Engaging science: pre-service primary school teachers' notions of engaging science lessons

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Abstract

If children are engaged in science lessons their learning is likely to be better and, in the long term, careers in science and technology will remain open. Given that attitudes can develop early and be difficult to change, it is important for teachers of younger children to know how to foster engagement in science. This study identified what a cohort of 79 pre-service teachers in England considered to be engaging elementary science lessons and compared their notions with teacher behaviours known to be conducive to engagement. First, all brought beliefs about how to engage children in science lessons to their training. They tended to favour children's hands-on activity as an effective means of fostering attentive participation in learning although many had additional ideas. Nevertheless, the means and ends of their 'pedagogies of engagement' tended to be simple and narrow. Trainers need to ensure that notions of engagement are wide enough to cope with a variety of teaching situations, as when hands-on experience is not feasible, effective or appropriate. At the same time, teachers will need to recognise that one approach may not suit all learners. Without this, there is the risk that they will lack the skills to engage children in science. Nevertheless, these beliefs could offer a useful starting point for trainers who wish to widen pre-service teachers' conceptions of engagement and increase their repertoire of teaching behaviours.

Keywords:

Pedagogies of engagement, teachers' conceptions, fostering engagement in science.

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Introduction

Partridge (1957, p. 350) described engagement as an "intellectual's vogue word" of the 1940s meaning involvement in a "not too strenuous course of action". Since then it has been used to describe, amongst other things, responses to school in general and, more narrowly, to school subjects individually. In at least the last respect, engagement can be mentally strenuous. We begin by exploring some aspects of engagement in the context of science and describe teaching behaviours thought to support it. Pre-service teachers' beliefs about such behaviours matter as they can impede their training and perpetuate ineffective and inappropriate practices (Burkhardt, Fraser & Ridgeway, 1990; Pajares, 1992). Accordingly, we describe a study of pre-service teachers' notions of engaging science lessons and some implications for their training.

Engagement

In science education, at least two meanings of engagement can usefully be distinguished. In the first, engagement refers to an involvement in a specific event, such as a lesson. The duration and quality of the involvement can vary with person and event. In the second, engagement (more commonly, disengagement) refers to a tendency to respond in a particular way to science-related events. Disengagement can be the label for an indifferent or inimical response towards learning science which results in an avoidance of it when possible (Osborne et al., 2003; Goodwin, 2006; Niemi, 2007; Rocard et al., 2007). Engagement in the first sense is a particular act; in the second, it is an attitude or tendency to act. The two are not independent: Millar (2001) points to the enduring effect of school science lessons on attitudes and Murphy and Beggs (2003, 2005) suggest that when primary school teachers fail to make learning engaging (as, for instance, when they prepare children at length for attainment tests) an enthusiasm for science wanes. In short, acts shape tendencies. Of course, experience of engagement in science is not the only shaper of attitudes; a masculine image of a science, for instance, is a strong determinant of career choice among adolescents, even repelling girls who find science interesting (Osborne et al., 2003; Jenkins, 2005).

Attempts to engage people in science have various purposes. For example, one is to persuade them to a point of view or to develop a favourable attitude in order to enlist their support. Another is to enable participation in science-related debate to improve the quality of democratic decision-making (Millar, 2001; Leshner, 2003; Wilsdon & Willis, 2004; Wellcome Trust, 2006; Boon, 2006). Yet another is to support attempts to develop someone's knowledge of science as a part of his or her education. These are not mutually exclusive but the first two tend be the goals of organisations which communicate with the public in order to "make more meaningful the fact that … science is an ever-more pervasive way of life for all people" (Leshner, 2003, p. 977; Wellcome Trust, 2006). Engagement to support learning amongst the young is usually a more systematic and extended endeavour that tends to be the province of the teacher. While the role of science in society can feature in that education, it is often not the main goal although it can be a vehicle for achieving it (Newton, 1988; Millar, 2006; but see The Royal Society, 2004).

