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Students have been reported to have stereotypical views of scientists as middle-aged white men in lab coats. We argue that a way to provide students with a more realistic view of scientists and their work is to provide them with the opportunity to interact with scientists during short, discussion-based sessions. For that reason, 20 scientists from 8 professional areas were asked to share their experiences of becoming and being a scientist, in short sessions with groups of 7–8 students. The student sample consisted of 223 students between 13 and 15 years. Student and scientist questionnaires were used before and after the sessions to assess students' views of scientists and their work, and scientists' experiences of interacting with students. The pre-session questionnaires revealed that students considered scientists as 'boring' and 'nerdy' whereas after the sessions students focused extensively on how 'normal' the scientists appeared to be. The face-to-face interactions with scientists allowed students to view scientists as approachable and normal people, and to begin to understand the range of scientific areas and careers that exist. Scientists viewed the scientist–student interactions as a vehicle for science communication. Implications discussed include the need for future training courses to focus on developing science communicators' questioning and interaction skills for effective interactions with students.

Keywords: *Secondary education; Views of scientists; Scientist–student interactions; LifeLab; Scientists' views of public engagement*

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One way of making science accessible to the public and providing opportunities to engage with it is through public engagement events where scientists are in a position to interact with public audiences (Besley & Tanner, 2011). Science communication through public engagement is perceived as aiming at educating the public about current scientific developments, and often their ethical and moral implications (Bauer & Jensen, 2011; Davies, 2008; Mathews, Kalfoglou, & Hudson, 2005). As a consequence of taking part in such events, individuals might learn more about the content of science, enhance their views of science and scientists (Christidou, 2010; Christidou & Kouvatas, 2013) and, in the case of school students, also gain an insight into a wider range of science career possibilities than those that are currently available to them during their secondary education years (Archer, 2013; Cleaves, 2005).

Yet, school-aged students' views of scientists as middle-aged white men in lab coats are widely reported to dominate students' views (Barman, 1999; Chambers, 1983; Finson, 2002). These views, often reinforced by the way scientists are portrayed in the popular media (Reis & Galvao, 2007), ignore social aspects of communication and interaction as characteristics of scientists' work (Hodson, 2012), portray science as a predominantly masculine domain (Christidou & Kouvatas, 2013) and often restrict scientific disciplines to lab-based work. As a result, the images of scientists and their work held by the majority of school students are partial, simplified representations creating and establishing stereotypes (Smith & Mackie, 2000), which are not representative of scientists. In this study, we argue that a way to provide students with a more realistic view of scientists and their work is to provide them with the opportunity to learn about science and how science works from practising scientists during short, discussion-based sessions. Such interactions might be of value not only for the students but also for the scientists, who can use such opportunities to further their public engagement record and skills.

There is an increasing number of calls for science communication to become more prevalent within scientific institutions (Davies, Mbete, Fegan, Molyneux, & Kinyanjui, 2012; European Commission, 2008; Leshner, 2003; McCombs, Ufnar, & Shepherd, 2007). However, this poses a challenge for some scientists since a number of studies report that many scientists lack the appropriate skills for effective science communication, or that they are not offered sufficient training opportunities in developing the communication skills needed (Davies et al., 2012; Ecklund, James, & Lincoln, 2012; *Royal Society*, 2006). Reported barriers to science communication engagement include time (Mathews et al., 2005), the perception that those who actively engage with science communication are 'not good enough' (*Royal Society*, 2006, p. 3) compared to practising scientists or academics, and scientists' own perceptions of their science communication skills (Ecklund et al., 2012).

The *Royal Society* (2006) reports on a survey of about 3,000 scientists which has identified clear gaps in the training of scientists that would allow them to engage meaningfully and actively in science communication, with 73% of scientists stating that they had never received any public engagement training. Although currently there are some studies that investigate scientists' perspectives on public engagement or science communication (Davies 2008; Poliakoff & Webb, 2007; *Royal Society*, 2006), these studies mainly focus on interactions with adults, leaving a gap in the literature about scientists' views on interactions with school-aged students, as well as how such interactions should be structured to allow maximum positive effect on students. Thus, the aim of this study was to explore the nature of short but reflective, discussion-based sessions between scientists and school students. The research questions guiding this study are:

1. What is the value of short, discussion-based interactions between scientists and school students for the development of students' views of scientists and their work?
2. What are the elements of these short, discussion-based sessions that create opportunities for effective engagement of scientists with students?
3. What do scientists think the potential impact of short, discussion-based interactions between scientists and school students is on themselves and on students?

Theoretical Framework

Students' Views of Scientists and their Work

Students' views of scientists and their work have been the subject of various studies for a number of decades (Barman, 1999; Chambers, 1983; Finson, 2002; Ford, 2006; Huber & Burton, 1995; Mead & Metraux, 1957; Rawson & McCool, 2014; Ruiz-Mallén & Escalas, 2012). One seminal study was that of Chambers (1983), who first used the 'Draw-A-Scientist' Test (DAST) to determine young students' views of scientists and their work and to establish at what stage of children's lives these views develop. Using seven common indicators identified in the literature (lab coat; eyeglasses; facial growth of hair; symbols of research, such as instruments and equipment; symbols of knowledge, such as books; technology; and science-related captions, such as symbols and equations), he analysed the drawings of almost 5,000 primary school children from Canada, Australia and the USA. He found children's images of scientists started developing in their second year of schooling and that these developed into stereotypical views which became more prevalent as children got older. These images presented scientists as predominantly white males wearing a lab coat and surrounded by traditional science equipment. Chambers (1983) also found that some children attributed negative images to scientists, portraying them as monsters and 'mad scientists'. More recent studies, conducted by Newton and Newton (1998) in the UK, and Buldu (2006) in Turkey, have yielded results similar to those of Chambers (1983) although variations of the dominance of stereotypical views are also reported. For instance, Huber and Burton (1995) found that 9–12-year-old boys hold more stereotypical images of scientists than girls. Fung (2002) compared Hong Kong Chinese primary and secondary students' images of scientists using the DAST and also found similar trends, with older students having more stereotypical images of scientists than younger students and with scientists being portrayed as predominantly male.

