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5. A CROSS DISCIPLINARY EMBODIMENT

Exploring the Impacts of Embedding Science Communication Principles in a Collaborative Learning Space

INTRODUCTION

Many scientists engage in educational outreach as part of their wider academic roles. Such activities can fall under the umbrella of public engagement activities in which scientists are increasingly encouraged to partake, fulfilling societal and university missions to engage with young people and stimulate their interest in science. These types of activities are often encouraged and supported by academic institutions that see them as a way to encourage young people to remain interested in science and consider studying science at higher levels and depending on the initiative may also support university agendas related to widening participation in higher education amongst underrepresented socio-economic groups (HEFCE, 2010; OFA & HEFCE, 2013). Increasingly, such engagements may also be seen to support funders' impact agendas, whereby public engagement activities are seen to promote public engagement with science and increase the impact of research.

Within this context, the authors developed a schools-based competition that challenges pupils to engage with genetics and genetic technologies through the medium of film (Weitkamp & Arnold, 2013). The competition brings together pupils from nearby secondary schools for a day of genetics and communication themed learning in a local school. Teams of pupils are then challenged to make a film explaining a genetics related technology and either considering a range of social issues arising from the technology or outlining an issue that could be tackled using the technology. After two weeks of independent study and filming, the students come together for an awards event and final debate.

The project sought to reach young people at around the time when they will be making choices about subjects for further advanced study (in the UK all pupils study science subjects through Year 11 (15–16 year olds), but from Year 12 onwards they typically specialise and many will no longer study science). In developing the project, the authors worked closely with teachers from the school hosting the project, seeking their input to develop a project that would both stimulate and engage pupils with contemporary issues in genetics and support (but not overlap) existing curriculum areas.

The authors first explain what the collaboration between science educators and science communicators entails. Then they describe the implications of their study that has a close fit with the preceding chapters on engagement, followed by the

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description of a workshop they have conducted with pupils on the topic of genetic engineering. By doing so, this chapter provides a bridge between engagement as a theoretical construct and as a practical tangible concept. It discusses the theoretical, professional and practical implications.

WORKING TOGETHER

By working together, science educators, scientists and science communicators can develop innovative and effective tools that contribute to pupils' science learning. The inclusion of a science communication perspective in this triad enabled the science discussed to be placed in a wider social context as argued by Stocklemayer et al. (2010), something which the scientist, herself, felt less comfortable delivering. As someone outside both the science and teaching professions, the science communicator was able to step outside both disciplinary conventions drawing on both thinking related to everyday creativity (Gauntlett, 2010) and public engagement to design a learning experience that involved the participants in *making* a film as a means of exploring and expressing views. This role could be provided by a teacher coming from a socio-scientific issues perspective, though it is unclear how easily they would be able to facilitate the scientific input in such an environment as this required regular discussion between the scientist and science communicator, who then also acted as the link with the busy teacher. Furthermore, as a University outreach project, we were able to mobilise physical resources available within the scientist's department that were not available within the school (the gel electrophoresis equipment) as well as volunteering the time and energy to create and deliver a workshop that involved pupils from several different schools, something the teachers clearly valued as they were keen that the pupils should be encouraged to work across schools where possible in the workshop activities. Thus, the combination of skills within the team ensured that pupils not only explored the scientific aspects of genetic engineering but also were encouraged to consider the wider social implications, both positive and negative. Furthermore, the project increased participants' interest in the relationship between science and society, an aspect that Bandiera and Bruno (2006) argue is key to young people's learning about science and which we postulate is essential for the development of scientific citizenship.

There appears to be a general belief that outreach (e.g. university or industry-based scientists visiting schools either to engage pupils in activities or to give talks) is worthwhile, but there is little theoretical conceptualisation about how these effects might coalesce to change knowledge, attitudes or behaviour in relation to STEM subjects. In designing the intervention used here, we drew on both public engagement and learning theories. The project was also influenced by research on the importance of ownership over the learning process (O'Neill & Calabrese Barton, 2007) and the argument that '… if students owned the science they were expected to learn, either by connecting science to their lives or helping students feel a part of the culture of science, then they would be motivated to learn science' (p. 293). We also drew on constructivist views of learning, designing an activity that would enable learners to build knowledge and understanding based on prior learning and place this science in a wider social context. Finally, the choice of group work combined with 'making' (the film), was influenced by Gauntlet's (2011) theories around happiness (enjoyment) and social capital.