Connell (1990), Finn (1993) and Fredricks, Blumenfeld and Paris (2004) distinguish between cognitive, behavioural and emotional engagement. The first largely refers to the kind of engagement which fosters a certain quality of thought, the second to that which induces participation in learning, and the last refers to engagement which engenders pleasure. At first glance, this intuitively appealing division is attractive but the categories are not entirely distinct. For instance, interest is presented as emotional engagement. While it may excite emotions, it also directs and sustains attention, a kind of behavioural engagement which could lead to productive cognition. One kind of engagement may, therefore, enter into or support others. A more holistic view, on the other hand, sees engagement as a more integrated and mutually supporting whole with the potential to enhance attainment and attitudes (see e.g. Guthrie & Wigfield, 2000). At the same time, the effect of an approach which engages children is unlikely to be narrow, even if the intention was. Stimulating interest by tying what is to be learned to the child's world, for instance, may attract and focus attention, help the child make mental connections and offer some emotional reward. A teacher is likely to value all these outcomes. A variety of such behaviours may be used to induce engagement in young children (Lanahan, et al., 2005).

Teaching behaviours which foster engagement in the classroom

Although the link is not always direct, teaching behaviours are commonly seen as being shaped by the teacher's beliefs about children's behaviour, thinking and learning (e.g. Bell et al., 2000; Daniels & Shumov, 2003; Water-Adams, 2006). Mestre (2005) uses the expression 'pedagogies of engagement' to describe a teacher's classroom beliefs about behaviours seen as fostering engagement. Pedagogies of engagement may be more or less coherent, more or less sophisticated, and more or less conscious. Knowing the pedagogies of engagement of trainee teachers of young children is important for several reasons. First, there is a substantial body of research, including work with younger children, which shows that engagement (often indicated by the learner's time on-task) leads to greater attainment (e.g. Capie & Tobin, 1981;

Marks, 2000). This means that a teacher who engages children in science may also increase their attainment. A second reason is that attainment keeps open long-term options of science/technology-related careers for such children. A third reason is that leaving a concern for engagement in science to the secondary school ignores the value of developing attitudes early (Silver & Rushton, 2005; Tytler et al., 2008). The skill to use and change teaching behaviours so that there is engagement in a variety of science lessons is valuable. Teachers do not always have this skill (Murphy & Beggs, 2003, 2005; Middlecamp, 2005) so learners' engagement in an event suffers and their predisposition to engage with such events in the future is threatened.

Some suggest generating engagement in science by selecting only content of intrinsic interest or of lower mental demand (Sturman and Twist, 2004). There is an ethical objection to this if it produces a science programme which does not honestly reflect the nature of science (for an example, see Abrahams (2007) or Buckley (2008)) and it does no favours for those who are seduced into a scientific career or who must participate in democratic decision making about complex scientific and technological issues. Instead, a first approach should be to identify teaching behaviours which tend to generate engagement in a representative science programme commonly believed to benefit rather than deceive the learner. When the limits of this approach are known, other actions may be cautiously considered. This view underlies what follows.

From a study of classroom management in the USA, Capie and Tobin (1981, pp. 412-413) report that teacher behaviours which foster learner engagement include maintaining "learner involvement" and "using teaching methods appropriate for objectives and learners', enthusiasm, 'comfortable interpersonal relationships", sensitivity and opportunities for learners to participate. Regarding enthusiasm, Bettencourt at al. (1983) took a group of teachers and measured the amount of children's on-task behaviour (time involved on the task in hand) during teaching and in the children's follow-up work. They then trained the teachers to show enthusiasm and repeated the measures. The training increased on-task behaviour from 76% to 87% during teaching and even more, from 71% to 86%, in the children's follow-up work. Students also tend to describe enthusiastic teachers as outstanding (Bauer, 2002). A more recent and comprehensive study of a class of 11 and 12-year-old students in an Australian middle school by Darby (2005) found two areas of teaching behaviour to be important for engagement in science: the nature of instruction and inter-personal relationships. The area of instruction involved generating interest and supporting understanding; that of relationships comprised teacher enthusiasm, providing a supportive learning environment and making the children feel emotionally comfortable or at ease. Arousing interest, for instance, is known from other studies to lead to better learning (Boekaerts & Boscolo, 2002; Krapp, 2002; Hoffman, 2002; Murphy et al. 2006). Similarly, a relationship between engagement and understanding has been demonstrated (Chong, 2009). Although Darby is not explicit about what counted as engagement in her study, it seems that her ethnographic approach was intended to be sensitive to quantity and quality of learning where views about the latter were shaped by constructivism. Another ethnographic study by Olitsky (2007) in the USA was of 8^{th} graders' engagement in science. She found that interest, valuing students' prior knowledge and providing a caring environment which enabled students to contribute without emotional risk were important (see also Turner et al. 2003). Again, what constituted engagement was not made explicit but it seems like that of Darby.

