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Informed opinions? : Understanding sustainability issues through socioscientific reasoning and teaching about climate change through organic pedagogy

Author(s): Athena Vongalis-Macrow* (submitting/presenting)

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The complexity of scientific dilemmas such as genetic cloning, climate change and stem cell research exemplify the infiltration of scientific issues into the social lives of all citizens. However, how people make decisions about scientific issues is a new area of research because there is greater demand for conceptual understanding of complex material and much of this understanding of information is contingent on social and cultural knowledge. Scientific understanding involves comprehension of scientific ideas from the ‘frontiers’ of science. Much of this information and its understanding is made available through media, schools, teachers, politicians, internet to name a few sources. The question arises about how people evaluate and make sense of this information and whether most individuals are not adequately prepared to make informed decision about scientific issues as this involves understanding complex social and scientific issues. The research paper presents preliminary results examining the link between conceptual understanding of sustainability, as a complex scientific concept, and the reasoning patterns in opinion making about sustainability. The study was undertaken with groups of undergraduate teacher educators to show how these prospective teachers used their own knowledge of sustainability, sustainability concepts, such as climate change, to form opinions about sustainability when given particular scenarios. The paper will present a discussion of some of the issues concerning socioscientific argumentation amongst pre-service student teachers.

Socio-scientific research is relatively new in the field of science displacing ideas that science education need only to focus on conceptual understandings of science content knowledge (Jenkins, 1990, Laugksch,2000). Rather, socio-scientific reasoning concedes that understanding of scientific context is often contextually constructed through social and cultural values and beliefs systems. Understanding scientific knowledge, as the special concern of educators, needs to take account of prevailing social and cultural milieu in order to contextualize scientific knowledge within the broader understandings and values.

Contact Details: Dr Athena Vongalis-Macrow, Deakin University, Melbourne Australia. Email: Athena.vongalis-macrow@deakin.edu.au
Underpinning the concern about scientific understanding is how this knowledge transfers to new contexts and situations. As many social and cultural developments are premised on new scientific knowledge which has a deep impact on our daily life. For example, stem cell research has the capacity to extend life, however it is also has led to robust ethical debates about the origins of the stem cells and the way they should or should not be used. This is one example of where scientific knowledge has necessitated a review of social values. Such an example captures the essence of this research and the presentation. It shows that in order to make decisions about the merits of the science, the decision maker needs to have a grasp of the science as well as an understanding of social and cultural debates. This research investigates what this socio-scientific reasoning process may look like and the implications for educators.

**Knowledge transfer research**

Researchers such as Sadler (2003) concluded that scientific learning “infrequently applied in all but the most similar circumstances” (Sadler, 2003, p528.) In their research, Sadler et al (2004) asked student participants to demonstrate their understanding of global warming as presented in two media articles. I do not have an exact copy of the media articles, but they included a diagram of the science behind global warming followed by explanations of the diagrams and the implications for earth’s temperature. The results showed that only 47% of students were able to understand and explain the use of data in the global warming articles. Of the student cohort, 53 percent of students were deemed to have a very basic understanding of the data. Further research investigating the transference of knowledge into decision making was also interesting. Studies by (Detterman, 1993, Haskell, 2001) also point to students lacking skills and strategies in tranfering their scientific understandings into informed decision making about a scientific issue.

Fleming (1986) investigated the scientific reasoning of high school students through semi structured interviews by providing students with scenarios and asking how they would respond and why. When the decision making process was deconstructed, the research reached conclusion that constructing opinions about scientific problems was mainly a process of drawing on experiential knowledge, that is, the individual student’s ideas about themselves and their experiences. Fleming conducted a follow up study to show the processes of scientific reasoning. He concluded that when asked a technical question, 91 percent of students were able to incorporate scientific terminology into their responses. However, when asked to assert their position with regards to a scientific issue, very few students drew on their scientific knowledge as a way to justify and articulate their opinions. What these two studies show is what appears as a disjuncture between scientific knowledge and how this knowledge is used to create opinions about scientific issues.

