Using YouTube video-stimulated discussion to train more socially-conscious physicists

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Introduction

Working as a physicist today involves significant social and professional challenges. Despite extensive efforts, female participation and recognition in physics, particularly at the highest levels, is still appalling low (Murphy and Whitelegg 2006; Brewe and Sawtelle 2016); for example, there have only ever been two female Nobel laureates in this discipline. Evidence of low public trust in scientists and expert opinion abound (Hmielowski *et al*, 2014; Leiserowitz *et al*, 2013) and there is a significant disconnect between 'scientific discourse and public debate' (Scheufele, 2013). Since institutional, national and international trends and politics dictate funding priorities, scientists need a strong understanding of the social context of research in order to ensure funding – almost all modern grant applications require justification of the research in terms, say, of its impact on society or its national importance. And this is only the start: Retzbach and Maier (2015) discuss how scientists' use of uncertainties creates difficulties when they communicate to the public via the media; Spier (2002) discusses the history and problems of the peer-review process; Hirsch (2005) introduces the ubiquitous H-index. It is imperative that a physicist knows about all these issues (and many more), yet they are very rarely addressed in formal physics education programmes. Students are instead left to find out about social and professional challenges mostly through personal experience and/or interaction with more experienced researchers; we are thus missing a huge opportunity to maximise the preparedness of graduating physicists for their forthcoming careers.

When tasked with incorporating training for such issues and producing more 'socially-conscious' physicists, course developers are often understandably perplexed as to how this can be done within a factually-orientated course already burdened with an ever-increasing set of lectures, labs, problem-solving workshops/tutorials and exams. Nevertheless, a learning environment must be constructed to encourage students to engage deeply with the social and professional challenges they will face as working scientists.

While teaching a voluntary extra-curricular course, we unexpectedly found a promising format: put on a YouTube video to introduce a relevant social and/or professional challenge, add a facilitator and six to twelve students and let them talk for one to two hours. Our first discussion was an exceptionally lively and useful debate about gender representation in physics; subsequent classes with the same format have considered, among other topics, the role of experts, trust in science and the career of a scientist.

Here, as a contribution to the goal of educating more socially- and professionally-aware physicists (and scientists), we explore this format and make recommendations for integrating discussion-based classes into a science curriculum.

2 Background

2.1 Science and Society

Science discipline teaching has evolved over time to incorporate elements beyond the scientific principles. In particular, it is now relatively common to incorporate some discussion of the history, philosophy, social and even ethical context of scientific topics, particularly at high-school level, where this has been shown to help promote scientific literacy (Kahn and Zeidler, 2016) and interest in science (Sadler, 2009); at university, however, science students are not usually trained to engage deeply with this context. We argue that this engagement is key to empowering students to face the social and professional challenges they are likely to encounter as working physicists.

There is a substantial domain of study which does consider engagement with the 'social dilemmas with conceptual or technological links to science' (Sadler, 2004): socio-scientific issues (SSI). We can thus look to this field for inspiration to help understand and increase the success of our discussion-group format.

The study of SSI involves engaging in substantive discourse, open inquiry and evidence-based reasoning (Zeidler 2016). Instruction in SSI can promote 'character and values for global citizens' (Lee *et al*, 2013), 'help students develop their understanding of how society and science are mutually dependent' (Simonneaux, 2007) and teach students 'the ability to identify bias and reflect critically' (Oulton *et al*, 2004). Berkowitz and Bier (2007) describe how students also develop increased socio-moral reasoning competencies (e.g. perspective-taking, moral reasoning), increased moral emotional competencies (e.g. empathy, sympathy), a prosocial self-system (e.g. moral identity, conscience) and increased relevant behavioural competencies (e.g. ability to disagree respectfully, conflict-resolution skills). Studies also report improved communication skills (Chung *et al*, 2016).

