Questioning the role of questions: new primary teachers' realisations of over-reliance on questions in scientific dialogue

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Abstract

This article reports on research undertaken with final year undergraduate student teachers, in which they examined their deployment of questions to promote children's observation and curiosity in primary science. The study adopted elements of action research methodology to enable student teachers to engage deeply with evidence-based evaluation of their practice. Specific aims of the study were for student teachers to extend their understanding of quality questioning in primary science and its impact on children's intellectual engagement, examine the detail of their practice of questioning through a supported action research process, and develop their understanding of data analysis for improving practice.

Student teachers taught lessons, on the topic of plant growth, to small groups of Year 2 children and evaluated their questioning strategies immediately afterwards and analysed transcript data of their interactions. They identified specific ways in which their practice of questioning could be improved and put these into practice in a follow-up lesson with the same children.

Student teachers were astonished to discover how over-reliant they were on questions as their default strategy for engaging children in science-related dialogue. The process of analysing transcripts was deemed to be insightful in helping them to identify ways to develop their practice and to define key characteristics of effective questioning in primary science and to appreciate the power of self-evaluation to enhance the quality of teaching and learning.

Keywords: constructivism, dialogism, questioning, primary science, student teachers, action research

Introduction and rationale

Furlong (2015, p 8) suggests that the best teacher education programmes: 'develop strong links between theory and practice in a way that helps students to understand and explore the interconnectedness of educational theories and classroom practices'.

This article reports on research undertaken with primary student teachers, focusing on the development of their ability to deploy an appropriate number of carefully chosen questions in the teaching of primary science, adopting elements of an action research methodology to enable deep engagement with evidence-based evaluation of practice. The study arose from several years of enquiry by the authors into the persistence of teacher questioning as the dominant approach to engaging children in scientific 'dialogue', despite some well-established limitations associated with this approach to teaching and learning, which will be explored in the literature review.

The study focused on the development of third year BEd student teachers, all of whom had selected science as a core subject to develop as a strength. The aims of the study were to:

- extend student teachers' understanding of quality questioning in primary science and its impact on children's intellectual engagement
- challenge student teachers to examine the detail of their practice of questioning through a supported action research process
- develop student teachers' understanding of data analysis for improving practice.

Literature review

Three key aspects of theory and research were identified in the literature and will be explored through this review:

- Constructivism: the theory of learning that underpins the approach to teaching and learning in science in the context under study
- Teachers' questions: the extant research into the effectiveness and limitations of questions when deployed by teachers to promote children's learning in science
- Action research: the methodological approach into which the student teachers were inducted.

Constructivism

In working with student teachers, the authors draw on and promote constructivist principles of teaching and learning in primary science, in which learners are not seen as passive recipients but active participants in their own learning and actively 'construct' their own knowledge of the world (Piaget, 1978). A clear definition of constructivism is provided by Selley (1999, p.3):

> *It is a theory of learning which holds that every learner constructs his or her ideas, as opposed to receiving them, complete and correct, from a teacher or authority source. This construction is an internal, personal and often unconscious process. It consists largely of reinterpreting bits and pieces of knowledge…to build a satisfactory and coherent picture of the world.*

Constructivist pedagogy focuses on a learner-centred approach and the importance of the learner's cognitive course of action during the learning process. It supports a view that it is important to provide learners with opportunities to make meaning and be dynamic contributors in the learning-teaching experience (Bhutto and Chhapr, 2013).

According to Bhutto and Chhapr (2013, p. 1), constructivists believe that the construction of knowledge involves social processes, interaction with the environment and self-reflection on the part of the learners. They subscribe to a framework in which they:

- encourage learner-centred experiences
- provide opportunities for learners to work together
- encourage individuals to make sense of information for themselves
- assist novice learners to develop expertise
- focus on the role of social interaction and the impact of socio cultural factors on one's ability.

On Bhutto and Chhapr's final point, the disposition of humankind suggests that individuals are active participants in the learning process both because of their social nature and their relationship with the society in which they live (Vygotsky, 1978, Burr, 2015). Vygotsky viewed language as a *cultural* tool for communicating and developing knowledge which shapes society and a *psychological* tool for organising our individual thoughts, planning, reasoning and reviewing our actions (Daniels, 2005). Mercer suggests that the relationship between language and thought has been widely studied but that less attention has been paid to the human capacity to think together, make sense of experiences and solve problems: a process he refers to as 'interthinking' (2000, p.1). Mercer sees language as 'not just a means by which individuals can formulate ideas and communicate them: it is also a means for people to think and learn together' (1995, p.4).

