Teachers' perceptions of Inquiry-Based Science Education (IBSE) and the implications for gender equality in science education

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Abstract

This paper explores the perceived effectiveness of teacher training covering inquiry-based science learning for primary school children in England. Teachers who initially took part in teacher training between 2011 and 2013 as part of the FP7 project Pri-Sci-Net were interviewed during spring and summer term 2014; teachers were asked to reflect on their students' reactions and engagement. Teachers' responses were thematically analysed, and the implications are discussed within the context of longer-term implications of primary science education on girls' attitudes and aspirations in science across their subsequent education.

Keywords: Gender, interviews, inquiry, professional development

Introduction

In England and in many other countries, there is a need for more students to study science in order to foster higher scientific and mathematical skills and to accordingly increase both individual and national prosperity (British Academy, 2015; OECD, 2015b). However, concerns remain over the relatively low numbers of students studying science subjects in further and higher education, and the low representation of girls studying science (Institute of Physics, 2014; Murphy & Whitelegg, 2006; Royal Society, 2006, 2011). Teachers have an important influence on students' engagement with science and their future choices: teachers can provide direct advice and support, show enthusiasm and help to foster the interest and engagement of students, and develop students' skills and experiences through various teaching and learning approaches (Murphy & Whitelegg, 2006; Reiss, 2004).

Attention has recently focused on primary school teaching to ensure that students' initial encounters with science can ideally be positive (CBI, 2015; Ofsted, 2013; Wellcome Trust, 2014). Fostering initial and continuing interest in science remains important, especially as declining attitudes towards science as students grow older have been considered a major cause of the low numbers of students studying science later in their careers, especially girls (Archer *et al,* 2010; DeWitt & Archer, 2015; DeWitt, Archer & Osborne, 2014; Murphy & Beggs, 2003; Murphy & Whitelegg, 2006; Royal Society, 2010, 2011).

Primary school students in England generally enjoy science, but have not necessarily seen themselves as becoming scientists; these students have perceived school science as less exciting than their ideas of 'real science', for example, and girls have had lower identification with some areas of science than boys (Archer *et al,* 2010). Similar results have been observed in other countries, where primary school students have enjoyed science and believed that they were good at it, although girls have expressed lower views than boys (Denessen, Vos, Hasselman & Louws, 2015). In another study outside of England, boys and girls have expressed similar attitudes towards a range of areas associated with science and everyday life, although slightly more boys than girls agreed that people need to be 'clever' to do science (Kirikkaya, 2011). While primary school students have considered science to involve investigation and recognise its benefit to society, they have not necessarily wanted to become scientists (Archer *et al,* 2010; Silver & Rushton, 2008). While they have enjoyed the practical and collaborative areas of science, their attitudes towards science and technology have been seen to decrease over time, and girls' enthusiasm for science has declined more than that of boys (Jarvis & Pell, 2002).

Teachers' attitudes and enthusiasm towards science have associated with primary school

students' enjoyment in learning science, where female teachers' attitudes especially associate with those of girls (Denessen, Vos, Hasselman & Louws, 2015). In primary schools, teaching practices may variously facilitate girls to engage or disengage with science through implicit gender dynamics, for example where girls may begin to defer to boys and take less initiative in investigations. Working together in single sex groups, or offering students the freedom to choose how they work, has been seen to help avoid such issues (Cervoni & Ivinson, 2011). Variation across primary school students has nevertheless been seen, with some girls exhibiting strong involvement, confidence and assertion (Cervoni & Ivinson, 2011).

Wider research indicates how important it is for teachers to present science in a way that engages girls and encourages their learning and development. Students with a high interest in their science lessons were more likely to want to continue with non-compulsory physics, and having the opportunity to engage in more hands-on learning was positively associated with secondary school girls wanting to study non-compulsory physics (Mujtaba & Reiss, 2013). Problematically, compared to boys, girls reported: fewer opportunities to explore, discuss, and test their ideas in class; lower perceived support from teachers in helping them to learn physics; and lower levels of looking forward to and enjoying their physics classes. Girls were also less confident about their ability in physics tests (Mujtaba & Reiss, 2013). Interviews with girls across primary and secondary schools have nevertheless highlighted that girls of all ages were positive about their school science experiences, with the older girls mentioning physical and biological areas as among their favourites, and preferring problem-solving and hands-on activities; however, teachers were often blamed for when science was perceived as boring or irrelevant (Baker & Leary, 1995).