An integral part of SSI instruction is 'perspective-taking', defined by Kahn and Zeidler (2016) as 'one's ability to recognise and consider the diverse cognitive and emotional viewpoints of others'. To some extent, perspective-taking can be facilitated by drawing out contrasting viewpoints from diverse groups within the class. However, in practice, there is usually some degree of homogeneity within a classroom and so alternative points of view may need to be elicited by the introduction of media. For example, Kahn and Zeidler (2016) discuss how literature was used, describing the effectiveness of the controversial example described in 'My Sister's Keeper' (Picoult, 2004) of deliberate genetic engineering of offspring to provide a suitable bone marrow donor. YouTube videos can play this role in our classes.

2.2 Constructivist and Social Constructivist Theories of Learning

Group discussion is a classroom method informed strongly by constructivist and social-constructivist theories of learning. A constructivist perspective emphasises the student 'not [as] a passive receiver but ... an active constructor of knowledge' (Duit, 2016). The social-constructivist perspective highlights the influence of the social processes on this creation of knowledge (Palincsar, 1998). Argumentation facilitates this social creation of knowledge through deep engagement with ideas, resulting in deep learning (Jonassen and Kim, 2010); it is seen as a skill that can be learnt and improved, one that incorporates such techniques as rhetorical, persuasive expression of an idea and dialectical engagement, in which people attempt to resolve differences in opinion.

In practice, constructivist and social-constructivist models of learning have powerfully transformed university pedagogy from traditional teacher-led and didactic to student-focused. In a constructivist classroom, the teacher's role changes – often to that of a facilitator of the process of learning rather than the source of knowledge. Fundamental to this style of learning is collaboration, with the facilitator aiming – in a classroom environment where learners feel safe to question their own opinions and those of others – to support 'collaborative construction of knowledge through social negotiation, not competition among learners for recognition' (Jonassen, 1994) and to help students to clarify their ideas and predict consequences.

3 Method

3.1 Core Teaching Aims

Our discussion classes focus on deep engagement with issues that affect scientists. They incorporate high levels of student-student/student-teacher interaction that encourage sophisticated argument representing multiple perspectives. We aim for a classroom which involves 'discussion, even arguments, in which students play a large role in directing the flow of topics and ideas' (Nystrand and Gamoran 1990). We strive to stimulate high-quality, substantively-engaging talk characterised by curiosity and interest between students. Our goal is not to impart knowledge but is instead to teach students how to develop and articulate reasoned, justified and nuanced opinions.

3.2 Analysis Methods

So, does the discussion classroom, stimulated by YouTube presentations of issues, provide a productive, supportive and stimulating learning environment where students may become familiar with and engage with matters likely to affect them as working scientists? We examine student response to the format and explore what characterised the more successful sections of the classes in terms of the facilitators' actions, the classroom environment and the lesson structure.

To address this question, we ran, recorded, transcribed and then analysed three discussion classes ranging in length from an hour to two-and-a-half hours. Each class was a mixed gender group of six to twelve undergraduate and/or postgraduate physics students with one to two female facilitators. Where appropriate, quotations have been taken from the transcription.

For our analysis, we used the classroom observations of both facilitators and some students; we also asked students to fill out a short questionnaire (results shown in Table 1) about their discussion-group experience, stating the extent to which they agreed with a set of statements. We used twelve student replies in our analysis – obviously a small sample size, but indicative enough to support classroom observations and transcription analysis.

Table 1. Results from course questionnaire.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The videos stimulated discussion	5	5	2	0	0
The videos were an appropriate choice for the topic discussed	7	4	1	0	0
I had a chance to express my opinion	11	1	0	0	0
My opinion was valued	8	3	1	0	0
The discussion classes were engaging	6	5	1	0	0
The discussion was vibrant	8	2	1	1	0
I felt the topic being discussed was important	8	3	0	1	0
I obtained a broader outlook of the role of science in society	5	6	0	1	0
I obtained a broader understanding of the social context of scientific research	1	6	3	2	0
I connected with the topic being discussed	6	4	2	0	0
My opinion was changed through the discussed class.	1	1	5	2	3

