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The experiences of active participation in academic conferences for high school science students

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ABSTRACT

Background: There is a diverse range of opportunities for high school students to undertake Independent Research Projects (IRPs) in science and this is recognised as a beneficial aspect of high school science provision. In Higher Education, the importance of students undertaking research as part of their learning, including presenting at authentic, academic conferences, is increasingly recognised.

Purpose: To date, research has little considered the experiences of high school students who present their scientific research at conferences in authentic settings, to audiences of academics and peers, and this study seeks to contribute to understanding in this area.

Sample: Twenty seven high school science students from four state-maintained schools in England participated in this study.

Design and methods: This qualitative research incorporates the 'Students as Partners' (SaP) approach. SaP is present in the ways in which teachers and students worked in research and in contributing to authentic conferences. SaP is also reflected in the composition of the author team of this article; the first author worked for the organisation that delivered the conferences, the second author was a school student who participated in one of the focus groups, having previously presented her research at one of these conferences, and the third author is based in a higher education institution. Student experiences were shared through five focus groups held at the students' schools and thematic analysis was used to explore these experiences.

Results: High school students benefit from the opportunity to present their research at academic conferences, but they need support and guidance in the pre-conference and post-conference phases as well as at the conference to gain the most from the experience.

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Conclusion: Future research must consider the ways in which students from under-represented groups can be supported to view IRPs and presenting research at conferences as opportunities that are open to them if these opportunities are to be genuinely open to all students.

KEYWORDS: high school science students, academic conferences, independent research projects (IRPs), student researcher, teacher scientist

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Introduction

This study explores the experiences of science students, educated in four English high schools, who actively participate in academic conferences by giving oral and/or poster presentations of their independent research projects (IRPs). In this context, academic conferences are defined as a space where students present independent research developed individually or, more often, as part of a collaboration with their peers, supported by their teachers and/or technicians, whilst at school. These conferences are held in professional environments that are external to the students' school (e.g. university departments) and have audiences which include academics, teachers and the students' peers who may also present their research. Students in high schools located in England, UK are aged 11-18 years. They usually complete seven years of high school education with examinations at the end of the fifth year (General Certificate of Secondary Education) in eight to twelve subjects with mostly compulsory and some elective subjects. Many students go on to take examinations at the end of the seventh year (Advanced Levels) in two to four elective subjects.

Research that considers the nature and impact of IRPs in high school students' science education (Bennett et al. 2018) shows that such projects can have considerable benefits for students in terms of engagement and a richer understanding of what it is for a scientist to undertake research. However, the IRP literature and our own experience suggests that dissemination opportunities (including oral and poster presentations at

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authentic conferences) for students who complete IRPs are limited. This is in contrast to the trend in Higher Education, where there is a growing literature that demonstrates the ways in which undergraduate students develop through presenting their research at authentic conferences (Cuthbert, Arunachalam & Licina, 2012; Hill & Walkington, 2016; Lopatto, 2007; Pavalakou & Walkington, 2018; Shanahan et al. 2015; Spronken-Smith et al. 2013; Walkington, 2008; Walkington, 2016a&b; Walkington et al. 2011; Walkington et al. 2018; Walkington et al. 2016).

The study presented here rests on the premise that all undergraduate students should have the opportunity to learn through "some form of research or inquiry" (Healey & Jenkins, 2009b, 7) and, that this can be implemented at the outset of students' academic studies (Healey & Jenkins, 2009a). Presenting at an academic conference provides students with further opportunities to learn and to develop research and research-related skills (Kneale et al. 2016). This student development occurs through the three phases of the academic conference identified by Kneale et al. (2016) as: pre-conference preparation; conference presentation and networking; and post-conference debriefing and reflection.

IRPs and science education

An IRP can be considered as a student-led, extended, open-ended investigation involving practical work, using Millar's (2004) definition of practical work, i.e. work that encompasses activities involving students in observing or manipulating the objects and materials they are studying. IRPs are usually undertaken during normal school hours, sometimes supplemented with time in after-school clubs. Occasionally, time is created within schools through 'intensive pull-outs' whereby students are taken off their

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normal timetable for a period to be dedicated to IRP work. In some countries, IRPs are associated with dedicated out-of-school events such as one- or two-week summer schools and camps.