Overall, a large body of research explores students' attitudes and perceptions of science, often relying on quantitative surveys of secondary school students, although some also consider primary school students (DeWitt & Archer, 2015; DeWitt, Archer & Osborne, 2014; Mujtaba & Reiss, 2013). While these methods are extremely helpful in exploring the relative importance of different aspects of students' attitudes to science, more research is needed in order to determine what facilitates students' engagement with science at primary school level, especially for girls, and the impact of different teaching approaches, such as inquiry-based learning.

Within England and across Europe, the importance of practical work in science has been highlighted at primary and secondary levels, including through applying inquiry-based approaches of learning to help foster interest in science (Braund & Driver, 2005; European Commission, 2007; Ofsted, 2013; Osborne & Dillon, 2008). Inquiry-based learning of science broadly includes more focus on observation and experimentation, *facilitated* by teachers rather than purely focusing on the dissemination of knowledge *by* teachers, and on where students can identify and solve problems (European Commission, 2007; van Uum, Verhoeff & Peeters, 2016). Essentially, on a conceptual level, inquiry-based learning may involve students applying a scientific method or approach during their studies. Inquiry-based learning has indeed been associated with improved learning when reviewed across multiple studies (Furtak, Seidel, Iverson & Briggs, 2012; Minner, Levy & Century, 2010). In a practical context, for example, Thornton and Brunton (2010) have advocated that practitioners make use of the Reggio approach to improve students' learning at school; this approach is synonymous with inquiry-based education and suggests that pupils' creativity should also be supported through the learning environment. Within inquiry-based learning, research skills and student-centred learning are considered to be fundamental to developing pupils' self-reliance, independence and the ability to identify, investigate and solve problems. Through these approaches, children can actively construct their knowledge through practical activities scaffolded by teachers asking questions (Chin, 2006) and by facilitating open-ended discussions (Duggan & Gott, 2002). Given these various benefits, further research is still useful when considering the impact of inquiry-based learning on other areas such as students' interest and engagement with science, especially at primary school.

In order to increase the number of people proficient in the sciences and to encourage more girls to pursue science in post-compulsory education, students' knowledge, skills and

enthusiasm for science should be encouraged in the early years and primary education. In primary schools, teachers' approaches can link with students' interests and daily lives, and involve group work, often via hands-on and problem-solving approaches, although time for student-led inquiry has often been limited in the primary school years compared to pre-school education (Cremin, Glauert, Craft, Compton & Stylianidou, 2015). Specifically, an implementation of inquiry-science in primary schools in Northern Ireland increased students' engagement through their interest and enjoyment of the classes, and also increased their confidence and communication (Dunlop, Compton, Clarke & McKelvey-Martin, 2015). Similarly, in Ireland, primary school students' engagement with and attitudes towards learning science have been increased by hands-on and inquiry-based approaches (Smith, 2015).

In England, another study involved primary school teachers being trained in developing and applying open-ended science investigations for their students (Jarvis & Pell, 2002). Following the program, primary school girls expressed higher enthusiasm for independent investigative science (and were then more enthusiastic than boys), while boys expressed relatively unchanged enthusiasm (Jarvis & Pell, 2002). The training was essentially able to facilitate the enthusiasm of girls. Inquiry-based learning has also led to increases in primary school students asking questions (Gillies, Nichols, Burgh & Haynes, 2014). The wider processes within their discussions, involving the students' inquiries, representations of their ideas, and explanations for their reasoning, were considered to be important for learning and understanding science (Gillies, Nichols, Burgh & Haynes, 2014). Nevertheless, teachers' engagement in continuing professional development (CPD) does not necessarily require extensive changes in the delivery of science, and management of change is often difficult and slow (Spooner & Tunnicliffe, 1991).