STUDY'S IMPLICATIONS

As Davies (2013) suggests, the framework within which this project took place was relational, in that the project focused on highlighting the connections between science (in this case genetic engineering) and society, and also provided a collaborative learning space in the form of group created films. Although the pupils in the project had been identified by their teachers as 'gifted' in science and all showed highly positive initial attitudes toward science, they had little initial understanding of genetic engineering. As a group, they were not particularly knowledgeable about the uses of genetic engineering in society, despite many having 'heard' about genetics in school, a picture similar to that identified by Dawson and Schibeci (2003a).

Over the course of two workshops and a period of self-directed learning, participants moved from a fairly sketchy knowledge of what DNA and genetic engineering are to more complex conceptualisations, broadening their understanding of DNA to include structural elements (e.g. base pairing), concepts of DNA as holding information and defining characteristics and genetic engineering as being about change. These responses were more detailed and complex, though in the case of genetic engineering, they were often subjective (for example the term 'improvements' was commonly used in the post-event questionnaire). The picture that emerges in relation to their understanding of genetic engineering is one of change (e.g. altering characteristics, transferring information), a view also consistent with the content of the films. To an extent, this was a case of 'regurgitating' content that was provided in the first workshop, but there is also evidence of the scientific concepts being consolidated, simplified and put into their own words (e.g. the notion of transferring genes or information between organisms), indicating a degree of ownership of the content which O'Neill and Calabrese Barton (2005) highlight as important for learning. Likewise, social issues were connected together and conclusions drawn in five of the films. Giving the pupils a task, to create a film, may have provided a focus that enabled this consolidation. They couldn't just 'walk away' having listened to an interesting lecture or participated in a workshop. Instead, they had to mobilise the knowledge they gained in the workshop (possibly with the addition of further investigation of their own) to create a response (the film). This approach, of giving participants a task to complete that requires them to use new information, could be usefully applied in other science communication contexts with both young people and adults. The nature of the task we set meant that there was time for pupils to reflect on what they had learned during the process of film creation, but it is possible to design activities that can be completed within a single day or session. For example, by the end of our one day workshops several groups had created fairly detailed storyboards of the films they were going to make.

Petts (2007, p. 301) argues that 'the transformative power of effective dialogue should promote learning about different views and that these are legitimate', which is also a goal of education. Controversial issues in science, such as GM crops, offer an avenue to explore different opinions, as suggested by those advocating socio-scientific issues (SSI) teaching methods (e.g. Ratcliffe & Grace, 2003; Tal & Kedmi, 2006), and offer young people a means to develop and express their ideas and enhance their understanding of science and society. It is evident that the workshops encouraged young people to think about these issues as reflected in the increase in the number responding positively to the question 'Do you think genetic engineering raises issues for society?' (90% post event vs 63% pre event) and the changes in their interest in the ways that science can affect society. This places science in its wider social context, which Dawson and Schibeci (2003b) argue is essential if young people are to develop informed views. We believe it can help young people to explore the ways that science is relevant to them and to acknowledge that others may hold different views about technological developments; something which they are likely to encounter should they participate in deliberative or dialogic public engagement activities in the future (see for example, Dodds, 2013). In many cases participants in this project used language which acknowledges divergent views on this subject, which was particularly encouraging.

CONTEXT: WHY GENETIC ENGENEERING?

Genetics has, in many ways, permeated society. In the US there is a growing consumer genomics industry and debate continues on whether the UK should allow commercial planting of genetically modified (GM) crops. This debate about GM crops in the UK was thought to arise at least partly from the legacy of food related regulatory failures in the UK and the consequent lack of trust in science governance (Frewer et al., 2004). In 2003, the UK government held a nationwide debate (GM Nation?) about transgenic crops, a response to a perceived lack of trust in science policy making in the UK. Widely recognised as problematic (Rowe et al., 2005), the debate also fed into an ongoing media discourse about GM foods. Augoustinos, Crabb and Shepherd (2010) explored media coverage in 2004, in the immediate aftermath of the debate and highlight 'how the issue was constructed as highly problematic and divisive – a "battleground" of competing interests between the British public, the government, the scientific community and the biotechnology industry' (p. 111), a discourse that is likely to form a background to public perceptions of GM foods. A special Eurobarometer report on biotechnology highlights widespread awareness of GM crops, with 89% of UK respondents indicating awareness (Eurobarometer, 2010). The report also reveals a high level of suspicion about GM crops across Europe, with 70% of all respondents indicating that GM crops are fundamentally unnatural. In the UK, 40% of respondents answered positively to the statement 'GM foods are not good for me and my family

(39% responded negatively to the statement) and 31% responded positively to the statement ‘GM food is safe for future generations’ (39% responded negatively), though respondents were more positive about the benefits of GM crops in developing countries, with 59% indicating they believe GM crops help people in developing countries (and only 24% responding negatively).