A systematic review of IRPs (Bennett et al. 2018) indicates that they are often associated with wider initiatives such as authentic science, problem-based learning and project-based learning. There is considerable variability in the nature of IRP work in relation to such things as the involvement of external partners such as universities and employers, funding and assessment. Most of the published literature on IRPs reviews explores areas such as conceptual understanding, motivation to study science once it is no longer compulsory, attitudes to science and the development of practical skills. Benefits of IRPs are found in relation to the learning of science ideas, affective responses to science, views of pursuing careers involving science and development of a range of skills. Studies focusing on traditionally under-represented groups indicate that such students felt more positive about science as a result of undertaking IRPs.

A more recent report of a single study (Dunlop et al. 2019) evaluated open-ended investigative project work for post-16 science students, where such projects give students a certain amount of autonomy but do not necessarily require them to undertake original research. It found that teachers who encouraged their students to engage in such projects believed that they were valuable for much the same reasons reported by teachers who enable their students to undertake IRPs.

Undergraduate student development through presenting at authentic conferences

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Engaging in research is an expectation for most undergraduate degree programmes, and the benefits of mentored research are well documented at higher education level (Gillies & Marsh, 2013; Healey & Jenkins, 2009; Hensel, 2012; Kuh, 2008; Lopatto, 2010) with this activity being considered a 'high impact' educational practice (Elgren & Hensel, 2006; Elrod, Husic, & Kinzie, 2010; Kuh & O'Donnell, 2013; Lopatto, 2010). A number of studies have demonstrated the importance of undergraduate research opportunities specifically in STEM subjects to enhance students' skills and university experiences (Graham et al. 2013; Hunter, Laursen & Seymour, 2007; Linn et al. 2015; Russell, Hancock & McCollough, 2007; Sadler et al. 2010; Thiry, Laursen & Hunter 2011; Thiry et al. 2012). Walkington et al. (2011) and Spronken-Smith et al. (2013) highlight the importance of involving undergraduate students in research at an early stage of their university education. The efficacy of mentoring undergraduate research is also well established (Shanahan et al. 2017; Walkington, Hill & Kneale, 2017). Mentoring at undergraduate level has been defined by Osborn and Karukstis (2009, 42) as:

> A serious, collaborative interaction between the faculty mentor and the student, in which the student is intellectually engaged in the scholarly problem or project. The faculty mentor guides the student into deeper intellectual engagement over the course of their collaboration.

In addition, Thiry et al. (2011) identify three forms of support which mentors of undergraduate research provide for students when bringing them into a scientific community of practice: intellectual support (with the research process), personal and

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emotional support (taking an interest and being available) and support with professional socialisation (e.g. networking and professional development).

Undergraduate research conferences are increasingly part of a student's experience of university education (Walkington et al. 2016), with opportunities to present their research at national, university-wide, faculty and disciplinary conferences in the UK, USA, Australia and parts of mainland Europe. Walkington et al. (2016) explored the impact on students who presented their research at conferences, in a study that involved 90 in-depth interviews with undergraduate students who had presented at a multidisciplinary National Conference of Undergraduate Research during 2012-14. Walkington et al. (2016, 416) found that presenting at conferences developed students' confidence, "giving additional value over and above the recognised benefits of engaging in research". A key feature of this experience is that the setting has authenticity as a space for genuine research dissemination and is a professional experience for students (Walkington et al. 2016). For undergraduate students, presenting at a research conference is a "threshold experience" that develops their capacity for self-authorship. Threshold experiences are events in a learner's development where, through participation in a defined event (e.g. presenting at a conference), they move to a more advanced stage of development. In the case of an undergraduate student, the threshold experience of presenting research at a conference can enable individuals to reposition themselves as a researcher as opposed to a student (Meyer, Land & Baillie, 2010).

Opportunities for high school students to disseminate and/or communicate research

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Although there are a variety of opportunities for students to undertake independent research in STEM whilst at school (Bennett et al. 2018), students have limited opportunities to widely disseminate their research beyond a short, internal and informal presentations of their findings. An example of an environment where high school students can communicate their research is through the authentic conferences hosted by the Institute for Research in Schools (IRIS). During the academic year 2017-18 over one hundred high school students in the UK have presented at IRIS conferences which have been hosted by universities and academic institutions including the Wellcome Trust, the Wellcome Genome Campus, the Rutherford Appleton Laboratory and the Physics Department at the University of Oxford. Conference audiences include academics, teachers and the students' peers who also present their research.

