Revealing Questions: What Are Learners Asking About?

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Introduction

Questions are clues. Asking questions shows curiosity, interest and intrigue on the part of the questioner. As learners attempt to access information, understand new content and form connections to their existing ideas they ask questions—questions are indicators of active learning. This chapter focuses on the questions asked by learners around science. The first section addresses literature around question-asking, and the second discusses data from a study into learners' questions within a museum.

New trends in educational theory and curricula have placed more emphasis on learner questioning. Inquiry-based learning in particular allows more space for students to explore their own questions and investigate their own areas of curiosity. With a focus on active participation in their own learning, students are encouraged to ask questions as well as offer answers to the questions of the teacher. Questions are particularly pertinent in science education. Science is described in the first line of the Australian National Curriculum for Science (ACARA 2013) as providing "an empirical way of answering interesting and important questions about the biological, physical and technological world". A parallel movement in science communication and learning in out-of-school settings has placed emphasis on encouraging non-experts to ask questions of experts. Rather than traditional one-way transmission of information, more recently two-way dialogue is encouraged, with questioning and discussion between non-experts and experts.

Questioning is endless, and happens throughout our lives. Questions arise in all environments and over time, and are not only confined to classrooms, but occur in museums . and online environments, at work, during conversations with friends and family, and they can be triggered immediately or much later after the original

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experience. A focus on learner questions, therefore, encompasses the notion that learning occurs across time and in different environments, and maintains the focus with the learner themselves, and their self-directed learning.

Although the study of questions is by no means new, in this chapter 1 argue that there is more that questions can tell us, and that exploring the questions learners ask as they come across new experiences can reveal much about the learner, and their own understanding, attitudes and interests. Looking at the progression of questioning can reveal the impacts of a particular learning experience and, therefore, may be of use as an assessment tool. An emphasis on learner questions also brings the learner into the forefront of their own experience and has implications for the way that learners can shape and help develop education experiences in, for example, classroom lessons, museum activities and online environments.

A focus on questions can therefore tell us much about the learner, compared to only focusing on the answers learners provide to the questions we ourselves pose as educators. The following section explores questioning in the classroom and what it might reveal about learners. The chapter then turns to questions asked when learning outside the classroom, in places such as online Ask-A-Scientist sites, and in museums. The chapter concludes by discussing a study into question-asking at the Natural History Museum, London.

Questions in the Classroom

The idea of a 'question-driven classroom' was championed by Shodell (1995), triggering a new wave of interest in student questions. Although researchers have raised concerns about the low number of questions asked by students in the classroom (Dillon 1988), new movements in science education have focused on using questions to drive students' learning. Early work from the University of Waikato recognised the value of children's questions to teachers and explored how students' ideas and questions could play a significant role in their science education (Biddulph et al. 1986). In particular, students have been encouraged to answer their own questions through open-ended learning activities, inquiry-based learning and problem-based approaches (Abrandt Dahlgren and Öberg 2001).

Abrandt Dahlgren and Öberg (2001) studied the questions generated by undergraduate students during a ten-week problem-based introductory course at a Swedish university. Within this programme, a problem-based approach was defined as involving "formulating important questions surrounding a concrete environmental problem" (p. 266). This quotation highlights the prominence of question-asking in problem-based approaches in science education. The researchers analysed diary notes written by the students, looking at the structure and content of the questions asked. Students moved between the five identified types of questions, including encyclopaedic, meaning-orientated, relational, value-orientated, and solution-orientated. Switching between question types suggests that the students may be undertaking a meaningful, deep approach to learning (as defined by

Bowden and Marton 1998), rather than a surface approach to learning which may only make use of encyclopaedic questions to gain factual information.

The presence of deep and meaningful learning in questioning is encouraging, as it is deep levels of learning that are often sought in educational interventions. Such 'deep learning' is where students try to make sense of and grasp the phenomenon as a whole, make connections between different aspects and concepts, challenging and relating new information to previous knowledge. This type of learning is long-lasting and connects with other experiences and information (Chin and Brown 2000). Surface approaches to learning, in contrast, do not include such strong links to other information and ideas, and therefore knowledge is less likely to be integrated and memorable. Question-asking within problem-based approaches may therefore provide an opportunity for a deep and meaningful type of learning.

Christine Chin and colleagues also investigated student-generated questions and their relationships to deep or surface approaches to learning. Their study involved six students aged 13–14 as case studies, and over the course of a nine-week chemistry module, observations, field-notes, interviews and learning journals were used to study the types of questions asked, and how these related to learning (Chin et al. 2002). There were relatively fewer 'wonderment' (high-level) questions asked (14 % of total questions), compared to basic (low-level) questions. Wonderment questions supported deep learning as they led to discussion, prediction and hypothesising, whereas basic questioning gave little opportunity for discussion. The findings of Chin et al. suggest that teacher-directed activities provided fewer opportunities for deep-level wonderment questions, compared to activities where students worked through problems and where inquiry was encouraged.