The outcomes of these studies have much in common. In particular, lessons which are likely to engage children in science are those which generate interest, use strategies which support learning, are given with enthusiasm, and foster a non-threatening environment in which children can make valued contributions and can receive support as needed. Olitsky (2007) added that interest in the subject is not always necessary if learners want to be valued members of their group. These studies do not discuss the independence of these behaviours (does one add to the effect of another or do they interact?), their relative contributions (has one a stronger effect than another?) or if a subset can be sufficient for producing a high level of engagement in science (say, interest and enthusiasm). The effect of teacher enthusiasm on engagement (as time on task) can be calculated from data in Bettencourt et al. (1983). Its effect size for teacher-led discussion was 0.98 which could be described as large (Cohen, 1988; 0.2 or 0.3 are commonly seen a small, 0.5 as medium, and 0.8 or more as large effect sizes, see also Borenstein, Hedges and Rothstein, 2009). That for subsequent pupil work was even larger at 1.36. According to Capie and Tobin (1981), this engagement is likely to enhance attainment but by how much is not known. In an unrelated study described by Waxman and Walberg (1986), the effects of students' 'motivation' and 'individualized instruction' on attainment were 0.34 and 0.32, respectively. 'Class morale' and 'cooperative learning' had larger effect sizes of 0.60 and 0.76, respectively. Insofar as these are different aspects of Darby's instructional and relational dimensions of engagement, it points to enhanced attainment. Nevertheless, the link between engagement and attainment may not be simple. Engagement may vary in quality as well as quantity and a brief period of one kind of engagement could be better than lots of another for certain kinds of attainment.

Instruments for assessing associated aspects of engagement in the classroom tend to include items which relate to these behaviours. For instance, Newmann

(1988), in the USA, compiled one to assess 'thoughtful engagement in the classroom in social sciences' in which engagement was the time spent on-task in discussion and in mental involvement (indicated by raised hands, postures of attentiveness and students asking questions). Items for rating included the extent to which children's contributions were used, their generation of ideas, and allowance for ability. In the UK, Thorp et al. (1994) offered an instrument to rate the 'individualized classroom environment' in the science classroom. It included the amount of teacher-student talk, the eliciting of student views, the differentiation of tasks to accommodate ability, the using of students' ideas, and consideration for students' feelings. Other learning environment instruments described by Fraser (1986) include provision for relevance, teacher support and friendliness. A useful caution follows from a study by Treagust (2004) who used such an instrument to explore views about learning environments in Indonesian schools. He found that those favoured by the teacher were generally not rated so highly by the students. Nevertheless, a review of adolescent students' beliefs about what motivates them to learn in the classroom described in eight European, North American and Australian studies showed students' preference for collaborative, informal activity drawn from the real world and an avoidance of appearing foolish in front of the class (Smith et al., 2005). While some of the preference could be interpreted as students' desire to be economical with mental effort and opportunities for off-task affiliation, it does again point to the importance of evident relevance and interpersonal relationships. Environments, contexts and topics favoured by boys, however, may not be the same as those favoured by girls and preferences may change with age (Burnett, 2002; Uitto et al. 2006).

In the classroom, these general descriptions of teaching behaviours have to become specific. Attention has tended to focus on generating interest. In theory, behaviours which address learners' psychological needs or personal goals are likely to induce interest (Newton, 1988, 2004, 2008; Deci et al., 1991; Krapp, 2002). Engle and Conant (2002) challenged 10-year-olds to solve a scientific problem (how to classify whales). The approach offered some novelty, autonomy, affiliation and the development of competence. A 'passionate engagement' with the problem was observed. Similarly, working with 8th and 9th grade students in Germany, Gläser-Zikuda et al. (2005) tested the effect of a combination of teaching behaviours relating to the need for competence, autonomy, interest, affiliation and practical activity. They found it produced engagement and more durable attainment than 'traditional instruction'. Simply using novel, physical objects in science lessons attracts attention and can generate interest (Valeras, et al., 2008). Teaching behaviours which foster understanding, a non-threatening environment and individual progress are known (e.g. Newton, 2000; Hanrahan, 2002) but, while their effect on attainment may have been measured, that on engagement has generally not. Presumably, some part of their effect could stem from greater or better directed engagement.

