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Free choice learning in school science: A model for collaboration between formal and informal science educators

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Abstract

The informal science education sector has been found to foster engagement with science, whereas formal science education has been criticised as disconnected from students' lives and experiences. Consequently, there have been calls for greater collaboration between formal and informal sectors. This study aimed to create such a 'third space' for science education by linking a university science educator with schools to create spaces for increased student choice in learning. The community of inquiry pedagogical model was used to manage a series of discussions about cutting edge science with 507 students aged 11-14 in 20 state schools in the UK. These classes substituted for school science lessons. Studying learning in free choice environments is challenging due to the range of possible outcomes. Data was collected using participant observations, questionnaires and interviews. Teachers' and students' responses were analysed using Falk and Dierking's Contextual Model of Learning. This allowed us to consider the totality of students' experiences whilst acknowledging the complexity of free choice spaces. Findings indicate that this third space allowed students to exercise choice and control over their learning, and to connect science with their prior knowledge and interests. However, choice can also act as a barrier to learning if students lack sufficient prior knowledge or are uncomfortable with content. Students identified the role of peers and facilitated discussion as important. This indicates that there are benefits to opening up spaces for free choice learning in school science, and we suggest the community of inquiry as a model to achieve this.

Keywords: school/university interface, science outreach, informal education, dialogue

Introduction

It is well established from international studies that while many students find science important, this does not translate into personal interest (Archer et al., 2015; Sjøberg and Schreiner, 2010). School science education has been criticised for lack of relevance, inappropriate images of science, and outdated content (Stocklmayer *et al*., 2010). Lack of student engagement with science has been attributed to the way science is taught in schools, particularly the use of transmissive teaching methods and lack of discussion; the presentation of scientific knowledge as dogmatic; a lack of attention to contemporary science and controversial and ethical issues; and a lack of and emphasis on students' own views (Krapp & Prenzel, 2011; Miller et al., 2006; Osborne and Collins, 2001). Stocklmayer *et al*. (2010) argue that there is a need for a 'third space' for science education, where formal and informal science educators work together to enhance what is learned in school, drawing on the strengths of each. Strengths of the informal sector include affective factors (free choice, interest and enjoyment), factors relating to learning science (considering multidisciplinarity and contemporary contexts), learning about science (facilitating interaction and presenting science as human and messy) and doing science (facilitating inquiry and interaction with scientists). In this project, we present a model of such a third space, located in schools, in which teachers work collaboratively with a university School of Biomedical Sciences over an extended period of time (6-8 hours duration total, taking place over a period of 2-8 weeks) to engage students in classroom dialogue about contemporary science in which students have freedom to choose what they learn. It was our supposition that the community of inquiry approach would lend itself to engaging young people with school science by foregrounding personal and sociocultural factors more commonly attended to in free-choice settings.

Framework for understanding learning in free choice settings

Free choice learning (Falk, 2005) emphasises learning that happens when the learner can choose what, when and how they learn, whereas informal and formal denote the settings. Typically, research on free choice learning has taken place in informal settings such as museums and science centres (e.g. Falk & Storksdieck, 2005; Rennie & Williams, 2006). There has been recent interest in free choice learning in formal settings, for example giving students freedom to choose the topic for a research project (Frohock *et al*., 2018) or incorporating students' interest into a learning sequence (Hagay & Baram-Tsabari, 2015). Free choice learning has been described as relying on curiosity, intrinsic motivation, choice and control (Bamberger & Tal, 2006). This has been contrasted with classroom practice where learning is sequenced linearly into units requiring prior knowledge. However, there is rarely a clear distinction between limited and no choice situations. Bamberger and Tal (2006) describe levels of choice: no choice, limited choice, and free choice, and constituents of choice such as subject focus, space, time, order and interactions. Choice can be limited by constraining any of the constituents of choice. The present study presents a situation where students had no choice about the physical context, nor about the stimulus for discussion, which was decided in collaboration between the university educator and teachers. However, learning was not focused on predetermined, fixed learning outcomes, but on questions created and selected by students, and their responses to these questions. Students had free choice over the subject, focus and their interactions.

Research on choice in learning has found that choice in itself is not necessarily motivating. The options must be matched to students' needs, interests, goals and backgrounds, and must be offered in a non-controlling accepting atmosphere (Katz & Assor, 2007). One way in which this can be achieved is to give students greater ownership over what they learn. According to Katz and Assor, three psychological needs must be satisfied in order to enhance intrinsic motivation and lead to internalisation of externally originated behaviours. These are autonomy (where students have ownership over the task and goal, and to choose how to evaluate their work, and where criticism and negative feelings are allowed), relatedness (where peer acceptance and empathy are encouraged and comparison and competition discouraged) and competence (where choices are matched to students' prior knowledge and non-comparative feedback is provided). Identifying how these needs are met is important where choice is to be incorporated into teaching and learning. In common with the idea that support is needed to make free choice situations motivating, Bamberger and Tal (2006) found that situations where choice was limited by providing scaffold and control to students enabled deeper involvement than no- or free-choice situations.