Little work has been done in the UK on young people’s attitudes to GM crops, though insights emerge from other countries and genetic engineering is covered in the UK national curriculum. Although now over 10 years old, Australian research suggests that teenagers have limited understanding of the uses of biotechnology, frequently confusing existing and potential uses and are unable to distinguish between genetically modified foods and selective breeding (Dawson & Schibeci, 2003a). Indeed, our teacher consultants highlighted the problems they face in teaching genetic engineering concepts, which pupils mistakenly associate with other technologies, including cloning. More recently, Goldschmidt and Bogner (2013) explored young peoples’ ‘hopes and fears’ about plant genetic engineering, finding that the majority of pupils had neither hopes for nor fears about plant genetic engineering. This is, perhaps, surprising given the continuing controversy and media attention given to GM plants. Those expressing hopes tended to frame them in economic terms (for farmers or consumers) and as a potential means to fight world hunger. These are similar categories to those found by Massarani and Moreira (2005) in a study of Brazilian pupils. In Goldschmidt and Bogner’s study, fears were associated with risks to human health and general risks, such as environmental harm.

Schibeci (2000) argues that biotechnology, including genetic engineering, is an ideal topic for discussions about the relationships between science and society because it has clear social, political and ethical dimensions. Bandiera and Bruno (2006) note that in the case of genetically modified organisms (GMOs), providing scientific information alone is insufficient to enable teenagers to engage effectively with either the scientific or the socio-economic aspects of GMOs and argue for the inclusion of cooperative learning methodologies (e.g. group work, debates) and strategies that encourage learners to contextualise the scientific information in relation to wider societal issues. Elsewhere Dawson and Schibeci (2003b) argue for the inclusion of social, ethical and political issues within the teaching of biotechnology to enable young people to develop ‘an informed, defensible view rather than a view based on ignorance’ (p. 10). Goldschmidt and Bogner (2013) argue that pupils should be enabled to explore their hopes and fears when learning about genetic engineering and that they should be encouraged to ‘define and develop their individual points of view within this complex matter’ (p. 148). With this in mind, we developed the project designed to enable young people to explore both the science and social issues surrounding GM crops and included mechanisms that would enable them to present their views and opinions on the matter.

It is interesting to speculate whether you could take a project like this out of the classroom. We believe this type of project (which combines workshop activities with a task to create an artefact that expresses societal or personal views) could be delivered in an informal learning environment provided the ‘artefact’ could be delivered within a single visit. For example, storytelling techniques could be used to create digital stories (see for example The Centre for Digital Storytelling, http://www.storycenter.org/) that express personal views about a technology following participation in a workshop. This would require some technical resources and staff support to enable participants to complete the task, but could be achieved with small groups of young people or adults. Stories could (with appropriate permission) be hosted in a public digital library (similar to the stories in the Nagasaki archive; http://e.nagasaki.mapping.jp/p/nagasaki-archive.html). Projects that require longer than a single visit are likely to be challenging, unless they form an activity provided to a group that meets regularly. Whether completed in a single visit or as part of a series of meetings, a key issue to explore would be how many participants complete the full range of tasks (i.e. deliver the final artefact). In our project, we had support from teachers to ensure that films were actually delivered. Without that support, it is likely we would not have received many entries; projects lacking that compulsory element would need to consider carefully what constituted success – what percentage of participants need to complete all elements for the project to be classed as successful? What learning happens for those who take part in only some aspects? Does it matter if the story telling element is not completed?

CASE STUDY INTERVENTION: ‘GENETIC ENGINEERING FILM COMPETITION’

Two workshops were delivered in the host school during the normal school day, with a period of two weeks between the workshops. Pupils participated from the host school and three nearby secondary schools. Workshops included a mix of didactic content, activities and discussion and were designed to introduce basic concepts in genetics (such as DNA and traits) as well as discuss some of the techniques used in genetic engineering. Sessions also provided advice on film making as a form of communication, explored the social impacts and concerns raised about genetic engineering and provided pupils with an opportunity to express their views.