Song and Kim (1999) investigated further students' images of scientists and their work employing a mixed approach to data collection using not only the DAST approach but also Likert scale questionnaires and students' narratives. Their work with 1,137 Korean students (of ages 11, 13 and 15 years) identified some differences with images of scientists reported previously—for instance, Korean students considered scientists to be much younger than the 'elderly' or 'middle-aged' characterisation reported earlier. More recently, Hillman, Bloodsworth, Tilburgb, Zeeman, and List (2014) also used a combination of methods to assess 485 primary, middle and high-school students' images of scientists and have found that these students' views, although consistent with the stereotypical images of scientists previously reported, they were not as dominant as previously reported. Nonetheless, Hillman et al. (2014) also report that scientists were consistently characterised by their students as wearing lab coats, using lab equipment and working in laboratories.

Dagher and Ford (2005) adopted a different methodological approach for assessing students' images of scientists and their work, by asking students to investigate real scientists' lives and then write the scientists' biographies. They found that the students' written accounts of scientists at times included personal characteristics of scientists, such as hobbies and interests. However, this attribution of personal characteristics by students was only specific to the individual scientists they were investigating, and not the way in which students viewed scientists overall.

The studies reviewed here would suggest that students' images of scientists and their work persist and are stereotypical since they do not provide a comprehensive view of scientists as professionals and as normal people nor do they indicate the range of activities scientists engage in as part of their profession. One reason for the persistent nature of students' stereotypical views of scientists might be the way in which scientists are still portrayed in the media and in popular children's science literature (Finson, 2002; Long, Boiarsky, & Thayer, 2001; Rahm, 2007; Rawson & McCool, 2014; Smith & Mackie, 2000). Reis and Galvao (2007) report two cases of students that provided narratives of scientists. The analysis of the students' narratives and interviews clearly demonstrated that these students' images of scientists were consistent with stereotypical views reported in the literature and also that these two students' stereotypical and negative perceptions of scientific activity were influenced by the way scientists' work was portrayed in the media.

Recent research on students' science aspirations indicates that although 10–14-year-old students find science enjoyable and believe that scientists do valuable work that can make a difference in the world, only a handful of them aspire to be a scientist at this age (Archer, 2013). Archer and colleagues (Archer et al. 2010; DeWitt et al., 2013) attribute this discrepancy between science interest and science aspirations to various factors including identity formation and science career advice. Cleaves (2005) also identified the lack of advice on future careers in science as a factor that influences students' decisions to pursue science in post-compulsory education. The image of science that students hold is 'highly incompatible' with the images they have, or want to have, of themselves (Hannover & Kessels, 2004, p. 52). As a result, students distance themselves from science and begin to consider it as 'not for me' (Archer, 2013), which has implications when deciding whether they would like to follow a science career. Consequently, there is a need to address students' views of scientists and their work to allow students to develop an inclusive view of science and its practices. One way to do this is to create opportunities for students to directly interact with practising scientists.

Scientist–student Interactions

The literature on scientist–student interactions is drawn mainly from summer school programmes and apprenticeship evaluations (Bell, Blair, Crawford, & Lederman, 2003; Bleicher, 1996; Knox, Moynihan, & Markowitz, 2003; Rahm, 2007) and focuses on how these programmes have influenced students' attitudes towards science and students' conceptual and epistemological understanding. For instance, Knox et al. (2003) investigated the impact of a summer school programme at a university research facility on 14–18-year-old students' interest in science and their perceived skills in laboratory work. They found that students' interactions with scientists and opportunities to do hands-on science in authentic microbiology laboratories had a positive influence on these students' attitudes towards science and their enthusiasm about science careers. Similarly, Gibson and Chase (2002) found that students participating in a summer school programme developed more positive attitudes towards science and towards science careers compared to students who did not participate in the summer school programme.

Bell et al. (2003) found that 15–17-year-old students, who participated in an 8-week science apprenticeship programme working alongside scientists covering a range of science procedures including research design, data collection and data analysis, did not change their views of scientific inquiry and the nature of science (NOS) considerably. Bell et al. (2003) argue that the extent to which explicit discussions about the NOS and scientists' work were taking place during these apprenticeships was vital for whether students would change or not their NOS views. The only student of the 10 participants who shifted her views of scientific inquiry was the one who had some explicit discussions about the nature of scientific knowledge and investigations with her scientist mentor. These findings suggest that reflection and discussion on scientists' work are crucial components in attempts to break away from the inaccurate stereotypical views of scientists that school students hold. Although Bell et al.'s (2003) conclusions are based on a single student case, they do indicate the important role that scientists have in such interactions with students, and that just doing science, even if it is in an authentic context does not necessarily mean that students will gain an informed understanding of the nature of scientific practices or the range of everyday activities that scientists need to engage in.

Further evidence on the importance of reflective discussions amongst students and scientists is provided by Rahm (2007), who conducted an in-depth exploration of seven adolescents' views of science and scientists and how these developed during an 8-week long summer gardening programme. Students between the ages of 13 and 15 years were given the opportunity through interviews and reflective discussions with scientists, at their place of work, to express their views and construct and deconstruct their mental images of science and scientists. The interviews students conducted with scientists were a means of breaking down barriers between them, and creating and discussing common experiences between students and scientists. For instance, scientists reflected on how they did not always like science in school, or how they did not always want to go into a science career. By the end of the project, the students' mental images of scientists were found to be moving away from inaccurate stereotypical images. Rahm (2007) argues that such changes were the result of the scientist–student interactions that allowed students the opportunity to access the world of scientists and science and see how they themselves could fit within that world.

France and Bay (2010) investigated scientist–student interactions and analysed the nature of the questioning that was produced by students before and after their interactions with scientists. Prior to the session, they asked 16–18-year-old students to identify a question they would like to ask. After the meeting with the scientists, students were asked to state which of the questions asked during their sessions with scientists they thought were most useful. An analysis of these questions identified five different areas of interest amongst the students. These were (a) science information, with questions focusing on procedural and conceptual aspects of the science discussed, (b) citizen decisions, which were questions that focused on the applications of science, (c) questions that focused on the nature of scientific disciplines and how science works and (d) personal responses, with questions that aimed to make links between the science discussed and the students' lives. France and Bay (2010) state that the comparison of the students' intended questions to those the students considered as the best after the sessions revealed that students became increasingly more interested in the personal life histories of the scientists.