There may, of course, be children who engage in a science lesson in the absence of deliberate attempts to induce engagement. They, presumably, find satisfaction in the lesson without additional inducement. Others, however, may need that inducement. It is these who need a teacher with a sound pedagogy of engagement.

Aims

The key to maximising the likelihood of engagement in science is the teacher's instructional behaviour (Yair, 2000) and, in particular, whatever part of it could be described as a pedagogy of engagement. Pre-service teachers may lack something which approximates to such a pedagogy and be unable to construct approaches likely to engage children, other than by chance. On the other hand, past experience of school, teachers and children may give pre-service teachers a pedagogy of engagement, sketchy, partial or otherwise, which guides the selection of behaviours, even unconsciously but not necessarily in desirable ways. It would be useful for teacher trainers to know the pedagogies of engagement their students bring to their course so they can consider the need for and nature of education and training needs. Accordingly, in the context of primary school teacher training in England (preparing teachers of 5-11 year-old children), this study aimed to identify some pre-service teachers' notions of engaging science lessons and consider implications for teacher training.

Method

Instrument

A questionnaire was used to elicit pre-service teachers' notions about teaching behaviours they considered to produce engagement in a science lesson. It asked them to "think of a science lesson you believe to be engaging", to provide an ordered account of the events in it, to identify the parts which made the lesson engaging for the children, and mark that part considered to be the most engaging. Accessing such notions through a specific context in this way can relate more closely to teaching behaviours than asking for generalisations (e.g. Strauss, 1993; Lunn, 2002; Beswick, 2004). Eliciting general notions can be less informative as they do not indicate how they might be interpreted or if the trainee can make them specific for classroom application. Nevertheless, the trainees were also asked if there were other ways of making a science lesson engaging and, if so, to describe them. The questionnaire was completed in the first week of the pre-service teachers' training course and took up to 45 minutes to complete. Its completion was supervised and there was no collaboration or collusion.

The pre-service teachers

A full cohort of seventy-nine pre-service teachers on a course to prepare them to teach primary school children in England completed the questionnaire. In common with most who want to teach in England, this was a one-year postgraduate course. The students were aged 21 years or older (mean age 23.6 years with some 51% being 21 or 22 years old). They held first (bachelor) degrees but only four of these were science-based, the largest single group being centred on languages (English and modern foreign languages). Others had history, geography, theology, social science, psychology and combined degrees. Nevertheless, during and after training all would be required to teach some science in accordance with the requirements of the English National Curriculum. None had received instruction in teaching at this stage but all had observed some teaching in a primary school prior to joining the course.

Data analysis

Following the procedure for identifying notions and conceptions described by Marton (1981), all responses describing teaching behaviours to produce engagement were collected to form a data pool. For example, the pool contained, *"eliciting prior knowledge"*, *"getting out of the classroom to look at objects",* and *"children can see, touch and feel what happens".* Half of the responses were sorted by the authors into groups according to the kind of teaching behaviour which the trainees considered to induce engagement. The process was iterative and continued until self-consistent, mutually exclusive groups and sub-groups were constructed, labelled and described. When this was achieved, all responses were allocated to these categories and subgroups independently by the authors. The inter-scorer reliability measure, Cohen's Kappa, was 0.83 (for which see Robson (1993); anything above 0.75 is described by Fliess (1981) as an excellent outcome). A few differences in scoring were resolved by further inspection and discussion. It can never be said that the list of groups is exhaustive. The procedure is usually applied to relatively small numbers of people, typically between fifteen and twenty, and a few more may add new groups. Here, however, with 79 respondents, no new groups were found necessary well before the end of the initial joint sort.

Results

The most common area of science in the lessons was biology-related (33 responses, e.g. *"Fruits and Seeds", "Animals and their Habitats"*), with chemistry and physics-related responses being roughly equal in second place (23 and 22, respectively, e.g. *"Soluble materials", "Electrical circuits", "Light and Dark"*; one response was not specific). Such students can be more interested in biology than in other sciences, not just in the UK (Fairbrother, 2000; Osborne, 2003; Baram-Tsabari & Yarden, 2005) but this uneven distribution could be a chance occurrence (χ^2 = 2.38, 2 df) so was not pursued further.