Given that the prevalence of scientific issues in the public discourse and these issues often encompass complex social dilemmas, the way that people form opinions and how informed these opinions and beliefs are informed by scientific knowledge has
implications for how society deals social ramifications of technological and scientific advances. Individuals make use of scientific content knowledge for argumentation associated with decision-making in relation to socioscientific issues and the social negotiation in interpreting the issue (Sadler & Fowler, 2006).

Dawson and Schibeci (2003) identified the importance of providing students with scientific background behind socio-scientific issues in order to strengthen the articulation and justifications of opinions and claims. The predominant rationale is that understanding the science content should go hand in hand with understanding the social context in which that content will have influence. It is therefore, essential for teachers to be able to teach both science and social cultural understanding of that science (Chamber and Zeidler (2004). The implications are that scientific literacy incorporates a social and cultural element and is a key literacy for the 21st century. Informed decision making is considered to be an important outcome of science education (Bybee, 1993; Fensham, 1988; Malcom 1987; Yager 1993).

One of the most pressing social and scientific problems of our time is climate change and sustainability. This problem has all the elements of socio-scientific problem. There is much conjecture about the science, which is both complex and difficult. In addition, the issue of sustainability is a contested global issue involving politics, economics and social values. In other words the issue of sustainability is a complex socio-scientific issue. The understanding of environmental issues requires that both scientific knowledge and social ramifications of that knowledge evolve simultaneously so that decision making is a synthesis of science and social understandings. Achieving a greater understanding of how social scientific arguments are formed and the way that social, scientific and personal reasoning develop would help inform the inclusion of socioscientific issues into science curricula as a way to better prepare and empower students in resolving complex scientific dilemmas. For this reason, the research investigating the socio-scientific reasoning of pre-service teachers focused on sustainability. The research project attempted to:

- identify how well the science of sustainability is understood
- identify how socioscientific arguments about sustainability issues are constructed
- evaluate the information in arguments pertaining to scientific understandings of sustainability and socioscientific factors informing decision making
- inform recommendations about incorporating socioscientific argumentation into science curriculum

**Preliminary Results**

A survey instrument was developed to gauge students’ responses to questions about students’ scientific understanding of key concepts relevant to sustainability such as climate change and greenhouse emissions. One hundred and ninety one students participated in the survey, although not all opted to answer every question. Overall, the response rate was 70.7 per cent or 135 students.
This study aims to examine scientific literacy of pre-service teachers in order to investigate their informal and formal reasoning patterns when presented with a social scientific issue. People use both formal and informal reasoning to clarify controversial scientific and social dilemmas. By using socio scientific argumentation the study is concerned with how pre-service teachers make and justify their opinions about complex social scientific reasons. The study outcomes seeks to inform practitioners about contextualised scientific literacy by providing educators with recommendations for incorporating socio scientific decision making in science based curricula.

Knowledge about the key concepts of climate change

Table 1 shows pre-service teachers’ responses when asked to identify green house gases. The participants were given a list of gases to choose and they were able to choose more than one gas. From the 152 responses who answered the question over 44 percent included all the gases. This shows that over 44 percent of pre-service teachers have some sort of misunderstanding about green house gases.

Table 1: Pre-service teachers response to meaning of green house gases

<table>
<thead>
<tr>
<th>What are greenhouse gases?</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon dioxide</td>
<td>42.10</td>
<td>64</td>
</tr>
<tr>
<td>methane</td>
<td>39.50</td>
<td>60</td>
</tr>
<tr>
<td>oxides of nitrogen</td>
<td>19.70</td>
<td>30</td>
</tr>
<tr>
<td>chlorofluoro carbons (CFCs)</td>
<td>37.50</td>
<td>57</td>
</tr>
<tr>
<td>ozone</td>
<td>7.20</td>
<td>11</td>
</tr>
<tr>
<td>all of the above</td>
<td>44.70</td>
<td>68</td>
</tr>
<tr>
<td>answered question</td>
<td></td>
<td>152</td>
</tr>
<tr>
<td>skipped question</td>
<td></td>
<td>39</td>
</tr>
</tbody>
</table>

The same cohort of 191 pre-service teachers was asked the meaning of climate change. The term climate change is used extensively in school curriculum and also has become a vernacular for sustainability in environmental studies, media and popular culture. It is a well recognised term and it was included in the survey for these reasons. The results follow.

