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Day, Stephen; Scott-McKie, Louise; Killen, Andrew

Published in:
Scottish Educational Review

Published: 31/07/2019

Document Version
Publisher's PDF, also known as Version of record

Day, Stephen P., Scott-McKie, Louise and Killen, Andrew (2019) Primary education students' engagement with socio-scientific discussion as an approach to learning for sustainability. *Scottish Educational Review* 51(1), 30-43

Primary education students' engagement with socio-scientific discussion as an approach to learning for sustainability.

Stephen P. Day*, Louise Scott-McKie and Andrew Killen.
University of the West of Scotland
*Corresponding author: Stephen.Day@uws.ac.uk

ABSTRACT

Sustainability is a complex, ill-defined concept that has been the subject of much debate over the last two decades (Wals and Jickling, 2002). The ill-defined nature of sustainability manifests itself within socio-scientific issues where conflicting reality constructions, values, norms, and interests interact. Initial teacher education as part of Higher education has a responsibility to critique the values and knowledge claims inherent within contemporary science issues and can meet this responsibility by supporting students to engage with socio-scientific discussions within the context of learning for sustainability. This paper explores how forty-four primary education students engage with discussions focused upon climate change. Students' prior educational experience, together with their disposition towards open-mindedness impacts heavily upon the way they interact during discussions. Online teacher-mediated discussion fora are useful for supporting primary education students' ability to cope with the inherent complexity and the differing values imbued within the multiple perspectives emergent within socio-scientific discussion.

Keywords: *Socio-scientific discussion; Learning for Sustainability; Blended Learning; Structured Academic Controversies*.

INTRODUCTION.

This paper aims to explore how a group of forty-four undergraduate primary education students engage with the socio-scientific issue of climate change as an approach to Learning for Sustainability (LfS) within an optional module entitled Science in Society as part of their initial teacher education. The paper is structured into three sections. The first explores the literature that situates socio-scientific discussion within the context of LfS. The second outlines an exploratory case study detailing how undergraduate primary education students engaged with the issue of climate change as a context for LfS as part of their initial teacher education. The third discusses findings from the case study, in the light of literature focused on the use of discussion as an approach to LfS and how they might provide some insights for future research focused on how LfS might be better incorporated in to ITE provision within Scotland.

DEVELOPING STUDENTS' SCIENTIFIC LITERACY AND THE ROLE OF SOCIO-SCIENTIFIC DISCUSSION AS AN APPROACH TO LEARNING FOR SUSTAINABILITY.

Modern life is increasingly characterised as complex, interconnected and messy, where society must deal with pressing issues such as climate change, population growth, poverty and political inequalities (Baptista, Freire and Freire, 2013). Issues such as the exploitation of natural resources and population growth have created downstream environmental problems such as deforestation, intensive land use and issues with waste management that raises questions as to the sustainability of such growth in economic, environmental and human terms. There has never been a greater need for citizens to interrogate the individual and cultural behaviours, attitudes and beliefs that underpin these issues. To this end, the United Nations General Assembly adopted Resolution 57/254 declaring the period between 2005 and 2014 as the UN decade of Education for Sustainable Development to emphasise the critical role that education

plays in advancing young people's understanding of the need for sustainability and to stimulate positive action towards tackling these issues.

Savage et al., (2015) argue that higher education has a responsibility to critique the values and knowledge claims inherent within contemporary science issues. Initial teacher education (ITE) can meet this responsibility by supporting students to engage with a diverse range of learning contexts, which expose them to pedagogies that open critical, democratic discursive spaces. One approach gaining traction within Scottish education, particularly in the light of the Scottish Government's response to the One Planet Schools report is Learning for Sustainability (LfS) - the preferred term as opposed to 'Education for Sustainable Development', which Griffiths and Murray (2017) suggests "... avoids, rather than resolves, some of the inherent tensions that stem from the Rio Declaration" (p. 40).

The General Teaching Council for Scotland (GTCS) views LfS as 'integral' to their Professional Standards Framework incorporating it into its' validation process for ITE programmes (GTCS, 2018). There is an expectation that programmes demonstrate how they meet the developing needs of students (in terms of LfS) to ensure continued registration with the GTCS (Clarke and Mcphie, 2016). This repositioning of policy from the GTCS brings to the fore questions as to how we educate prospective teachers for sustainability. We would argue that the ill-defined nature of sustainability manifests itself (especially within science education) in how students engage with socio-scientific issues, where conflicting reality constructions; values; norms; and interests interact.

Typically, LfS involves students' active participation in the practical application of critical thinking (Sipos et al. 2008). When ITE students engage with socio-scientific issues such as climate change, they are required to engage with the inherent complexity of such issues. By exposing students to the main arguments that underpin the multiple and often conflicting perspectives that impinge upon such issues, tutors challenge students' own thinking, particularly if these challenges are political, social, moral or ethical in nature.