Three groups were found to accommodate the responses: Interaction (involving talk between people), Task (activities for the children which do not involve direct experience of the scientific phenomenon or event under study), and Direct Experience (activities for the children which do involve direct experience of the scientific phenomenon or event under study). These groups and their subgroups are as follows:

1. Interaction

Teacher (T): The teacher elicits or provides information which bears upon the topic in hand *(e.g. "eliciting prior knowledge", "children listening carefully", "asking children [questions about what they are doing]".*

Children (C): The children discuss with one another some aspect of the topic in hand *(e.g. "children share ideas", "collaborative talk", "pupils generate new ideas and share these", "working in a group", "team work".*

2. Task

Finding/Developing knowledge (F/D): The children are set the task of acquiring information vicariously as from books, software, the Internet, video recordings, or they have the task of developing or consolidating knowledge similarly by, for instance, using games, simulations, quizzes, model making in order to illustrate a phenomenon *(e.g. "children play games to consolidate learning", "getting children to be planets", "Applying their knowledge to the [food] chain").*

Recording (R): The children write, draw or otherwise make a record of their work or learning *(e.g. "the children like to draw to explain [what they did]").*

3. Direct Experience

Hands-off (HOF): The children observe scientific phenomena or events produced by others *(e.g. "teacher lighting a bulb", "getting out of the classroom to look at objects", "teacher giving demonstrations", "showing real-world objects", "the class is outside", "gathered around looking at real examples",*

Hands-on (HON): The children experience or use scientific phenomena or events directly *(e.g. "The children are doing the testing", "they have to get the apparatus and work it out for themselves", "they can do the experiment themselves", "making circuits from diagrams", "children make decisions for themselves [about what to do]", "carrying out an investigation", "children can see, touch and feel what happens", "they got to investigate for* *themselves", "the children were each able to use the thermometer", "they can decide what to test with the magnet".*

Table 1

The frequency of all teaching behaviours stated as engaging and those marked 'the most effective' appear in Table 1. Hands-on experience (a subgroup of Group 3) was the most frequently mentioned source of engagement and was considered to be the most effective means by about two-thirds of the trainee teachers. For example, one response drew attention to the value of *"Children able to carry out practical activity [making electrical circuits] themselves"*. One in ten added only variants of this source of engagement in both the lesson and in the more open opportunity subsequently. The much less frequent endorsement of Hands-off experience in which the child is a more passive observer of events indicates that it is not direct experience alone but a physical involvement with the direct experience which counts. (If the groups were equally likely to be chosen as most effective then this distribution is unlikely to occur by chance: $\chi^2 = 41.2$, 2 df; $p<<0.001$.) Tasks which have the child actively collect, develop and record information and consolidate learning (Group 2) were also seen as potentially engaging. For example, in learning about light, one such task had children cut out pictures and sort them into sources and reflectors of light to be attached to paper for a display. About one in five of the trainees considered these tasks to be the most effective means of engaging children. Teacher-children and children-children interaction (Group 1), often in the form of talk about prior experience, questions, anticipated outcomes and ideas for action were commonly highlighted as sources of engagement although less commonly (one in eight) as 'most effective'. For example, one trainee highlighted, *"Children sharing previous knowledge [about fruits and seeds] with both teacher and others"*.

What did these pre-service teachers hope these behaviours would achieve? Forty-two (52% of the sample) supplied answers. Nineteen believed it stemmed from the generation of interest in the pupil arising largely from the relevance of the topic to everyday life (15) or from allowing the child some autonomy of thought or action (4). (For instance, interest was felt to stem from, *"making lessons meaningful to everyday life"* or by demonstrating *"the practical application of science"* and some autonomy is allowed by, letting he children *"choose from a variety of materials and test what they want"*.) Nine teachers referred to the value of *"fun"* and *"enjoyment"* and one described the engaging effect of striving for competence in learning about electricity, *"When the light bulb lights up, they know they have done that themselves using electricity"*. Five pointed explicitly to the motivating effect of activity, three to the teacher's enthusiasm and one to the engaging effect of understanding. Four others used the word, 'motivating', in a non-specific way. Clarification was sought from twelve pre-service teachers chosen at random and interviewed individually. Their responses centred mainly on direct and indirect experience as being engaging. One said, *"So I showed them some photos [of] some birds covered in oil"* while another response was, *"Practical work, especially that the pupils can be involved in or do independently, nearly always motivates children."* When asked what is meant by a motivating activity in science, they described it as one which generates interest. Two added that it focused attention, increased task completion and produced more learning. One added that a motivating activity was *"fun*" and two saw interest as also generating *"good behaviour"*. These referred to the meaning of engagement as responses in a given lesson. Interestingly, one student hinted at something more durable, a tendency to act: *"... the desire to learn more about a particular topic".*