Table 2: Pre-service teachers responses to meaning of climate change

<table>
<thead>
<tr>
<th>Do you think climate change means</th>
<th>Response Percent</th>
<th>Response Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>change in average</td>
<td>65.40</td>
<td>102</td>
</tr>
</tbody>
</table>
The results show a slightly more comprehensive understanding of climate change. Over 65 percent of respondents were able to answer correctly. However, over 46 percent answered that climate change means global warming, which although the concepts are related, they are not interchangeable. This points to a major misunderstanding of climate change. Over 31 percent of students showed a misunderstanding of climate change and as in table 1, nearly 23 percent of students opted not to answer. From these two basic indicators of working knowledge and understand of two key concepts relevant to sustainability, the results show a lack of sound knowledge about climate change and greenhouse gases. Of course, there are limitations in assuming that pre-service teachers lack knowledge about these two concepts because knowledge can be demonstrated in a variety of ways, one of which is defining and explaining. However, these two tables show that pre-service teachers’ knowledge about sustainability can be improved.

Table 3: Pre-service teachers opinions about issues related to climate change

<table>
<thead>
<tr>
<th>Issue</th>
<th>Per cent of responses in Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Governments should do more</td>
<td>94.8</td>
</tr>
<tr>
<td>Industrial practices have to change</td>
<td>93.5</td>
</tr>
<tr>
<td>I have a role to play</td>
<td>92.2</td>
</tr>
<tr>
<td>Low carbon activities are better</td>
<td>85.1</td>
</tr>
<tr>
<td>Drought will increase</td>
<td>79.9</td>
</tr>
<tr>
<td>Polar caps will melt</td>
<td>78.6</td>
</tr>
<tr>
<td>CC more important than economic considerations</td>
<td>78.4</td>
</tr>
<tr>
<td>Governments should set the agenda for CC</td>
<td>76.7</td>
</tr>
<tr>
<td>Sea levels will rise</td>
<td>74.7</td>
</tr>
<tr>
<td>Global warming is the most important issue</td>
<td>66.9</td>
</tr>
<tr>
<td>Eco systems will collapse</td>
<td>66.3</td>
</tr>
<tr>
<td>CC is the most important issue</td>
<td>66.3</td>
</tr>
<tr>
<td>Recycling is the best option</td>
<td>63.7</td>
</tr>
<tr>
<td>Scientific knowledge about GHG well established</td>
<td>61.7</td>
</tr>
<tr>
<td>CC is more important than social considerations</td>
<td>56.5</td>
</tr>
</tbody>
</table>
When examining the very strong beliefs of prospective teachers, (90% or higher) three items are concerned with government actions, industry actions and the relations of the self towards action and change. These items suggest the firmly held beliefs critical of both government and industry. This indicates a suspension of a nationalist alignment to the local practices, because both government and industry are nationally based endeavors and thus constitute a national interest. These prospective teachers are highly critical of these national interests. The conceptualization of self within actions plans for changing current practices towards climate change, the prospective teachers strongly situate their professional role as an active agent immersed within the climate change agendas. In another survey item, when pressed about their role in reducing climate change, 90% of the surveyed teachers strongly agreed that they had a role to play in creating solutions. There appears consensus around the active role for teachers to address issues such as climate change.

