> 'The skills pipeline for the future manufacturing workforce begins with primary school children and young people, whose interest in manufacturing needs to be consistently sparked, captured, maintained and stimulated. Given the likely future demand for workers at apprentice, technician and degree level with STEM qualifications, greater effort needs to be made in reaching out to children at primary school to ensure that they are encouraged to study STEM subjects to keep their future career options open, and to stimulate their interest in science, design, and 'how things are made and work.' (Foresight, 2013, p. 188)

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