The videos discussed in our class include: ‘Science is a Girl’s Thing’ (European Commission), ‘Hack A Hair Dryer’ (IBM), ‘Science needs women’ (L’Oreal Foundation), ‘Are MRIs safe?’ (PhysicsGirl), ‘Climate Science: What You Need to Know’ (It’s Okay To Be Smart), ‘#OursToLose: Climate Change Affects The Things We Love’ (YouTube Focus Group), ‘Shocking Percentage of Americans Don’t Trust Science’ (The Young Turks), ‘Newswipe: Ben Goldacre on MMR Hoax’ (Newswipe), ‘How Science Experts Make Movies Better’ (Inside Science), ‘Science Wars: Acapella Parody’ (ASAP Science). Links and brief teaching notes on these and other videos can be found on Laura McKemmish’s web page (https://sites.google.com/view/laurakmckemmish/science-education/suggested-videos).

For this paper, we also ran (but didn’t analyse) another discussion group with six volunteer students and two facilitators focusing on the respective influence of Brexit and of the election of Trump as US President on science and scientists in the UK. An edited version of this discussion group is presented as partner material to this written paper.

4 Analysis

4.1 Video as stimulating discussion

Stimulating discussion is often quite challenging, particularly with science students. Our classroom observations and questionnaire results showed that a YouTube video was, in practice, much better for generating discussion than a monologue or slides. That YouTube is familiar to most students – they frequently referred to both YouTube creators of videos and their films – makes it a good medium for introducing more unfamiliar topics. Their very engaged responses were accordingly astute, with evident analytical and summative skills: “it wasn’t just a flashy car advert ... you could actually see the hairdryer being used for something other than just doing your hair”. They did not regard what they watched as authoritative, but considered in their exchanges the videos’ contexts and the motivations of the creators – for example, what may have motivated the funders of ‘Hack a Hair-dryer’.

The very controversial ‘Science is a Girl’s Thing’ had the greatest impact, completely engaging the classes in more vibrant and prolonged debate than other, less polemical short videos. Students’ reactions to it bear out the view of Simonneaux (2007) that controversy provides ‘opportunities for differing views and for engaging in argumentation’ and their comments, such as ‘It was very patronising’, demonstrate how video content can evoke emotion. In particular, the video’s presentation of female ‘bimbo’ stereotypes triggered long and complex conversations drawing strongly on the students’ experiences and beliefs. The short length of the film allowed for significant, engaged, in-depth analysis of content, with focus upon specific shots or scenes. Students sympathised with the video producers’ goals – “I get what they were trying to do” – but they suggested alternatives and improvements: “show the real scientists”.

4.2 Creating a Supportive and Stimulating Environment

Creating a safe environment and building group trust was extremely important. Zeidler *et al* (2009) highlight the importance of this trust and mutual respect: “If students perceive disrespect or lack of emotional support, they may be less willing to engage in challenging discussions or to take the intellectual and personal risks required for development”. Students all felt they could express their opinions and generally felt their opinions were valued (see Table 1). Humour and/or sarcasm used by students reflects their generally high comfort levels. Participants engaged with each other: “I agree”, “I know what you mean” or “I am sceptical”. Further, students felt comfortable enough to direct the conversation and re-visit points: “Actually, just before going on to that, just one thing I wanted to add”; “Just one more thing on…”. One classroom anecdote illustrates the importance of creating student rapport and comfort through mutual sharing of views: when an unfamiliar person came into a discussion mid-way through, interactions became more stilted until the new participant’s substantial contribution to the discussion restored the group’s sense of comfort and the confidence of individuals to voice opinions.