From an educational perspective, an important aspect of socio-scientific discussion (in the context of LfS) is that such activities allow ITE tutors to scaffold students' learning in terms of the development of critical skills such as the application of academic 'habits of the mind' i.e. open-mindedness, rational scepticism, self-reflection and metacognitive processing. Thereby, providing opportunities for tutors to apply pedagogical approaches such as cooperative learning that facilitate students' communication, argumentation and social skill development, enabling the tutor to situate learning within the context of issue being discussed (Day and Bryce, 2013; Bryce and Day, 2014). Students' ability to critically examine and make thoughtful decisions regarding socio-scientific issues has long been recognised as a way of developing students' functional scientific literacy (Zeidler and Keefer, 2003), which is a major goal for science education (OECD, 2001; Rutherford and Ahlgern, 1990).

Broadly speaking, the importance of conceptualising scientific literacy as including practices which develops skills related to informed decision making; dealing sensibly with moral reasoning and ethical issues; and understanding the connections inherent in socio-scientific issues is recognised as being specifically related to the democratic values important to, and implicit in, the drive towards promoting students as global citizens. Furthermore, the call for development of action competence as being fundamental to environmental education and, by extension, LfS (Almers, 2013) intensifies the argument for the inclusion of practices that hone abilities to reflect critically on root causes, visions for change and knowledge of how to influence specific contexts for change.

To better understand how learners engage with the context and content of socio-scientific issues, Sadler, Barab, and Scott (2007) developed the socio-scientific reasoning (SSR) construct to capture the practices used by citizens as they participate in discussions across multiple socio-scientific issues. Sadler, Klosterman, & Topcu (2011) also suggested that the underlying premise for the SSR construct was that "most, if not all, socio-scientific issues regardless of the specific scientific and social contexts, share certain features" (Sadler, Klosterman & Topcu, 2011, 57). They also suggested that the SSR construct was developed as a means of understanding student practices relative to the invariant features of socio-scientific issues. The invariant features of socio-scientific issues being (1) the recognition of the inherent *complexity* of socio-scientific issues; (2) examining issues from *multiple perspectives*; (3) appreciating that socio-scientific issues are subject to *ongoing inquiry*; and (4) exhibiting *scepticism* when presented with potentially biased information. It can be argued that as learners interact with specific socio-scientific contexts, they become more aware of, and better prepared to respond to the implications of these invariant

features of diverse socio-scientific issues (Sadler, et. al., 2007). Science education is in a unique position to help students develop skills that enable them to respond critically to media reports on issues with a science dimension.

While scientific knowledge and inquiry practices are useful for the negotiation of controversial socio-scientific issues, scientific practices alone cannot provide solutions. Thus, ITE science tutors need to draw on concepts and practices from other disciplines in order to avoid the practice of privileging the science perspective over alternative points of view. We would suggest that these aspects of socio-scientific discussion accurately describe the pedagogy employed in the current study as outlined in the next section.

It can be argued that the affective domain must necessarily be developed in working towards more sustainable futures. Alsop (2005) suggest that science educators need to give greater emphasis on developing the affective domain and more attention given to the emotional side of learning, which moves from cognitive to affective, before addressing an existential dimension where students are prompted to challenge their own values and actions; an empowerment dimension where a sense of responsibility is prompted through resolution of the existential crisis; and finally, to an action dimension where informed choices can be made personally, socially and politically. In light of the need for action around sustainability issues, and considering the ill-defined nature of these issues (Sipos et al, 2008), socio-scientific discussion becomes a more useful pedagogy for transformation, requiring students to develop affective skills such as the ability to listen; respond in interactions with others; demonstrate attitudes or values appropriate to particular situations; demonstrate the ability to balance and consider different perspectives; display a commitment to principled practice and willingness to revise judgement and change behaviour in light of new evidence.

Raskin (2008) cited by Sterling (2011) suggests that,

> The shape of the global future rests with the reflexivity of human consciousness – the capacity to think critically about why we think what we do – and then to think and act differently (p.19).

However, factors hindering such development hinge upon the practitioner, given that traditional models of education, similar to that of 'banking education' coined by Freire (1972) often promote passivity on the part of the student and reinforce the view of practitioners as disseminators of information (Zandvliet, 2012).

Consequently, the lead researcher in this study explicitly challenged students with conflicting viewpoints, value-laden positions and ethical dilemmas. Paulus (2016) supports pedagogies that include pluralist viewpoints, arguing that pluralism and criticality are related: if students are not challenged to reflect on their values and views through alternative perspectives, they are unlikely to reflect on them. Pluralist pedagogies seek to inter-relate diverging values, norms and interests, rather than privileging particular views over others and moulding one universal reality, or ignoring the differences altogether (Wals, 2010).

In order to capture the dynamic nature of the interactions within the classroom and the Virtual Learning Environment (VLE), it is incumbent upon researchers to adopt methodologies that maintain and reflect this complexity. Data gathered seeks to provide a rich picture of the emergent thinking rather than reduce the interactions to a set of measurable variables. In the next section, the research methodology, data gathering and data analysis processes are described.