Understanding learning in free choice situations is challenging because it is highly individualised, depends on prior knowledge, experience and motivations, and it involves interactions with others including peers and teachers. A useful framework for understanding such learning is Falk and Dierking's (2000) Contextual Model of Learning (CML). Although the model was developed to understand learning in museums, it can be applied to other free- and limited-choice situations because it describes how personal, sociocultural and physical contexts overlap, over time, to promote learning as both a process and a product. The CML enables us to organize the personal, sociocultural and physical contextual factors that contribute to young people's engagement with science. In this study, we analyse teachers' and students' experiences of a third space for science education. This approach allows us to consider the potential of increasing student choice in schools science for engaging students with science.

A pedagogical model for a third space for science education

There exists a body of literature about choice in school science in relation to scientific inquiry practices in which students have ownership over their question or topic for inquiry (see for example Bennett *et al.,* 2016), however practical inquiry places a heavy burden on teachers in terms of managing and supervising laboratory activities extending over long periods of time necessary for independent inquiry, not to mention managing health and safety and resourcing. It has been argued that "engaging students in good science includes not only inquiry but also philosophical inquiry, in that it needs to satisfy curiosity about the world around them as well as engage them in meaningful dialogue around the construction of scientific knowledge, ideas and processes" (Burgh & Nichols, 2012, p.1052). This is an important feature of science education for scientific literacy, in which people are competent, comfortable and confident with science, able to follow new advances and to express an opinion on related social and ethical issues (Millar & Osborne, 1998). A pedagogical approach which shows promise in such situations is the community of inquiry.

The community of inquiry is a pedagogical approach associated with Lipman's (2003) Philosophy for Children programme. Although a community of inquiry can be created in different ways, it necessarily involves a group learning environment in which students cooperate, to test, share and improve on their thinking together, through dialogue (Splitter & Sharp, 1995), in response to a philosophical question. Philosophical questions may be constrained by science, but they do not require empirical methods, rather they rely on reasoning as a method as they are open to informed, rational and honest disagreement (Floridi, 2013). Such questions demand a dialogic approach in which students construct and examine claims, suggest hypotheses, present evidence, identify consequences, and develop counterarguments, elements common to both scientific and philosophical inquiry. Dialogue is facilitated by an adult, a position Burden and Williams (2001, p.139) describe as "pedagogically strong but philosophically neutral". A (philosophical) community of inquiry in science presents the possibility for students to engage with science, its methods and consequences without the need to advocate for science. Furthermore, where dialogue exists, there is an opportunity for students to choose what they learn, and to practice forming and shaping questions and opinions in relation to science. Student choice is a necessary component of working in a community of inquiry, but to ensure that such choice is motivating support for autonomy, competence and relatedness must be provided (Katz & Assor, 2007). These are presented in Table 1.

[Table 1 here]

One approach to creating a philosophical community of inquiry that improves attainment in other subjects (Gorard *et al.,* 2015), improves scientific reasoning (Sprod, 1999) and promotes a range of other cognitive and socio-emotional gains (Trickey & Topping, 2006; 2008) is that in which students create, select and discuss their own philosophical questions in response to a stimulus (Lewis & Chandley, 2011). This approach is uncommon in formal science education, yet presents the possibility of bringing together the cultural worlds of school and community in a way that values students' knowledge and interests. The research question we addressed was how can students' experiences of learning through a community of inquiry in school science be understood in terms of the contextual model of learning? We also reflect on the strengths and limitations of this model of a third space for science education.

The collaboration model

In this study, a university educator (the participant observer) was trained by SAPERE[1] to facilitate the community of inquiry sessions. The university educator was a science graduate research associate based in a School of Biomedical Sciences with responsibility for contributing to 'Science in Society,' a public engagement and outreach initiative. Although the educator in this case had teaching experience, this was not essential because all necessary facilitation skills were introduced via the SAPERE training. The facilitator's role is to create the conditions for inquiry, encourage students to ask questions and to support them to explore answers by creating, analyzing and critiquing claims made in response. It is advantageous to have this role filled by a person outside formal school discipline and reporting systems to help students take risks in what they ask and how they contribute.

Teachers worked with the university educator to agree the themes for and intensity of the discussion sessions. All schools were able to stop participating at any point. The community of inquiry sessions about cutting edge science were planned by the university educator in response to teachers' needs. The sessions took place during timetabled science classes to minimise barriers to participation. Each session was facilitated by the university educator and observed by the teacher. Both discussed shared priorities for the group before and after each session. Each discussion was stimulated by a brief teaching activity (typically 10-15 minutes) introducing cutting edge science, linked to curriculum concepts. This included stories, images, songs, games and presentations. Each session, students created philosophical question in response to the stimulus, refined these in small groups and voted for the

[1] Society for the Advancement of Philosophical Enquiry and Reflection in Education

question(s) for discussion. Examples of questions generated from students are found in Table 2. There followed discussion, and the session concluded with reflection on the process and content of the inquiry.

[Table 2 here]

Methodology

Participants

The research was conducted in 20 schools in Northern Ireland (Table 3). Schools were purposively sampled (Creswell, 2003) to test the model in different school types. Teachers self-selected to participate with at least one class of children aged 11-14. Class sizes ranged from 13 to 28, with a mean of 22 students per class. Interviews were held with 8 teachers. A total of 429 student questionnaires (response rate 85%) and 11 teacher questionnaires (response rate 55%) were returned. Response rates reflect student absences and competing teacher priorities during data collection on the last session.