The facilitator’s role was to stimulate the conversation and invite engagement from all participants and facilitator talk accounted, overall, for about one third of the time recorded. An effective tactic for generating discussion was for the facilitator to voice personal opinion about the video or issue and then to invite student comment with such questions as ‘Is this a fair statement?’, thus building student trust and confidence. Once the facilitator had led the way, participants felt able to state their opinions, with much less fear of being judged for what they said (especially if they happened to share the facilitator’s view, though this could lead to a much more one-sided conversation). Furthermore, the facilitator was then able to capitalise upon increased comfort levels by drawing out conflicting opinions, which meant that difficult issues were addressed with due consideration of the arguments from opposing sides. Introducing bold, sweeping statements, such as ‘there’s no consensus between the community how science should be carried out’, often generated significant engagement, as indicated by more people contributing in smaller bursts. We suggest that such statements were effective as they invited students to find and discuss the subtleties in the topic.

The facilitator used questions in a variety of ways, and with various effects, during the class. Generic questions like ‘What did you think?’ and ‘Discuss it amongst yourselves’ tended to lead to confusion about what students should be discussing or commenting on. More specific questions like ‘Whom would you assume it was aimed at?’ proved more effective. Answers could at first be given as simple statements (e.g. ‘Eight-year-olds’) – everyone could thus become acclimatised to offering opinion – and then elaborated upon afterwards. These short initial contributions by all students paved the way for deeper engagement. Diverging opinions understandably generated more discussion than simple agreement, but the degree of divergence could be small (e.g. different opinions on the target audience of the video) and still generate debate and good discussion. Commonly, students were encouraged to expand on points they raised: ‘What sort of other motivations?’; ‘What makes you believe it?’. (Nystrand and Gamoran (1990) describe how this process of following and promoting a line of inquiry initiated by the students themselves is extremely beneficial to creating a high-quality classroom discourse.) The facilitator also encouraged students to question themselves and their opinions: e.g. ‘Is a scientist what you do or who you are?’.

Students agreed that the discussion classes were engaging and vibrant (see Table 1). The pace of the conversation changed as the topics changed and different people contributed. Sometimes the conversation was fast-paced and interactive, with overlapping conversations and no silence. Other conversations were characterised by frequent pauses and silences as people developed their opinions and considered how best to express their thoughts. Often, one person gave an extended viewpoint largely uninterrupted, whilst at other times several people contributed actively to the conversation. Though there is, of course, always the potential for one person to dictate or overwhelm the conversation, we found this was rare and easy to address; in such circumstances, the opportunity for short, sub-group interactions helped: ‘Everyone’s going to talk to their neighbour for thirty seconds and then we’re going to bring it back, okay?”. Additionally, students who were naturally quieter were often asked directly for their contributions.

It is important to consider logistical issues, particularly classroom setting, group size and group diversity. An intimate, circle environment used in discussion classes 1 and 2 was much more conducive to a lively discussion in a safe environment than the rows of classroom desks used in discussion class 3. A group size of ten is probably best for these classes, as this is generally large enough to contain some more talkative students who can start the discussion, allowing more reticent participants to join in once the discussion is flowing more smoothly.

It was sometimes apparent that students prefer to see themselves as isolated from a particular negative consequence, such as the influence of money on physics research. The facilitator plays an extremely important role here in making sure that students do not avoid complex issues but, instead, engage directly with them and view such challenges as likely to take place in their future. (In the case of physics and money, it is a fairly simple case of discussing funding and the grant system determining what research occurs.) We found also that students implicitly separate themselves from scientists who experience problems. For example, during one session focusing on mistakes in science and their negative influence on public trust, the general mood of the room was that only ‘bad’ scientists make mistakes and that good physics researchers (i.e. themselves) would not make these mistakes. However difficult, it is extremely useful in this situation for the facilitator to be prepared to demonstrate some vulnerability and humility by sharing experiences of personal shortcomings in the scientific process, as one did by giving an anecdote of how a simple typographical mistake, a mathematical one, in her paper did not get picked up until the very final stages of proof reading despite review by numerous people over time. That this facilitator divulged her own lapse encouraged student engagement, questioning of the peer-review process and, overall, thoughtful, in-depth consideration of related complex issues. The implicit message of this admission was that the facilitator had the confidence to admit responsibility and that she had sufficient trust in her student audience to reveal something potentially detrimental to herself. Her self-confidence paid off: students responded positively. For example, when discussing an example with perhaps greater possible impact – ‘the guy who first measured the mass of the electron [who] accidentally messed up a number in his actual publication’ – students concluded it was ‘not his fault’. Students did then try to allocate responsibility to the reviewers, to which the second facilitator responded: ‘I wouldn’t expect an examiner to pick up everything’. Overall, students were forced by this discussion to engage with uncomfortable realities of the limitations of the scientific process.