Context of Study

The *Meet the Scientist* sessions are part of a wider initiative at the authors' institution to promote health literacy through science education. The LifeLab project aims to engage 11–16-year-old students with the science behind chronic diseases and enable them to discover first hand, how their diets and lifestyles lay the foundations for a healthier life, and how their own health is linked to the health of the children they may have in the future (Grace et al., 2012, 2013). The LifeLab programme involves a professional development day for science teachers, a scheme of work incorporating lesson plans and resources for 10 school-based lessons and a 'hands-on' practical day in an out-of-school context. As part of this day, students take part in *Meet the Scientist* sessions where they have the opportunity to meet and talk to scientists, from both academic and clinical backgrounds.

Methodology

Fifty-six scientists who had previously indicated that they were interested in participating in public engagement activities were invited to take part in the *Meet the Scientist* sessions. Twenty of these (10 male and 10 female), from 8 different professional areas (bioengineering—3; genetics—3; cancer research—7; asthma research—1; nutrition—3; cardiovascular research—1; placental research —1; and bone and joint research −1) and at different stages of their career (doctoral and post-doctoral researchers, lecturers, medical professionals and professors), took part in the study. From the 20 participating scientists, 14 had worked previously with school students through other outreach programmes and 6 did not have any prior experiences working with school students. The student sample consisted of 180 mixed-ability Year 9 students (14–15 years) and 43 Year 8 students (13–14 years) from four state secondary schools in England. Students were put into groups of 7–8 and each group attended two *Meet the Scientist* sessions on the same day, each lasting between 10 to 20 minutes. Both student and scientist participants were identified through convenience sampling, based on their interest and willingness to participate in the LifeLab project. Each scientist ran at least two sessions (two scientists had four sessions and two had three sessions), with a total of 49 sessions recorded. Students were aware that they would be meeting and talking to scientists and were encouraged by their science teachers to formulate questions they would like to ask during the sessions. The discussions taking place during the sessions were not guided by the authors in any way. Scientists were informed that they would have short sessions with secondary school students where they would be providing information about their work as scientists and would be answering students' questions. They were not given any additional training or guidance, allowing us to gain an insight into how scientists are able to communicate with young students.

A mixed methods approach to collecting and analysing data was used (Creswell, 2009). Data collection methods included pre- and post-session paper questionnaires for students, pre- and post-electronic questionnaires for scientists and audio-recordings of the *Meet the Scientist* sessions. The student questionnaires were administrated on the same day as the *Meet the Scientist* sessions, which took place at the authors' institution, and aimed to answer the first research question of this study. As discussed previously, the DAST is a commonly used tool in investigations of students' views of science. However, it also imposes some challenges such as the fact that it often forces students to make a choice (Barman, 1999) and that it might not capture adequately the students' full characterisations of scientists (Hillman et al., 2014). For instance, students are required to choose their scientist's gender, ethnicity and surroundings, although these might not necessarily be representative of their views of what scientists look like or what they do. As the student participants of this study were old enough to be able to provide short written descriptions expressing their views, a questionnaire was used to collect their perceptions of scientists and of their expectations from the *Meet the Scientist* sessions in a descriptive manner (Hannover & Kessels, 2004). All student participants completed the pre- and post-questionnaires. The questions used in the pre- and post-session student questionnaires are provided in Appendix 1. The scientist questionnaires were sent to participants via email, before and after the sessions and consisted of open-ended questions (Appendix 2). Questionnaire data were analysed using qualitative data analysis software, initially using exploratory word searches and word frequency searches in order to identify the main themes emerging from the data. Subsequently, categorical aggregation (Stake, 1995) was used to organise the data into main themes and sub-themes.

The qualitative data from the 49 sessions were transcribed verbatim and then coded thematically. A grounded approach to data analysis and the constant comparative method (Glazer & Strauss, 1967) were employed in the analysis of transcripts from the *Meet the Scientist* sessions. The analysis of the student questioning during these sessions was theory-driven, based on France and Bay's (2010) categorisation of student questions to scientists. An iterative cycle of revision and refinement of the categories identified took place (Patton, 2002). One member of the research team conducted the first round of analysis and then a second member applied the same framework to all the transcripts. Inter-rater agreement was higher than 90% with all differences of opinion discussed and resolved.

Findings

Students' Views of Scientists and their Work

The pre-session questionnaire required students to note what kind of people they thought scientists to be (Appendix 1). Results are presented in Table 1. The most frequently used characteristic attributed to scientists by students was 'clever'. Overall, in 61% of responses, students made 111 references to scientists as 'clever', 'smart',

Table 1. Students' most common descriptions of scientists

Attribute	Percentage of responses[a]	References[b]
Clever	61	111
Normal and ordinary	14	26
Passionate/interested in science	14	28
Educated	11	24
Hard-working	9	15
Specialism (e.g. doctor and biologist)	9	61
Curious/inquisitive	8	18
Creative/imaginative	8	17

[a]One hundred and seventy-two responses in total; % total greater than 100 as in most cases students used more than one attribute to describe scientists (e.g. clever and smart).

[b]How many times an attribute was mentioned by students.

'intelligent', 'brainy' or used a combination of these when describing what kind of people scientists are.

Some students were able to provide a more complex and multidimensional view of scientists as both intellectual and creative individuals. For instance, one student commented that scientists are 'clever and brave; they are very interested in science; they are very creative people and they believe in science; they're atheists and they're not superstitious' (PreS38). In addition, 14% of students' responses referred to scientists as normal people, commenting that anyone could be a scientist, although this statement was in most cases qualified, for example, 'anyone ([but] needs to be clever)' (PreS166).