[Table 3 here]

Data collection

Data was collected through participant observation, followed by questionnaires for students and teachers and interviews with teachers following the full series of sessions. As each group could decide on the focus and content of discussion (see table 2) it was not appropriate to test learning pre- and post-intervention. Instead, a reflective diary and field notes were collected, including students' reflections on individual inquiry sessions and 'exit tickets' asking what was learnt and how it was learnt, during participant observation. The questionnaire was short and asked about students' experiences of the approach, their engagement with the sessions, and their perceptions of learning about science, and some items relating to the framework for Thinking Skills and Personal Capabilities (CCEA, 2007). Example items are found in table 4. Items were positive and negative (e.g. I found the sessions interesting/boring), and contained several open items to elicit in-depth perspectives on the approach. For the closed items, scales for engagement and perceptions of learning were constructed, with values of Cronbach's a calculated (0.730 and 0.779 respectively) indicating that the questionnaire was reliable. The semi-structured interview guide asked teachers to reflect on the strengths and limitations of the approach observed and its impact on students, allowing triangulation of teacher and student perspectives.

[Table 4 here]

Data analysis

Quantitative data (5-point Lickert-type items) were analysed using descriptive statistics. Qualitative data from the questionnaire, interviews and participant observations were analysed using the contextual model of learning (CML) as a framework. Applications of the CML in museum and field trip contexts (Falk and Storksdieck, 2005) have used pre-and post-visit test items to look for changes in learning. However much learning in free choice settings does not follow a prescribed, predictable course and may consist of recontextualisation and reorganisation of knowledge, shaped by personal factors (motivation and expectations; prior knowledge, interests and beliefs; choice and control) and sociocultural factors such as within-group sociocultural mediation and facilitated mediation by others (Falk & Dierking, 2000). These factors were used to interpret students' responses to the community of inquiry sessions.

Findings

We proposed that the university-school model for creating free choice learning environments in schools represents a third space for science education in which formal and informal science educators work together to enhance what is learned in school by fostering engagement with science by valuing students' interests and knowledge.

In the self-report data obtained from student questionnaires, the majority of participants reported that they enjoyed the sessions (93%), found them interesting (88%) and talked about topics after leaving class (71%). Most students (89%) reported that they gained knowledge about science and that the sessions helped them to understand science (86%). Only 4% students said that they didn't know any more about science, and 7% found them boring.

In terms of learning to question, 88% agreed or strongly agree that the sessions helped them to ask questions that can be explored, 85% that they helped them to investigate ideas and 89% that the sessions helped them to think how questions could be answered. Students were less positive in their reports in relation to how the sessions helped them to question other points of view or justify their own ideas (75% agreed or strongly agreed that they did) reflecting that fewer were confident in how they were supported to meet more challenging social and/or learning demands through the sessions.

Although the majority of students responded positively, responses do not adequately reflect the variation in individual responses, and here we turn to the qualitative data. In the following section, we analyse responses in relation to the factors hypothesised to influence learning (Falk and Dierking, 2011) with a particular focus on the personal and sociocultural contexts.

The personal context

In this section, we examine how students' responses to working in a community of inquiry correspond to the personal context of learning. Student responses are presented in italics, and teachers are identified by school type.

Choice and control

Students had choice and control over three aspects of each session: the questions created, the questions selected for discussion, and what, how and when they contributed to the discussion.

(i) Question creation. Many students commented positively on the opportunity to choose a question for discussion. Students liked that they could ask *fun and important questions* that they wanted to talk about, and felt that they *got more involved as we were asking the questions*:

> *I thought that it was good that we got to get into groups and make up our own questions and have a vote on which question we wanted to discuss. I now have different views on the answers of the questions and realise that not everyone has the same outlook on all the questions.*

Likewise, teachers saw student choice and control as something that was important:

> *I think it has encouraged me to have both more discussion and different type of discussion. You know, allowing them to lead it more … they are finding out what they need to know.* Teacher, coeducational non-selective school

Some students found it difficult to create questions, and others felt uncomfortable sharing questions with others. Although they enjoyed listening and trying to answer others' questions, choice and control was felt by some as an obligation:

> *You felt you had to say something and come up with a question.*

By the end of the series most students were able to create philosophical questions in response to a stimulus and to participate in productive dialogue:

> *Boys are more confident in asking questions. Extended experience of this would see greater improvement.* Teacher, selective boys' school

(ii) Question selection. Many students reported that they liked voting for questions, but giving students choice and control over the selection of questions was risky. Non-philosophical questions were sometimes selected, resulting in scaffolded meaning-making exercises rather than philosophical dialogue. The question selected sometimes required students to apply different scientific ideas to those anticipated. Where students had limited prior knowledge about the science at stake, the community of inquiry was not the most appropriate approach to introduce these new ideas. One teacher who used this approach with another group reported how she handled it:

> *When it got to the choosing a question bit they totally avoided what I had been aiming at and, almost unanimously, wanted to know what happened when there was an extra chromosome … they haven't really done anything about genetics, so it provided the opportunity to go do a bit of homework and we attempted their discussion on the second lesson … We all learnt quite a bit about Down's Syndrome.* Teacher, coeducational non-integrated, non-selective school

The final way in which question selection presented as a challenge was when students tested the extent to which they had freedom by creating questions that some students considered 'silly' or 'pointless,' although perfectly legitimate, and relevant to (some) students' interests. Although uncommon, where this happened, some students reported that it would preferable for the facilitator to choose questions. However students were generally positive about the freedom they had during the discussion, in particular *it was good the way you got to question other people's opinions*, and these situations present an opportunity for students to learn about responsibility for their learning and about what freedom to choose means. Free choice spaces are very unusual in schools, and although there was some testing of freedom in early sessions, students generally selected questions that bridged between their own interests and science.