4.3 Values Education

We aimed not to prescribe or enforce specific views or values, but encouraged students to formulate and develop their own opinions stimulated by ours, their peers’ and the video stimulus. When considering two contrasting approaches to research, the facilitator was impartial: ‘I don’t think it’s right or wrong’. Reiss (1999) argues that instruction in ethics heightens the ‘ethical sensitivity, ethical knowledge and ethical judgment of students’; we argue that these discussion classes contribute in much the same way – in heightening the sensitivity, knowledge and judgement of our science students to the societal aspects of being a scientist in the twenty-first century. Students generally felt the topic discussed was important and that they gained a greater understanding of the role of science in society (see Table 1). Students wrestled with the question of the social responsibilities of a scientist, such as in 'promoting scientific literacy', education, outreach and political engagement.

4.4 Engagement and Connection

Overall, students connected to the topic (see Table 1). The language used by participants reflects their engagement with the topic: when the third person pronouns 'they' and 'them' were used, the discussion was usually far less interactive than it was with the first and second person pronouns 'I', 'we' and 'you'. In the almost 40,000 words transcribed, commonly-used words include 'I' (1025), 'you' (856), 'we' (259), all illustrating a personal connection to the topic. Zeidler *et al* (2009) highlight that people tend to engage and reason out more when the subject is relevant to them personally or contextual.

The discussion was most vibrant when students were personally connected to the topic. This connection was most frequently characterised by the sharing of personal experiences or anecdotes about family and friends. School experiences and the motivations to study physics were particularly useful as they served as a common point of reference and comparison between student experiences. A particularly interesting case was the lively response to what a student had to say about school in India, which conflicted with the experience of many others. There was also significant evidence of reflection upon the experiences, not simply narration.

The use of contextually-relevant examples and evidence is very important to ground and direct the discussion, especially for a scientific audience. It enables reasoned argumentation, identified as a key goal of socio-scientific issue instruction by Zeidler *et al* (2009). To illustrate the importance of evidence and examples, consider two conversations from the transcribed classes. In one conversation, significant details from two examples of the way in which scientists present results to the media (the incorrect discovery of gravitational waves in the cosmic microwave background; the faster-than-light-speed measurement of the speed of the neutrino) were used to great effect to produce a lively and nuanced discussion. In another case, a very short reference to the 'GM and the MMR vaccine' was not sufficiently understood and/or remembered by all participants and led to very little further discussion. It is also important that the examples and evidence are contextual and relevant to the students; for example, a student's question 'I wonder what the statistics are for Britain of how many people believe in climate change?' demonstrates a lack of connection with the topic, which led to the conversation's quickly moving on to other matters.

Stereotypes were a very frequently used vehicle for students to engage, discuss and debate complex issues. Most commonly, stereotypes were rejected as simplistic or 'stupid'. Students generally articulated quite subtle views: for example, when discussing the 'Science is a Girl's Thing' controversy, one student stated, "I suspect a lot of the backlash to this was actually sexism in and of itself because it played into that stereotype of, well, people who act like that can't be scientists". The cultural diversity of the group allowed for contrasting stereotypes from different countries to be discussed.