Eliciting beliefs in a science lesson context is intended to produce specific responses rather than broad, vague generalisations. But it could have the effect of leaving some notions unsaid although an opportunity was provided to express additional beliefs and was taken by all except one. Nevertheless, another ten pre-service teachers also training to teach in the primary school were chosen at random from another cohort and were asked to "Think of approaches to science teaching you believe to be engaging for children". They were encouraged to list as many as they could. All offered Hands-on Direct Experience as engaging and rated it as the most effective (e.g. *"Practical work, active, hands on in all topics"*). Indeed, four listed only variations of this kind of experience (e.g. *"Children using equipment"*, *"Class trips [with] field experiments"*, *"Hands-on approach [in] museums*"). The others offered Interaction and Task teaching behaviours. The aim of these approaches was largely to arouse interest (e.g. *"seeing real-life applications [of the science]"* or provide "*fun*". These observations broadly reflect the findings in the science lesson context and, like them, tended to focus on engagement in terms of attentive, hands-on participation.

Discussion

The evidence points to these pre-service teachers having a belief in the efficacy of active participation in learning. Their responses generally related to behaviours intended to induce children to contribute to a lesson through interaction, to become involved in a task, and to experience phenomena and events personally. However, it was engagement through hands-on, direct experience which was most popular. But hands-on experience is not always possible. Even when it is, it is not a panacea. For instance, Mant et al. (2007) made a particular effort to introduce "cognitively challenging, practical, and interactive science" into the lessons of 10 and

11-year-olds to enhance engagement and attainment. They claim an enhanced enthusiasm for and engagement with science and were pleased with the 10% increase in pupils achieving the highest level of attainment but their data allowed the effect size to be calculated. At only 0.15 it hardly warrants the effort: it is possible to have engagement without attainment. Productive engagement needs more than a faith in practical activity: the activity should, for instance, catch and hold interest in the science, support the construction of scientific meaning, and allow for individual support. Furthermore, gifted learners can be less motivated by hands-on activity than by something new and different (Rogers, 1991).

Of the 42 pre-service teachers who stated what the teaching behaviours were intended to achieve, 34 cited interest (mainly in terms of relevance to daily life). Amongst these, this interest was commonly associated with inducing attentive, sustained participation (a behavioural engagement which might support cognition). There were also some who saw it as offering fun and enjoyment (in other words, emotional engagement). Of the engaging behaviours described by Darby (2005), these beliefs touch usefully but narrowly on provision for interest and understanding. Both, for instance, seemed to be seen in simple terms but, in reality, they comprise components which may differ in their effect on engagement. Furthermore, their effect may vary with the learner. For instance, the effect of teaching behaviours on engagement is known to vary with gender (Patrick et al., 1993) and a given behaviour is unlikely to suit all learners. Krapp (2002) has divided interest into situational (stimulated in an event) and personal (an enduring interest in science which transcends single events) although he argues that these form the ends of a continuum ranging from catching interest through holding interest to nurturing interest. Different teaching behaviours to catch, hold or nurture these kinds of interest may be needed.

As Rivera and Ganaden (2001) point out, there is a need to match the approach and the learner. Other engaging teaching behaviours described by Darby were rarely mentioned: support for understanding (other than that stemming from interest) was mentioned by only one person; a teacher's expression of enthusiasm was mentioned by three and none mentioned individual support or the development of an atmosphere conducive to learning. Similarly, there was no mention of behaviour which could be described as inducing engagement through affiliation to a group in the way described by Olitsky (2007).