CASE STUDY: PRIMARY EDUCATION STUDENTS WITH THE CLIMATE CHANGE DISCUSSION.

This research utilised an exploratory single case study research design to develop an in-depth exploration of the complexity of the interactions between undergraduate primary education students as they engage with socio-scientific discussions over the course of an elective module entitled Science in Society (Yin, 2018).

The rationale for choosing this design was the need to critically assess the extent to which undergraduate primary education students engage with socio-scientific issues that can foster the development of values and dispositions related to learning for sustainability. Also, the objective of this case study was to capture the circumstances and conditions present within the Science and Society module that support the development of socio-scientific (and sustainability) reasoning (Yin, 2018). The next section outlines the context and defines the case.

Context: The Science in Society module.

Science in Society is an optional module in year two of the BA (Hon) Primary Education programme that follows on from a core module in Sustainable Development. The module is taught using a blended learning approach that consists of eight, four-hour workshops with twelve interactive online reflective tasks that focus on how students' reason through and negotiate each socio-scientific issue covered over a twelve-week period. Table 1 summarises the content and pedagogical context of the Science in Society module.

Teaching Session	Workshop content	Task Outline
1	Introduction to Science in Society module	Defines socio-scientific issues and justifies the module design Outline of the end-of-module summative assessment, success criteria and assignment-scoring rubric. Present Argumentation theory and how this can be used to improve academic writing.
2	Climate Change and Global Warming	Graffiti board task to illicit students' prior knowledge about global warming. Poster-drawing task designed to unpacked students' conceptual understanding. Analysing greenhouse gas data activity. Students draw and interpret graphs about greenhouse gases. Seven short video clips (2-4 minutes long) presenting the science pertinent to the climate change debate. These videos present the alarmist and sceptics perspectives.
3	Climate Change and Global Warming	Lecture on the complex nature of climate change and global warming as a socio-scientific issue. Whole class discussion where students engaged in a structured debate about the issue, facilitated by a series of open questions that allowed students to think aloud, develop their arguments and to practice communication and democratic citizenship skills.
4	Use of Animals in Research issue	Presentation of the statistics behind the use of animals within research within the United Kingdom. A presentation of the scenario that contextualised the role-play that would be performed in the next teaching session was made by the tutor. Students' gather information related to their assigned 'role' within the coming role-play. Each student group made a poster presentation of the information that they found. The class discussed their initial feelings on this subject in an open whole class- discussion
5	Use of Animals in Research issue	Filmed role-play session Debrief for the role-play.
6	Case-based Learning – Embryonic Stems Cells-*in vitro* fertilisation	A case study is presented to students. Students identify the important elements of the case study. These are then used as the focal point their Internet searches to gather information required to help them negotiate the case. The tutor taught/revise the concept of Mendelian inheritance to establish a common scientific understanding of how genetic diseases are inherited. Students searched the Internet and gather information required to help them understand the concepts which impact on this case from multiple perspectives and students drew together the information that the gathered from their enquiries and shared information.
7	Case-based Learning – Embryonic Stems Cells-*in vitro* fertilisation	Filmed whole-class discussion.
8	Consolidation session	Feedback session, peer/tutor support session for end-of-module summative assessment.

TABLE 1: OVERVIEW OF THE SCIENCE IN SOCIETY MODULE CONTENT.

The module aims to (a) support primary education students to develop their personal knowledge and understanding of how science impacts on, and at time conflicts with, modern society; and (b) to develop primary education students' scientific literacy and socio-scientific reasoning skills by undertaking inquiry tasks focusing on how socio-scientific issues arise, why they are often controversial and how the general public might interact with such issues to make informed democratic decisions about how best to resolve such issues.

In order to support students' engagement within the issues discussed as part of the module, the tutor used online discussion fora and wikis to both support developing understanding of the information provided and scaffold questioning of that information from multiple perspectives. Pedagogically, the use of blended learning opened discursive spaces both within the workshop sessions and the VLE that supported engagement with the materials provided and questioning of each other's views.

The participant sample.

All participants (n=44; n=40 Female, n=4 Male) within this case study gave written consent for their class work during the module teaching sessions, discussion forum and wiki posts on the Science in Society module VLE to be analysed.

Data

The data was drawn from undergraduate primary education students' classwork (posters, worksheets and graffiti boards) and discussions (on the VLE [Moodle™] discussion forum posts) focused on the issue of climate change only. In addition, the university tutor's reflections upon the individual teaching session were captured in a series of recorded discussions with a critical friend (who also observed each teaching session) immediately after each teaching session. However, these reflections are not outlined within this paper.

Data analysis

Data from the students' discussion forum posts was analysed using thematic analysis to identify students' value positions, their understanding of the concepts involved in the issue, and their understandings of the arguments posed within opposing perspectives. The main themes drawn upon in the analysis are theoretically derived from Sadler, Barab and Scott (2007) who posited the socio-scientific reasoning construct which suggests that there are four invariant components to reasoning [*complexity* of the issue; *multiple perspectives*; *ongoing inquiry* and *scepticism*] that cut across socio-scientific discussion regardless of context.