Following the session, students were asked to explain whether the scientists they met were as they had expected them to be (Table 2). Overall, 49% of students stated that the scientists they met were not as they had expected them to be, providing a range of reasons in support of their answers, as summarised in Table 2. Students' expectations of the scientists' appearance and personality were the two most commonly cited reasons. Students pointed out that the scientists they met were not as expected because they thought 'of a stereotypical scientist [as] a nutty professor' (PostS12), or because they 'thought that they would be mad and posh' (PostS190)

Table 2. Students' responses to the question: 'Were the scientists as you expected them to be?'

Student response	Percentage of responses[a]	Number of references	Number of responses (%)
No			96 (49)
Personality (e.g. casual, normal, not posh and not boring)	42	40	
Appearance (e.g. no white coat and young)	32	31	
Nature of interaction (fun and interesting)	28	27	
Other (e.g. qualifications)	8	8	
No reasons given	7	7	
Yes			79 (41)
Personality (e.g. intelligent and normal)	41	45	
Nature of scientists' work	15	12	
Nature of interactions	11	9	
Appearance	4	3	
No reasons given	29	23	
Undecided			19 (10)
Appearance	16	3	
Personality	21	4	
Nature of scientists' work	5	1	
No reasons given	63	12	

[a]Percentage of responses greater than 100 as some students referred to more than one reasons in their responses (e.g. not posh and interesting).

and that 'they were normal and chatty; they didn't wear goggles' (PostS127). Although the students were not asked directly 'What kind of people are scientists?' again at the end of the sessions, which would allow for more direct pre- to post-session comparisons, the responses presented in Tables 1 and 2 exemplify the inaccurate stereotypical images that most students held but most importantly, these statements also exemplify the students' emergent views of scientists as normal, and even interesting, approachable individuals.

In their responses, students also commented on the difference between their expectations of the *Meet the Scientist* sessions, and their experiences during these sessions. As one student noted, 'I thought they would be quite boring but actually they were quite interesting' (PostS111). Even when students stated that scientists were as they expected them to be (41%), their reasons drew on positive attributes such as their intelligence, or their 'normalness' (Table 2). One student stated that 'they were a lot like I expected because they were both very bright and were very enthusiastic about what they were doing' (PostS18), whereas another pointed out that scientists were 'normal people who had a passion to understand their specific subject' (PostS116).

Students who were uncertain whether scientists were as they expected them to be expressed explicitly the contradiction amongst their own views of scientists and their impressions of the scientists they had met either due to the scientists' appearance or the fact that scientists were easy to understand and approachable (Table 2). As one student noted, 'I believe they were [as I expected them to be] because they are knowledgeable and use complicated words; but also no because they did not wear glasses and [they] sound like they know how to talk to kids' (PostS6).

When asked 'What (if anything) surprised you about the scientists you met?' the most common responses referred to scientists' appearance and personality, reinforcing the findings reported in Table 2. Students focused extensively on how 'normal' the scientists appeared to be, with one student stating that they 'were just normal people, and very unlike mad scientists in films' (PostS202).

Table 3 provides a summary of the main themes that emerged from the students' responses to this question. It should be noted that 46% of students stated that nothing surprised them from meeting with the scientists. However, this is not surprising as 41% of students responded positively when asked whether scientists were as they had expected them to be (Table 2). The way the scientists communicated with students (at their own level and as ordinary people) had also pleasantly surprised the students, who commented in their post-questionnaire that the scientists 'spoke to us equally and didn't over complicate everything' (PostS116).

Scientist–student Discursive Interactions

As the aim of this study is to determine to what extent scientist–student interactions are valuable for students and scientists and investigate the nature of such interactions, we analysed the discursive interactions between students and scientists, looking for features that would indicate participation and engagement. Fredricks, Blumenfeld,

Table 3. A summary of students' responses to the question 'What (if anything) surprised you about the scientists you met?'

Student response	References	Percentage of responses
Normal and approachable	21	12
Appearance (age, nationality and looks)	21	12
Fun, enjoyable, passionate and interesting	18	9
Science careers and opportunities	15	8
Nature of their work	16	5
Ethical issues	4	2
Science information	3	2
Shy and awkward	3	2
Intelligent	2	1
Successful	2	1
Nothing surprised me	90	46

and Paris (2004) argue that student engagement can be analysed based on three constructs: behavioural, emotional and cognitive. Question posing can be considered as a task that demonstrates both behavioural and cognitive engagement, as students demonstrate active participation in the lesson, especially if they initiate discussion, and can make their thinking process visible to the teacher and other students. Thus, within our study, students' questions were considered as an indicator of attempts to actively engage with the topic under discussion and to make links with their existing knowledge and experiences (Chin & Osborne, 2008; France & Bay, 2010; Morgan & Saxton, 1991; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). The following sections present the findings about the nature of interactions that took place based on (a) the content of the discussions and the strategies scientists used to engage students in the session and (b) the content of students' questions to the scientists.

Scientists' discursive actions and structure of sessions. Three main themes emerged from the analysis of the scientist–student discursive interactions (Table 4). These were (a) what scientists do, where scientists presented or discussed the nature of their work; (b) science career interests and aspirations, where scientists mentioned their own career pathways and finally, (c) perceptions of science and scientists, where scientists reflected on the views that they or others held about scientists and science. In all sessions, scientists spent time explaining to students the nature of their work. Most of the instances in which the applications or consequences of the scientists' work were discussed were related to cancer treatment and finding cures, as this formed part of the scientists' background. Discussing applications of their work was a way to make their job and the science behind it relevant for the students, and it is consistent

Table 4. Coding scheme derived from the *Meet the Scientist* transcripts

Themes	Number of sessions (%)
What scientists do	
Scientist discusses nature of their work	49 (100)
Scientist discusses applications or consequences of their work	34 (60)
Science careers	
Scientist provides information on science careers	36 (92)
Scientist discusses students' science interests and career prospects	26 (86)
Scientist discusses his/her own career pathway	26 (34)
Perceptions of science and scientists	
Scientist explains why their work is exciting or important	25 (43)
Scientist discusses perceptions of science and its purpose	30 (58)
Scientist discusses perceptions of scientists-appearance	7 (12)
Scientist discusses perceptions of scientists-personality	7 (12)

with evidence that suggests that scientists consider relevance as an essential element of science communication events (Davies, 2008).