Workshop 1

On arrival, participants were asked to complete a pre-event questionnaire (see below) and following this were given details of the project, judging criteria and instructions. Once all participants had arrived, we welcomed participants and outlined the project. This was followed by an initial ice breaker activity that introduced participants to the concept of ‘traits’. In this activity, each team was given an envelope with sequences of four different pictorial codes, these were matched to plant characteristics (big or small leaves, different coloured flowers) (this activity was adapted from the ‘recipe for traits’ activity found at: http://teach.genetics.utah.edu/content/ [accessed 20/6/14]). Each team drew a plant with the indicated traits and these were posted on the wall for later reference. Using this as a starting point, Dawn Arnold, a professor in molecular plant pathology, introduced basic genetic concepts (e.g. what DNA is, base pairs) in an interactive discussion with pupils that included exploring existing knowledge and pupil interests. To illustrate the connection between our genes (genotype) and our outwards appearance (phenotype) a number of easily identified single gene human genetic traits were explored (e.g. tongue rolling, arm folding) and pupils asked to count how many people fell into each of the relevant categories (e.g. either you can or cannot roll your tongue, you either have your left or right arm on top when you fold your arms).[1] Ratios for each characteristic were approximated and we discussed whether the room was representative of the expected distribution of traits within the population.

Other activities carried out during the workshop were running of a DNA electrophoresis gel and discussion of how it is used to separate DNA fragments and how these techniques could be used by scientists. Base pairing was explored through a bracelet making activity (this activity was modified from one that can be found at: www.yourgenome.org [accessed 30/6/14]) and a short presentation used to introduce two ways that genetic modification can be undertaken (agrobacterium and gene guns), including showing a short film of the gene gun process. This led to a discussion of the types of traits one might want to introduce into plants and why and to a discussion of the issues GM technology has posed for society, including a look at some recent media reports (positive and negative) on the topic. Pupils suggested a number of issues GM technology raised for society and discussed the pros and cons of these technologies.

In the final session Emma Weitkamp, a science communication lecturer, introduced pupils to the use of narrative and the ways that stories are told in the media and worked with the teams to develop initial story ideas. This session involved viewing example films from different genre (e.g. news reports, promotional films, personal stories) and critiquing these. Throughout the day, two science teachers contributed to the sessions, facilitating student engagement through additional questioning or contributing their ideas, such as a YouTube film one of them particularly liked.

Throughout the day there were opportunities for pupils to ask questions and to engage in discussion with the scientist, science communicator and teachers. We also sought opportunities to check that each team understood the requirements for the film and had some ideas to develop over the following 10 days.

Film Submission and Judging

Pupils were provided with a flip cam to use for filming, but were not provided with specific instruction on film editing software (it is our experience that young people of this age are both highly creative and knowledgeable about tools available for creating short films). Pupils were asked to make films addressing one of the topics shown in the box below in their films, but were not instructed to use a specific filmmaking style or narrative genre. We also provided written material with links to suggested resources covering genetics, such as the BBC Bitesize website.

Box 1. Written information provided to pupils as part of the project

Challenge: Our challenge is for you to create a 6 minute film on **ONE** of the topics below:

- A film explaining what GM crops are and identifying a trait you would introduce to a food (e.g. salt tolerance or vitamin A for better nutrition) and why you have chosen that trait.
- A film explaining what GM crops are and exploring a social issue raised by GM crops (e.g. concerns about environmental impacts). Make sure you explore both sides of the argument.

You should make your film for young people (e.g. 14–18 year olds) who are not necessarily knowledgeable about biology. This might mean that you need to explain a little bit about genes and the traits they produce. You should also make a story that is interesting to this age group. For example, you could create a news report, a music video or a short story.

Your film must be your own work. You should **not** copy short sequences of video film and animation from other websites or YouTube. If you decide to use images (e.g. photographs) from other sources, you should acknowledge these sources either with a caption running at the bottom of the image when it is shown or as a credit at the end of the film clearly identifying the image and listing its source. If you use music in your film you should credit the composer (or band) at the end of the film (you might make a section titled 'Credits').

Films were submitted via teachers. A panel of judges comprising a University Science Technician, a Lecturer in Genetics, a Science Communication Lecturer and a Science Writer was convened (neither author was part of this panel). The Judging Panel was given the same criteria for judging as provided to the pupils and were asked to identify first, second and reserve films (three were chosen in case one film also received the award from the participants, see below).

Workshop 2

Workshop 2 took the form of a film festival, with pupils asked to vote for the most creative film. Films were introduced by the compere, shown and then a short recap provided. After all films had been shown, our compere provided a further short recap before voting commenced.

In the second part of the workshop, pupils were split into four teams for a debate about the social impacts of GM crops. Debate topics were: a) The UK Government should promote GM crops to meet our nutritional needs and b) The government of Kenya should promote GM crops to meet the nutritional needs of the Kenyan population.[2] With a group for and a group against for each topic. Following preparation time, each side put forward their arguments and at the end of the two debates we had a general class wide discussion about the issues raised. Pupils then completed the post-event questionnaires before the awarding of the prizes for Best, Runner Up and Most Creative (student prize) Film.