In this context, student teachers are introduced to research related to dialogic teaching (Alexander, 2006) that informs the development of understanding about effective,

child-centred practice. The term ‘dialogic teaching’ entered the professional vocabulary as a result of Robin Alexander’s international *Culture and Pedagogy* analysis of classroom talk (Alexander, 2003) and refers to the power of discourse to stimulate and extend learners’ thinking and advance their acquisition of knowledge and understanding. Alexander suggests that dialogic teaching is, in fact, ‘dialogic pedagogy’, both the act of teaching and the ideas, values and principles that accompany it (2008, p.49). He visualises an image of the teacher continuously reflecting, evaluating and adapting practice in order to justify the many different kinds of decisions that are required to support effective learning. In a classroom context, dialogic teaching as an activity that is:

- collective: teachers and children address tasks together
- reciprocal: teachers and children listen to each other, share ideas and consider alternative viewpoints
- supportive: children articulate their ideas freely without fear of embarrassment over ‘wrong answers’ and they help each other to reach a common understanding
- cumulative: teachers and children build on their own and other’s ideas and chain them into coherent lines of thinking and enquiry
- purposeful: teachers plan and steer classroom talk with educational goals in view. (Alexander, 2008, p.185)

The first four characteristics sit well with the notion of dialogic communication; however, Alexander’s final suggestion of ‘purposeful’ interactions is a point of interest in terms of the extent to which ‘educational goals’ (learning objectives) are instrumental in governing the nature of the talk that takes place in classrooms. In an

authoritative communicative approach, ideas that do not contribute to the 'learning goals' are often reshaped or ignored and lecturing style may be used (Scott et al, 2007). When considering teachers' talk, Alexander (2006) noted that, in British classrooms, the majority of teachers' questions were driven by the voice of authority (the 'educational goal').

Teacher Questions

There are many reasons why teachers of primary science may see questions as an important aspect of their teaching practice: questions can be used to assess and evaluate children's ideas and progress, to promote scientific thinking, to encourage both dialogue and curiosity, and to support the management of tasks and pupil behaviour.

However, several researchers have found that teachers tend to ask too many questions (Grigg, 2010), which can have a negative impact on children's learning. Amos (2002) suggests that one-fifth of teacher talk is in the form of questions while Carr (2002) estimates that teachers ask twenty two questions per hour and that, in the same time, children ask just five questions themselves. Albergaria-Almeida (2010) cites estimates of 300-400 teacher questions per day, using 50% of class time, while children are observed to ask just one question a week. Hastings (2003) estimates that teachers ask two questions per minute, every day. Wood (1998) identifies that there is a negative correlation between the number of questions that teachers ask and the extent to which children can engage intelligently in a dialogue: 'frequent, specific questions tend to generate relatively silent children' (Wood, 1998, p. 175). This suggests that the more questions teachers ask, the less opportunity there is for children to engage in explicit higher order thinking and this is reflected in Ofsted's (2013) concern that many science lessons involve too much teacher talk that does not

maintain pupils' natural curiosity or invite children's own questions. This is a longstanding concern, with Postman and Weingartner (1971) identifying the tendency of teachers to arrange the classroom environment so that significant question asking by learners is not valued.

In addition to asking too many questions, research suggests that many teachers over-rely on the use of closed questions (those with just one 'correct' answer) that tend to promote little intelligent response (Albergaria-Almeida, 2010; Chin, 2006) but allow teachers to deliver pacey lessons and maximise perceived "knowledge transmission" (Smith and Hackling, 2016). Harlen (1999) agrees that such lower-order questions, requiring only factual recall, tend to dominate teachers' questioning, limiting opportunities (and encouragement) for more creative and enriching thinking. In science, higher order questions that require children to engage in analysis and evaluation can help deliver scientific enquiry skills, including "formulating hypotheses, seeking and using evidence and drawing conclusions" (Koufeta-Menicou and Scaife, 2000, p.79). Open questions that allow divergent responses, and promote and value dialogue, can promote meaning-making and application of concepts to new situations (Smith and Hackling, 2016).