Within this context, this article has two roles. Firstly, it outlines an implementation of inquiry-based training for teachers and the impact that teachers felt this training had on their classrooms at Key Stage 1 (Years 1-2, ages 5/6 to 6/7). Secondly, the findings are related to broader issues in science education, primarily whether a change in teachers' pedagogy can have a positive impact on students' attitudes to science and, more specifically and in the longer term, to girls' engagement with science. Within the context of primary education in England, it is useful to remember that at Key Stage 1 as well as at Key Stage 2 (ages 7/8 to 10/11), there are no compulsory teaching times set, although there is guidance available about the number of hours that teachers need to spend on each subject. Science is allocated approximately 7% of total teaching time at Key Stage 1, and 9% at Key Stage 2, while maths is allocated around 18% percent at both Key Stages, and English is allocated 24-36% at Key Stage 1 and 21-32% at Key Stage 2 (TES, 2016; QCA, 2002).

Methods

The training

The training referred to in this paper makes up part of the FP7 Pri-Sci-Net project funded by the European Commission. As part of the project, inquiry-based science learning tools were developed by a group of international science educators for use within primary schools. The activities were initially developed, selected and then were trialled for their adaptability. Comments from the trial were reported back to all European partners; for example, teachers in England highlighted preferences for clear activities for specific topics that could be applied within one session. The project partners then collectively worked on improving the trialled activities to be used within the main part of the project involving the training of teachers. Subsequently, the final activities that were used by teachers in England were those that best fitted their work plan at the time. Teachers did not wish to have data collection methods and valuation guidance, instead preferring to put together activities for lessons in accordance with their relevant needs or policies, such as concepts to convey, cross-curricular theses, assessment requirements and their schools' contexts. An example of one of the activities is given in Appendix 1.

Training within Pri-Sci-Net was developed for science teachers, covering the potential benefits of the methods and how they can be applied to their teaching. Training also involved encouraging teachers to use everyday classroom materials to demonstrate investigations and then foster student-led learning; the training essentially

showed the teachers how to encourage students to think and do science. Information was disseminated throughout the primary science network to which we had access at the University, and groups of teachers in England were invited to attend a free training workshop, either in a local school or in the science department of a large university. Training in England was limited to one day, given that there were no funds for supply teacher cover. Similar events were also undertaken in other European partner countries, although, for increased contextualisation, the following results only consider teachers in England. The majority of the training sessions were provided in the summer terms between 2011 and 2013.

Forty teachers who had attended a training session were subsequently contacted to establish whether and how the training session had influenced their thinking and practice. Organising contact and gathering teachers' views was difficult, given the other demands on their time. Methods were adapted to maximise accessibility and accommodate teachers' other commitments: five teachers took part in recorded telephone interviews; ten teachers allowed notes to be taken in non-recorded conversations; and three teachers responded via online interview questions. Teachers' views were gathered between the spring and summer terms of 2014.

The teachers were from London and the south east of England. We asked teachers eight core questions:

Results

The responses were analysed by (thematic) content analysis (Cohen, Manion & Morrison, 2007): teachers' responses were read and initial themes were identified, consolidated and/or refined; responses were then re-read and coded against the final themes. The following themes emerged across the teachers' discussions of the effectiveness of the science inquiry-based learning activities: intrinsic motivation (interest); replicability; children's engagement; the relevance to curriculum; and support. Many of the teachers spoke about being interested or intrinsically motivated to try out the activities in their classrooms after having attended the training sessions. Teachers who had used the inquiry-based activities had done so because they felt that the activities were both replicable and relevant to the learning goals of England's science curriculum as set by the National Curriculum (Department for Education, 2013). All the teachers who tried out the activities within the classroom spoke about how engaged their students were, and believed that the activities were an engaging way for children to learn about scientific concepts. However, there were some problems with trying out (and possibly implementing) inquiry-based activities in the classroom: the reported barriers largely concerned the availability of school resources and senior management teams not allowing teachers the independence to decide what was the most appropriate way to teach science within their classrooms. It is interesting that teachers felt that there were barriers to the teaching of science and that they had not raised

THE INTERVIEW SCHEDULE

- Do you enjoy teaching science?
- Have you ever used Inquiry-Based Science techniques prior to the training given by the trainer?
- How easy or difficult did you find learning Inquiry-Based Science techniques as demonstrated to you by the trainer?
- Did you apply the techniques learned at the training day to your classroom?
- How did the children react to your Inquiry-Based Science lessons?
- Was the children's engagement with science any different to the way children reacted to traditional teaching methods?
- Research suggests that girls are less engaged with science lessons than boys. Did you notice any difference in girls' engagement with the Inquiry-Based Science lessons as compared to the use of more traditional methods?
- Were girls more engaged, less engaged, or was there no difference?

such issues for other subjects; this may be a generic issue within all primary schools in England, where limited time is allocated to science, particularly compared to English and mathematics.