This current study makes a contribution to our understanding of the ways in which younger students (aged 11-18 years as opposed to undergraduate students who are at least 18 years old) experience the learning environment of an academic conference in the context of science IRPs. This may provide findings relevant to high schools that use IRPs and/or academic conferences as part of their science provision. The central research question is: What are the experiences of high school science students who actively participate in authentic academic conferences?

Methods

Approach

The 'Students as Partners' (SaP) approach, where all those involved in research are, "in a relationship … and … are actively engaged in and stand to gain from the process of

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learning and working together" (Healey, Flint & Harrington, 2014, 12). Mercer-Mapstone et al. (2017, 2) acknowledge the "range of practices and pedagogies" included in SaP approaches and identify the common thread as "re-positioning of the roles of students and staff in the learning endeavour, grounded in a values based ethos". This research draws on the SaP approach in two distinct ways. First, this SaP is found in the ways in which teachers and students worked together in research projects that were disseminated at authentic conferences. Secondly, the SaP approach is found in the authorship of this article, as the second author was a high school student who was both a conference participant, contributing to a poster and to an oral presentation given as part of a group of three students from School A at Conference 1 (Table 1), and a focus group participant (see below). The value of SaP approaches to teaching and learning are increasingly recognised in undergraduate courses (Healey et al. 2014; Mercer-Mapstone et al. 2017). Higher Education institutions have identified that undergraduate teaching and learning approaches that promote the value and importance of research are associated with enhanced student outcomes (Lopatto, 2007; Taraban & Logue, 2012; Walkington, 2015; Walkington et al. 2011), whilst also acknowledging the challenges of implementation and barriers to participation (Bovill et al. 2016; Marquis et al. 2018). This partnership approach to research is consistent with the philosophy of IRIS, an organisation that supports STEM research involving school students and their teachers and facilitated the four research conferences included in this study.

Participants

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Twenty seven students from four state-maintained schools located in England, UK (Kent, London, Sheffield or North Yorkshire) were recruited for the study (Table 2). Teachers from all the schools that participated in the conferences listed in Table 1 were contacted to be part of this current study and four schools elected to host focus groups. Three schools have students aged 11-18 years and one has students aged 4-18 years. All participants presented their science research at conferences held during 2017, in locations outside of their school communities (Tables 1, 2). Twenty four participants were from non-selective state-maintained schools and three were from a selective grammar school. Of the four schools attended by the participants, three were in the 10-30% least deprived areas of England and one in the 20% most deprived, as measured by the Income Deprivation Affecting Children Index (IDACI) included in the Indices of Multiple Deprivation (2015) (Table 2). The age and sex of the participants were recorded; however, further participant information, such as ethnicity, was not collected. Nineteen of the participants were in the post-16 phase of high school education and these students were all studying at least two STEM subjects. Information regarding all participants' academic achievement was not formally collected; however, conversations between the first author and the four teachers involved revealed that these students were considered 'academically able' students who were likely to achieve at least a B grade (a high grade) in their post-16 examinations. The 27 participants represent 25% of the student population who had presented at IRIS conferences during 2017-18 and 1% of all students who participated in IRIS projects throughout 2017-18.

[Table 1 near here]

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[Table 2 near here]

Data collection

Five focus groups (each lasting between 30 and 45 minutes) were conducted, one each in Schools A, C and D and two in School B (Table 2). Focus groups with small numbers of participants (3-9 people) were used to collect rich data in a relaxed, open setting (Coolican, 2014) to provide self-reported, introspective accounts (Bluck & Habermans, 2000) (Table 2). Participants were recruited through email requests to the teachers who had supported students' contributions at the conferences. The school teachers were the gatekeepers for the focus groups, which were held at the participants' schools, during the school day and in the presence of at least one teacher so that the focus groups complied with best safeguarding and ethical practice. A focus group schedule was prepared with questions in three main sections: background information, including information about the students' school subject choices and involvement in research; the students' experience of presenting at the conference and the challenges; and benefits and challenges of this experience. These questions were shared with the teachers prior to the focus group. At the beginning of the focus group the researcher explained the nature of the study and participants were told that they could withdraw their data at any point and that any comments used would be cited anonymously. The focus groups were audio-recorded and transcribed. Participants were informed that they could see a copy of the anonymised transcript once it had been prepared. At the end of each focus group the researcher explained that there was an opportunity for each focus group participant

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to contribute to the analysis of the data and to co-author a research paper based upon five focus groups. One participant accepted this invitation (the second author of this paper).