These pre-service teachers are like many in other teacher training institutions in England and elsewhere (Newton & Newton, 2009) and so trainers may recognise their own students amongst them and relate these findings to them (for the concept of relatability, see Bassey, 2001). While general and individual weaknesses regarding these teachers' notions of engagement in science are present (and to be expected, given that they are pre-service teachers at the beginning of their training), it is evident that, as a group, the notions they bring provide potentially useful starting points for discussion and development aimed at widening their pedagogies of engagement. Although beliefs about effective classroom behaviours are not the only things which shape teaching, being able to change these when appropriate is at least useful (Hardy & Kirkwood, 1994). It is essential if they are to engage children in science - particularly when novel, direct experience is not possible or appropriate - and so avoid the effects noted by Murphy and Beggs (2003) when engagement fails.

However, trainers should be reminded that it is never certain that all relevant beliefs have been collected. Those collected here are probably what come most readily to pre-service teachers' minds and so are likely to shape their attempts, if any, to engage children in learning science. Nevertheless, trainers may find other notions amongst their pre-service teachers. At the same time, those pre-service teachers who cited hands-on, direct experience as the 'most effective' means of inducing engagement, often also mentioned a teaching behaviour in one of the other groups. This extra behaviour, however, never usurped hands-on, direct experience as the main event. Instead, it was used to introduce or round-off that direct experience. Nevertheless, its existence means that at least some might try another teaching behaviour when direct experience is not feasible. Perhaps through case studies, trainers may find it useful to show how such behaviours could become strong alternatives that introduce variety and provide for individual inclinations. Finally, while we found it meaningful to capture the essence of the responses in the three categories, Interaction, Task and Direct Experience, and their subgroups, others may have divided the data pool differently. Those inferred here relate readily to meaningful classroom behaviours of talking about the topic, setting learning tasks for the children and providing experience of phenomena and events and so can usefully inform discussion about classroom practices and the questions we asked.

Given the backgrounds of pre-service teachers, the trainers' attention is often on possible deficiencies in their scientific knowledge and understanding. But, as far as engagement is concerned, having a strong knowledge of science does not, in itself, guarantee the making of a good teacher of science. In fact, Kind (2009) has shown that those who begin with a relatively weak knowledge of a topic can produce effective science lessons; such students tend to see the task from the learner's perspective. One of the trainer's goals is to widen this empathy to encompass a broad understanding of engagement.

Conclusion

These pre-service teachers could be said to bring pedagogies of engagement, albeit narrow, with them to their training. The aim of their pedagogies was most commonly that of gaining a willing, attentive participation in a science lesson. The most favoured way of achieving this end was through a child's direct involvement with phenomena and events. This notion is a useful one but, by itself, it has a serious weakness: hands-on experience is not always feasible, appropriate or effective. It is also simplistic in that it may not recognise the complexity of engagement, the value of support for understanding (other than through interest), teacher enthusiasm, individualised instruction and a supportive learning environment or that one kind of approach may not suit all learners (a one-size-fits-all model). Teacher trainers may need to teach behaviours which contribute to engagement in these other ways and point out that a favoured teaching behaviour may not suit all children. They may also draw attention to the ethical dilemma of teaching only those aspects of science which seem to have an intrinsic attraction for learners.

There is a need for further research into how to engage learners in science (see, e.g., Osborne, 2003; ASE, 2006). In broad terms, there are clear indications of what supports engagement but each item is itself complex and its effect alone or in combination with others is not entirely clear. In addition, engagement varies in quality as well as quantity. Perhaps because quality can be more elusive than quantity, it may receive less attention than it deserves. Regarding pre-service teachers' notions of engaging science lessons, they can be narrow but teacher trainers do have something to build on. Furthermore, given the relatively limited scientific knowledge of some pre-service teachers, the features of engagement could be used to give structure and direction to training courses in science education (Newton & Newton, 2009).

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Table 1. Teaching behaviours which generate engagement: numbers in each category. (T = Teacher, C = Children; F/D = Finding/Developing knowledge, R = Recording; HOF = Hands-off, HON = Hands-on.)

	Interaction		Task		Direct experience	
Behaviours	T	C	F/D	R	HOF	HON
All	44	35	24	29	12	72
Most effective	9	1	10	6	1	52