In a later study, Chin and Chia (2004) used question-driven problem-based learning to investigate the types of questions 13–14-year-old students were asking during problem-based work in biology classes. They focused on the inspirations behind students' questions, the types of questions students asked when in groups and individually, and the implications for knowledge construction. Additionally, they looked at the evolution of questions and how questions may show progress in students' thinking. Four sources of inspiration for questions were identified: cultural beliefs and folklore, advertisements and the media, curiosity from personal encounters or observations, and issues from previous lessons at school. Studying the inspiration for questions allows us to see the possible sources of any preconceptions or misconceptions, which might affect the questions asked. Sources of questions also highlight where connections may be made to previous knowledge and, therefore, where deep learning might be encouraged. In this way, questions are a valuable source of information for teachers and educators.

Earlier work investigating student-generated questioning was carried out by Alison King. One study with undergraduates looked at the effect of training students in asking questions, and the role of guides for questioning, on students' achievement and knowledge construction. It was found that students who had been trained in using guided questions during a reciprocal questioning exercise asked more high-level, critical thinking questions, gave more elaborate responses, and demonstrated higher achievement in a post-test compared to students in control

groups who had unguided or no question training (King 1990). In work involving younger students, King (1994) compared students' interactions and post-test knowledge maps of those trained in two types of questioning. The first group, trained to ask questions not only about the content of the lesson they had just received but also to relate this to prior knowledge and experience, drew more complex and advanced knowledge maps, compared with the second group who were trained only in question-asking about the lesson. Further, both the groups trained in questioning asked more higher-level questions (including integration and comprehension) compared to a control group with no question training. Similar findings were reached in a later study with students (King 2002), showing that higher-level question prompts could encourage higher-level cognitive processing, that is, making inferences, conclusions, generating hypotheses, comparing and evaluating.

Research on student questioning in science education therefore shows that encouragement and training in question-asking can lead to deeper learning. Questions have also been used to provide information on the source of student inspiration, and therefore motivation for learning, as well as pointing to potential sources of misinformation and misconceptions. While some of this work predominantly focused on the level of students' explanations and the knowledge construction taking place, student-generated questions were a prerequisite of the explanations given and the type or level of questions were shown to affect the explanations given and the learning taking place. Therefore, studies have shown that a focus on questions, rather than explanations alone, might have promise for understanding students' learning and encouraging deeper engagement, as well as pinpointing areas of interest for students and potential misconceptions. The chapter now moves to focus on questions that learners might ask outside the classroom, exploring how these questions might reveal how individuals are developing their understandings and identifying differences in their areas of interest.

Questions Outside the Classroom

Research in science education has provided much insight into why student questions might be important and useful. However, we don't only ask questions when we are at school. The majority of questions asked will be asked outside school, throughout our lives. With Internet search engines at the tips of our fingers and with us all the time on our mobile devices, questions are 'googled' constantly. The word 'googleable' has even made it into the Oxford English Dictionary. It is increasingly easy and common to ask questions about things we encounter through our daily lives and gain instant information or feedback. Other examples of where learners are able to ask questions and participate in inquiry around science outside of school are discussed by Selwyn and Cooper (this volume).

Learners have an increasing number of opportunities to voice their own questions in science learning environments outside the classroom. Here I will cover two

contexts in particular—museums . and Ask-A-Scientist websites—but these are just two examples of a whole suite of learning opportunities available to us as we engage with science throughout our lives. Many of the assumptions on which the work in formal education is based are also relevant to museums and out-of-classroom settings, and the pedagogies and learning opportunities have been studied (Stocklmayer et al. 2010), highlighting the relevance and overlap work in these two fields may have, and ways in which they can be integrated. Investigating question-asking outside the classroom in a similar way to how it has been investigated within schooling may give further opportunities to link classroom activities to field visits, for example, and promote integrated holistic learning, as opposed to visits to museums being one-off, dislocated experiences. Finally, as the majority of the research into learner-generated questions has been focused within schools, looking at contexts such as museums allows us to study questions asked by adults, who, of course, are not still at school but are very much still learning.

Following a period of concern about public attitudes towards science and scientists, the way in which science was presented to the public was re-examined, leading to an influential report by the UK House of Lords Science and Technology Select Committee entitled *Science and Society* (2000). This report called for public engagement with science using a more active and two-way model of science communication than had been the case before. Learning science outside school therefore became much more focused on the learners, who became active participants in their own learning rather than submissive vessels to be filled with knowledge. Part of this vision was to create active learners who engage with science, including asking questions of science and scientists, and taking part in dialogue and debate around scientific issues. Questions became important in the world of public engagement with science and learning outside the classroom and, subsequently, research focused on the nature and topic of those questions.

Ask-A-Scientist Websites

In line with the expansion of online learning environments, websites have emerged enabling students to ask questions to scientists or other experts. These websites are one way in which information and communications technologies (ICTs) are playing a part in science education, connecting students with scientists and scientific research and enabling learners to develop media literacy (see Shanahan, this volume). For example, 'I'm a scientist get me out of here' in the UK (imascientist.org.uk) has been running annually since 2008. It is an online event supported by the Wellcome Trust where students can chat to scientists online, ask them questions, and vote for the scientist they would most like to win a prize of £500 to communicate their science. These types of websites are useful fora to study learner-generated questions—questions are posed to experts in a relatively anonymous and free-choice way.