Research limitations

The first author is employed by IRIS, and it is not uncommon for evaluations of IRPs to be authored or co-authored by those involved in the implementation (Bennett et al. 2018). At the outset of the focus groups, the first author explained that participants were free to say exactly what they thought, although it is possible that IRIS' role in facilitating the four conferences may have limited some participants in sharing any challenges they faced or prevented them from being critical of the experience. However, the first author's experience of school student research through IRIS, including attending three of the four conferences, was important in developing a level of trust so that detailed accounts could emerge. In moving between the roles of researcher, former teacher and IRIS employee, the first author sought to identify a space that supported scientific research of a qualitative nature.

The second author was a participant in the study as well as being a co-author. The second author's first-hand experience of presenting at a conference may mean that conclusions drawn are more faithful to student experiences. At the same time, the student co-author's own experiences may have influenced her interpretations of other students' contributions. In addition, her closer relationship with members of her own group may have led to a more favourable analysis of the focus group she took part in,

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for example, by potentially maximising the successes and minimising the challenges identified in her own focus group. However, there is no evidence for this.

Analytical process

The focus group transcripts were analysed jointly by the first and second authors in a shared process using the six phases of thematic analysis outlined by Braun and Clarke (2006; 2012). The two of them met twice a month over a six-month period and began the analysis after reviewing relevant literature and exploring appropriate analytical processes. Each of the six phases of thematic analysis were discussed before the two of them began the formal analysis. Each worked independently between each of the twelve meetings, sharing ideas via email. The third author assisted in the writing of the submitted manuscript.

Analysis began from the premise that what participants say about their experience is a reflection of their reality and lived experience (Braun & Clarke, 2006; 2012). As such, the analysis that is used in this study employs an inductive, semantic approach that allows theory to emerge from the data. A semantic, rather than a latent, approach was chosen to code the data, as this enables those undertaking the analysis to focus on experiential meanings, rather than possible social constructions of meaning that it might be believed that participants could and/or should have intended. In reality, is not possible totally to separate analysis from the research context (Clarke, Braun & Hayfield, 2015); therefore, the research limitations have been set out above. The first author's familiarity with the work of Kneale et al. (2016) was brought to the analysis of the transcripts and the inductive analysis should be seen in this context. In Phase 5, the

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identification and naming of themes, both descriptive (data used to illustrate themes) and interpretative (data used to understand latent meaning) analysis were used. Braun and Clarke (2012) demonstrated that these two approaches can be successfully combined.

Results

Kneale et al. (2016) delineate three phases of students' experiences of conferences: pre-conference preparation; conference presentation and networking; and, conference debrief and reflection. Data analysis allowed the coded experiences of students to emerge and was structured by the conference phase where they were identified and evidenced (Table 3). Students discussed the conference presentation and networking phase most frequently (number of student references (i.e. comments): n=129), compared to the preparation phase (n=56) and the debrief and reflection phase (n=30). Table 3 shows how the themes for each phase of the conference experience were built up from sub-themes and clustered; the sub-themes are presented in order of the number of references made during the focus groups (so, totals are sometimes greater than the number of participants). These conference phases are now explored in more detail.

[Table 3 near here]

Phase A. Pre-conference preparation

Three main themes were identified in the pre-conference preparation phase (Table 3). First, some students identified that they did not always have sufficient resources to

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enable them to prepare. Secondly, students highlighted three different approaches for conference preparation that had different implications for both students and teachers. Lastly, some students experienced anxiety and nervousness in the conference preparation phase.

Theme 1. Lack of resources

Students identified that they did not always have enough time to prepare for the conference:

> We hadn't had a lot of time to prepare what we were going to say so we kind of split up the lines and we were practising them on the day.

Students also reported that it was not always possible for all the students who had worked as part of a research project to attend and present at the conference because they had other school-related commitments:

> We didn't have our spokesperson at the conference … she was on a school trip at the time, so it was up to us to have to adapt our plans and the presentation so that it worked for the conference.

Students who identified these resourcing challenges also described their ability and, in some cases, their responsibility to overcome them during the conference presentation phase.

Theme 2. Preparation of presentation

Students identified three approaches to conference presentation: preparation led by a teacher; preparation led by student teamwork; preparation supported by a teacher. Presentation preparation led by a teacher involved teachers determining the structure of the presentation, identifying content, dividing up the talk and assigning roles and responsibilities for students:

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> Miss asked for volunteers who were willing to speak, and she gave us a brief breakdown and Miss broke it into sections for us and we each chose a section that we would like to take.