(iii) Contributions to the discussion. Students were able to express choice and control in relation to the process. Students exerted ownership of the discussion by rephrasing questions, identifying more fundamental questions that required attention and changing the topic when uncomfortable with content or vocabulary, as in one discussion about embryo implantation. Although it is important to develop students' confidence to use scientific vocabulary, discuss controversial topics, manage differences of opinion and see the value in dissonance, this was done gradually to prevent students feeling alienated, scared to participate or unable to ask an important question for fear of feeling uncomfortable.

The choice and control that students had was important in shaping their views about the community of inquiry sessions. Students appreciated the opportunity to ask and select questions, and to discuss their views with others. They and their teachers valued their ownership of each class and being able to learn about things they wanted to know. Such freedom is novel in formal contexts, and educators working in this way need to be prepared to be tested by students on the extent to which they have been given freedom, and to give students practice in dealing with freedom to choose.

Motivation and expectations

Falk and Dierking (2010) recognise that expectations about what people will do and learn shape their experiences of the setting. In creating this third space for learning, we were interested in how students' expectations of their science lessons shaped their response to the community of inquiry sessions. Students reported that sessions met their expectations of science because they featured similar topics (e.g. reproduction, genetics, cell structure and function), they involved learning, and that there was talking about the subject. However, a range of differences between the their usual science classes and this third space were reported. These are organised in relation to three of Slocklmayer et al.'s (2010) factors that encourage learning in the informal sector.

(i) Learning science. Students reported learning facts and concepts, e.g. *I really enjoyed the classes and learned a lot about what I didn't know* but more often discussed learning about each other, about how scientists do their work, and about how they came to new understandings through discussion, for example *I found the lessons really helpful and fun in many ways … it helped me understand things.* Students contrasted the community of inquiry with the usual methods used in their science class, most notably working from textbooks, practical work and writing. This approach was different because *there was debates, discussion and the whole class was involved – it was different teaching method which I enjoyed*. Many students highlighted the novelty in working outside their usual group, with the whole class. Some felt the sessions classes were more active or *more practical and you got to give your opinion more*. Students reported that the sessions *helped us learn in a different way*, and valued thinking: *I learned more by listening and thinking* and *I would think that if we did more discussions in class we would be learning a lot more.*

(ii) Learning about science. Students reported that this third space for learning involved *more fun and controversial subjects* and allowed them to *explore a topic in more depth than they would in science.'* They also appreciated the chance to create their own argument, an important aspect of doing science: *I think [discussion] was a good method of learning because it taught us how to come up with an idea, justify it with evidence and respond to what others thought about our ideas.* Students reported learning elements of how science works, such as how to test scientific ideas, that there is not always one answer, that scientists don't know the answer to everything, and that science is based on evidence, for example, *the key to science is experiment and observation*. Authenticity was important, with students most positive about sessions which were about *something of the present and most likely the future*. The link to science as a messy and human endeavour was important, with students reporting that *I liked talking about real life issues* and *we have a right to know about* [DNA databases]. Teacher responses also indicated that the approach helped students to appreciate real science:

It is useful…because they can start to identify the difference between what they believe and what is a theory and it gives you … opportunities as a teacher to discuss that with them, because who does off the top of their head really know the answers, where do you find the proof for things, it leaves them a lot to think about so I think in that sense they are learning about life…it is not going to help them a lot in an exam maybe but again it gets them thinking about the things that matter. Teacher, non-selective, non-integrated school.

Evaluation is a key part of how science works, and that was definitely a big part of what they were doing afterwards, and the thinking of questions too, that deeper level of thinking is encouraged in this. Teacher, non-selective, non-integrated school.

Students sometimes expressed discomfort with uncertainty during discussion and lack of resolution at the end of lessons. They often found themselves disagreeing with their earlier position on an issue upon hearing good arguments. For some, this was unsettling.

It was really confusing because some people changed their thoughts.

This demonstrates the potential for students to learn about the nature of science through reflection and discussion. However, as one teacher observed:

They like to know the answers. They are leaving feeling more confused than they were when they came in because it is an open ended thing. They might think that's a barrier to learning but I think it is useful. Teacher, non-selective, non-integrated school.