Researchers suggest that, following teacher questions, limited thinking time (also referred to as 'wait time') can make it hard for children to construct thoughtful responses (Rowe, 1974, Wragg and Brown 2001). Hastings (2003) estimates that teachers offer children wait time of less than a second and often throw the question to another child or answer it themselves if the right answer is not offered quickly. Rowe (1974) suggests that even lower order recall questions should be allowed three seconds thinking time, with more substantial, higher-order questions benefitting from up to ten seconds for children to contemplate the meaning of the question and what

might constitute an appropriate response. Teachers, especially those new to the profession, can find such pregnant pauses rather awkward, greatly over-estimating the time they have allowed and rarely 'practising quietness to give children the chance to make sense of their own ideas' (Van Zee et al, 2001, p.181).

In summary, the review of literature reveals that teachers tend to ask too many questions, ask too many closed questions and often dominate the intellectual exchanges within classrooms, limiting both the depth of response to their own questions and any scope to explore children's questions.

Action Research

In this study, action research is adopted as a guiding methodology to support the student teachers in their professional development. As explored by Forster and Eperjesi (2017), action research places an emphasis on the use of evidence as the basis for improving aspects of practice, in order to impact more positively on outcomes for learners (McNiff and Whitehead, 2010), since many aspects of teachers' practice are based on assumptions and are the product of habits that have developed over time. Interrogation of both the perceived *quality* of personal practice and, more importantly, the *impact* on the progress and development of learners enables teachers to challenge such assumptions and explore ways in which they might improve their teaching.

While there is a wealth of existing research on 'good practice' in many aspects of teaching and learning, this can have a relatively limited impact on the quality of teaching and learning of individual teachers. As ever, as humans, we are more able to learn from our own experience (including our own mistakes) than from someone else's view of what we 'should' be doing. Putting the teacher 'centre-stage' in their

own research process enables them to engage deeply in the analysis of their practice (McNiff, 2016).

Action research is often thought of as a cyclical process (Koshy, 2010), in which a rich understanding of the quality of an individual teacher's practice enables them to identify significant steps for improvement that might have enhanced impact on outcomes for learners. It is characterised by repetitive and incremental improvement, based on the detailed analysis of evidence directly related to their teaching and the progress of their learners. This approach is endorsed by Furlong (2015, p.6), who suggests that the teachers of the future should be 'able to evaluate and use different sorts of evidence relevant to the improvement of practice'.

In this report, we show how student teachers were inducted into the action research approach, based on a constructive view of their own learning, as well as that of the children with whom they were working.

Research process

The research process had several stages. Throughout, appropriate ethical safeguards were put in place, in relation to the school, parents, children and the student teachers, to ensure that all parties gave informed consent and anonymity and confidentiality were maintained (BERA, 2018).

Teaching

To begin the process, to provide them with appropriate preparation for teaching, the student teachers were engaged in an exploration of the published research about questioning and dialogic teaching. They were encouraged to reflect on the reasons why asking lots of questions might limit children's ability to engage intelligently with scientific subject matter. They engaged in discussions about alternatives to asking

questions when teaching, such as making statements, pausing or rephrasing the children's questions or comments. In a discussion about how many questions it is reasonable for teachers to ask, they suggested that, in a half hour lesson, a reasonable number of teacher questions might have an upper limit of fifteen.

Student teachers then worked in pairs to prepare a half-hour lesson for Year Two children, on the subject of plant germination and growth, using bean seeds at various stages of germination as their primary resource to promote observation and curiosity. In their planning, they identified questions that they might ask and, just as importantly, strategies they could deploy to avoid asking too many questions. In their pairs, the student teachers then taught their prepared lessons to small groups of Year Two children. The interactions in each group were audio-recorded.

Evaluation

Immediately after the lesson, the student teachers were invited to write brief evaluations of teaching and learning, with a particular focus on both their use of questioning and its impact on the children's learning. On reviewing these reflections, it became apparent that most pairs had struggled to find ways of engaging the children without using questions and that, for some, their use of questions had been almost impossible to control. One group noted that they '*asked some POINTLESS QUESTIONS'* (their capital letters) and another guessed that they had '*asked <u>80-100 questions</u> during the 30 minutes of teaching!!'* (their underlining and exclamation marks). Another pair of student teachers noted that: '*it seemed that the children became quite reliant on our questioning*'. The students were beginning to realise that the impulse for teachers to ask questions is very strong and not always productive or positive in relation to the children's learning.