The results affirm the beliefs embedded in sustainability pedagogy which suggests that the responsibility is not the domain of one discipline, but the responsibility of all teachers. For example, in the Pedagogy of Indignation (2004), Friere wrote, “Ecology has gained tremendous importance at the end of this century. It must be present in any educational practice of a radical, critical, and liberating nature” Friere (2004:47). Certainly, to new, cosmopolitan teachers, the importance of environmental sustainability creates an interdisciplinary professional identity in which all teachers have responsibility. From Friere’s philosophical advocacy for more radical and liberating ecology centred practice, current pedagogical reforms embed sustainability education into a broader framework of learning. Most recently, Huey-li Li (2006) in promoting a new ‘terrestrial’ pedagogy stated that “…the recent 2002 World Summit on Sustainable Development asserted that the pursuit of sustainable development must go beyond economic progress to include “peace, economic and social justice, concern for future generations and nature itself.” Huey-li Li (2006:88). The results echo these comments in identifying that prospective teachers regard themselves as part of the creative solution to environmental issues. Pre-service teachers are aware that knowledge about the environment and sustainability blurs disciplinary boundaries and has something to do with practices, values and beliefs beyond the classroom and beyond science. Perhaps in order to give more authority to pre-service teachers in their understanding of social and economic aspects of environmental education, teacher education program need to be inclusive of government policy and the critique of government policy. This would enable new teacher to have not only a suspicion of what may be in government policy, but also, have
a greater understanding of political content of environmental policy and how this may impinge of education, practice and reform.

**Reasoning Patterns in forming opinions**

Thus far, the research results illustrate that overall, the students have a tenuous understanding of fundamental climate change concepts. In contrast with their understanding of basic science explaining climate change, the students have very strong views about the role of government, industry and the economy as it pertains to climate change. Part of the strongly held views by student teachers is to also question or at least have some reservation about the scientific evidence that purports to explain climate change as a certain phenomenon. This poses questions about how the participants can hold very strong view about climate change and the role of industry, government and the economy while casting doubt on the science and demonstrating a shaky understanding of basic concepts? Of interest is how the students reasoned their opinions. Students were placed in twenty groups, ranging from 3 or more members and each group was given time to consider the scenario and then come up with a group response. The groups response is the considered opinion of the group and attempts to capture the agreed upon argumentation.

Responses to question one: Climate change (CC) and global warming (GW) are more important than economic and social considerations

In question one, students were asked to assess the relative importance of CC and GW against the importance of the economy and social issues. The reasoning pattern in this kind of question assesses the relative risk in prioritizing one element at the expense of the other. Most of the twenty groups reasoned that a collapse in the economy would be more risky than climate change. For example,

*Economy is more important because without a good economy we wouldn’t be able to change or help our ways to deal with climate change and global warming.*

*Social Issues and economic issues are more important in the now whereas climate change and global warming are more important in the future.*

Overall, the majority of the groups, understood the systemic interrelatedness of climate change and the economy. There appears a systemic reasoning pattern (SRP) which focuses on explaining connections. The conclusions drawn is that the social and economic conditions are inexorably linked and thus of equal importance.

*They are inter-related. Without a strong economy we can't change global warming and climate change issues. We can't lose sight of all the issues in the world, just to fight climate change and global warming. Climate change and global warming are social considerations.*

*The three are equally important. None is more important than the other. Without a stable economy, the country has the potential to fall in economic recession.*
One factor in the relative risk argumentation is the question of time. The arguments propose that the economy is a more short term risk, thus, can impact on everyone quickly, while climate change requires a systematic and behavioural change over time.

*We think of social and economical considerations as a short term issue whereas climate change and global warming are long term changes that cannot be fixed now.*

*Climate change and Global warming are things that happened over time and need to be dealt with through change in behavior, however society needs to deal with the ongoing economic and social issues effecting us now, for example rising interest rates and housing, racial discrimination and resulting poverty etc.*

*Overall, in demonstrating their reasoning about the relative risk posed by climate change, one key factor in the understanding and reasoning process of climate change is the factor of time. Whether an issue has a short term or long term change impact will influence the assessment of risk and the relative importance in constructing opinions.*

CC and GW are the most important issue of our times hence we and governments should act effectively to solve this issue.