Approximately three-quarters of the scientists (14/20) attempted to engage students by making their work relevant or personal to the students. For instance, one scientist involved in asthma research started his session by asking students whether any of them had asthma and moved on to explain why he was researching this area, as follows:

> Does anyone have asthma? Okay, so I study asthma, I want to know why some children get asthma and some children don't. We know that in this country about one in six/one in seven children will develop asthma as a child. Some will grow out of it, some will [have] asthma right through [their lives], and we don't know why. It's important because at the moment we can't cure asthma. (Sc6 m)

In the aforementioned example, the scientist was being responsive to his audience (Bray, France, & Gilbert, 2012) by making links between his own knowledge and research and the students' own experiences and young age. He also provided a short rationale for his work based on what is known so far, and the aims of his research. Providing a rationale for their work was an element found in all of the recorded sessions, and is consistent with previously identified perspectives on science communication where scientists consider the need to provide the 'big ideas' and reasons guiding their research as more important than going into further detail about the science behind it (Davies, 2008). Another example is provided in the later text where a different scientist used a model of a heart to show students its different parts and as a way to explain her own line of research.

> This bit in this heart is really small and that means that that heart can't pump [blood] very well. Some children are born with hearts that are like this and I'm trying to find out the reason for that and we think it's probably because of a mistake in one of their genes. So I'm spending my time trying to find out why it is that some babies are born with this problem and some aren't. And I'm trying to help families who have children who have

> that condition, which means that they have to have lots of operations and stay in hospital. And I became interested in it because I met a little boy in a clinic who had exactly that heart problem. Does anybody have any vague idea about how I might go about that? What are your ideas? (Sc2f)

As well as explaining to students the reasons for conducting their research, in some cases scientists also attempted to prompt students to think about ways of investigating such problems by asking open-ended questions, as shown in the aforementioned extract. When scientists were discussing the nature of their work, they attempted to engage with the students by presenting it to a level that they believed students could understand. The scientists presented their work to students by using images (e.g. x-rays), models (e.g. a real heart) or other materials (e.g. an ultrasound machine) to explain concepts and aspects of their work. Such artefacts were used in two-thirds of the sessions (33/49) by 19 of the 20 scientists. Table 5 presents strategies used by scientists during the sessions that aimed at raising interest and engaging students in dialogue. All scientists asked questions during their sessions, with 647 questions posed in the 49 sessions. Most scientists were proactive in asking questions, with 14 of the 20 scientists used questioning to elicit students' current knowledge and understanding of the issues discussed. Additionally, 18 of the 20 scientists explicitly encouraged students to engage in the sessions by prompting students for questions at least once in their sessions and 8 scientists prompting students for questions 5 times or more during their sessions.

For example, one scientist asked questions to elicit students' ideas about what the work of a public health nutritionist (her area of work) would involve by asking students questions such as 'I'm what you call a Public Health Nutritionist, and does anyone know what that might mean?' and 'What do you think the public health bit means?', and then she had the students brainstorming about the areas in which she could be potentially investigating. She said:

Table 5. Strategies for engaging students in the 49 sessions

Strategies	Number of sessions (frequency)	Number of scientists
Use of analogies, metaphors or examples in scientists' talk	39 (74)	19
Asks question	49 (647)	20
Closed questioning	44 (266)	20
Open-ended questioning	30 (154)	15
School science questions	18 (33)	11
School science choices questions	11 (20)	9
Science interest questions	15 (30)	10
Science career interest questions	22 (65)	14
Views of scientists or science questions	12 (29)	8
Introduction through questioning	22 (22)	11
Prompts for questions	40 (89)	18

> we're doing an intervention at the moment with women of childbearing age that are having young babies or that have children under the age of five and what we're trying to do is tackle or look at some of the things that might influence their diets [. . .] Now, I want us to do a bit of a brainstorm and think about what kind of different things might influence a woman's diet. *What do you think*? (Sc3f)

This scientist used the same structure for all her sessions and in these sessions students were able to identify all the elements she was researching, and also exchanged ideas about what influences diet and healthy living. Strategies such as brainstorming and explicitly prompting for questions have been found to increase the presence of student questioning in science classrooms (van Zee et al., 2001), and consequently, the students' active engagement and participation in the thinking and learning process. The last question that the scientist asked (indicated in italics) was an open-ended question which invited students to actively engage in this session by expressing their ideas in response to the scientist's questions.

In the 49 sessions that took place, a range of types of questions were posed by the scientists (Table 5). Closed questions are those requiring a short, and often right, answer to a question or that may be answered by a yes/no response (Morgan & Saxton, 1991). Open-ended questions were considered as those that aimed at higher order skills such as analysis, synthesis and evaluation (Chin, 2007; Morgan & Saxton, 1991). As shown in Table 5, although closed questioning was more frequent and present in more sessions compared to open-ended questions, approximately 25% of questions posed by scientists were categorised as open-ended with 15/20 scientists asking open-ended questions such as 'what do you want to know about cancer? (Sc15 m), 'what's important about looking and helping women that [. . .] are having babies to have a healthy diet? (Sc3f), 'what do you know about stem cells? What does it mean to you?' (Sc16 m).

Finally, 11 scientists began their sessions by initiating discussion and 'question and answer' (Q&A) exchanges with their groups instead of beginning their sessions with a presentation of their work. This 'introduction through questioning' strategy made the sessions more student-centred, and as a result offered more opportunities for students to actively participate in the sessions since they had more opportunities to answer questions posed by scientists and also to ask questions. The range of questions asked by students is presented in the following section.

Students' questioning during the sessions. Based on France and Bay's (2010) categorisation of student questioning during scientist–student interactions with 16–18 year olds, we organised the students' questions in four main themes as detailed in Table 6.