Analysis

Following the lesson, the audio-recordings were transcribed. One week after the teaching episode, each pair of student teachers was provided with a copy of their own transcript and supported in exploring ways in which to analyse this data, such as counting the number of questions that they asked during the lesson, coding questions by type (such as open, closed, attention-drawing), or identifying the best response from children to one of their questions. They were also invited to reflect on their least effective questions, based on the children's responses, and to identify their most 'cringe-worthy' questions, those that, with hindsight, they were embarrassed to admit to asking.

In their analysis of the transcripts, this last group of 'cringe-worthy' questions became a significant focus for discussion, reflection and, even, soul-searching and led to the identification of two sub-categories of questions of which they were not proud: 'blind alley' questions and 'guess the answer' questions. Students also reflected on their own uncertainty in responding to children's answers and how few questions the children asked.

Blind alley questions

Students found that some of the questions that they asked were baffling or unanswerable. In the following example, the student teacher has laid out two bean plants for observation.

> **Student teacher:** Why is this one the most grown?
>
> **Child A:** Because that one is smaller.
>
> **Child B:** And that one is shorter, that one's bigger, that one's taller and that one's bigger.

It is difficult to know if the student teacher is asking the Year Two children to suggest reasons why one broad bean plant may be more developed than another or if she is simply asking (as the children appear to assume) how, from looking at the plants, we could know that one is 'more grown' than the other. In the first case, the question is impossible to answer and, in the second case, the question is 'self-answering': the one that looks like it has grown more is the 'most grown' one.

Most notable, in this and many other extracts, is the way in which the children continue to do their best to respond, even when the teachers' questions are not of the highest quality. In the following example, the children are again examining bean seeds and plants at different stages of growth.

> **Student teacher:** How much older do you think this one is, compared to the first one?
>
> **Child A:** Really older.
>
> **Student teacher:** So talk in your partners. How much older? Is it a day older, a week older, a year older?
>
> **Child B:** That will be six. That will be one.
>
> **Child C:** That one is growing and that one is going to grow bigger.

In reviewing the transcript, this student teacher identified that she had taken the conversation down a 'dead end' by asking children to estimate the relative ages of the bean plants. It became an unproductive guessing game (much longer than the extract included here) and may have been more valuable had the children been invited to observe closely to identify any evidence that might help them to think about the stages of growth.

Guess the answer questions

Student teachers noted that many of their questions were closed questions, with just one right answer, and some were even worse than that: some were questions with several possible answers, only one of which was deemed to be 'correct'. In the following extract, the children are looking at some plants that are already growing in the classroom. In addition to being unable to curb the number of questions asked, the student teacher has just one answer in mind for her final question and other answers are ignored.

Student teacher: What are they near?

Child A: They are near the window.

Student teacher: They are near the window.

Child A: Because they take sun from the window.

Student teacher: Because they take sun from the window. Child B, is that what you were going to say?

Child B: They need sunlight.

Student teacher: They need sunlight. Why do they need sunlight? Child C?

Child C: To get their food.

Student teacher: To get some food. And what does that do, Child B?

Child B: To make you healthy.

Student teacher: To make you healthy and to make them…?

Child A: Strong.

Child B: Grow.

Child A: And tall.

Student teacher: Good girl, Child B, to make them grow.

Uncertainty in responding to children's answers

Many of the student teachers' questions were designed to support the children's observation of the bean seeds and plants. In their analysis, the student teachers identified that, in many cases, they had been unsure about how to respond to the children's observations, which led to some wondering why they had asked the questions that they did. In this example, the student teacher is encouraging the children to look closely at the bean seeds and plants.

Student teacher: Does your bean look the same as Child B's and Child C's? Shall we look at other beans? Because we've got three more.

Child A: That one looks really interesting.

Child B: There's also some black marks on it.

Student teacher: There's also some black marks on your bean. Good girl, Child B.