While this case study seeks to explore the value positions expressed by students during the Climate Change discussion, we acknowledge difficultly in divorcing those values from their wider understanding of the key concepts involved within the issue or their ability to apply those 'funds of knowledge' and other critical competencies and skills together with 'habits of the mind' such as rational scepticism and open mindedness [both of which are components of critical thinking] (Sosu, 2013).

Findings

To allow student voice to emerge as part of the analysis, the findings outlined in this section utilises excerpts from students' writing within the VLE and examples from their class work to illustrate the points being made. Each example is followed by a code to protect the anonymity of the student where the code used stands for Primary Education Student (PES) followed by a number. The findings will be outlined under the emergent themes of knowledge, scepticism and values.

Knowledge

Analysis of students' writing in the online discussion fora indicates that in terms of knowledge, twenty-seven students (61% of the sample) acknowledge they lacked sufficient knowledge prior to the start of the climate change discussion sessions.

> My previous knowledge of climate change and global warming was particularly limited prior to university, having only briefly touched on it at school (PES 3).

> Before the workshop, I had a general idea about climate change and global warming ...Overall my knowledge was very limited (PES 2).

However, ten students (23%) thought they knew more than they did about climate change when exposed to all the arguments within the workshop discussions as the following extracts from student reflections on the first workshop exemplify.

> I found the session quite challenging, as my knowledge was not as strong as I thought it was. I will need to do more research to make sure that I have full knowledge and from there I can create an opinion. (PES 40)

> I thought that human activity was affecting the earth's ozone layer, which then caused global warming. I then thought that through global warming, the climate would change and therefore that is where the term 'climate change' came from… I now have more of an understanding regarding the greenhouse effect. Whereas first I thought it was to do with human impact, I was in fact over complicating it and not focusing on the natural process… Today I learned that I do not know anywhere near as much as I should. I know the very basics of the topic, this is something that I should change to raise my awareness. I learned that I am easily influenced by other opinions and that I need to read more in order to form my own opinion of the topic. (PES 25)

Most students explicitly suggest that their prior knowledge comes from a combination of secondary school science [18 students], Sustainable Development (a compulsory module taken prior to the Science in Society module) [26 students], and from the press and media [17 students].

However, the following extracts suggest that students have a general lack of awareness of the potential bias – how editorial decisions influence the style and type of information reported either from an alarmist or sceptical perspective - within media reports (also see the example from PES 9 under scepticism).

> It's easy to get confused with climate change due to many unknown facts and the medias representation of it. (PES 40)

> I notice now that I was unaware of all the bias and twisting [of] information that comes with climate change and greenhouse gases. (PES 12)

In terms of students' conceptual understanding of the greenhouse effect, fourteen students did not know they held misconceptions until a group poster activity where the most common misconception surrounding the role of ozone and the ozone layer in relation to global warming surfaced. The above exemplar from PES 25 and Figure 1 A and B evidence this.

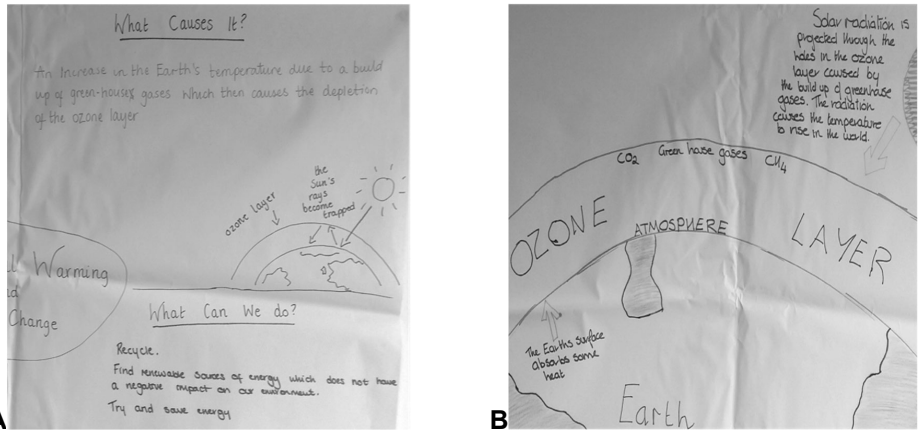

FIGURE 1. EXAMPLE OF TWO STUDENT GROUP POSTERS ILLUSTRATING COMMON GLOBAL WARMING MISCONCEPTIONS

This general lack of subject knowledge and students' awareness of media bias is problematic in several ways. First, thirty-one students (70% of the sample) struggled to deal with the complexity of the issue finding the climate change sessions challenging. Twelve students indicated these sessions challenged

their beliefs about climate change with nine students indicating that their knowledge had been challenged. Students also claimed that the volume of information to be considered (13 students), pace of discussions (10 students) and the form that most of the information took [complex graphs] (12 students) was particularly difficult to manage.