Teachers who provided support for students' preparation gave students some impetus and structure to creating the presentation, helping students to assign roles and rehearse the presentation to internal audiences prior to the conference and giving guidance on how to prepare for possible questions:

> We started to go through the practice runs and [our teacher] got some students, some teachers, to have a listen and [then] we just went through a lot of practice runs …

Students frequently described their experience of presenting at a conference as the result of teamwork. Student-led presentation preparation was done working in collaboration to write, rehearse and deliver their oral presentation or poster, as students recognised that they were "working together to become experts".

Theme 3. Student anxiety and nervousness

Students often expressed their anxiety during the pre-conference preparation phase, describing nervousness about speaking too fast and concerns that their nerves would limit their ability to express themselves articulately and with clarity. Although teachers were not involved in the actual delivery of the presentation, they often had an important role, providing emotional support and reassurance to students who were preparing for a novel and intellectually and emotionally challenging experience. This reassurance sometimes came by providing explanations to the students during the pre-conference presentation phase about some unfamiliar aspects of attending and presenting at a conference:

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> [Our teacher] did let us know what people were going to talk about … so we were able to do some research before we got to the conference so that we could ask better questions.

Reassurance was also provided during the conference presentation and networking phase, when teachers typically created a light-hearted and humorous atmosphere that reduced the anxieties of the students.

Phase B: Conference presentation and networking

Theme 1. Validation through professional experience

The conference venue, audience and the opportunity to engage with the scientific community were three aspects that created a strong sense that this was a professional, authentic experience for students. Students who presented at the Wellcome Trust conference commented upon the building and features of the venue that they were impressed and enthused by, and one participant described her excitement at presenting at a venue which had "so much history" and where people were working in science. The audience was also commented upon by the students. The audience was linked to a sense that this was a "professional" experience compared to students' prior experiences of sharing their research with their school communities. Students recognised that in the conference they had an opportunity that was infrequently available to them or other school students and that part of the novelty of this experience was the opportunity to engage with members of the scientific community. They identified different groups from this community, including leading academics, experienced researchers and PhD students. Many high school students reported that they felt better able to identify with the PhD students than with the leading academics because they perceived the PhD

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students as being closer to them in experience. One high school student explained that the experience of presenting her research at the conference gave her an understanding that she was able to 'think and work in the same way as the other scientists' she encountered at the conference. Students frequently described the inspiration that sharing their research with academics gave them, and some students reported that this further encouraged them to explore careers in academia and science.

Theme 2. Student skill development

Students' reporting of their own skills development was focused on communication and confidence. Students recognised that they were able to present and communicate their research to a range of audiences, including those who had more and others who had less expertise than themselves as both presenters and researchers:

> … you have to talk to the scientists in a different way to your peers, and … [with] younger children … you have to explain the ideas behind the research in a different way, you can't use the same language …
>
> When we prepared for the talks we had to remember what it was like not to be an expert … what it was like to not know the terminology and these ideas and we had to explain them.

Students' confidence in public speaking, ability to manage their performance anxiety and ask and respond to questions developed alongside this enhanced ability to communicate to a range of audiences. One student said, "my confidence has definitely grown more since last year and I think the conference was an important part of showing me that I could stand up and talk about this project to an unknown and different audience".

Theme 3. Gaining new disciplinary knowledge and understanding of the research process

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Students recognised that participating in conferences gave them an important opportunity to learn more about their research area and the process of research that was outside their normal experience:

> I do think this experience has helped me understand research because it has shown me it is quite independent, and you need initiative to do things and contribute but, you also work in a team and build on the work of other researchers.

Some students identified that they encountered barriers to gaining knowledge from the conference as their unfamiliarity with some of the technical language and content made it more challenging to engage with other research presentations and limited their capacity to ask questions:

> I found it hard [to ask questions] because it was something new we were hearing about so it was … very hard to think of a question because everything was brand new to us.

Theme 4. Collaboration and shared experience

Students frequently described their experience of presenting at a conference as the result of teamwork, working with their peers and with the support of their teacher to deliver their research presentation or poster. This collaboration and shared experience provided students with the support they needed to navigate the unfamiliar conference environment, and peer-to-peer support provided some students with the additional support needed to overcome nerves and anxieties. The conference as a shared experience between students was more frequently reported than as a shared experience with teachers. Through this peer shared experience, students were able to express their pride and sense of accomplishment of what they had achieved together, in a way that they felt was not "big-headed". One student said:

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> … what I really got from the conference was that I was really proud of what we had achieved together and what our group of students had contributed to the research and that we had done so much to get our project know beyond our school.