Intrinsic motivation for teaching science

In total, almost all the teachers (94%, or 17 of 18) indicated that they enjoyed teaching science; this result was unsurprising as we had expected most people to enjoy their profession. This question was asked irrespective of what they thought about inquiry-based science techniques; there was no indication that those who did not enjoy their teaching were less engaged with learning new ways to teach their students (although, with the low number of teachers who expressed that they did not enjoy their work, this was not necessarily definitive).

We asked teachers to elaborate on why they enjoyed primary science teaching, and their responses resolved into core themes, specifically: wanting to make a difference, and enjoying science. As an illustrative quotation, one of the teachers stated: *'I have always wanted to be a teacher, nothing is more rewarding than knowing that, by the end of the year, before the children move on, they are armed with new skills and knowledge all down to my input…every once in a while I feel I have really made a difference, not so much in science but in the attitudes of young people… sometimes you know it's not about reaching key stage levels, its knowing that a kid wasn't interested in school and I made them interested'.*

Experience of inquiry-based science education

Teachers were asked if they had used inquiry-based science techniques previously. In total, a third of the sample (six teachers) reported having used such techniques before in various forms, while two thirds of the sample had not. It is possible, however, that teachers had various interpretations of inquiry-based learning; for example, working scientifically (as covered within the National Curriculum), or practical work in general, might be interpreted as inherently involving some degree of inquiry, while others might only consider inquiry-based learning as applying specific approaches, exercises or tools.

It was also important to establish how easy it was for teachers to understand how to teach inquiry-based science techniques. Reassuringly, a large majority of teachers (78%) felt that they were able to replicate what they had learnt in the workshops. It was possible that the limited provision of training (covering only one day) was relevant as a potential limiting factor. Some teachers cited that their students, rather than their knowledge of approaches, could be a limiting or deciding factor. For example, one teacher highlighted that: *'I don't think I will be able to easily replicate these findings; for one, I'd have to have faith in my students that they would be able to independently look for interactions between different parts of the investigation, I have trouble getting them to sit still and focus, let alone encourage them to lead their own investigations…is there a course on getting students to sit still?!'.*

In response to being explicitly asked *'Did you apply the techniques learned at the training day to your classroom?'*, around half the teachers reported that they had indeed applied aspects of the training. The training they applied were simple examples of how to use everyday materials found in classrooms for science lessons and apply them to inquiry-based science lessons (see Appendix 1 for an example), where students were directly involved in and directed their investigations and learning. Whilst the subject matter and teaching accessories/ equipment may have been the same as in traditional lessons, it was the way that the lesson was delivered that was the key difference. However, there were indications that lasting changes could perhaps be less clear, and potentially limited by the teachers' contexts. As an exemplar, one teacher responded that: *'Hey yes, of course! I left the course feeling really enthusiastic about teaching science in this way and even created my own version of an inquiry-based approach. However, it was simply an experiment on my part, kind of fun to see how receptive my class would be but, to kind of use it in a long term way, I would need support, learning materials, time to learn and the Head would have to be on board…a whole can of worms is opened when you want to go about changing things…there's the parents, could I teach something different than the way others are teaching without informing parents? I think the school would have to have a unified approach to the way lessons are taught. That doesn't mean I won't use these techniques and I intend on using them again, but for now I don't think I can adopt the approach as a bog-standard way of teaching'.*