> The first session was not challenging in the sense of its difficulty, the concepts discussed and information presented was clear and understandable. Where the challenge came was from firstly realising how little I knew about a clearly very important current affair; secondly accepting this fact, taking time to listen to what was said, acknowledge that my initial opinion was based on very limited information and be prepared that it may change after further study of the topic. (PES 26)

> I thought that today's input was really interesting however it required a lot of attention and thinking when processing the information we were given. It was really thought provoking and got my brain thinking and it was really engaging. (PES 37)

Second, the tutor observed that the majority of students (81% of the sample) were unaware of important concepts (such as the difference between correlation and causation) and that temperature data is often presented as an anomaly relative to a climate normal as opposed to raw temperature readings. During the teaching sessions, students also exhibited difficulty reading and interpreting graphical information and struggled to relate different lines of evidence to the main arguments posed for and against the theory of anthropogenic climate change.

Third, thirteen students suggested that because they found the complexity of the evidence challenging, they felt disconnected from the issue.

> I really am quite oblivious and dismissive to the issue of climate change and global warming. I think the wrong stance I take in this situation is that if I don't understand it, I automatically shut off from it, which is the completely wrong attitude to have. (PES 38)

None of the students studying the Science in Society module have chosen to focus on climate change within the end-of-module assessment, suggesting that the complexity of the issue puts students off seriously engaging with it.

Scepticism.

As a result of engaging with the climate change discussion, thirty-four students (77% of the sample) report not being as aware of biased reporting in the climate change debate in the media than they ought to have been.

> Before the input, I did not realise how bias [sic] the information from the media can be. I also did not comprehend how little knowledge I had on this topic. (PES 9)

> My previous knowledge on climate change was lacking and I feel it was modelled around what I had read in the media and also from school. What I thought took place during climate change and global warming was also enlightened during this session and I feel more comfortable learning in this subject. (PES 4)

This module aims to support students developing socio-scientific reasoning. However, scepticism within the context of the climate change debate is problematic. Bryce and Day (2014) point out that scepticism has been used as a pejorative term linked to denial, which is unfortunate since scepticism, particularly rational scepticism is a vital component of criticality and arguably is an intellectual virtue. Scepticism, as presented to these students, focused upon supporting the suspension of judgement, doubting the veracity of knowledge claims and the motives and prerogatives of others. This way scepticism is seen as a 'habit of mind' to be practised.

While students found the complexity of the issue difficult to negotiate, the practice of scepticism was an alien concept to them as the following examples suggests.

> Before taking this class, I would have believed everything I read in the media, as I never thought to question it before. I was naive and thought that as it was on the news or in the paper it had to be true. I have now realised that this is not the case. (PES22)

> I found today's session intense but also extremely interesting, it made me question everything I have ever been told about this topic, and been left wondering why I was never taught all the facts

> previously... I grew up never questioning anything, I just assumed it was always true. However, I have realised I am terribly wrong. (PES 26)

After studying this issue, students reported that they are now aware of the need to critically question knowledge claims and the evidence that supports them.

> Looking at information in such a critical way has made me question if I can trust data as before I would have believed anything presented on the news or in articles to be the truth. Now if I look at data I will have to look at the author to see if they are trustworthy and look at other experts evidence to back up what they are stating, the more evidence, the more truth worthy the data. (PES 19)

> I feel I was subject to the classic misconceptions about climate change and global warming. I now know that there is a lot of bias attached to these misconceptions so when researching these topics, evidence is required and perhaps a little scepticism. (PES 2)

While the above examples seem to suggest that students now see the need to be sceptical when engaging with evidence as part of socio-scientific discussion, this is perhaps not the whole story. Module evaluation questionnaires for the Science in Society module found, seven students suggesting that the climate change issue should be dropped to give more time to work on "the more important issues in the module", suggesting that (at least for those students) studying climate change has limited educational value, which leads us to question their values.

Values.

During the climate change discussion, students struggled to articulate their understanding of values. Eventually, following tutor probing, students put forward a basic definition of a value as something of worth but struggled to expand upon this. The inter-relationship between our values and behaviour is captured by Leiserowitz, Kates and Parris (2006) who suggest that values, in the context of sustainability, are "abstract ideals that define or direct us to goals and provide standards against which the behaviour of individuals and societies can be judged" (p.418). However, Schwartz (1994) defines a value - as a *belief*, pertaining to desirable goals or *modes of conduct* that transcends specific situations, they *guide the selection or evaluation of behaviour*, people, and events, and are *ordered by importance relative to other values* forming a stable system of value priorities. Schwartz further suggests that what distinguishes one value from another is the type of goal or motivation that the value expresses.

In the context of climate change (and LfS) the extent to which students recognise (a) the values involved, and (b) the extent to which such values may compete is important and adds to the complexity of the issue. For example, the public may value environmental protection and economic prosperity but in practice these two values often conflict: such as shifting to cleaner but more expensive energy sources versus polluting but cheap fossil fuels. This aspect of decision-making and prioritising values brings politics into the debate.