Questions asked by 9–18-years-old school students on another Ask-A-Scientist site (MadSci) were analysed in order to uncover student interests within different science topics (Baram-Tsabari et al. 2006). The researchers found significant differences between girls' and boys' interests in different topics. Girls asked more school-related questions than boys, that is, questions that were sparked by something the students had covered at school. In addition, the frequency of asking school-related questions increased with age (Baram-Tsabari et al. 2006).

A further study on the same Ask-A-Scientist site revealed gender and age differences in student interests, using question data collected over a decade (Baram-Tsabari et al. 2009). Female students asked more questions than male students although the gap decreased with age. The boys and girls showed different levels of interest in different scientific topics, providing more evidence that boys prefer physics-related subjects and girls show more of an interest in biology-related topics. Comparisons between different countries showed that female participation in asking questions on this site was found to be correlated with the difference between girls' and boys' achievement in science, but not correlated to levels of gender equity within the participating countries.

This finding demonstrates how student question-asking outside the classroom could be a valuable tool for investigating interests and attitudes around science over a long period of time, and over a wide geographical area. The Relevance of Science Education (ROSE) project, for example, compared interest in different scientific subjects of students aged 15 from 40 different countries. Students from countries who were classed as less economically-developed were more interested in a wider range of science subjects than those students in more economically-developed countries (Sjoberg and Schreiner 2010). The challenge is, therefore, how to create a context in which learners are stimulated, interested and able to ask questions about science. Questions asked by students could therefore be a useful resource for teachers aiming to gauge attitudes to a new subject, or for educators developing new programmes for museums, science centres and other events such as science festivals.

Museums

Museums aim to make their visitors think, wonder and ask questions, and exhibits and text are designed to challenge and engage visitors. Researchers have suggested that activities that focus on the learner and the questions they arrive with, and that encourage them to ask more questions as a result of their experiences, may increase the levels of engagement and learning on museum visits (Griffin and Symington 1997). However, despite some work into visitor engagement with thought-provoking text labels or displays, there has been little work into what questions visitors ask at museums, and particularly how museum staff and experts could support the generation of visitor questions. There has been research into learning conversations in museums, and within these conversations there will

almost certainly be some learner-generated questions (such work includes Ash 2003; Leinhardt et al. 2002; Sanford 2010; Zimmerman et al. 2010). The work on museum visitor conversations follows the shift from constructivist approaches in museum learning to socio-cultural perspectives, where learners are studied as part of a social context, constructing knowledge together rather than as individuals. The vast majority of museum visitors come to the museum with at least one other person, often in groups, and therefore conversations, including questions, and social contexts will be relevant in most museum experiences.

Exhibits and museum displays are designed to engage visitors with the concepts presented, prompt questions, and challenge thinking around the content. One of the ways in which museums . might support this kind of behaviour is by using thought-provoking exhibit labels that prompt visitors to think about the exhibit and talk amongst their accompanying group. Hohenstein and Tran (2007) investigated the impact of adding a thought-provoking question to science museum exhibit labels on the conversations of groups of visitors. They found that for some exhibits, adding a question to the existing label prompted more questions and explanatory talk in visitor conversations. This finding suggests that with the right prompting in the form of questions on exhibit labelling, visitors can potentially generate questions and explanatory talk about exhibits, both of which are important components of inquiry and learning conversations.

Elsewhere, researchers in San Francisco were also investigating how to prompt inquiry behaviour amongst exhibition visitors. Josh Gutwill and Sue Allen at the Exploratorium attempted to devise a programme whereby visitors could develop their questioning, exploration and investigative skills through ‘inquiry games’, which were played by groups of visitors while engaging with museum exhibits (Allen and Gutwill 2009; Gutwill and Allen 2010). By identifying inquiry skills from the literature and developing a programme designed to support families using these skills while interacting with the exhibits, greater inquiry behaviour was observed among the groups compared to control groups. Inquiry behaviour included time spent engaging with the exhibit, the numbers and durations of questions or statements, and interpretive talk, both individual and collaborative. Although other measures of inquiry behaviour increased following training in the inquiry games, the number of proposing actions did not show any significant change. This finding indicates that families did not ask any more questions after inquiry training compared to before. However, the duration of proposing actions and coherence of investigations increased after participation in the games, suggesting that families formulated more sophisticated or complex questions that were related to prior and future investigations. Thus a focus on the actual questions visitors are asking at exhibits is crucial to understand any impacts on their learning—just looking at numbers of questions gives a limited picture of what is going on. Through studying what learners actually ask, we can start to explore some of their attitudes, understandings and interests, and use this information to shape the development of future learning experiences.