Pupil learning

Within the museums context, informal learning is often framed in terms of generic learning outcomes (GLOs), a framework divided into five categories: knowledge and understanding; skills; attitudes and values; enjoyment, inspiration and creativity; and activity, behaviour and progression (Hooper-Greenhill, 2007). Within the science filmmaking project, we anticipated changes might occur primarily in the categories of knowledge and understanding; attitudes and values; and enjoyment, inspiration and creativity and we therefore conceptualised the likely impacts of the project along the following dimensions:

– Knowledge and understanding – changes in factual knowledge about genetics and genetic engineering; more sophisticated understanding of the relationships between science and society.
– Attitudes and values – greater awareness of a range of views of genetic engineering and genetically modified plants (in particular), change in interest in the relationships between science and society.
– Enjoyment, inspiration and creativity – extent to which feelings of enjoyment, engagement and enthusiasm are reported by participants, enabling creative exploration and presentation of both the science and society issues related to genetically modified crops, sense of self-worth and self-esteem arising from participation in the project.

We explored these potential impacts using a pre and post questionnaire and through content analysis of the films produced. Although there is clearly a need and interest in exploring the longer term impacts of such science outreach projects, the nature of the data collection period means that we are only able to measure short term impacts of the workshop.

Participants' Background Knowledge and Interest

The pre-event questionnaire was used to learn more about the background knowledge and interests of the participants. As pupils had been selected by teachers as high achievers in science, we anticipated that most would indicate a strong initial interest in science as seen in Table 1. Given that this project was about film making, we also asked pupils whether they enjoyed watching science related films (72%, n=18, strongly agree/agree) and read about science in books (52%, n=13, strongly agree/agree). Participants were also asked to indicate whether they had heard about genetics either in school, from reading books or watching documentaries. Results indicate that 82% (n=22) of participants had heard about genetics in school, 50% (n = 13) indicated that they had watched a documentary or TV programme about genetics or DNA and just over 30% (n=9) indicated that they had read about genetics or DNA. Furthermore, 69% (n=20) of pupils reported having made a video or film as part of their schoolwork.

Table 1. Participant interest in science

	Mean (5 point Likert scale, where 1 is strongly agree)	Sd	N
I am interested in the ways science can affect society	2.28	0.980	25
I don't find science interesting	4.00	0.816	25
I like watching programmes and films about science	2.22	0.934	27
I read about science outside of school	2.78	1.368	27
I think science has a big impact on how we live	1.35	0.562	25

To understand more about participants' existing knowledge and beliefs about genetic engineering we asked them to indicate how they think the technology is currently used (Figure 1). It is perhaps not surprising that 100% indicate that the technology is used to protect crops from pests, given that their teachers knew that the workshop would be exploring genetic engineering in agriculture and would likely have informed the participants of this. It is also, perhaps, not surprising that nearly 80% (n = 21) confuse cloning with genetic engineering, given that the teachers we worked with to develop the workshop mentioned that they had difficulty getting pupils to understand the difference between these technologies and this was given by teachers as a reason why we should focus on genetic engineering in the workshops. The approximately 50/50 split in the other answers indicates limited awareness of the uses of genetic engineering in society.

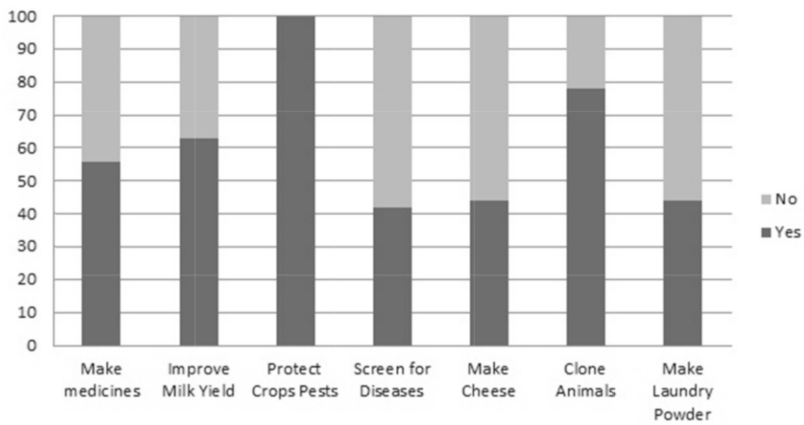

Figure 1. How do you think genetic engineering is used?