When asked to reflect on the values brought to bear within the climate change discussion, eleven students recognise that people take up different positions based on their political beliefs or their attitudes towards the validity of evidence: PES 31 suggests that...

> It is important to understand that not every individual shares the same values when it comes to climate change. People will be selective on the areas of climate change they care about dependant on where they live, their cultures and perhaps political stance. An individual's values towards an action such as dropping litter may be influenced by factors such as social contempt or upbringing. This social contempt questions whether our actions reflect our own morals or whether they are influenced by society. (PES 31)

Linking of personal values to those of society within the above exemplar is important. First, it highlights an understanding that within a democracy, different groups hold different views, value positions and priorities. Second, it questions tolerance within society to those who hold different values and beliefs from our own. Third, it highlights who decides which value positions are privileged and why?

The extent to which societal values influence personal values lies at the heart of how education might support efforts to combat societal issues related to sustainability, such as how to tackle increasing poverty, issues of population growth and increased pollution and their impact on climate change. This moves the debate away from the science towards the moral and ethical dimension.

Fourteen students were exercised by whether climate change is a moral and ethical issue. One student stated strongly that it is a moral question through recognising competing values of economic prosperity verses a sustainable lifestyle.

> Morally, it is our choices that are contributing to the damaging effects of Global Warming. Consumerist behaviours vastly outweigh our interest in creating a more sustainable lifestyle. Ethically, our governments control our planet's future and it is their responsibility to ensure sustainability is prioritised for the sake of future generations. (PES 31)

While another student was unsure stating that climate change mitigation may be futile…

> You could argue that it is both [moral and ethical] due to loss of wildlife and the resources we are leaving behind for future generations because we are using more than we can replace. However, global warming and climate change are issues out of our control. If we lived the greenest lives possible, we would still pollute the earth so how can it be a moral and ethical issue if there is no way for us to fully prevent it? (PES 35)

This group of primary education students found the pluralistic nature of the issues raised and the pedagogical approaches used in the module as different to what they might expect from science education i.e. where there is one correct answer (perhaps a throwback to their secondary school science experience). This is not surprising since most students experience of school science is dominated by *learning* [the concepts and big ideas] and *doing* [experiments and investigations] science as described by Hodson (2014) but rarely *learn about science* [the nature of science and how science interacts with society].

DISCUSSION

In this final section, we will discuss the findings of the case study within the context of the literature on socio-scientific discussion and relate the emergent themes from the research to the learning context of the students' programme of study and current policy directive to include Learning for Sustainability within Scottish Initial Teacher Education. We will structure our discussion around three themes, Primary education ITE students' preparedness to engage in socio-scientific discussion, values and implications for pedagogy in ITE.

STUDENTS' PREPAREDNESS TO ENGAGE IN SOCIO-SCIENTIFIC DISCUSSION.

The question of how prepared primary education students are to meaningfully engage with socio-scientific discussion is critical since LfS requires students to learn about, negotiate and form opinions on complex issues. Indeed the GTCS Standards for Registration, clearly indicate that teachers need to be able to "plan systematically for effective teaching and learning across different contexts and experiences" (GTCS 2012, standard 2.3.1 p, 8) and "have knowledge and understanding of the ways in which natural, social, cultural, political and economic systems function and of how they are interconnected to professional practice" (GTCS, 2012, standard 3.1.2, p.12) which suggests that ITE needs to provide students with experiences that allows them to develop a deeper understanding of how such complex socio-scientific issues manifest themselves and affect society in multiple and uncertain ways.

Within the context of the case study, students struggled to deal with the climate change issue in several respects i.e. in terms of subject knowledge, lack of scepticism, coping with the complexity of the issue and inability to see the educational relevance of the climate change issue within the context of the module.

Issues with students' prior knowledge.

Zeidler (2014) suggests that research focused on students' engagement with socio-scientific discussion yields some insights into the way that students frame knowledge of scientific content and how that knowledge is utilised within different modes of socio-scientific instruction. Nielsen (2012) found that students represent scientific knowledge as either an explicit, assertive or implicit expression, where the content serves as a means for establishing a normative factual baseline from which to "jump-off" for subsequent engagement.

Our findings indicate that students' understanding of the baseline scientific content knowledge was at best lacking, and for most contains misconceptions. During the teaching sessions there was a need to

correct misconceptions and set the baseline information for the students. Previously, Day and Bryce (2013), working with 13-14-year-old secondary school students found their basic scientific understanding was confused, full of misconceptions and dominated by media bias.