Children's reactions to inquiry-based methods

Almost all teachers (94%, or 17 out of 18) reported that, when they implemented the inquiry-based lessons, their students appeared to be engaged with such teaching methods. The majority (61%, or 11 out of 18) reported that their students appeared to be more engaged with inquiry-based lessons compared to their usual teaching techniques. Caution needs to be applied as to what extent a few lessons had on student progress in science over a longer-term period; it was not possible to assess this within the limits of this research. Even so, the result is still encouraging, given the context that teachers were only provided with one day of training and had no further support in implementing inquiry-based learning. As an illustrative quotation, one teacher highlighted that: *'I was quite surprised to find [that one particular student] showed leadership skills in a positive way! Usually he is quite disruptive but, for once, rather than play the clown he led the group into thinking about cause and effect and even helped another group of students repeat the experiment. It is too early to say whether such teaching would have a profound effect on students, their learning and grasp of science, but what I can say is my class certainly were more involved and interested in the lesson than is the case generally…but then students are always more excited about practical experiments…who knows, it went well though'.* Another teacher remarked how she had not expected one of her female students to be so interested in science: *'Usually [the student] is quite good at getting her homework done and answering questions about anything other than science. I always thought she wasn't that interested actually. And then I repeat one of the activities I picked up off the Internet, following on from the workshop I decided to look things up online, and guess what, [she] was really interested in taking the lead. I paired the class up in no particular order and she was working with [a boy], but it was [she] who was, remarkably, leading their little investigation'.*

Girls' science engagement

The interviews involved highlighting that research suggests that girls are less engaged with science lessons than boys, and asked teachers to think about such issues within their own settings; teachers were then asked if they had noticed any difference in girls' engagement with the inquiry-based lessons compared to the use of more traditional methods (as being more engaged, less engaged, or with no difference having occurred). Half the teachers (50%) reported that girls within their inquiry-based science lessons were more engaged with the teaching as compared to using different teaching styles. As one teacher said: *'Actually I found that girls were more engaged in science, whether this was because we were doing an investigation or whether this was because I expected them to think for themselves, I don't know. What I can tell you is that if you want more girls to engage with science you do need to actively engage them with science – boys seem to take over sometimes and we as teachers can forget that the quiet ones in science are probably that way because of confidence'.*

Some teachers (22%) nevertheless considered that girls were less engaged with science using such approaches, whilst others (28%) reported that no difference in girls' engagement was apparent. It was possible that teachers were not always or easily able to determine their students' engagement, and preconceptions or prior experiences may have sometimes been relevant. As an example, one teacher commented that: *'Aren't girls at this age less interested in science because they prefer to be playing with other girls, are less hands-on than boys? [The teacher was then asked what she meant by "less hands-on"]…boys like breaking things and fixing things, at this age girls just want to draw pretty pictures. [The teacher was then asked if she was sure the inquiry-based lessons had no impact]…well, yes, I suppose girls did try and get more involved in the task'.*

Discussion

The responses from primary school teachers highlighted that inquiry-based learning was perceived to be easy to learn and apply; teachers perceived that their students reacted positively and, in half the cases considered, teachers believed that inquiry-based learning facilitated engagement from girls within their classes. Nevertheless, the sample was very small, students' views were not included, and teachers received only one day of training; more extensive training, undertaken over longer periods, is usually recommended in order to achieve lasting changes (European Commission, 2007; Osborne & Dillon, 2008). The responses from teachers highlighted that some indeed believed that further support would be necessary; this

coheres with earlier research, which highlighted that inquiry-based learning relies on skills and knowledge from teachers and also from students in order to direct their own learning, requiring support for both teachers and students (Yoon, Joung & Kim, 2012).

In addition, the results highlighted that inquiry-based learning could potentially facilitate engagement between girls and science. Prior research has highlighted that girls often reported lower confidence than boys (OECD, 2015a), and it is possible that inquiry-based learning can help avoid confidence issues and similar factors becoming barriers to engagement, given the comments from teachers. Similarly, inquiry-based learning, through practically considering research questions and experimentation, may be perceived as more reflective of 'real science' by students. In prior research in England, primary school students have perceived differences between 'real science' and 'school science', which may potentially start a longer-term process of disenchantment or disengagement (Archer *et al,* 2010); similarly, research with students in the United States has highlighted that girls strive to make a connection to science and are able to see the relevance of science in their everyday lives, but are largely unable to come across such understandings in their science lessons (Buck, 2002). Girls do not always have positive perceptions of science and scientists, and have sometimes perceived that the work of a scientist has little relevance for social problems, and that scientists are isolated with little time for a social life (Miller, Slawinski Blessing & Schwartz, 2006). Engaging girls with science at primary school may help to diminish negative perceptions or stereotypes about scientists and about science itself.