Participants were asked to rank (from most important to least important) a series of plant-related issues. These were chosen because they form part of the discussion in the workshops and are all areas amenable to genetic engineering though this was not stated in the question. There are few patterns evident from the data; nevertheless, the majority of participants identified growing enough food to feed all the people in the world as the most important issue, with an average rank of 1.92, suggesting some awareness of population pressures and their potential implications for food security. The next most important issue was "developing crops that can grow in difficult climates" (average rank 3.41), whereas "finding ways to stop pests damaging crops" was perceived to be least important (average rank 4.85). This suggests that while the participants identify food security as a primary driver for the development of genetic engineering of crop plants, they do not know how this could be achieved (as finding ways to stop pests damaging crops is one of the most important issues currently being addressed through genetic engineering of plants).

Thus, our participants had some familiarity with the term genetics, primarily gained in a school environment. It was clear that teachers had provided them with some information about the topic for the workshop events (as judged by the fact that they all identified controlling pests as a reason that plants might be genetically engineered), though their broader awareness of the uses of genetic engineering in society was quite limited. The group also had some awareness of the impact of population pressures on food resources and broadly felt that this would be a reason to use genetic engineering, though they were clearly unaware of the ways that genetic engineering might be used to tackle this issue. Against this backdrop, what affects did the outreach activity have? This is discussed in relation to the following categories: knowledge and understanding, attitudes and values, enjoyment, inspiration and creativity.

Changes in Knowledge and Understanding

We explored changes in knowledge about DNA and genetic engineering by asking participants to 'briefly describe what DNA is' and to 'briefly describe what genetic engineering is'. While pre-event responses indicate some background knowledge of and familiarity with the term DNA, they were typically brief. A number of responses indicated a basic understanding of the biology of DNA, such as, "DNA is the information that makes up who we are and describes everything, e.g. eye colour. We get our DNA from our parents" (I090599). While others showed limited knowledge, "DNA are particle type things that build up to make yourself" (R020599).

Responses to the post-event questionnaire show that participants connected concepts and information that was presented in the workshops. For example, codes for DNA as holding information (particularly information, data, codes and genes and genetic information) are consistent with the workshop activities, as both the initial warm up activity linking traits to characteristics, information presented through discussion and the bracelet making activity either directly or indirectly suggest DNA holds information. Codes for characteristics and 'who we are' linked to activities, such as the activity designed to identify single gene traits in the population (tongue rolling) would support this type of understanding. While responses remained short, there was evidence of an increase in sophistication, for example:

> DNA is a molecule that codes for your genes. (pre-event response C010198)
>
> DNA codes for everything that makes you, you. Its [sic] made of base pairs AT CG. (post-event response C010198)

Pupils were less familiar with the term genetic engineering at the start of the workshop. Furthermore, 7 (26%) replied 'No' to the question 'Have you heard of genetic engineering'. All (29) participants provided an answer to the question 'Please briefly describe what genetic engineering is' on the final questionnaire, though these ranged from 'altering a genome to fit a certain need' (I220299) to 'Genetic engineering is when one organisms [sic] features are added to another organism to help an issue, such as droughts and floods or nutritional benefit' (D270799). Table 2 shows the distribution of responses across categories and themes.

Table 2. Coded responses to the question: 'Please briefly describe what genetic engineering is'

Broad theme	Sub-category	Pre-event response (%)	Post-event response (%)
Subjective characteristics	Unnatural	4	0
	Improvements	26	41
Altering organisms	Change DNA	30	21
	Add or remove genes	19	21
	Change characteristics	15	55
	Inheritance	0	3
	Transfer between organisms	0	21
Inaccurate	Using cells	4	0
	Selective breeding	4	3

Note: Percentages reflect the number of times a theme appeared across all respondents. The totals are more than 100% as answers were coded to more than one theme.

The majority of responses to both the pre- and post-event questions reflect either subjective statements, such as making improvements to a crop, or statements that link genetic engineering with change, such as changing the characteristics of an organism. Selective breeding was coded as inaccurate in this context because, although many scientists make an analogy between genetic engineering and selective breeding, they are technically not the same thing. Both in the first workshop, when participants were introduced to genetic engineering, and in the second workshop through the film viewing and debate topics, there was some discussion of what is involved (the technique), why it might be used and the issues it might raise for society. These discussions focused around changes that might be introduced to plants (e.g. nutritional benefits, pest control) and it appears that participants connected this discussion to an idea of genetic engineering as being about changing the characteristics of an organism.