The student teacher is positive about the child's observation and repeats her words back to her but, having asked the child to observe, it seems that the student teacher is not sure what to make of the observation or how best to direct the child to a more meaningful observation. Having considered 'wait time' as an important aspect of practice when asking questions, the student teachers identified that they should also give themselves 'thinking time' before responding to children's answers and this was seen as a significant learning point by many.

Children's questions

Only one pair of student teachers made a concerted effort to focus on the children's questions rather than their own. However, they were very focused on writing these down on post-it notes, and perhaps forgot to really listen and were a bit too focused on ensuring the children raised questions rather than engaging them in authentic dialogue, as seen in the following short extracts.

Student teacher: Have you got a question?

Child: You know the white thing, poking out?

Student teacher: Shall I put 'what is the white bit?' What do you think that is?

-

Child: then they grow and they get some sun and then they grow. They start to help the seed.

Student teacher: Brilliant, so what's your question?

As a result, student teachers were often task-focused and missed opportunities to engage children with the meaningful questions that they raised, as in the following extract.

Student teacher: We'll give you a few more minutes to write your ideas down.

Child A: It looks a bit like a seed. What is it?

Student teacher: I'll put them back in the middle if anybody wants to have another look.

Child B: It's brown. Why is it brown?

Student teacher: You can write that down if you want to.

It was also noted that, while children did not ask many questions about the scientific content of the lesson, they were happy to ask unprompted questions about the requirements of the task, as in this extract.

> **Student teacher:** You can write down the things that you know that you might know and maybe something that you want to find out about it. Do you want to write down on your piece of paper?
>
> **Child A:** We need to do names first.
>
> **Child B:** Do we need to do our name at the top?

This child's question about the need to put their 'name at the top' reflects Postman and Weingartner's (1971) suggestion that, in a learning environment that typically stifles children's ability to raise independent and creative questions, they are often keen to ask 'technical questions' about how to complete the tasks they are required to undertake, reflecting underlying concerns about getting things 'right' and conforming to expectations.

Developing practice

Student teachers were able to triangulate the findings from the analysis of the transcripts with their own evaluations written shortly after the lesson and, as a result, they were able to identify specific ways in which their practice of questioning could have been improved. These were different for each student teacher but included, across the group, an intention, in future science lessons, to say less, to ask fewer questions, to give children more 'air time', to listen more carefully to children and to pause before responding to children's contributions.

They put these into practice in a follow-up lesson with the same children, in which digital microscopes were used to stimulate children's curiosity and develop their

observation skills as they examined parts of plants in great detail. In this lesson, the student teachers applied their own learning, and were able to let the children lead discussions and, as a result, the children were given good opportunities to raise their own questions. Given that these were year two children, the sophistication of their questions was impressive, with the following questions being raised, among many others: *Why do plants close up sometimes? Why do plants have so many roots? Where do seeds come from? What are the hairs on the leaves for? Why are there a lot of lines on the leaf? Why do plants grow so slowly? Why do plants need leaves?*

***Review*:** In the first stage of this enquiry, the student teachers were astonished to discover how over-reliant they were on questioning as their fallback strategy for engaging children in science-related dialogue, even following consideration of the limitations of questions and when making a particular effort not to ask too many questions. The process of analysing transcripts of their own interactions with children was highly significant in their evaluation of their practice. As a result, they were able to identify ways to develop their practice to have a greater impact on outcomes for children and to explore these in practice in the second teaching session.

As a conclusion to these learning episodes, we asked the student teachers to define, for the benefit of future cohorts, some key characteristics of effective questioning in primary science and they suggested the following:

- *Don't fill every silence with a question: enjoy silences*
- *Don't dominate the children's thoughts*
- *Allow children time to respond*
- *Listen to children's responses*

- *Use statements instead of questions: good statements can be just as good to promote thinking*
- *Plan your questions beforehand*
- *Ask the children if they have any questions: sit back and listen*
- *Think before you ask!*
- *Have more confidence that children will make interesting comments without you drawing their attention to things.*
- *Allow time to really take in the children's comments before rushing to respond.*

The suggestions highlight that, through reflective practice, the students developed their pedagogical understanding of the importance of providing learners with opportunities to make meaning and be active contributors in the learning-teaching experience, as espoused by Bhutto and Chhapr (2013). In terms of teachers' questioning, they offer practical approaches that have the potential to address some of the key issues that were explored in the literature, such as wait time, a general over-reliance on questioning as the main communicative approach and the importance of offering meaningful responses to the children's answers, remarks and ideas.