Theme 5. Developing networks and professional contacts

For some students, the conference experience gave them the awareness and confidence to develop networks that would benefit them professionally. One student described how, having presented at a conference, he now had the confidence and the awareness to approach a vet at another event and secure work experience. This was not a universal experience as a greater number of students reported that they encountered barriers to developing new opportunities at the conference. Some students described anxiety about networking with the audience, with one student describing an audience member who viewed her research poster as being "really scary" but this was acknowledged as the exception and by the student who said that most of the audience were "really nice". This anxiety during the conference presentation and networking phase inhibited some students and limited their ability to interact and network with established academics, PhD students and other school students:

> Most of the time we stayed in our own group … we were not sure what to do and we had our presentation last so we were nervous about that.

Phase C: Conference debrief and reflection

Data analysis revealed that students did not clearly articulate this final phase of the conference experience. For some students, the focus group itself appeared to be the first opportunity that they had had to reflect on their experiences either individually or as a

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group. Students did not identify their teachers as having played any part in this phase of the conference experience.

Theme 1. Sharing conference experiences with family and friends

Students' limited references to reflection and/or conference debrief were mainly restricted to a description of how they had shared the experience with their family and/or friends. Students reported that they shared their positive experiences of the conference with their peers, including those who had no previous involvement with their research project, e.g. friends who did not attend the same school. In some cases, students recounted how proud their parents were of them having presented at a conference.

Theme 2. Student identification of future professional benefits

Students recognised that the conference experience had professional benefits that extended beyond the day itself and some made an explicit connection between presenting at the conference and an opportunity to enhance their CVs and university applications, with students in every focus group making that connection. Fewer students made a link between the conference and the opportunity to develop their professional networks. Students did articulate how their understanding of research and of careers in research science had been expanded through the conference experience; for some, this had made the distinction between a medical career and a career as a research scientist easier to understand.

Theme 3. Student reflection on the conference experience

Few students reported that they had individually reflected on the conference experience. Two students from one focus group reported that they had reflected on how the

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conference experience had positively shaped their understanding of themselves as scientists, with one student describing how the conference experience showed her that research should be something that benefits people and that she identified as a scientist because of this understanding of the purpose of science: "… that makes us scientists, right? We want to do research that benefits people".

Discussion

In this Discussion we interpret our findings concerning our central research question, 'What are the experiences of high school science students who actively participate in authentic academic conferences?' in relation to what is currently known about the benefits of high school students presenting their research at academic conferences.

High school student participation at academic conferences

Positive aspects of the high school students' experiences

The school students in this study who participated in academic conferences were overwhelmingly positive about the experience, recognising that this was a novel opportunity where they engage professionally with the scientific community in a way that validated their contribution. The students recognised that presenting at conferences enabled them to develop some aspects of their communication skills, e.g. speaking to large audience in a formal setting and managing their performance anxiety. Every participant said that given the opportunity to present at a conference again they would do so, and many described a sense of pride and accomplishment in the achievement of presenting to an academic audience, in an authentic venue. A key aspect of the positive

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experience described by students was their recognition that through the experience of the conference they had communicated their research to an audience of scientists and through this dissemination to the academic community, their efforts had been recognised and validated.

The students described how they had been able to explain their research to an unknown audience with varying levels of familiarity with the research area and/or technical language. Hill and Walkington (2016, 227) have described this ability observed in undergraduate students as students "repurposing content", and some of the students in this study described how they were able to achieve this. IRPs can provide high school students with experience of science education that can positively shape views towards careers in science and develop a range of skills that better prepare young people for science careers (Bennett et al. 2018; Dunlop et al. 2019). The vast majority of IRPs do not have provision for students to present their research findings beyond, sometimes, a mini-viva voce style presentation to a small panel of internal assessors. Providing students with the opportunity to share their research through academic conferences gives them an opportunity to experience another aspect of a career in science and/or research as a contributing participant rather than a visitor or observer. At the same time, students who present at conferences can develop communicating and networking skills that are likely to enhance their future employment prospects.