(iii) Affective factors. Learning flows from appropriate motivational and emotional cues Falk and Dierking (2000), and this was observed in students' responses. Many commented on their emotions during the classes. These were often positive, and highlighted excitement and interest in the topics and activities. The majority of students described their best sessions as *interesting*, *fun*, *cool* or *great*. The worst classes were described as *creepy*, *disgusting*, *weird*, *yukky* or *scary.* Many students highlighted the best sessions as those that featured discussions based on novel science, authentic ideas and opinions, and those that featured a political dimension. This was also found in data from teachers:

I think it makes learning personal to them and gets into parts of their inner thinking that maybe you wouldn't reach otherwise, maybe into the ethical nature of the whole thing Teacher, non-selective, non-integrated school.

Data from students who responded negatively to the sessions was of particular interest to us. The main issue in relation to motivation and expectations was discomfort. Some students reported that *I don't like talking about that stuff* in relation to some of the bioscience topics, subjects that presented injustices, practices to which they were opposed or unlikely to participate in, or ideas with which they disagreed. In terms of the methods, some students did not feel that creating a community of inquiry was helpful:

I really didn't like this and missed out on a lot of classes we could of spent revising or studying.

These findings indicate that the sessions were offering something that was different to science lessons as usual, and which corresponded to some of the affordances of free-choice environments more usually entered outside of school. This third space has the potential to be a motivating environment for learning as it allows students to focus on issues of interest and importance to them and require students to think about science and themselves. This demands a different approach to teaching and learning. For many students, this is motivating, but some students experience difficulty in dealing with uncertainty, complexity and discomfort or wish to prioritise examination preparation.

Prior knowledge, interests and beliefs

Meaning that is made during free choice experiences is framed within and shaped by prior knowledge, interests and beliefs (Falk and Dierking, 2000). This was found to be the case in the communities of inquiry. Whilst students were engaged by new topics and familiar topics in unusual contexts (*we didn't know as much so we were interested*; *it was informative*), students did not like it when they had to struggle to understand. In one case, students wanted to discuss evolution although they had not been taught it previously. After attempting the discussion and identifying information they needed to inform their discussion, students reported that *we didn't have enough evidence to prove some of our points* and *I would like more information before we discuss the topic.* This clash between interests and prior knowledge is a challenge in free-choice learning, particularly with an external educator and limited flexibility in timetabling.

Students' prior interests were evident in the content and type of questions that they asked individually and selected as a group. For example, table 5 identifies how the focus of discussion was shaped by questions on the same stimulus. Students identified 'good' questions as open, interesting, based on real life, and where there was a diversity of responses from the class.

[Table 5 here]

This approach elicited one group's disinterest in climate change: *I don't care so much for the environment because it is thrown in my face so much*. Knowing the students' interests can help teachers to plan science that is more sensitive to their concerns. As the teacher noted:

> *Finding out the girls' opinions about learning about the environment really concerns me…I know now that I have to be really creative and plan ways to talk about this so they are interested.* Teacher, selective girls' school.

Teachers identified these questions as a particularly positive feature of the sessions:

> *I think this showed them that there was a bit more freedom if they wanted to go down a different route … if something was annoying them or questioning them, they would maybe ask instead of not asking and not knowing.* Teacher, coeducational, selective non-integrated school.

> *It has reminded me of the importance of questioning, asking questions and [letting the children] generate questions…that actually this is a really important part of [learning] …when you do take the time to do it they remember those lessons better …*

[it] makes them question more. Teacher, coeducational, selective non-integrated school.

Whilst some students preferred to discuss familiar ideas and topics they had an existing interest in, others were more interested in new and unfamiliar ideas.

I really enjoyed talking as a group and then agreeing or disagreeing with other people. My overall favourite was the talk we had about bringing back extinct animals..because I love animals and we discussed that cloning would be good to bring back extinct animals and I argued back saying that there is not enough natural resources or habitats for them...I learnt a lot of things I never knew before.

Teachers and students reported that interest generated in the sessions extended beyond the classes, for example:

Talking about these topics later with pupils showed interest extended beyond the session. Teacher, selective boys' school

Given that students have varying prior knowledge and interests, it is important to consider how the questions are created and selected to ensure that particular voices do not dominate. Strategies to achieve this included analysing the questions prior to voting, anonymous question generation and 'blind' voting, where students cannot see what their peers are selecting.

Many of the questions brought to the fore students' beliefs about issues such as abortion, human rights, nature, and implications of science for religion and vice versa. Students reported that they liked sessions that provoked diverse, authentic responses and arguments, and which related to them. Working in a community of inquiry allowed these beliefs to be shared, connected to science, and subjected to scrutiny by others. Students appreciated being able to answer honestly and reported that *it was good the way you got to question other people's opinions*. Likewise, teachers reported that:

> *Pupils have a better understanding of ethical and social issues in science.* Teacher, non-selective girls' school.

Students' prior knowledge, interests and beliefs were important in shaping students' responses to the free space for learning. New, interesting and important topics were engaging, as were those that provoked a positive emotional response. Topics considered irrelevant to them, too speculative or which provoked negative emotional responses were more divisive. Whilst some students liked controversial topics, others found these uncomfortable. Students reported finding it difficult to concentrate on the dialogue when they didn't like the topic.