Questions as Interest

Arguments for a focus on learner questions have been outlined above, including the potential to provide a useful insight into learners' interests, motivations and knowledge construction, and into the impacts of a given intervention. Support for this argument can be drawn from work in educational psychology that looks at what constitutes interest and how it is related to learning and motivation (Krapp 1999; Renninger et al. 1992). Interest is "a content-specific motivational variable that can be investigated and theoretically reconstructed" (Krapp 2007, p. 5). Interests are content-specific, that is to say, explicitly tied to one 'object of interest', an experience, concrete object, area of information or idea. Interests are linked to motivations, drivers of future behaviour or thoughts, usually to find out further information about the object of interest (Krapp 2007). Interests are outcomes of interactions between the person and the object of interest, in a suitable environment or context (Hidi and Renninger 2006). Therefore, interests are strongly linked to motivations, positive emotions and knowledge about the interest object, and drive questions as the individual strives to find out more:

> a person who is interested in a certain subject area is not content with his or her current level of knowledge or abilities in that interest domain. Rather there is a high readiness to acquire new information, to assume new knowledge and to enlarge the competencies related to this domain. (Krapp 2007, p. 10)

Looking at questions as predictors or outcomes of the appearance or growth of interests not only requires an explanation of what constitutes an interest, but also an exploration of interest development. Krapp (2007) discusses a three-stage model of interest development in his person-object theory of interest. He argues that initially situational interests are triggered by external stimuli, following which they then may last during a phase of learning. If they are significantly engaging, the situational interest then becomes an individual interest, which is enduring and incorporated into the person's beliefs, goals and actions by a process of internalisation. The four-phase model of interest development, posed by Hidi and Renninger (2006), builds on Krapp's earlier work. The four phases identified were: triggered situational interest, maintained situational interest, emerging individual interest, and finally well-developed individual interest. The additional emerging individual interest stage is particularly relevant to this work as it is argues that this is the phase in which learners begin to formulate their own curiosity questions about the interest. In their paper describing the four-phase model, Hidi and Renninger (2006) emphasise the importance of external support in the development of the early stages of interest. This emphasis on external support highlights the potential that other people, such as teachers, parents and museum staff, may have in supporting interest development in visitors. Questions may be more numerous or complex in some phases of interest development compared to others but will still provide clues as to which interests are present and what stage the development of interests has reached.

France and Bay (2010) looked at student questions as an indicator of interest. The questions of 399 Year 13 students (aged 16–18) in New Zealand were collected using

questionnaires in order to explore the interests of the students and their reflections on a day at a biomedical research centre. Students took part in a number of activities as part of their visit, including three practical workshop sessions and a small group discussion with two research scientists. Through two questionnaires, one administered before and one after the visit, France and Bay were able to compare the questions students intended to ask the scientists they met with the questions they considered the most interesting or useful that they had heard asked during the day. This comparison gave an insight into the views of students on science and scientists, and also their reflections of the day. The predominant finding of the study was that students showed an interest in the scientists themselves, asking more personal questions about their life and experiences, than would have been expected from the pre-visit questions. Students also made personal connections to the scientists they met, asking questions about the scientists' career histories and attitudes towards their jobs, as they themselves tried to explore their own science identities and consider their own futures. France and Bay argue that such questions are a tool students can use for cultural border crossing: through exploring their interests they can broaden their science literacy and explore the scientific research culture at the biomedical centre.

The argument for using questions as indicators of interest is not without its limitations. Without following up data collected on questions asked, researchers cannot be sure that these truly reflect the interests of the individual learner. A study of an online environment attempted to control for some of these problems by separating school-motivated questions from spontaneous questions, arguably those prompted by the students' own personal interests (Baram-Tsabari et al. 2006). However it is still not known whether these spontaneous questions are rooted in a long-term, genuine and sustained interest of the individual or, perhaps. the result of hearing something on television or from conversations with friends, sparking a more immediate, short-term, topical interest. Situational interests are primarily caused by external factors—a work or social situation, for example. Individual interests emerge from situational interests and are long-lasting, stable interests in which motivations to find out more about the object of interest are related to the object itself or its associated knowledge domain, as opposed to work- or context-specific motivations. In the study above, school-motivated questions might be classed as indicating situational interests, whereas spontaneous questions could be outcomes of individual interests. Both types of questions are, therefore, important, as those indicating situational interests may indeed form the basis for individual interests in the future. Therefore, a study into questions holds promise for revealing interest development as well as areas of interest.

Questions in the Natural History Museum, London

Museums aspire to be inspirational places, often full of new, exciting and rare objects, and as such are places where questions are sparked, asked and answered. Museums, therefore, are fruitful places to study questions, exploring visitors'

learning, investigating what grasps their interests, and gaining indicators of impacts of museum experiences. Research at the Natural History Museum, London, undertaken by the author (Seakins 2014) used visitor-generated questions as part of a study into the impacts of interactions between visitors and scientists from the visitor's perspective. The questions formulated by visitors to ask scientists were studied in order to explore any impacts of the session on areas of visitor interest, and in particular their interest in, and therefore connection to, the scientists themselves. In this study, the learners were a diverse group of people—adult visitors and A-level biology students aged 16–18.

Studying Visitor Questions

Two elements of the Natural History Museum's educational programme enable visitors to meet some of the museum's scientists and were sites of data collection:

- Nature Live events: daily half-hour sessions where one museum scientist, accompanied by a science communicator ('host'), discusses their research with visitors.
- A-Level days: A-level biology students (aged 16–18) attend a behind-the-scenes tour with a museum scientist, followed by a Nature Live event.