4.5 Articulation and Evolution of Thought

There was significant evidence of students' engaging with difficult issues and articulating their points of view. For example, out of the approximately 40,000 words transcribed, the word 'think' occurred 331 times. The extremely frequent occurrence (790) of 'like' usually indicated that students were trying to articulate a thought that they found difficult to express. Students regularly predicted scenarios and consequences in relation to their opinions, as quantified by the high occurrence of the word 'if' (210): "it's really sad if we only educate groups of people that are good at Chemistry". When the facilitator gave time for students to think and find the words to articulate their thoughts, students responded positively. Disjointed sentences, adapting of phrasing and pauses were all evidence of this process of articulation and were present throughout all transcripts. The facilitators allowed these pauses, giving the students time to formulate their thoughts, and then helped the students develop their ideas. The ultimate aim of a process like this is to assist students in composing 'coherent, logically consistent argument that included an explanation and rationale for the position taken', identified by Simonneaux (2007) as a key goal of socio-scientific instruction.

Though there was significant evidence of productive argumentation and articulation of thought, students overall did not feel that their opinion was significantly changed (see Table 1). This perhaps reflects that fact that, for most topics, the group shared a consensus view and were mainly discussing the details and implications.

4.6 Diversity and Perspective-taking

Diversity of perspective amongst the discussion group participants was vital in stimulating students to challenge their pre-conceived views and to give the conversation sophistication, complexity and depth. We achieved group diversity in terms of gender, nationality, ethnic background and education level. Note that we didn't experience any difficulties with PhD student opinions' overshadowing those of undergraduates. Since the disparity between the views of undergraduate students, postgraduate students and post-doctoral facilitators was, in many instances, stark, the mutual sharing of views was of huge value (especially, to undergraduate students, thereby to gain insights into the day-to-day reality of research, including writing papers, presenting research and seeking funding). An additional important source of diversity for some of our classes was a science communicator who provided a different perspective and numerous concrete examples of previous controversies involving the media and scientists.

Despite the diversity we did achieve, there was considerable commonality of views, leading to relatively homogeneous opinions on many topics. Group self-identification as physicists, and more generally as scientists and university-educated critical thinkers, was powerful. To allow argumentation in this context, Simonneaux (2007) highlights the importance of establishing a counter-position with which students can engage, thus improving the quality of argumentation. This counter position was clearly established in all classes, with students demonstrating strong awareness that there were others with opposing views. This was often articulated by considering the perspective of 'most people', those less involved with science and generally with lower scientific literacy. Consideration of the opinion of this generic population significantly enhanced the ability of the class to debate different aspects of an issue and engage in productive and reasoned argumentation. Students engaged on both a personal level (e.g. "My family still seem to think a PhD just means I'm going to lectures for another three years") and a more global level, particularly with respect to trust in science (e.g. "Most people don't understand [that] a small temperature change is actually a massive significant result."). Students broadly demonstrated strong skills in perspective-taking, with significant evidence of articulating (but usually not agreeing with) alternative points of view. Students described possible reasons for other, different, opinions, though they had difficulty empathising in some cases, especially when the opinions were very negative or did not align with scientific evidence, e.g. climate change deniers. Students also demonstrated awareness of limitations in their ability to understand the opinions of others.

YouTube videos can assist in providing this counter-position. However, a video with a starkly-opposed viewpoint (for example, that of a climate denier) may serve only to entrench a student's viewpoints as s/he focuses on rejecting, not understanding, the video's perspective. Instead, videos aimed at helping to explain alternative viewpoints may be more appropriate.