Nielsen (2012) found that students struggled to view the reasonable disagreements within the issue discussed from different perspectives, focusing on persuasion rather than on making sense of alternative viewpoints or varied contexts. Our findings corroborate Nielsen's findings in two ways. First our students made explicit reference to the dominant view that humans are the cause of climate change without any real understanding of the greenhouse effect or the theories attributing the enhanced greenhouse effect to human behaviours. Second, during the workshop sessions it was apparent to the tutor that students struggled to take on board the alternative view that there might be a natural component to present global warming. This lack of understanding of basic subject knowledge caused cognitive dissonance within the students as they all, to varying degrees, found content knowledge challenging; citing processing volume of information and pace of the sessions as being difficult to follow. Linking this lack of understanding to students lack of scepticism towards sources of information previously presented to them, questions the meaningfulness of their engagement with the climate change issue. Despite the lack of knowledge, and to the students' credit, they engaged well in class and in the online discussion using the discussion fora more to explore their opinions on climate change and to seek clarification regarding consequences of action than as a space to examine knowledge claims. The tutor-mediated online discussion forum gave students a reflective, open space to express their developing views and debate. However, no real student debate took place due to an unwillingness to challenge one another's view in the online space.

Lack of Scepticism

Many of the students within the case study were disturbed to find that their knowledge from the previous school and university experience, and from the media was often misconceived and scientifically inaccurate. This finding is somewhat puzzling given that students will have been introduced (in some form or other) during secondary school experience to the concept of bias within source information. All students must possess Higher English to enter the primary education programme and will have been exposed to aspects of critical thinking within the analysis and evaluation unit of Higher English.

Rational scepticism, as a form of epistemological doubt, alongside critical openness is a key component of critical thinking (Sosu, 2013). From an educational perspective, for students to admit taking what they are told by teachers, media and politicians at face value and as factually correct is troubling. This raises questions of how best to support students to critique contestable knowledge claims. To what extent has students' prior educational experience positioned them as passive receivers of knowledge as opposed to critical consumers of knowledge? How can ITE support students to become actively critical citizens able to negotiate the complexity of issues within a pluralist democratic setting?

Within the case study, students were taught Toulmin's argumentation pattern technique (Toulmin, 2003) to support their understanding of how arguments are structured and framed. They were presented with two credible but opposing theories to explain the modern period of global warming. In addition, the political dimension of the arguments for and against each theory was critiqued, thereby *modelling* how to *operationalise* scepticism. In between workshops, students engaged in tasks within the VLE designed to support their ability to spot bias within information and to reflect upon and discuss aspects of the workshops. This discursive space was utilised well by students and, as outlined within the case study, students felt supported in this regard. If we are to maintain the development of these students, on their learning journey, as critically competent professionals we must consistently provide opportunities for them to exercise scepticism within their degree programme.

Coping with complexity

Climate change is often described as a super wicked problem (Lazarus, 2009), due mainly to the complexity of the science and dynamics of political arguments that are marshalled to mitigate the issue. Engaging students in socio-scientific discussion is often problematic due to the difficulty of establishing scientific knowledge within the issue, especially when risk and uncertainty come to the fore (Bryce and Day, 2014). Complexity includes, the degree of conflict, the number of stakeholders within the issue, the level of confidence held in the information pertinent to the issue, numerous alternative perspectives and

theories posited, knowledge of possible outcomes envisioned and the probability of those outcomes coming to pass. When an issue is complex, students often tend to simplify tasks into more understandable and manageable parts to aid assimilation. Often, they are dealing with complexity since, students often answer the easy questions, ignoring the difficult ones without noticing the substitution (Kahneman, 2011).

Handling complexity is problematic because it can be characterised at the issue level, and within the students' unfolded and situated discourse. Byhring and Knain (2016) suggest that complexity is construed by students as acts of meaning, through the interplay between the demands of the situation, and the dispositions of the individual and their personal experience with similar situations. The act of meaning is a 'transformation of experiences' into meanings according to the interests of the individual, resources available and the individual's competence.

Our findings suggest that these students struggled to cope with the complex nature of the climate change issue, due to their lack of basic knowledge, realisation that their knowledge was flawed, and lack of scepticism when presented with evidence. In terms of how students problematised the issue of climate change, it was clear that while they understood the complexity of climate change, engagement with the debate often resulted in simplification of the issues and perspectives to cope with the complexity. This reductionist approach is to be expected given their prior science educational experience. This lack of online discussion and challenge of one another's thinking suggests that perhaps more thought is required as to the construction of online tasks that scaffold and encourage greater discussion.

Educational relevance of the climate change discussion.

The issue of climate change was presented to the students as an issue of sustainability and was placed first in the sequence of issues to provide a link between the previous Sustainable Development module and the Science in Society module. However, as previously stated, seven students suggested that the climate change issue should be dropped to provide more time for "more important issues in the module" presumably the issues of the use of animals in medical research or the embryonic stem cell issue. While the students' perspective in this regard is important and requires further exploration, this suggestion is worrying. Firstly, because it seems to suggest that (at least for these students) climate change and global warming is somehow less important than the use of animals in medical research and embryonic stem cell research issues also studied in the module.

Secondly, it highlights that the many skills and competences introduced during the Climate Change sessions regarding rational scepticism, looking for bias within evidence presented, coping with complexity and dealing with competing arguments using Toulmin's argumentation pattern technique are somehow less important or are possibly lost on these students. This begs the question *do these students realise the importance of acquiring such competencies and skills for their ongoing engagement with these other issues?* Thirdly, with respect to values, what does such a suggestion say about these students' attitudes and beliefs about climate change and the issue of sustainability?