Nature Live events are half hour events scheduled every afternoon and involve museum scientists speaking about their areas of research, recent projects or field visits, or areas of the collections in an informal discussion format. Events are hosted by one of a team of five Nature Live facilitators, all of whom have degrees in science communication. Scientists often bring along specimens from the collection or research equipment, show photographs and diagrams, videos from their fieldwork or even bring along samples for the audience to taste, such as edible insects or chocolate. The audience is encouraged to get involved in the session, ask questions, make comments, answer questions, handle specimens, and vote when given options by the host or scientist. A-level behind-the-scenes days are programmed especially for biology students (aged 16–18), including a behind-the-scenes tour with a scientist into laboratory, collections or research spaces, where the scientist discusses their research with the students. The A-level day also includes a special Nature Live session and a workshop on taxonomy.

The study involved a pre-and-post interview research design. Visitors were interviewed before and directly after the session, and then again six to eight weeks later. One or two visitors, depending on whether they were visiting alone or in a pair, were recruited for data collection for each Nature Live event. In total, 81 visitors from 52 events spread over 6 months were interviewed. Groups of four students were recruited for each A-level day. In total, 38 students from nine A-level days took part in the study (extra students were recruited as some were absent on days of follow-up interviews). Semi-structured interviews established what visitors felt they learnt or got out of the session, what had surprised them, and what

Table 1 Summary of data collection methods for visitor question data

Time period	Data collection method
Pre-session	Pre-session interview question: "What questions would you like to ask the scientist, or what things would you like them to speak about?"
	Data from study participants only
In-session	All questions asked by all audience members were recorded in field notes and checked against filmed recording of the session
	Study participants were asked in post-session interview: "Did you ask any questions? What did you ask about?"
	Data from audience in general and study participants
Post-session	Post-session interview question
	"If [scientist's name] were to come and sit down with us now, what questions would you like to ask them, or what more would you want them to talk about?"
	Data from study participants only
Post-visit	Post-visit interview question: "Have you thought of any other questions you might like to ask the scientist you met, if you were to meet them again, or anything more you might like to hear about?"
	Data from study participants only

questions they might like to ask, or would have liked to ask, the scientist. Table 1 indicates where and how data on visitor questions were gathered. As is evident from the table, study participants were asked about their questions in interviews, whereas the questions of the audience in general were recorded during the session.

Interview transcripts were analysed using a thematic coding strategy searching the transcript for the key themes which were then coded and arranged in a frame. This qualitative analysis provided the basis of the majority of a larger study (Seakins 2014). Further analysis focused on the questions visitors formulated to ask the scientist before the session, during the session and afterwards. Some visitors and students asked more than one question and some could not think of a question, explaining the differences in frequencies of questions asked. Questions from interviewees only were collected from the pre-session, post-session and post-visit interviews, whereas questions from the entire audience were included in data collected during the session.

Analysis of the topics of visitor questions points to areas of interest and curiosity held by the visitors. Changes in these topics from before to after the sessions indicate an impact on interest as a result of meeting a scientist. Question topics were coded based on the approach used in the study mentioned earlier by France and Bay (2010). Categories included those about scientific processes, science content, the scientist themselves and their career history, and social and ethical decisions in science (see Table 2). Questions were identified in interview transcripts and field-notes taken during the session itself. Questions were defined as an expression of interest to find out more information, for example, preceded by 'I'd like to hear more about…' or 'I would have been keen to ask…' Each question was coded under one category only—the category most applicable to the question—although it

Table 2 Question topic categories

Category	Description	Examples	Total occurrence
Personal	Questions about the scientist themselves, their career history and life as a scientist. Asking for information on what scientists might do day-to-day, how the scientist chose and got to their job in terms of studying, about the individual scientist and what they think about different aspects of their job	And what kind of things did they, like, study? And when did they make the decision that that was something they wanted to like specialise in?	163
		Also how did you become, go from a scientist to, like, when did you decide to work in the museum? And not just in a lab?	
Science information	Questions about scientific concepts, facts and phenomena. This is usually related to the topic of the meet-the-scientist session, so the area of expertise of the scientist. About factual scientific content or concepts	What kind of algae is there—it all looks pretty algae-y to me, but is there colourful algae, living, like algae that eats things?	407
		Can you notice, have the ostracods changed at all over [time], from the fossils to the present day?	
Science process	Questions about scientific research, how science is carried out and techniques and methods. May be to do with accuracy, taking samples, using equipment or techniques, or about the process of publishing or gaining consensus about scientific findings. Anything about the process or procedures in science	I would like to hear how people classify new animals/organisms, and the criteria for doing so.	110
		I have one question, that's could you ever find out how much a dinosaur fought from its bones?	
Social and ethical issues	Questions about broader issues in science and scientific research relating to science and society, the future and potential implications, culture and moral and ethical dilemmas. Often about the wider implications of research, how it relates to society and culture, relating to funding, differences in opinion, opposition to science, or societal or political decisions which must be made in relation to research	Is there any opposition to the work that you are doing, you know, if someone wanted to build on the site of a plant which was at risk?	48
		And why it was important for us to actually know, well what's going to be the future, what's going to happen as a result of this. Are we going to try to create, is it all to do with trying to create life?	

is recognised that often questions might fit into two or more categories. The proportions of questions asked on each topic were compared; in particular the changes in the proportion of questions that were about the scientist, their work and career history, were investigated, to examine whether visitors and students were identifying more closely with the scientist as a result of the interaction.