Students teachers' reflections on the research process

During some interviews to establish the student teachers' perceptions of the process that they had experienced, they revealed that they had not previously had the opportunity to analyse the detail of their teaching in such depth. They stated that they identified and were able to analyse critical incidents that they would not have noticed had they been retrospectively evaluating their teaching in the way that was usual

practice. Their comments revealed that some powerful transformations had occurred, in terms of their learning and their attitude towards reflective practice.

> *Student A: 'I realise that we have developed our practice to ask questions that 'control' behavior, i.e. to show understanding but not so much to encourage thinking or question raising.'*

> *Student B: 'I am much braver in allowing children to build their own questions. I wouldn't have wanted to do that before because I would have been worried that they might not have come up with 'good' questions'.*

These comments reveal that the students have developed their pedagogical understanding of the purpose of teachers' questions from 'teacher-centric' to 'learner-centred' (Selley, 1999, p.4). Furthermore, Student B has developed his subjective view of children's capacity to engage in intellectual activity and ask intelligent questions about scientific phenomena.

> *Student C: 'I liked being able to look back and notice, when it came to the second session, I stepped back a bit. I am now more aware of the words that I choose; in school, I have asked a question and then considered the impact and repeated using different words so that all children could understand'.*

> *Student B: 'Going into next year, I feel much more confident and would want to build it into other subjects too'.*

Student Teacher C demonstrates a positive response to reflective practice and is mindful of how her analysis had an impact upon her approach. Furthermore, she demonstrates an awareness of how reflective practice can be instrumental in

transforming practice ‘in the moment’, while Student Teacher B is inspired to continue his journey of professional learning into his NQT year.

The comments revealed that authentic professional learning occurred through the students internalising and acting upon their initial evaluations and establishing a focus for their practice in the follow up activity. Not only did they have a clear vision about what they had learnt and the implications for their future practice, they also demonstrated positive affective responses to the process and a desire to engage in enquiry based learning in their future practice.

Conclusion

When student teachers were given the opportunity to analyse and evaluate both the perceived quality of their practice and, more importantly, its influence on the children’s engagement and questioning, they responded with self reflection, self-regulation, adaptations to their practice and changes to their subjective theories of the teacher’s role in primary science. These experiences were transformative because the student teachers intended to enact their professional learning in their future practice.

This study has shown that engaging student teachers in the process of action research can lead to deep professional learning that is likely to have a positive impact on the quality of their practice and promote the intellectual engagement of children.

References

Albergaria-Almeida (2010) ‘Classroom questioning: teachers’ perceptions and practices’, *Procedia- Social and Behavioural Sciences,* 2(2). doi 10.1016/j.sbspro.2010.03.015.

Alexander, R. (2003) Talk in Teaching and Learning: International Perspectives in Qualifications and Curriculum Authority, in Myhill, D., Jones, S. and Hopper, R. (2006) *Talking Listening, Learning: Effective Talk in the Primary Classroom*. Berkshire: Open University Press.

Alexander, R. (2006) *Towards dialogic teaching* (3rd edn.) New York: Diálo.

Alexander, R. (2008) *Essays on pedagogy*. London: Routledge.

Amos, S. (2002) ‘Teacher’s questions in the science classroom’ In: Amos, S. and Boohan, R. (eds) *Aspects of Teaching Secondary Science.* London: Routledge Falmer.

Bhutto, S. and Chhapra, I. (2013) ‘Educational research on “constructivism” – an exploratory view’. *International Journal of Scientific and Research Publications,* Volume 3, Issue 12 (online) http://www.ijsrp.org/research-paper-1213/ijsrp-p2406.pdf [Accessed 17/05/18].

British Educational Research Association [BERA] (2018) *Ethical guidelines for educational research,* fourth edition, London. https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018

Burr, V. (2015) *Social constructionism (3rd edn*). Hove: Routledge.