Finally as ITE tutors, this suggests a need to acknowledge that developing student teachers' ability to engage critically with complex and dynamic issues, particularly if Learning for Sustainability is to make an impact, requires ITE moving away from the narrow view of only developing ITE students ability to cope in the classroom, towards a more holistic view developing critical professionals and responsible citizens able to cope in an increasingly complex, dynamic and messy world. Arguably the former leads our students to chart a pathway through their initial teacher education that narrowly focuses on practice, and leads to avoidance of 'messier' topics in assignments as illustrated above. Consequently, perpetuating a habit of 'compliance' and illustrating how uncomfortable students are when they engage with such ill-defined issues.

VALUES.

The United Nations Millennium Declaration outlines 60 pledges (that eventually evolved to form 8 development goals) for peace; development; the environment; human rights; the vulnerable, hungry, and poor and is founded on a core set of values (Leiserowitz, Kates and Parris, 2006). These include - Freedom, Equality, Solidarity, Tolerance, Respect for nature, and Shared Responsibility (UNGA, 2000). While individuals (and societies) may support and espouse such abstract values as economic growth, security, freedom, and environmental protection in isolation, it must be recognised that in the realm of

decision-making, these values are often incommensurate, with trade-offs having to be made. In terms of the climate change debate, cognisance of individual's values is important since it is often where most disagreements arise.

Our research raises some interesting points regarding how ITE Primary Education students understand '*values*' in general and how they problematise the issue of climate change. The fact that a significant proportion of students in our sample struggled to articulate their understanding of values is worrying and indicates the need to provide real world examples of how different values manifest themselves within behaviour at the individual, local and global level. In addition, there is a need to make explicit how our personal values relate to, and at time might conflict with the values espoused by the profession with respect to the GTCS Standards for Registration i.e. social justice, integrity, trust and respect, and professional commitment (GTCS, 2012).

Most students in the case study took the view that climate change was a moral and ethical problem that moved beyond their understanding of science towards the need to make good life choices. While it is correct to suggest that climate change has a moral and ethical dimension, the more interesting question is how teachers harness this aspect pedagogically to encourage our students to become active rather than passive participants within the democratic process?

IMPLICATIONS FOR PEDAGOGY IN ITE.

Findings from this case study indicate two clear areas for consideration in ITE programme design: development of academic habits of mind (particularly rational scepticism) and action competence; and consideration of epistemological perspectives inherent in the pedagogies used in ITE.

The former might be somewhat less challenging to integrate than the latter. By evaluating the opportunities students must develop open-mindedness, rational scepticism, self-reflection and metacognition, practitioners can plan for progression across programmes to reflect this need, drawing on theory to inform this. Approaches are generally, interpretivist in nature and include the development and assessment of affective outcomes to encourage engagement (Shepherd, 2008); adoption of a systems approach that allows for students to question key concepts and have opportunities to develop metacognition and to reflect on the foundations of those thoughts (Sandri, 2013). Owens et al (2015) offer some suggestions from field schools, that might be adopted by more mainstream HE institutions: immersion and continuity in the issues; giving students direct, active learning experiences; create/provide a supportive learning community; use place-based learning, story and examples to embed learning. Furthermore, Barrett (2006) suggests viewing action competence as knowledge addressing "visions, causes effects and possible responses" (p.507). Making it palatable to traditionalist views in Higher Education.

These views highlight the second proposal, which has plagued education for some time: how can educators position themselves as both the disseminator of (key forms of) knowledge, and the challenger to the very structure of knowing that privileges the view that knowledge is somewhat fixed and neutral (Barrett, 2006). As educators who have a responsibility to stay abreast of developments in our fields, it seems easy for us to slip into this conflict. Further, Shepherd (2008) questions whether we can separate students' cognitive learning about sustainability from the development of values that occur during their time in university, whilst Warbuton (2003) argues for the necessity of deep learning in LfS, with focus on understanding and not just assessment.

The current study indicates that students were most influenced by commonly held attitudes and beliefs as the realm of probable knowledge and popular opinion. Yet, the problem was that they accepted this as true and certain knowledge. However, teachers require a degree of practical wisdom when dealing with complex socio-scientific issues when one intends to arrive at defensible value-laden decisions and is useful when analysing and understanding decision-making about a variety of science-related events and issues. This also includes an understanding of the political, moral, and ethical aspects of such issues. The students in this study demonstrated a lack of this.

A broader issue lies in the neglect of practical wisdom in ITE programmes and in education beyond Primary generally. A shift in the Higher Education status quo is needed to communicate the emerging view that knowledge not only has an inherent degree of change and variability given the tentative nature of scientific knowledge, but that in many of these complex issues (such as Climate Change) the only true and certain knowledge seems to be that knowledge will change, often rapidly.

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