Dialogue in a community of inquiry allows students to engage in discussion about scientific advances, their perils and pitfalls, without advocating a particular perspective, but rather searching for meaning, understanding different perspectives, and holding all knowledge and beliefs up for question. It is through engaging with situations that require choices to be made between better and worse alternatives to be made that rich understandings of either science and ethics develop (Rogers et al., 2007). Like studies in informal contexts, this study demonstrates that choice and control and attention to students' knowledge, interests and beliefs have specific affordances in school-based free choice contexts. Working in a community of inquiry gave students a context in which they had choice and control over expression of their prior knowledge, interests and beliefs. Depending on the topic or question chosen, it had the potential to motivate students to learn science. However, it is not an appropriate approach where the teacher requires students to meet predetermined learning outcomes, and it is important to ensure that students have sufficient knowledge about the topic they are discussing.

The sociocultural context

The dialogic approach of the community of inquiry assumes that learning takes place through facilitated peer talk. We first discuss students' responses to facilitated mediation by others, followed by within-group sociocultural interaction.

Facilitated mediation by others

The role of the facilitator (the university science educator) was to introduce the topic, link to curriculum concepts and then to support students to create and select questions, and create, analyse and critique arguments in response. For each class, the initial focus was on encouraging students to contribute to the discussion (quantity of contributions), moving towards a focus on argument (quality of contributions), and the topic, question and group dynamics shaped the facilitation. Teachers had differing views on student contributions. Two teachers noted that some quieter pupils were still reluctant to respond in whole class discussions at the end of the series:

Some of the quieter pupils have not developed enough confidence to join the discussion. Teacher, Selective boys' school

However, several teachers, and students, highlighted the engagement of more reticent students as a strength of the approach, commenting that there was increased contribution and engagement from some whose contribution might be limited, for example *I think that the classes achieved people's ability to speak out if they were very shy and share their ideas with different people* and:

The best part was watching some pupils who rarely state opinions ask questions, come out and take part. Teacher, Selective boys' school.

Students took a broader view of 'contribution' identifying listening and thinking as contributions, as well as suggesting questions, voting, and participating in small group discussion. It is important to value these less visible contributions. In secondary science classes, it is unrealistic for all students to contribute to every discussion, and a balance must be struck between encouraging students and developing confidence to contribute over time, with practice. As one student noted, they didn't know what the sessions were going to be like and some were shy at first: *I wasn't used to it at first and gradually found it more fun.* Teachers reported that they would have preferred reduced class size, but classes were not split because this is unlikely to be possible under usual teaching conditions.

Students responded positively to dialogue that allowed deep discussions, exploration of arguments, and contributions from most of the class. Students liked being made to think – to give reasons for their views and to think about why they agreed or disagreed with others.

Students didn't like discussion dominated by a few individuals or where contributions were repetitive. When asked who had said the most important thing in classes, students often cited people who '*went against my statement'* or those who had asked a question. As one student reported:

> *They were fun but you also learnt a lot in them…there was quite a lot of arguments but this helped me to decide which side I was on.*

Disagreement was important to many. A supportive environment for disagreement was created by establishing ground rules and by asking each class to identify targets as a result of reflection on their inquiry each session. As such, '*everyone argued but we were friendly at the same time'*.

The class-facilitator relationship presented some challenges. It took time to develop a relationship, and the facilitator did not always know what knowledge each particular group of children had at the beginning of the classes:

> *Some of the subject matter was too advanced ... this improved as … the ability of the class was gauged.* Teacher, non-selective, non-integrated mixed school.

Introducing philosophical dialogue through a community of inquiry has the potential to promote learning because it allows the class to share knowledge and experiences and to link science with their lives. The majority of students continued their discussion beyond class and appreciated that they were able to find out more about science, and also each other through discussion.

Within-group sociocultural mediation

The interactions between students were important in learning through a community of inquiry. One student observed how the group worked together to help answer a question:

> *Some of the questions were hard but were easy to work out as each person's answer was helpful to work on from to make your answer. We found out lots of things we did not know about before ... It boosted people's confidence by letting them talk.*

Likewise, a number of students appreciated being able to work with their friends:

> *I think the classes are a very good way to learn and a good way to really think about what you're learning and you have fun with your friends while talking about your subject.*

Other students contrasted this with their usual science lessons and highlighted the value in being made to think by their peers, either by *working together and having arguments* or by being made to think about a question that they had never previously considered, and which led on to more questions, for example:

> *We also learned a lot more because we weren't just writing it down we were openly discussing it with the rest of the class ... I think this was a good method of learning because it taught us how to come up with an idea, justify it with evidence and respond to what others thought about our ideas I think this skill would be useful in life because*

when we're older we might have to go to a meeting in our job and we might have to do something similar about something else.

Some students found it difficult to manage increased control over, and responsibility for, their learning. Skills such as listening, questioning, self-regulation and developing confidence to cope with disagreement and challenge insensitivity take time and support to develop, but teachers noted that:

The sessions encourage some pupils, particularly the quieter boys, to express opinions and discuss issues constructively. By the last session pupils of various abilities were able to discuss intelligently in small groups with little or no adult participation. Teacher non-integrated, non-selective coeducational school.

Silence was identified as an uncomfortable characteristic of the dialogue, but it serves an important purpose, giving students time to think. Many teachers noted that listening was something that had improved over the series of sessions.

The class as a whole seems to have evolved into a 'team' – more supportive. Teacher, selective girls' school.