Carr, D. (2002) ‘The art of asking questions in the teaching of science’, In: Amos, S. and Boohan, R. (eds) *Aspects of Teaching Secondary Science.* London: Routledge Falmer

Chin, C. (2006) 'Classroom interaction in science teacher questioning and feedback to students' responses', *International Journal of Science Education,* 28(11), pp.1315-1346. doi 10.1080/09500690600621100

Chin, C. (2007) 'Teacher questioning in science classrooms: approaches that stimulate productive thinking', *Journal of Research in Science Teaching,* 44(6), pp.815-843. doi 10.1002/tea.20171

Daniels, H. (ed.) (2005) *An introduction to Vygotsky*. London and New York: Routledge.

Forster, C. and Eperjesi, R. (2017) *Action research for new teachers: evidence-based evaluation of practice*. London: SAGE.

Furlong, J. (2015) *Teaching tomorrow's teachers*, Oxford: Oxford University Press.

Grigg, R. (2010) *Becoming an outstanding primary school teacher*, London: Longman

Hastings, S. (2003) 'Questioning', *Times Educational Supplement* 4th July (available at 1st Sept 2018 from https://www.tes.com/news/questioning).

Harlen, W. (1999) *Effective Teaching of Science. A Review of Research*, Edinburgh: Scottish Council for Research in Education.

Harris, D. (2006) 'Open or closed – that is the question', Paper presented at the British Educational Research Association Annual Conference, University of Warwick, 6-9 September 2006.

Koshy, V. (2010) *Action research for improving educational practice: a step-by-step guide (2nd edn)*. London: Sage Publications.

Koufeta-Menicou, C. and Scaife, J. (2000) 'Teachers questions – types and significance in science education', *School Science Review*, 81(296), pp.79-84

Ofsted (2013) *Maintaining curiosity: a survey into science education in schools*. Manchester: Crown copyright.

Mercer (1995) *The guided construction of knowledge*. Clevedon: Multilingual Matters.

Mercer (2000) *Words and minds: how we use language to think together*. London: Routledge.

McNiff, J. (2016) *You and your action research project* (4th edn). London: Routledge.

McNiff, J. and Whitehead, J. (2010) *Doing and writing action research*. London: SAGE

Ofsted (2013) Maintaining curiosity: a survey into science education in schools, Manchester: Ofsted (available at 1st Sept 2018 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/379164/Maintaining_20curiosity_20a_20survey_20into_20science_20education_20in_20schools.pdf).

Piaget, J. (1978) *The development of thought: equilibration of cognitive structures*. Oxford: B. Blackwell.

Postman, N. and Weingartner, C. (1971) *Teaching as a subversive activity.* Harmondsworth, Penguin Books Ltd.

Rowe, M.B. (1974) 'Wait-Time and Rewards as Instructional Variables: Their Influence on Language, Logic, and Fate Control'. Presented at the National

Association for Research in Science Teaching, Chicago, Illinois, April 1972.

Scott, P. Ametller, J., Mercer, N., Staarman, J. and Dawes, L. (2007) *An Investigation of Dialogic Teaching in Science Classrooms*. Paper presented at NARST: New Orleans April 2007.

Selley, N. (1999) *The art of constructivist teaching in the primary school.* London: David Fulton Publishers.

Smith, P. M. and Hackling, M.W. (2016) 'Supporting teachers to develop substantive discourse in primary science classrooms', *Australian Journal of Teacher Education*, 41(4), pp.151-173. doi 10.14221/ajte.2016v41n4.10.

Tofade, T. Elsner, J. & Haines, ST (2013) 'Best practice strategies for effective use of questions as a teaching tool', *American Journal of Pharmaceutical Education*, 77(7), pp.1-9. doi 10.5688/ajpe777155.

van Zee, E., Iwasyk, M., Kurose, A., Simpson, D., Wild, J. (2001). Student teacher questioning during conversations about science, *Journal of Research in Science Teaching*, 38(2), pp.159-190. doi.org/10.1002/1098- 2736(200102)38:2<159::AID-TEA1002>3.0.CO;2-J

Vygotsky, L. (1978) *Mind in society: the development of higher psychological processes*. Cambridge: Harvard University Press.

Wood, D. (1998) *How children think and learn* (2nd edn). Oxford: Blackwell.

Wragg, E.C. & Brown, G. (2001) *Questioning in the secondary school* (revised edition), London: Routledge Falmer.