Content analysis of the films also provides insight into changes in pupils' knowledge and understanding. In terms of scientific content, two films included very limited (and in one case inaccurate) scientific content. The remaining four films ranged from a basic outline of what genetic engineering could do (i.e. it is used to modify the traits in plants) to two films that explored in some detail what is involved in genetic engineering and mention of two techniques (gene gun and bacterial transfer) that are used in genetic engineering (both of which were discussed in workshop 1). Three of the four films that included scientific content presented it largely accurately making distinctions for example between selective breeding and genetic engineering and explaining what DNA is and how it is packaged in a cell. Within four of the films, there were examples of scientific content being simplified and put into participants' own words. For example the excerpt below which shows students taking a concept discussed (the process of genetic engineering, for example using agrobacterium) in the workshop, simplifying it and relating it to other knowledge (scientific method, which was not a focus for the workshop) and drawing conclusions (that you can manipulate genetic material, which was the focus of the workshop):

> Genetic engineering is the development and application of scientific methods that help people manipulate genetic material. (Film 3)

In one case, participants used a visual metaphor, a Rubics cube, to help them explain the large number of genes in a plant and how this might result in many different potential combinations. In the example below, the visuals accompanying this dialogue are of someone manipulating the faces of a Rubics cube to 'complete' the puzzle:

> In many ways, this Rubics cube represents the DNA of a plant and how it can be genetically engineered. Each face represents different variations of traits and millions of combinations on top of the Rubics cubes' trillions of combinations, where each has a different overall outcome. There is only one combination where all the colours align and create the perfect crop. (Film 1)

Attitudes and values

We did not set out to promote a particular view of genetic engineering, but to provide an opportunity for participants to learn about the technique and explore a range of societal views of this technology. Therefore, in the context of our study, we explore whether pupils were able to express a range of societal attitudes toward genetic engineering in their films and whether the workshop stimulated their interest in the relationship between science and society. Furthermore, in analyzing both participants' responses and the films content we found few examples of personal views. Instead, participants present a range of societal attitudes toward genetic engineering, e.g. 'some people think'. It should be noted that we did not explicitly ask them to provide personal views, and it may be that the nature of the project (which involved group work) discouraged this type of presentation. Either way, we are not able to identify changes in individual's attitudes to genetic engineering.

Participants were asked whether they thought that genetic engineering raised issues for society both in the pre-event and post-event questionnaires, with 60% (n = 17) indicating that genetic engineering raises issues for society before the workshops and 90% (n = 26) after the workshops. Responses uncovered a wide range of areas where genetic engineering might raise issues for society, though these changed as a result of participation in the workshop. Pre-event responses centred on morality and unnaturalness, unintended consequences, uncertainty about change and the potential of the technology being applied to humans. There was also a group of responses about social institutions (influence of the media, relationship with low income countries and consumer perceptions), for example:

> I think the media play a large part in it because of films and propaganda, etc. demonstrating how things could go wrong, but also many people disagree with genetic engineering. (D070699)

Post-event responses strongly reflected the issues raised in the films (see below) and the final debate (positive and negative economic outcomes, moral issues, environmental risks and benefits). This may reflect the fact that the film viewing and final debate occurred immediately before the questionnaire was completed, so these arguments were fresh in participants' minds. Equally, the films between them covered quite a wide range of societal issues, and reflect not only what was discussed in the first workshop, but also the further work the young people undertook when making their films. For example the comment below reflects points in the films about religious issues, as well as ethical issues related to transferring the technology to a human context which was not the focus of any of the classroom discussions, although it was implicit in one of the films.

> There are ethical issues. People think if you change plants whats [sic] to stop people from changing babys [sic]. Also people think you are playing god. People don't know the dangers of this. (D19199)

Not surprisingly, the presentation of social issues in the films was varied; only one film did not discuss social issues at all. The remaining five films all raised issues across the following themes: Religious/moral issues (playing God, unnatural, people being unaware they were eating GM products); risk (e.g. to human health, potential environmental harm, potential to disadvantage developing countries); economic issues (profit for farmers but also multinationals); providing solutions to human problems (e.g. food security and world hunger); opinions and debate (that this is a topic for debate). The themes explored in the films were covered in the workshops, though in three cases the participants had explored these in greater depth in the films than was presented or discussed in the initial workshop and all five films showed evidence of consolidating these concepts and in some cases connecting them together.

Pre/post questionnaire analysis reveals that there was a significant increase in participants' interest in the ways that science can affect society (pre-event mean 2.28; post-event mean 1.92, p< 0.002), even though they reported a strong interest in this area before the workshops (Figure 2). There was also a significant increase in pupils' interest in science following the workshops (a more strongly negative response to the statement 'I don't find science interesting'; pre-event mean: 4.00; post-event mean 4.16, p<0.01).