Challenges experience by high school students

Accompanying these positive aspects of the conference experience were challenges that participants reported encountering when preparing for the conference and, to a lesser extent, in their experience of the conference itself. Some students reported feeling

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anxious and nervous during the pre-conference preparation phase because they encountered difficulties in getting sufficient time to prepare for the conference and were not always able to have members of their research team available to present with them at the conference. Some nervousness and performance anxiety is to be expected, as the students were participating in an experience that was novel and challenging. However, this study underlines the difficulties that high school students currently face in participating in an educational experience that is more usually first encountered at university. School students are not currently equipped to negotiate the challenges posed by often inflexible and busy timetables and are reliant on adults to access financial resources to enable them to attend these sorts of conferences. This can cause students to feel nervous and anxious during the pre-preparation phase of a conference. Some students also reported that they were anxious about the unfamiliarity of the conference environment, particularly understanding the nature of the conference audience. With greater support and guidance during this first phase of conference participation, students are more likely to be able to prepare effectively and feel a greater sense of confidence. This support and guidance in the pre-preparation phase could also enable students to present at an academic conference who otherwise might lack sufficient confidence.

During the conference and networking phase, less than 10% of the references made by students were linked to networking, and those references were overwhelming linked to the challenges students faced with this aspect of the conference experience. Students described how they needed more opportunities to develop the skills required to network effectively and to engage with the research of others, for example, by asking good questions. The networking aspect of conference participation has been identified

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as challenging for undergraduate students; Hill and Walkington (2016, 229) found that undergraduate students presenting at conferences recognised that they needed to "develop social competence", with many comments referencing networking. The high school students who contributed to this study identified that they wanted more specific guidance in the preparation phase of the conference; for example, making abstracts of the conference presentations available prior to the conference would enable them to prepare and to ask more questions and more relevant questions. The students also suggested that more time with their peers from other schools, and with near-peers (e.g. PhD students), during the conference would enable them to develop professional networks and explore careers in research in a way that was more natural and felt more immediate to their life stage.

The phase of conference participation that was least frequently discussed by students was the post-conference debrief and reflection one. This is a significant gap in high school students' experience of participating at a conference. Development of this phase could include a debriefing session facilitated by teachers, so students could share their experience, collate their learning and identify future steps for their research project and for their individual development. Part of the debrief and reflection phase could also include a presentation to other (including younger) students to share their experiences which may encourage greater participation in research activities and gain recognition within their local community for their efforts.

Widening participation for high school students

Previous research has highlighted the propensity for adolescent students to develop an understanding of scientists' identities as 'geeky' and socially isolated, and of science

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careers as difficult, lacking creativity and requiring technical rather than social competence (DeWitt, Archer & Moote, 2018; Hazari, Sonnert, Sadler & Shanahan, 2010; Masnick, Valenti, Cox & Osman, 2010), even amongst those who are good at science. Masnick et al. (2010) suggest that in order to increase the likelihood of students' choosing STEM courses post-18 it is important to know more about how young people perceive science so that ways of countering these negative beliefs can be developed. High school students' perceptions can be challenged through participation in conferences, where social competence, networking and communication are key aspects of what it is to be a scientist. Future research could explore the understandings high school students have of scientists' identity before and after these students participate in a conference and with groups of students who do not have this opportunity.

If presenting at academic conferences is an opportunity that is to be made more widely available, careful consideration needs to be given to the barriers to participation identified in this study and in previous research. Previous research concerning provision for undergraduate student research and partnership opportunities has highlighted concerns surrounding equity in student participation (Bovill et al. 2016; Healey et al. 2014; Mercer-Mapstone et al. 2017). Marquis et al. (2018) suggest that open applications for student research and/or partnership opportunities are not sufficient to widen participation as some students do not identify themselves as the type of student who applies or is accepted for these types of opportunities. Future research should consider the experiences of students who are typically marginalised from IRPs so that opportunities, including presenting at academic conferences, are genuinely inclusive.

The role of teachers in mentoring high school student research

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Author 1 and Author 3 (2019) suggest that when science teachers are actively involved in research with their students, their professional identity can transition from science teacher to 'teacher scientist'. A teacher scientist has a multifaceted role of teacher, researcher, coach and mentor, and part of this role involves mentoring school student research. Students in this study who included teachers in discussions of their conference experience frequently described these teachers as occupying mentoring type roles, although they did not use the term 'mentor'. Students reported that their teachers had an important role in guiding and encouraging participation in the conference, supported pre-conference preparations and helped them navigate the unfamiliar conference environment. Supporting undergraduate students to contribute their research through conferences is recognised as a valuable mentoring practice (Shanahan et al. 2015; Walkington et al. 2018) and this study suggests that teachers effectively mentored high school students in some aspects of conference participation. These included: support with preparing presentation and poster structure and content; rehearsing public speaking to a variety of audiences; and providing emotional support to help manage nerves and performance anxiety in both the pre-conference and conference phases.