4.7 Lessons and Advice

For most physics teachers, leading a discussion class will probably be a new and maybe quite terrifying prospect, but, from our experience, we can offer the following advice:

The role of the teacher in these discussion classes is that of a facilitator. Creating a safe environment where students feel free to explore and develop their opinions of the topic is crucial. Techniques such as summarising what has already been said, active listening and encouraging contributions from quieter students (and male students in the case of gender issues) are extremely valuable. If the discussion stalls, doesn't progress, goes into unhelpful – or, worse, possibly harmful – directions, the teacher should take a more proactive role, asking a new, possibly leading, question to change the direction of the conversation. Personal anecdotes from the teacher or raising external examples and opinions is often appropriate, as long as the students and their thoughts and opinions remain central in the class. The bold, sweeping statements mentioned above can be useful to help engagement and challenge preconceptions and ideas. When the student ideas are relatively homogeneous, the facilitator should help students establish a counter-position and encourage students to empathise with, understand and engage with this alternative perspective. As preparation for the class, we recommend that facilitators prepare some evidence on the topic, but be ready to follow where the students lead. In-class research time could be used. It was important to us that these discussions ended as largely empowering, not demotivating. This was achieved by suggesting possible (partial) solutions and encouraging students to brainstorm positive actions and/or solutions to perceived issues.

5 Accompanying Material

For the purposes of this article, we have produced a video based on the filming of a discussion class with student volunteers. This can be found at https://www.youtube.com/watch?v=rS4hETwCbP4. This video illustrates many of the points discussed in this article in a classroom setting.

A regularly-updated list of suitable videos for these discussion classes are provided on Laura McKemmish's website (https://sites.google.com/view/laurakmckemmish/science-education/suggested-videos).

6 Looking forward and conclusions

Physicists today face a multitude of challenges with, for example, continuing gender inequality, increasing public mistrust of scientists, the growing importance of science to society and the multitude of pressures on scientific research funding. It is imperative that we train physics students with awareness of – and the ability to engage with and positively influence – the social and professional context and environment of their scientific research. Watching YouTube videos is an easy and yet very useful 'icebreaker' and starting point for discussions on the social and professional challenges faced by working physicists. The resulting discussion classes, analysed in this paper, can serve to create more socially- and professionally-aware and responsible scientists who make greater contributions to society as a whole, not just to the scientific world.

The most lively and interactive discussions took place when: 1) students felt comfortable with each other, facilitators and the environment; 2) a significant number of students and/or facilitators regularly offered opinions, anecdotes, examples and evidence; 3) there was a personal connection to the topic being discussed; 4) there were solid facts, evidence or events on which to base the discussion - YouTube videos can be useful in providing this in an (often) enjoyable and (usually) digestible format.

In our case, once a supportive and stimulating environment had been correctly established (with the facilitator playing a key role here) and participants given the opportunity, time and freedom to develop and articulate their opinions, students flourished and demonstrated sophisticated reasoning skills. They were keen to articulate subtleties of opinion, appreciate and empathise with alternative perspectives and engage in productive debate about the complex social and professional challenges relating to science and scientists.

The class format is easily replicated and relatively cheap (with teacher time the most substantial resource). To fit into existing module structure, it could be integrated as part of (compulsory) lab or tutorial class time. Once-a-month video-watching-and-discussion sessions with ten to twenty students would be an easy and successful way of incorporating this content and helping to develop more socially- and professionally-aware physics students.

Perhaps most importantly, students enjoyed these classes, appreciating the opportunity to learn more about the research world and the life of a physicist and to articulate and explore opinions on a topic they love: science and being a scientist.

Reference list

Berkowitz, M. W. and Bier, M. C. (2007) 'What works in character education.' *Journal of Research in Character Education*, 5(1), 29.

Brewe, E. and Sawtelle, V. (2016) Editorial: 'Focused collection: Gender in physics.' *Physical Review: Physics Education Research,* 12(2), 020001.

Chung, Y., Yoo, J., Kim, S.-W., Lee, H. and Zeidler, D. L. (2016) 'Enhancing students' communication skills in the science classroom through socio-scientific issues.' *International Journal of Science and Mathematics Education*, 14(1), 1-27.

Duit, R., (2016) 'The constructivist view in science education – what it has to offer and what should not be expected from it.' *Investigaçóes em ensino de ciências*, 1(1), 40-75.