Following a pilot study, the categorisation used by France and Bay (2010) was adapted and adjusted for the Natural History Museum context, removing 'Nature of Science' as no questions were asked in this category. The absence of questions about the nature of science is interesting and may have been due to the differences in activities around which questions were generated. In the France and Bay study, for example, students took part in experiments and workshops alongside talking with the scientists. In the Nature Live events studied at the Natural History Museum, visitors and students took part in a talk/discussion rather than doing any experimentation themselves. The difference between the two studies suggests that the type of activity may have implications for the questions asked and, therefore, the interests that develop.

The coding is detailed in Table 2. Categories were added or adapted as more questions were coded, to ensure that they accurately reflected the types of questions that were being asked. Two second coders recoded all questions (half each), using the category descriptions and framework in Table 2. The percentage agreement achieved between coders for initial coding was 85.1 % for the A-level student question data, and 83.1 % for the adult Nature Live question data. Coders discussed any questions they had categorized differently, and reached an agreement on one code through discussion.

Trends in Visitor Questions

The proportion of questions on each topic was calculated for each time slot so that the relative proportions of questions on each topic could be compared over time. This strategy allowed for the trends in relative interest in each topic to be explored. Data from adults attending Nature Live events are shown in Fig. 1, and for A-level students in Fig. 2. To illustrate where the most questions were asked, the total number of questions is provided for each data collection point (pre-session interview, in-session, post-session interview and post-visit interview).

Taking the adult questions first (Fig. 1) two key trends can be observed. First, although interest in science .information, the conceptual and factual subject of the session, peaks during the session itself, relative interest in the scientific topic decreases following the session. In contrast, relative interest in the scientist and personal aspects about their career and job increases as a result of the session and over time. Two months after the museum visit, visitors are asking the same proportion of questions about the scientist as the scientific topic, whereas before the session, questions about the latter had been much more abundant. These trends

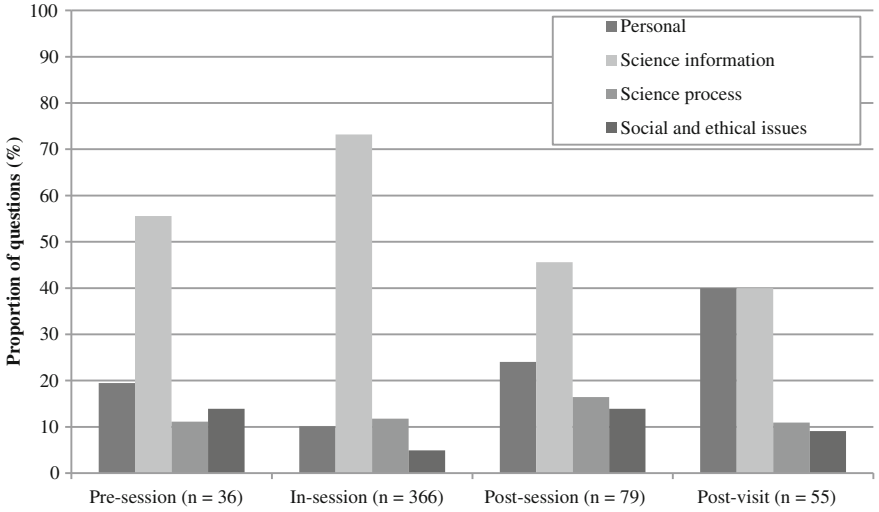

Fig. 1 Questions asked by adults in Nature Live events (n = 536)

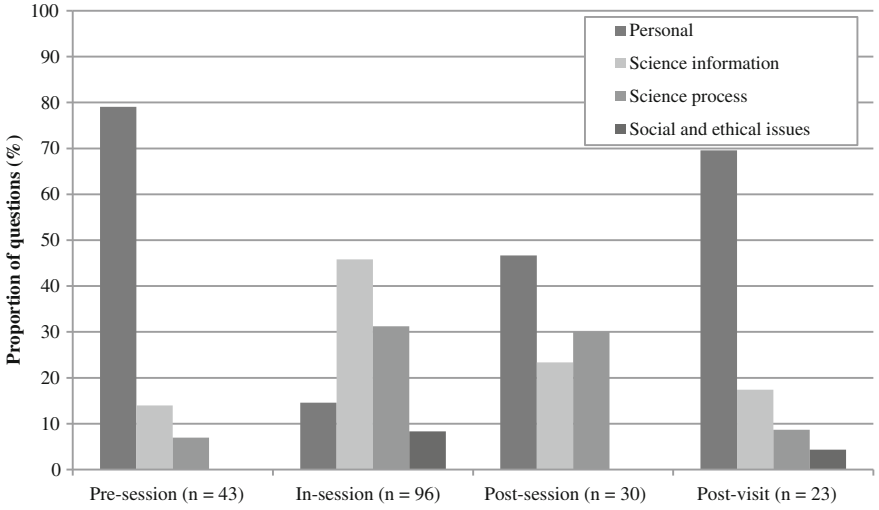

Fig. 2 Questions asked by students attending A-Level days (n = 192)

therefore suggest a long-lasting impact on interests of the visitors, with the scientists themselves becoming relatively more interesting than before.