Students in this study were all supported by teachers who had some previous experience of school students communicating their research at conferences. Aspects of what have been identified as the ten salient practices in excellent (undergraduate) student mentoring (Shanahan et al. 2015; Walkington et al. 2018) were visible in the practice of the teachers in the pre-conference preparation phase. High school teachers balanced rigorous expectations with emotional support and appropriate personal interest. This combination of high expectations and emotional support was described by

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students as being present both in the preparation for the conference and at the conference experience itself. This study therefore gives further insight into the role that teachers have in supporting student research in science; however, teachers need greater guidance and training if they are to become 'excellent' research mentors. Further research could develop this guidance, reflecting upon the experiences of teachers whose school students present at conferences in the context of the findings of Shanahan et al. (2015) and Walkington et al. (2018), and develop a set of practices for teachers who support research partnerships with school students, including those of the 'teacher scientist'.

To conclude, academic conferences can provide high school students who are already engaged with IRPs with opportunities to develop their experiences as researchers and scientists in an authentic environment. Students require support in the pre-conference preparation phase, the post-conference debrief and reflection phase and in developing professional networks as part of conference participation. Further research is needed to better understand ways of enabling student participation from under-represented groups who may not see student research activities as opportunities open to students like themselves. Teachers have an important role as mentors of student research and further research should consider guidance that can be developed to aid this aspect of teacher professional development.

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Table 1. Conferences presented at by school students

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Location and year of conference	**Discipline**	**Poster/Paper**	**Participating schools**
1. Wellcome Trust, London (2017)	Biology	3 x poster 3 x paper	A, B (group 1) & C
2. Rutherford Appleton Laboratory, Oxfordshire (2017)	Physics	1 x paper	B (group 2)
3. York Philosophical Society, York (2017)	Biology	3 x poster	D

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Table 2. Participating schools and students

School (total student population)	**Schools' socio-economic context**			**Gender**	**Age in years (mean age)**
	IMD 2015 ranking	**% students eligible for FSM in last six years (national average = 29%)**	**% students with EAL (national average = 16%)**		
A. Grammar, selective, Kent (n=1103)	10% least deprived	5.6%	9.8%	2 female 1 male	17 – 18 (17.3)
B. Academy, non-selective, Sheffield (n=1682)	30% least deprived	16%	17%	Group 1: 4 female 4 male	16 – 17 (16.4)
				Group 2: 1 female 3 male	17 – 18 (17.5)
C. Academy, non-selective, London (n=1432)	20% most deprived	65%	82%	1 female 2 male	17 (17.0)
D. Comprehensive, non-selective, North Yorkshire (n=643)	30% least deprived	13%	4%	7 female 2 male	12 – 16 (13.0)

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Table 3. Themes reflecting students' experience of the three phases of a conference

Themes	**Number of references in focus groups**
Phase A: Pre-conference preparation	**56**
1. Lack of resources	*24*
a) Time available for students to prepare	11
b) Competing demands limiting student participation	13
2. Preparation of presentation	*21*
a) Preparation led by teacher	8
b) Preparation led by student teamwork	7
c) Preparation supported by teacher	6
3. Student anxiety and nervousness	*11*
Phase B: Conference presentation and networking	**129**
1. Validation through professional experience	*45*
a) Engagement with the research community	23
b) Conference audience	13
c) Conference venue	9
2. Student skill development	*36*
a) Communicating work to a range of audiences	11
a) Increased confidence in public speaking	11
b) Managing performance anxiety	6
c) Asking and responding to questions	8
3. Gaining new disciplinary knowledge and understanding of the research process	*19*
a) Positive experiences	15
b) Barriers encountered	4
4. Collaboration and shared experience	*19*
a) With students	15
b) With teachers	4
5. Developing networks and professional contacts	*10*
a) Barriers encountered	8
b) Positive experiences	2
Phase C: Conference debrief and reflection	**30**
1. Sharing conference experiences with family and friends	*14*
2. Student identification of future professional benefits	*13*
a) Enhanced CV and university application	6
b) Enhanced professional networks	2
c) Enhanced understanding of research and careers in research	5
3. Student reflections on the conference experience	*3*

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