Some teachers observed more widespread improved listening skills and confidence amongst their classes, noting that:

Pupils have gained confidence and more likely to offer own opinions. They are more open and can listen much better to each other. The quieter pupils are more willing to *volunteer views and the less able two or three are speaking out more – gained confidence.* Teacher, selective co-educational school

I feel they are more willing to listen to other pupils' opinions. A number of pupils are more confident in their own thoughts, that they will be valued. Teacher, non-integrated, non-selective coeducational school.

Over time, students and teachers noted how the group changed to work more collaboratively and independently:

By the last session pupils of various abiltiies were able to discuss intelligently in small groups with little or no adult participation. Throughout the sessions, pupils seemed comfortable, focused and well behaved. Teacher, coeducational non-integrated, non-selective school

The community of inquiry approach values interactions between students, and puts their ideas central. Taking increased ownership of the dialogue requires time and experience, and foundational capabilities such as listening, turn-taking, questioning and responding to others. It is important that the facilitator pays attention to these interpersonal capabilities as well as to the academic content and process.

Discussion and Conclusions

This study set out to describe a way in which universities and schools could work together to realise a third space for science education (Stocklmayer *et al*., 2010). The study has contributed a working model of a third space for informal and formal educators to work in a complementary way. The model requires few resources, and allows formal and informal educators to work together to incorporate the affordances each sector, i.e. valuing contemporary contexts for science, student choice, interest and enjoyment whilst paying attention to curriculum content, timetabling and other barriers to schools' engagement with the informal sector. With the rise of the impact agenda for universities, this suggests a way in which university scientists might engage a wider public with their work, in a more sustained way that promotes dialogue in relation to the interests of students over 'top down' dissemination of research. This approach is consistent with calls for more open and honest discussion about the benefits, limits, perils and pitfalls of scientific advances (Leshner, 2003) and for attention to students' experiences and interests in the construction of curricula, teaching materials and classroom activities (Schreiner & Sjoberg, 2007). This model promotes greater synergy between the formal and informal sectors, providing for choice, entertainment, interest and enjoyment. It values real contexts and multiple perspectives, and takes place in a context that facilitates social interaction.

The model for collaborative working rested on the use of an appropriate pedagogical approach, the community of inquiry.

The study also contributes understanding of a how the community of inquiry approach can create free choice spaces in a school context. This contrasts with more transmissive approaches to science education and science outreach, which emerge from a deficit model, in which the young people, or the public more generally, are perceived to be inadequately informed about, and disinterested in science (Varner, 2014). This is important because many science outreach project rely on the participation of schools. The research question we asked was how can students' experiences of learning through a community of inquiry in school science be understood in terms of the contextual model of learning? This study contributes understanding of a pedagogical model for incorporating scaffolded free-choice into science lessons. Our findings, based on participant observation and students' and teachers' perceptions, suggest that the majority of students find this approach interesting, enjoyable, and that this extends beyond the classroom sessions. Analysis using the CML (Falk & Dierking, 2000) suggests that the community of inquiry is different to school science because it gives students greater choice and control over what is learnt and how they contribute; it allows students to act in accordance with their knowledge, interests and beliefs; and it values facilitated interactions with peers. This creates an environment in which students can build social bonds, share knowledge and experiences, co-construct and critique claims, and make meaning of science and of philosophical (e.g. ethical, epistemological) issues, drawing in knowledge and experience from beyond the classroom. To optimise the quality of discussion, students must have prior knowledge about the topic. Where external educators are facilitating sessions, they need to consider how they will deal with situations where students do not have enough prior knowledge to participate in a meaningful discussion. The approach does not lend itself well to learning predetermined content for reproduction in examination situations, so educators considering introducing free choice learning situations need to distinguish such situations from 'business as usual' and time these carefully to avoid conflict with examination periods. In the context where it was introduced, the curriculum was such that the overall aim of the curriculum: "*to empower young people to achieve their potential and to make informed and reasonable decisions throughout their lives*" (CCEA, 2007) was intended to drive learning rather than individual subjects, with a move away from detailed programmes of study towards minimum requirements and increased emphasis on the infusion of "thinking skills and personal capabilities" (CCEA, 2007) A community of inquiry approach might be more challenging to introduce in more content-heavy curriculum contexts, where teachers are under greater pressure to teach specific content so that students meet predetermined learning outcomes, and have less capacity to explore ideas and questions of interest to young people within scheduled science lessons.

Our findings suggest several implications for practitioners. We suggest that the community of inquiry pedagogical model is an appropriate way in which both university scientists and teachers can engage young people with science. It was an approach that teachers could – and did – incorporate into their own teaching following the ecologically valid modeling of the approach, suggesting that working with university educators has the potential to widen their pedagogical repertoire. Although we did not systematically follow up with all participating teachers following their participation, those we worked with on an extended basis, e.g. by contributing to dissemination workshops, reported using the community of inquiry in an extended range of contexts and in a diagnostic way, for example at the start of a topic (to find out what ideas students had, and what they were curious about) and at the end of a topic (to identify and explore remaining misconceptions), often for different topics such as light, space and environmental science. Further research might involve investigating how teachers create classroom communities of inquiry, and the extent to which student choice and control can be maintained under school conditions. Encouraging participation of all students can be challenging, and an extended period of time and demonstrable support is needed so that students understand the different approach and feel comfortable and supported to contribute orally. Teachers (and students) need time to practice working in an unfamiliar way, and to adapt to a different locus of responsibility. This can be challenging, and students may test the extent to which their choice is free through their selection of questions, but to take responsibility, they must first be given responsibility. Continuing professional development (CPD) could support teachers to facilitate inquiry, but this should be sensitive to existing research evidence which suggests that the method should be modelled in practice, with opportunities to try in school and evaluate successes and failures (Gilbert, 2010).