A-level students also demonstrate changes in their interest profile over the period of the study (Fig. 2). Students entered the session with a high level of interest in the scientist themselves; they were focused on asking many questions about the life of the scientist and their career path. This finding is not surprising given the age of the

students, who are themselves soon to be making decisions about university courses and future jobs. The event they were due to attend at the museum is called 'a day in the life of a scientist', and therefore they are expecting, and likely hoping, to hear about the work and career of a scientist. Interestingly, within the session, the interest profile was very different to that predicted by the pre-session interview data. Students asked more questions during the session about the scientific information and the processes involved in the science research than might be expected given the questions they arrived with. There were relatively few questions asked about the scientists themselves. Immediately after the session the number of questions about the scientist increases once more, with proportions of questions on each topic returning towards the pre-session profile by the time of the post-visit interview 2 months after.

Issues and Implications

An examination of the questions visitors generate to ask scientists has revealed trends about the audiences, their interests, and the impacts of the session on the learners. The differences between the adults and the A-level students in the proportions of questions asked in the pre-session interviews on different topics indicate that the two types of visitor studied begin with very different interests. This is useful information for the museum's programme developers to be aware of, and will aid targeting of session content to the needs of the different audiences. It also seems that within the sessions themselves audiences are not asking the original questions they came with, perhaps due to the set-up or format of the session or because something else sparked their interest during the event itself. An awareness of the interests of the audiences before they enter the event will enable hosts to allow for any pre-existing interests to be nurtured, as well as sparking new directions of interest. A comparison of the differences between the pre-session and post-visit questions for both adults and students suggests that the meet-the-scientist sessions at the museum are more impactful in terms of interest for adults than students. An alternative explanation might be that adults are more dynamic and changeable in their areas of interest than students aged 16–18. The differences in the proportions of questions are greater when comparing adults' pre-session and post-visit data than for students, which suggests that adults have changed the areas they are interested in as a result of meeting the scientist.

Looking at question-asking over time indicates that the adults attending Nature Live events experienced the sparking of situational short-term interest by meeting the scientists, and that they had maintained these interests beyond the immediate experience and, therefore, may be developing a longer-term personal interest in the people behind the science. Following work in educational psychology into interest development (Hidi and Renninger 2006; Krapp and Prenzel 2011) it could be suggested, therefore, that the questions posed in post-visit interviews are evidence that the adults have developed a sustained interest in the scientists as well as the scientific information they heard about, and that this interest may be something they

continue to pursue in future. This would be a very promising impact of the museum's education programme. Questions reveal areas of interest and troublesome points in the mind of the learner, but also indicate the progression of learning as well as interest development.

Using the analytic frame originally developed by France and Bay (2010) enabled the questions to be coded according to topic of interest. The framework was adapted slightly for the purpose of the museum study to account for differences in the experiences of the learners, in this case the adult visitors and A-level students attending meet-the-scientist sessions. The analytic framework proved to be a useful tool to code the questions of the learners and could be adapted for use in classrooms and other learning environments. Questions could play a role in assessment, revealing how learners are developing interest throughout their education and indicating areas of misconception or misunderstanding. Coding of questions over a period of time could enable tracking of the progression of students over the course of a term or year, for example. I believe there is much potential in the incorporation of the analysis of questions into current education practice.

Looking at the questions learners ask might provide clues as to how to set the scene for stimulating question-asking within classrooms, museums, . websites, and other learning environments. How might education contexts and activities promote curiosity so that learners ask questions of the information they encounter? Could training students in question-asking extend learning experiences further in settings such as classrooms and museums, as seen in the work of King (1990, 1994)? Facilitating and encouraging learner questions may be a way in which educators might stimulate student engagement with science, and a way of keeping track of, and up to speed with, changing and developing interests (see Simon and Davies, this volume). Further areas that would be useful to research are levels of questioning in out-of-school contexts, for example, to examine where museum exhibitions might play a part in stimulating deep-level learning and to study how long that learning might last. The study presented here from the Natural History Museum suggests that audiences of Nature Live events are diverse and arrive with many different areas of interest and, therefore, questions. More detailed exploration of the differences between individuals' questions would be useful in pinpointing differences between cultures, gender, ages and backgrounds. Understanding this diversity in more depth would be of value to educators who have the difficult task of creating stimulating environments for a broad range of learners to ask their questions and develop curiosity, while managing expectations and hopes in situations when not all questions might be answered immediately.