Students' questions during the *Meet the Scientist* sessions focused mainly on conceptual and procedural information based on the scientists' research area and expertise. Morgan and Saxton (1991) assert that asking content-related questions as opposed to questions about procedural aspects of a lesson is an indication of a higher level of engagement. Hofstein, Navon, Kipnis, and Mamlok-Naaman (2005) also note that the content of one's questions is an indicator of the level of their thinking on a cognitive level. Therefore, it could be argued that the focus of

Table 6. A summary of students' questions during the discussion sessions

Type of question	Example	Percentage
Science information	'What is stem cell research?'	83
How science works	'How long do you think it would take to solve this problem? How much time do you think a scientist would have to devote to trying to answer one question like that?'	7
Citizen decisions	'What is your opinion on animal testing?'	5
Personal responses	'Do you enjoy being a scientist?'	5

students' questions on science information indicates their interest in the topics discussed. This claim is further supported by the students' responses to the question 'What was the most interesting thing about your sessions?' where the majority of students' responses (69%) focusing on aspects of scientific information the scientist in their sessions discussed. In addition, the second most frequent response to this question (11%) focused on the scientists' career pathways or general science career questions. Such findings are important, as they demonstrate the potential value of scientist–student interactions in raising student interest particularly about scientific topics and also, although to a lesser extent, about possible science careers.

Scientists' Perspectives on Interacting with Students

Scientists' views and perceived potential benefit on themselves and on the students were explored through pre- and post-session open-ended questionnaires. Currently, studies focusing on scientists' perspectives on science communication mainly focus on the potential impact of such outreach activities on the scientists themselves (Ecklund et al., 2012; *Royal Society*, 2006). Prior to the scientist–student interactions, scientists' perceived impact of the *Meet the Scientist* sessions on the students was found to fit into four areas, as presented in Figure 1. One scientist noted their commitment and willingness 'to help students understand what being a scientist is all about, to dispel myths about nerds in white coats and to inspire the next generation of scientists' (Sc6m_pre), while another scientist hoped that students would be able to 'see what "cutting edge" scientists are like, i.e. we're normal! I also hope they'll see how enthusiastic about it all we are!' (Sc15m_pre).

After the sessions, scientists were asked whether their thoughts about how the *Meet the Scientist* session impacted on students changed. The scientists' responses indicate that they still considered the sessions a worthwhile experience for the students as follows:

> I thought the students would be more interested in the career path to becoming a scientist and less so in the actual science. I think they were just as interested in science and *in giving them that information it may spur them into scientific careers*. (Sc17f_post)

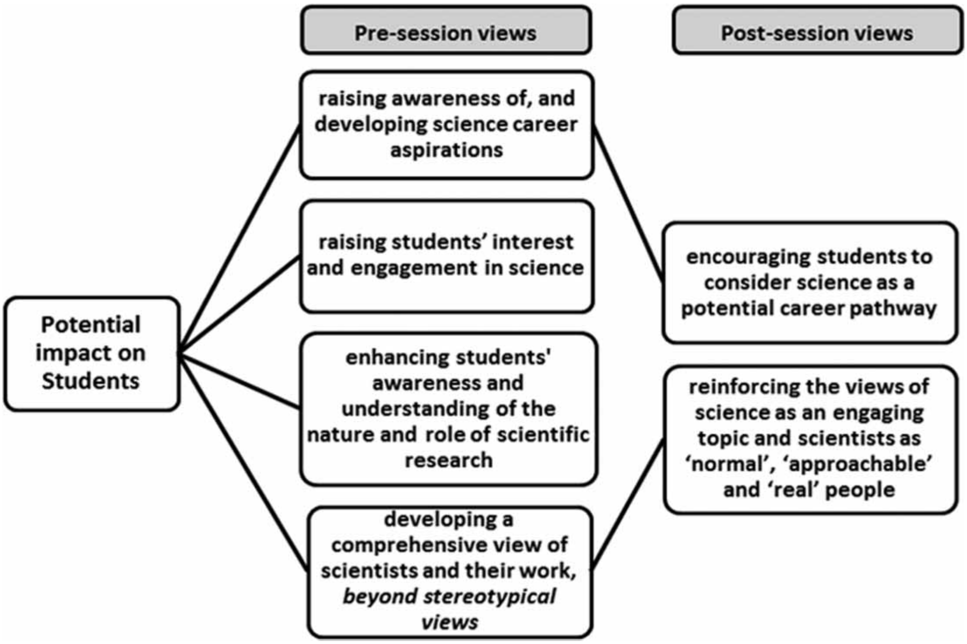

Figure 1. The scientists' views on the potential impact of the sessions on students

> Yeah, some asked very specific questions about careers that they were interested in. *I think meeting people who have been through some of the stages they require may help them.* (Sc20m_post)

All scientists reiterated their original perceived benefits of the sessions for the students in the post-questionnaires, but two of the four themes were focused upon, as shown in Figure 1. These were (a) encouraging students to consider science as a potential career pathway and (b) reinforcing to students the views of scientists as 'normal' 'approachable' and 'real' people. It was interesting that scientists were aware of the stereotypical images held by students and that this was an area they considered as needing attention in order for students to become more interested in science.

The scientists also responded to a pre- and post-session question about the personal benefit of scientist–student interactions to themselves. The pre-session responses included (a) developing their communication skills, (b) dissemination of their work to a wider audience, including other scientists and (c) further engagement with young people as a means to enthuse and inspire them into science (Figure 2). The potential impact they hoped that these sessions would have upon themselves, especially for their science communication skills, emerged as the main motivating factor for taking part in *Meet the Scientist*. As one scientist noted, 'I will (hopefully) be able to explain in non-specialised language what I do, which is an excellent quality for grant applications etc.' (Sc18f_pre), while another pointed out that, 'many top funding bodies (e.g. Wellcome Trust) are now incorporating aspects of public engagement within their calls. I'm therefore very mindful of gaining these transferable skills, volunteering for exercises such as LifeLab' (Sc14m_pre).