Hirsch, J. E. (2005) 'An index to quantify an individual's scientific research output.' *Proceedings of the National Academy of Sciences*, 16569-16572.

Hmielowski, J. D., Feldman, L., Myers, T. A., Leiserowitz, A. and Maibach, E. (2014) 'An attack on science: media use, trust in scientists, and perceptions of global warming.' *Public Understanding of Science*, 23(7), 866-883.

Jonassen, D. H. (1994) 'Thinking technology: Toward a constructivist design model.' *Educational Technology*, 34(4), 34-37.

Jonassen, D. H. and Kim, B. (2010) 'Arguing to learn and learning to argue: Design justifications and guidelines.' *Educational Technology Research and Development*, 58(4), 439-457.

Kahn, S. and Zeidler, D. L. (2016) 'Using our heads and hartss*: Developing perspective-taking skills for socio-scientific reasoning.' [*humanities, arts, and social sciences] *Journal of Science Teacher Education*, 27(3), 261-281.

Lee, H., Yoo, J., Choi, K., Kim, S.-W., Krajcik, J., Herman, B. C. and Zeidler, D. L. (2013) 'Socioscientific issues as a vehicle for promoting character and values for global citizens.' *International Journal of Science Education*, 35(12), 2079-2113.

Leiserowitz, A. A., Maibach, E. W., Roser-Renouf, C., Smith, N. and Dawson, E. (2013) 'Climategate, public opinion, and the loss of trust.' *American behavioral scientist*, 57(6), 818-837.

Murphy, P. and Whitelegg, E. (2006) 'Girls in the physics classroom: A review of the research on the participation of girls in physics.' Institute of Physics. Available at: http://www.iop.org/education/teacher/support/girls_physics/review/page_41597.html (Accessed: 8 October 2017).

Nystrand, M. and Gamoran, A. (1990) 'Student engagement: When recitation becomes conversation.' Available at: https://eric.ed.gov/?id=ED323581 (Accessed: 8 October 2017).

Oulton, C., Day, V., Dillon, J. and Grace, M. (2004) 'Controversial issues-teachers' attitudes and practices in the context of citizenship education.' *Oxford Review of Education*, 30(4), 489-507

Palincsar, A. S. (1998) 'Social constructivist perspectives on teaching and learning.' *Annual review of psychology*, 49(1), 345-375.

Picoult, J. (2004) *My Sister's Keeper*. London: Hodder and Stoughton.

Reiss, M. J. (1999) 'Teaching ethics in science.' *Studies in Science Education*, 34, 115-140.

Retzbach, A. and Maier, M. (2015) 'Communicating scientific uncertainty: Media effects on public engagement with science.' *Communication Research*, 42(3), 429-456.

Sadler, T. D. (2004) 'Informal reasoning regarding socio-scientific issues: A critical review of research.' *Journal of research in science teaching*, 41, 513-536.

Sadler, T. D. (2009) 'Situated learning in science education: socio-scientific issues as contexts for practice.' *Studies in Science Education*, 45(1), 1-42.

Scheufele, D. A. (2013) 'Communicating science in social settings.' *Proceedings of the National Academy of Sciences*, 110 (Supplement 3), 14040-14047.

Simonneaux, L. (2007) 'Argumentation in science education: An overview.' In: *Argumentation in Science Education: Perspectives from Classroom-Based Research. Dordrecht: Springer,* 3-27.

Spier, R. (2002) 'The history of the peer-review process.' *Trends in Biotechnology*, 20(8), 357-358.

Zeidler, D. L. (2016) 'Stem education: A deficit framework for the twenty first century: a sociocultural socioscientific response.' *Cultural Studies of Science Education*, 11(1), 11-26.

Zeidler, D. L., Sadler, T. D., Applebaum, S. and Callahan, B. E. (2009) 'Advancing reflective judgment through socioscientific issues.' *Journal of Research in Science Teaching*, 46(1), 74-101.