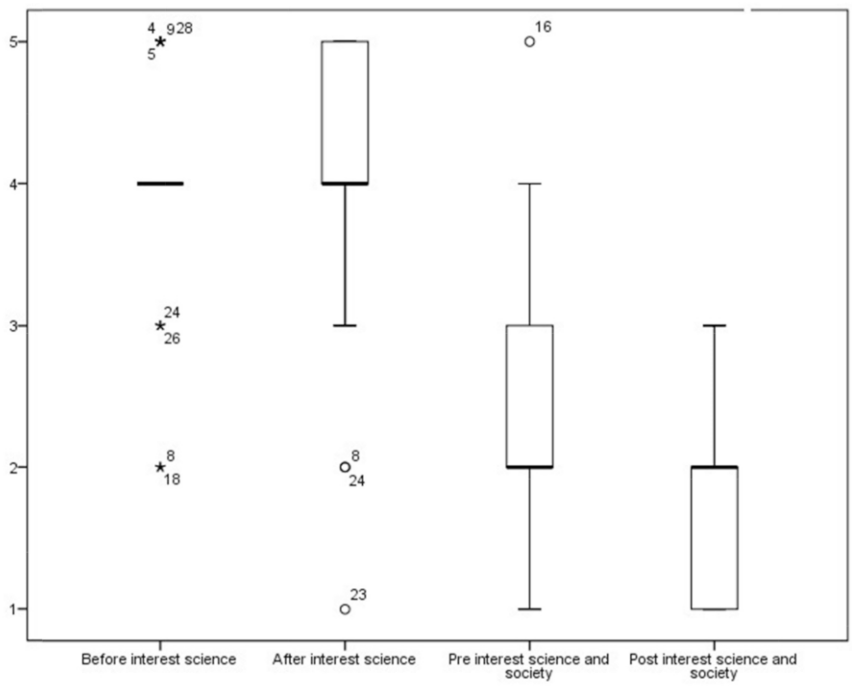

Figure 2. Pre- and post-questionnaire responses to 'I find science boring' and 'I am interested in the ways that science can affect society'. Responses on a 5 point Likert scale from 1 strongly agree to 5 strongly disagree. Note: case 23 does not have a matching pre-questionnaire

Given that workshop participants were asked to produce a short film about genetic engineering, we were interested to explore how they felt this had influenced them. Over 70% reported that making the film had encouraged them to think about how genetic engineering could be used for the benefit of society (Figure 3); When asked whether "making the film had made me more concerned about the effects of genetically engineered plants on the environment or society", 38% (n=11) agreed or strongly agreed, 38% (n=11) indicated it had not influenced their views and 24% (n=7) disagreed or strongly disagreed with the statement.

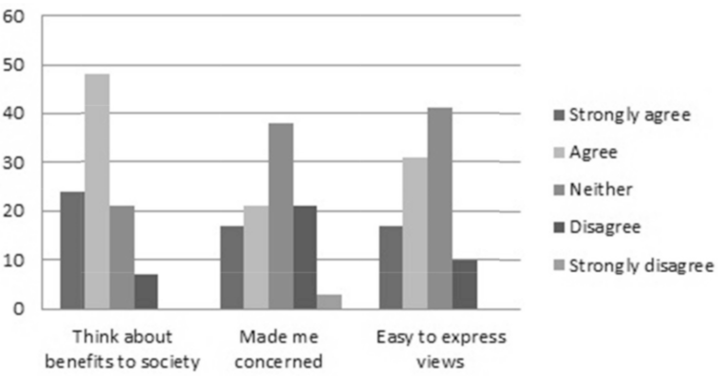

Figure 3. Impacts of film making on participants

Enjoyment, Inspiration and Creativity

Nearly all participants indicated that they would like to participate in this type of project again (mean 1.9; no pupils disagreed/strongly disagreed) and that they had enjoyed making the film (mean 1.79); 55% indicated they were more interested in science as a result of the project and all the films showed elements of creativity in the presentation of ideas. Laurson et al. (2007) and Saab (2010) highlight that involving scientists in the classroom can increase interest and engagement with science. In this project, a practicing scientist delivered the science content but also contributed to the debates about the issues that genetic engineering raises for society, giving her views and justifications, but acknowledging divergent opinions. The responses from participants about their increased interest in science and the more accurate responses to open questions about genetic engineering in particular highlight the benefit of this input. This research suggests that inclusion of a science communication perspective has a similar effect, with participants showing a greater interest in the relationship between science and society and increased awareness of the impacts of science on society.

NOTES

1 In future iterations, we suggest pupils be given a trait and asked to collect evidence from other classes, which they could then present back to the group with a discussion of why this might be. This requires additional planning with the host school.

2 In future, we suggest that debate topics are co-created with the participants.

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