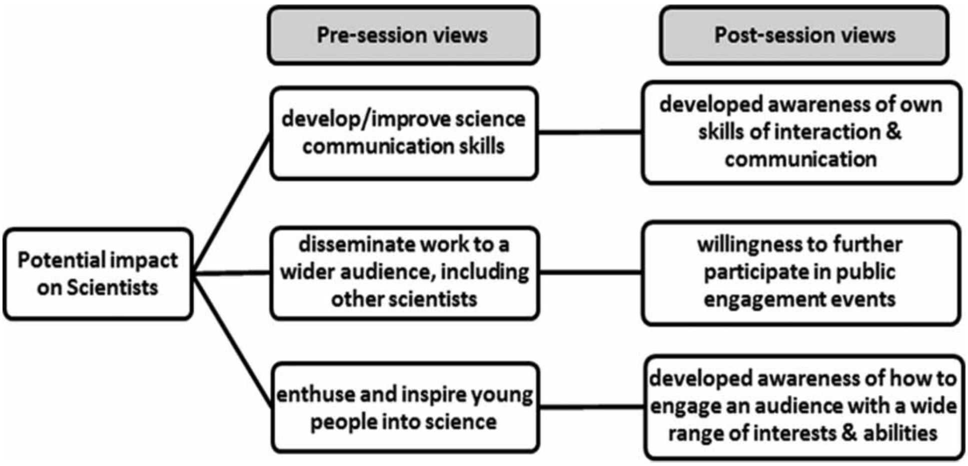

Figure 2. The scientists' views on the potential impact of discussion sessions on themselves

Given the opportunity to reflect on the impact of *Meet the Scientist* on themselves after the sessions, it was clear that the initial thoughts of developing communication skills stated in the pre-session questionnaires, now became more specific and included not only developing skills in communication but also in *interaction*. For example, one scientist pointed out that he needed to be more prepared to answer questions about his own career pathway into science. Others reflected on their interactions with students and considered how to improve them, for instance, by communicating more effectively with their audience, or through bringing with them prompts or objects that they would use to initiate discussion, as follows:

> I think I need to be clearer about how my work fits with or challenges students' concepts of science and improve the way I convey my work to students. I found it challenging to provide an activity regarding my work that would provoke questions from the students. It was good to teach me to improve my skills in communicating about my work. (Sc3f_post)

> In hindsight I think it would have been useful to have brought in an object such as a piece of Osteoporotic bone to spark thought and conversation. (Sc7f_post)

Another theme emerging from the scientists' reflections was the sense of enjoyment felt as a result of taking part in *Meet the Scientist*, which consequently led to them considering positively further participation in public engagement events. The following responses capture these ideas:

> Upon reflection, it has made me consider other 'public engagement' programs. This could be very rewarding and it was good fun. (Sc14m_post)

> It was enjoyable, and I think there might be a real need for scientist exposure as it appears A-level students choose Psychology, as it is better represented in media, etc. (Sc8f_post)

The post-session questionnaire analysis also revealed that the two most common elements that surprised the scientists were (a) the varied level of engagement demonstrated by students and (b) the quality of the students' questioning. Almost half of the scientists (9/20) mentioned that although the sessions were interactive, the nature of interactions was different than they had expected either because students asked more questions about the nature of their work and subject-related questions, or because some students were more difficult to engage than others. It seemed that scientists were not prepared for the range of abilities, interest and engagement that exists normally in classrooms. As one scientist mentioned, 'the amount of questions—about all aspects of my job and research—a few of which were prompted but most spontaneous. The genuine interest shown by the majority surprised me' (Sc5f_post).

On the whole, the participating scientists considered interactions with secondary school students as valuable for both parties. Having taken part in the sessions, scientists pointed out that these were of value to them, especially for developing their own communication skills and being able to disseminate their work to a wider, younger audience. Scientists seemed to have a positive stance towards public engagement, a factor found to be significant in motivating them to take part more systematically in such events (Poliakoff & Webb, 2007). The most effective ways to engage students with a wide range of abilities and interests emerged as a challenge for many of the participating scientists. This was evident in two main respects. Firstly, according to the scientists, the students were asking 'provoking' and 'interesting' questions, that the scientists felt that they were not able to respond to at a level that the students would understand. Secondly, the gap between those that were able, or willing to ask such questions, and other less vocal students posed a further challenge for the scientists.

Discussion

Meeting scientists and interacting with them in a friendly and informal context allowed students to alter their prototypical (and predominantly stereotypical) images of scientists (Hannover & Kessels, 2004) and consequently, narrow the gap between perceived and actual images of scientists. Deconstructing stereotypes of scientists and their work (Rahm, 2007) by bringing students in contact with practising scientists is essential for allowing students an insight into the world of science, and what it means to think scientifically and to work as a scientist (Brickhouse, Lowery, & Schultz, 2000; Chen & Cowie, 2013).

Smith and Mackie (2000) discuss how stereotypes of groups of people can be altered or rejected by individuals if they get in contact and interact with members of these groups. For stereotypes to be successfully altered, they state that experiences provided need to include stereotype-inconsistent examples, which 'cannot be explained away, subtyped, or contrasted' (p.194). Such stereotype-inconsistent experiences were provided during the *Meet the Scientist* sessions, since students were given the opportunity to interact with two different scientists, with different backgrounds, ages and experiences. This approach seemed to influence positively the students' views of scientists, as shown in Table 3, with students' views after the sessions emphasising how 'normal' and interesting scientists were. As a result, the *Meet the Scientist* model of scientist–student interactions allowed the creation of a shared space for science communication and interaction amongst scientists and young people.

The students' emergent views of scientists as ordinary and approachable individuals are consistent with suggestions that students need to contextualise their experiences of science in order to make the experiences more personal and relevant, enabling students to perceive themselves as future scientists. As Finson (2002, p. 335) asserts, 'individuals who have negative perceptions of science or of scientists are unlikely to pursue science courses of study and, subsequently, enter a science/science-related career'. This has implications for students' decision-making with respect to science careers. If students develop and embed notions of scientists as normal people then it is more likely that they will be more interested in pursuing a science career.

Students' experiences of school science often lead them to associate science careers with the three traditional science subjects that they are taught in secondary school. Archer et al. (2010) report that in the UK, most students at ages 10–14, and many parents, believe that science qualifications can lead to careers such as becoming a doctor or teacher, but are not aware of the wide range of post-16 opportunities provided by gaining science qualifications. These authors also point out that schools often fail to convey to students how studying a science-related degree might be valuable in gaining access to a wide range of careers. In our study, the scientists' perceived impact of the sessions (Figure 1) and the fact that science career interests and aspirations were discussed in more than 90% of the sessions (Table 4) strongly support the view that face-to-face, discussion-based interactions are valuable in helping students learn more about science careers.