Some comments from the teachers highlighted that it remains important to be mindful of and self-reflective about potential preconceptions about what students could or should do, and what students may or may not be interested in; for example, interest may not always be immediately apparent. Teachers can help foster students' own interest and engagement (Murphy & Whitelegg, 2006; Reiss, 2004), but parents and teachers may sometimes encourage boys' interest in science more than girls' interest (Jones & Wheatley, 1990), and teachers and their approaches can partially determine how science is perceived (Baker & Leary, 1995). Gender stereotypes or preconceptions may inadvertently ensure that gender differences and under-representation persists throughout science education (Institute of Physics, 2013, 2015). Research has suggested that some teachers do not encourage girls to try and understand science concepts to fit in with their own needs and understanding of the scientific world around them, and that traditional teaching approaches themselves do not necessarily help address such areas (Buck, 2002); girls often have to adapt to existing structures or preconceptions already in place within science education (Carlone & Johnson, 2007). Inquiry-based learning does not seek to push children to fit within a structure, but to use their own knowledge and skills to explore science and understand it using approaches with which they are comfortable, which may facilitate engagement and personal identification with science.

Our work has implications for teaching at Key Stage 1. Primary school students have associated 'doing science' and 'acting like a scientist' with hands-on activities and practical work, and have distinguished science in school from real science (Zhai, Jocz & Tan, 2014). In primary schools in England, differences between perceptions of science, scientists and students' perceptions of themselves have been considered relevant for girls who did not hold aspirations towards science: for example, notions of 'femininity' may be perceived to contrast with notions of 'being a scientist' in the sense of a career (Archer *et al,* 2013). Again in primary schools in England, students in Year 2 (age 6/7) have enjoyed science lessons and expressed a good understanding of what scientists do and how to be a scientist; students' attitudes appeared to have developed from books, visits to doctors/dentists, television and their parents' jobs, and notions that scientists are 'clever' (Turner & Ireson, 2010). By Year 6 (age 10/11), students were still positive about science and enjoyed science lessons, but expressed that they generally did not undertake science activities in leisure time and were not necessarily interested in science careers (Turner & Ireson, 2010). This decline in science interest could be addressed with classrooms adopting more student-led approaches to learning, for example, as our teachers had applied by implementing inquiry-based approaches. This also appeared to increase girls'

confidence and engagement, according to our teacher interviews. However, the longer-term benefits of this approach need further investigation; we cannot conclude whether students' engagement and aspirations in science would continue.

On a wider level, the field of social psychology indicates that, when teachers teach students to set themselves goals, this has a positive impact on enhancing their cognitive efficacy, academic achievement and intrinsic interest in subjects (Bandura & Schunk, 1981; Schunk, 1989). Inquiry-based learning in science aims to achieve all these outcomes, although more research, including views from students, is required into the short-term and long-term effects of using a different way to teach science and taking part in more hands-on science activities.

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Appendix 1

IBSE TEACHER TRAINING ACTIVITY DESCRIPTION

Age range: 6-8 years

Title of activity: Magnetic force

Objective:

1. To investigate the strength of magnets.
2. To support pupils' measuring skills and observation techniques.

Equipment:

Everyday objects, both magnetic and not magnetic, a variety of magnets, ruler and worksheets.

Process:

1. Working in small groups, the pupils test a wide variety of objects for magnetic properties.
2. Within the groups, allocate roles – observers, recorders, planners.
3. Record their findings on the table – pupils can write or draw their observations.
4. Ask pupils to test their magnets – which is the stronger?
5. How will they do this? Pose the question and give time to investigate.
6. Record findings on the table.
7. How can we measure the strength?

Outcomes:

What have we learnt?
How might this be used in 'real life'?
What differences were there in the strengths of the magnets?