Students see the community of inquiry approach as active in that it makes them think. Many students reported learning through the community of inquiry sessions, but this learning was not investigated directly because of the range of possible learning outcomes resulting from students' questions, and to determine the specific content to be learnt in advance would corrupt the element of free choice that is inherent in the approach. The contextual model of learning provided a useful framework for understanding students' experiences of working in a community of inquiry. The next step will be to analyse the range of learning outcomes that students valued, and the characteristics of classroom interactions in a community of inquiry to find out *how* talk supports learning. Given the range of possible science learning outcomes, future research on learning through a community of inquiry could benefit from a focus on how children develop oral argumentation practices. Existing progression frameworks (e.g. Osborne et al., 2016) have potential to be fruitful here.

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Support required	**Requirements**	**In a community of inquiry**
Autonomy	Options relevant to students' interests and goals	Young people create questions. Although these are related to the theme, students have autonomy to create questions relevant to their interests and goals.
Competence	Options must not be too numerous, complex or easy	Question options are narrowed in small groups before the whole class decides. The group decides on the complexity of the question (this can be misjudged). Procedural questions are used to help students negotiate options.
Relatedness	Options must be congruent with the values of students' families and cultures	Students have freedom to create questions and contribute in ways consistent with their own values. Valuing sensitive disagreement during discussion encourages airing of alternative perspectives. Anonymous contributions, small group and silent discussions also provide ways for all to contribute.

Table 1: How student choice can be supported in a community of inquiry.

Theme	**Curriculum concepts**	**Sample student questions**
Cloning mammals	Cell structure Reproduction	Is it right to clone people? How are the clones inserted into the female? I'm not skinny ... would my clone be skinny? Why is it illegal to clone humans? Should cloning be used to regenerate nearly extinct animals or are they meant to die off? Is using embryos for research the same as having an abortion? Should we keep a cell bank of all animals on Earth?
Plant cloning	Selective breeding Pesticides Genetic modification	If we had a major famine would we be able to battle it better than last time? Why haven't scientists found a cure for panama disease and black sigatoka? Would the banana be the same if it was genetically engineered? Should we mess with the genes of the banana? Are bananas natural? Should we let bananas die out?

Table 2: Questions generated from the same stimulus

School type	Number of classes	Number of students	% of type
Co-educational	14	283	56
Single sex (boys)	4	98	19
Single sex (girls)	6	126	25
Integrated[1]	6	110	22
non-integrated	18	397	78
Selective	10	232	46
Non-selective	14	275	54
Total	**24**	**507**	**100**

Table 3: Participating students by school type

[1] An integrated school is a mixed religion/cultural school with approximately equal proportions of Protestants and Catholics. All integrated schools in the study were non-selective and coeducational. Selective schools require students to pass an entrance examination at age 11.

Questions about engagement and perceptions of learning	**Questions about thinking skills and personal capabilities**	**Open response questions**
Please state your response to the statements below on a scale of 1-5 where 1=strongly agree and 5=strongly disagree: • I found the sessions interesting • I found the sessions boring • I enjoyed the sessions • I now know more about science • I didn't learn anything during the sessions • The sessions helped me to understand ideas	Please state your response to the statements below on a scale of 1-5 where 1=strongly agree and 5=strongly disagree. The sessions helped me to: • Ask questions that can be explored • Think about how questions can be answered • State my ideas • Back up my ideas • Investigate ideas that were not my own • Take risks in what I say	• Did you talk about the topics after leaving the class? Yes/No. If yes, which? • Which was the best session? Why? • Which was the worst session? Why? • What was the most positive thing about the sessions? • What was the least positive thing about the sessions? • How were the sessions similar to usual science classes?

Table 4: Sample student questionnaire items

Question	Content of discussion
How are the clones inserted into the female?	Reproduction, in particular the process of fertilization and the structure of the female reproductive system.
I know I'm not skinny. Will my clone be skinny or not?	Variation, genetics and epigenetics (is weight heritable?), factors affecting personality and behaviour, healthy diets.
Is it right to mess with nature?	How to differentiate between 'natural' and 'not natural'; the impact of humans on the environment, ethics.
What impact would legalising cloning have on the evolution of the human race?	Immunity to disease, variation, natural selection as the mechanism for evolution, evidence for evolution, religious ideas.
Why would anyone want to clone?	Advantages and disadvantages of cloning, distribution of medical resources, infertility, different types of family.
Should cloning be used to regenerate nearly extinct animals?	Interdependence (food chains, predator-prey relationships), human impact on the environment, captive breeding programmes.

Table 5 Interests by question and content of discussion.