The analysis of the discursive interactions between scientists and students, which aimed to answer the second research question of this study, revealed that the nature of the discursive interactions in this study had characteristics consistent with van Zee et al.'s 'guided discussions' between teachers and students (2001), which were found to be conducive to increasing student questioning, active participation and thinking during science instruction. These characteristics included (a) explicit prompting for student questioning by the scientists, (b) using familiar contexts or links to everyday life through discussing applications and implications of their work and (c) being flexible so as to allow time and space for answering the students' questions. The dialogic nature of the *Meet the Scientist* sessions was based on an interactive, reflexive model of science communication, where scientists participate in dialogue with their audience (Nielsen, Kjaer, & Dahlgaard, 2007). Students were given the opportunity to interact with scientists beyond the transmission model often adopted in science communication interactions (Bray et al., 2012) and one-way communication, which is frequently perceived by scientists as the norm in science communication events (Davies, 2008; Nielsen et al., 2007; *Royal Society*, 2006). In such transmission models of science communication, few opportunities are given to the audience to pose questions and develop a dialogue with the science communicator. The students' questioning focused predominantly on science content knowledge and information (Table 6) indicating that students were genuinely interested to know more about the scientific fields of the scientists they met, as a result of listening and talking with the scientists about their work.

Bray et al. (2012) conducted a Delphi study investigating the essential elements that a science communication course should put forward for valuable interactions between scientists and the public. They concluded that in such interactions the audience should come first; science communicators should be aware of the needs of the audience and attempt to empower them to take part and engage with the science presented to them, by allowing them to participate in the process, by taking account of their needs and by using techniques such as storytelling to make the topics discussed accessible to them. The *Meet the Scientist* sessions fulfilled the aforementioned conditions. The number and nature of student questions indicate that the majority of participating scientists put the students first, and the scientists' reflections on their own ability and skills of engaging and interacting with students showed that they had considered their audience and how they could have improved these interactions.

Reports on scientists' participation in outreach activities indicate that often scientists do not have the necessary skills to engage in dialogic, interactive models of science communication (Ecklund et al., 2012; *Royal Society*, 2006). In our study, the scientists' views on the impact of interacting with the students focused on their awareness of their own communication skills, and the skills necessary for engaging students in discussion. The opportunity to take part in face-to-face interactions with students raised the scientists' awareness of the need to engage their audience actively when communicating their work at live events, and consider their communication skills in relation to the audience's ability to understand the nature of their work (Figure 2). The scientists' perceived impact of the sessions on themselves emphasised the importance of *interaction* during the sessions. This led to most scientists structuring their sessions in a more interactive way than simply making a presentation, an approach generally used by scientists when taking part in public engagement events involving children (Ecklund et al., 2012).

Conclusions and Implications

The aim of this study was to explore the value and nature of short, face-to-face interactions between scientists and teenage students. It demonstrates how short, discussion-based sessions between students and scientists can have a positive influence on students' perceptions of scientists and their interest and motivation to learn about current scientific research. Learning *with* and *from* scientists (Hodson, 2012) through face-to-face interactions with scientists allowed students to view scientists as approachable, ordinary people, and start to understand the range of scientific areas and careers that exist. Elements of the sessions found to be effective in promoting scientist–student engagement and interaction were putting the students' interests and questions first; using examples from everyday life and discussing applications/implications of their work in order to make it relevant for students; using support materials and making links to school science; and discussing science interests and career aspirations with students. The informal and reflective nature of the *Meet the Scientist* sessions encouraged scientists to share their experiences of being a scientist, discuss their work and give advice about how to become a scientist.

Based on the findings of our study and the challenges that scientists faced during the *Meet the Scientist* sessions, a model of training for face-to-face interactions with school-aged students could be designed, which could maximise the benefits of such interactions for both groups. The questions that students ask can be seen as a negotiation of meaning and attempts to establish links between themselves and the scientists (France & Bay, 2010) and thus narrow the gap between perceived and actual images of scientists. However, the questioning taking place during the sessions posed a challenge for the scientists, who were not all prepared to answer some of these questions (e.g. about their own career pathway) or were not able to do so at a level that the students would find interesting or engaging. This suggests that training is required that prepares scientists to ask a range of both closed and open-ended questions as a means of maximising engagement and participation. Questioning should also be responsive to the students' needs, and scientists should be offered help in identifying ways in which their work could be contextualised for the students, providing the main aims and rationale of their work in a way that points out its significance but is also simple enough for students to understand.

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Appendix 1: Questions posed to the students before and after the *Meet the Scientist* session

Pre-session

1. Have you ever met a scientist before? If so, what was their job?
2. What kind of work do scientists do?
3. What skills does a scientist need to do his/her job?
4. What kind of people are scientists?
5. What would you like to find out more about from the scientists?

Post-session

1. What were their [the scientists'] jobs?
2. Were the scientists as you expected them to be or not? Explain.
3. Did anything surprise you about them? If so, what?
4. What was the most interesting thing they told you about?
5. Is there anything else you wish you'd ask them about?

Appendix 2: Questions posed to the scientists before and after the *Meet the Scientist* session

Pre-session

1. Job title
2. Number of years working at [researchers' institution] (up to 2011)
3. Number of years working in scientific research
4. What prompted your involvement in the *Meet the Scientist* session?
5. Have you been involved in work with school students previously? If yes, what did this involve?
6. What are your thoughts about the upcoming session?
7. How do you think the school students will benefit from a session such as *Meet the scientist*?
8. What kind of questions do you think the students will ask you (e.g. about your work, about science, about your career)?
9. How do you think you will benefit from a session such as *Meet the scientist* (if at all)?

Post-session

1. Were the students as you expected? Please briefly explain.
2. Did they surprise you in anyway? If so, in what way?
3. Were you surprised by any of the questions they asked? Please briefly explain.
4. Have your thoughts about how this session will impact students changed and if so how?
5. Have you thoughts about how you will benefit from this session changed and if so how?
6. Would you be interested in taking part in a session like this again?
7. Other comments/observations