Conclusions

I have argued that a focus on the questions learners are asking reveals much about their prior conceptions, interests, inspiration, motivations and development, and could be utilised more within education. Consideration of 'what's in it for the

learner' requires attention to what the learner is motivated by and interested in finding out, which affects the questions they formulate. What are students asking their friends as they leave the lesson? What are visitors to a museum googling on their phone on the train journey home? What are children asking their parents when they get home from school? What are university students wondering as they catch the bus back home from the campus?

Research in the Natural History Museum, London, has demonstrated how visitor-generated questions can reveal much about the interests of visitors and the impacts of events and experiences on those interests. Building on the work into student questioning from science education, and interest development from educational psychology, the study of questions might just give us new insights into the minds of our students and learners.

> Learn from yesterday, live for today, hope for tomorrow. The important thing is not to stop questioning. (Albert Einstein)

References

Abrandt Dahlgren, M., & Öberg, G. (2001). Questioning to learn and learning to question: Structure and function of problem-based learning scenarios in environmental science education. *Higher Education, 41*(3), 263–282.

Allen, S., & Gutwill, J. P. (2009). Creating a program to deepen family inquiry at interactive science exhibits. *Curator: The Museum Journal, 52*(3), 289–306.

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching, 40*(2), 138–162.

Australian Curriculum Assessment and Reporting Authority [ACARA]. (2013). *Rationale. Australian national curriculum for F-10 Science.* Retrieved from http://www.australiancurriculum.edu.au/Science/Rationale.

Baram-Tsabari, A., Sethi, R. J., Bry, L., & Yarden, A. (2006). Using questions sent to an Ask-A-Scientist site to identify children's interests in science. *Science Education, 90*(6), 1050–1072.

Baram-Tsabari, A., Sethi, R. J., Bry, L., & Yarden, A. (2009). Asking scientists: A decade of questions analyzed by age, gender, and country. *Science Education, 93*(1), 131–160.

Biddulph, F., Symington, D., & Osborne, R. (1986). The place of children's questions in primary science education. *Research in Science & Technological Education, 4*(1), 77–88.

Bowden, J., & Marton, F. (1998). *The University of Learning*. London: Kogan Page.

Chin, C., & Brown, D. E. (2000). Learning in science: A comparison of deep and surface approaches. *Journal of Research in Science Teaching, 37*(2), 109–138.

Chin, C., Brown, D. E., & Bruce, B. C. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education, 24*(5), 521–549.

Chin, C., & Chia, L.-G. (2004). Problem-based learning: Using students' questions to drive knowledge construction. *Science Education, 88*(5), 707–727.

Dillon, J. T. (1988). The remedial status of student questioning. *Journal of Curriculum Studies, 20*(3), 197–210.

France, B., & Bay, J. L. (2010). Questions students ask: Bridging the gap between scientists and students in a research institute classroom. *International Journal of Science Education, 32*(2), 173–194.

Griffin, J., & Symington, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education, 81*(6), 763–779.
Gutwill, J. P., & Allen, S. (2010). Facilitating family group inquiry at science museum exhibits. *Science Education, 94*(4), 710–742.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127.
Hohenstein, J., & Tran, L. U. (2007). Use of questions in exhibit labels to generate explanatory conversation among science museum visitors. *International Journal of Science Education, 29* (12), 1557–1580.
King, A. (1990). Enhancing peer interaction and learning in the classroom through reciprocal questioning. *American Educational Research Journal, 27*(4), 664–687.
King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American Educational Research Journal, 31*(2), 338–368.
King, A. (2002). Structuring peer interaction to promote high-level cognitive processing. *Theory into Practice, 41*(1), 33–39.
Krapp, A. (1999). Interest, motivation and learning: An educational-psychological perspective. *European Journal of Psychology of Education, 14*(1), 23–40.
Krapp, A. (2007). An educational–psychological conceptualisation of interest. *International Journal for Educational and Vocational Guidance, 7*(1), 5–21.
Krapp, A., & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education, 33*(1), 27–50.
Leinhardt, G., Crowley, K., & Knutson, K. (2002). *Learning conversations in museums*. Mahwah, NJ: Lawrence Erlbaum.
Renninger, K. A., Hidi, S., & Krapp, A. (1992). *The role of interest in learning and development*. Hillsdale, NJ: Lawrence Erlbaum.
Sanford, C. W. (2010). Evaluating family interactions to inform exhibit design: Comparing three different learning behaviors in a museum setting. *Visitor Studies, 13*(1), 67–89.
Seakins, A. (2014). *Meeting scientists: Impacts on visitors to the Natural History Museum, London.* Unpublished PhD dissertation, King's College London.
Shodell, M. (1995). The question-driven classroom: Student questions as course curriculum in Biology. *American Biology Teacher, 57*(5), 278–281.
Sjoberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings*. Retrieved from http://www.cemf.ca/%5C/PDFs/SjobergSchreinerOverview2010.pdf.
Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education, 46*(1), 1–44.
UK House of Lords Select Committee on Science and Technology. (2000). *Science and Technology—third report*. London: House of Lords Science and Technology Committee Publications. Retrieved from http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm.
Zimmerman, H. T., Reeve, S., & Bell, P. (2010). Family sense-making practices in science center conversations. *Science Education, 94*(3), 478–505.