*Question: Climate change (CC) and global warming (GW) are more important than economic and social considerations.*

This question asked the student teachers to assess the relative importance of CC and GW against the importance of the economy and social issues. There is a moral element in the reasoning pattern in this kind of question because it assesses the relative risk in prioritizing one element at the expense of the other. It addresses the common concern with climate change that it is an intangible concern and thus other more visible social issues are generally seen as more important and relevant (Pruneau et al, 2001). Reviewing the opinions of the twenty groups, it becomes clear that the majority of the groups reasoned that a collapse in the economy would be more risky than climate change.

For example,

*Economy is more important because without a good economy we wouldn’t be able to change or help our ways to deal with climate change and global warming.*

*Social issues and economic issues are more important in the now whereas climate change and global warming are more important in the future.*

The majority of the groups understood the systemic interrelatedness of climate change and the economy and explaining the systemic connections was key in the reasoning showing that both social and economic conditions and climate change are inexorably linked and thus of equal importance. However, in assessing the relative risk, the concept of time was critical. The imminence of economic collapse, “*We can’t lose sight of all the issues in the world, just to fight climate change and global warming*”, and the scale of impeding threat was a factor in the reasoning about importance. The arguments propose that the economy is a more short term risk, thus, can impact on everyone quickly, while
climate change requires a systematic and behavioural change over time. The students stated that “We think of social and economical considerations as a short term issue whereas climate change and global warming are long term changes that cannot be fixed now.” Another groups reasoned,

Climate change and Global warming are things that happened over time and need to be dealt with through change in behavior, however society needs to deal with the ongoing economic and social issues effecting us now, for example rising interest rates and housing, racial discrimination and resulting poverty etc.

Overall, in demonstrating their reasoning about the relative risk posed by climate change, one factor key in the understanding and reasoning process of climate change is the factor of time. Whether an issue has a short-term or long-term change impact and how this is perceived by students, will influence the assessment of risk and the relative importance of the scientific evidence. In his response to climate change, Giddens (2009) considers it a collective problem which presents humanity with a paradox. Because climate change is intangible, not immediate and not visible to everyday life, the very real threat is pushed to the back on people’s mind. The paradox is that the nature of the threat of climate change is also the thing that makes it so difficult to confront and by not confronting it, we create greater problems.

Futures education specifically focuses on immanent perspectives and problematizing about the future. Pedagogy, which helps students reflect on their possible futures and hypothesize happenings in distinct situations, is of particular value in dealing with the ‘intangibility’ of climate change. Since the notion of time is a critical factor in moral reasoning and decision-making, inviting students to predict and imagine, thus confronting the notion of time as a variable in different situations, helps to bring future reflections into the everyday. Futures pedagogies dealing with the notion of time and its relativity in inciting concern and action, builds on the systemic understandings of student teachers. They have an understanding of the systemic interrelatedness of social and economic systems, and how they intersect with climate change. Pedagogy which promotes systemic awareness and systemic change helps to construct more tangible ideas about the future as a continuum of the present and past. The continuum of human change and system change is not only a concern for history disciplines, but very real phenomena of humanity.

CC and GW are the most important issue of our times hence we and governments should act effectively to solve this issue.

What governments should do also requires a moral judgment about the social justice role of government. For most groups the reasoning around this question begins with a phrase indicating the importance of climate change and global warming. This phrase is followed by a conditional qualifier such as ‘but’ or ‘however’, followed by statements identifying other crucial social issues. These issues ranged from global problems such as poverty, the proliferation of nuclear weapons, terrorism, famine, war and disease. For example, “To some this may be true other may have other thoughts on things that are more
important or pressing issues that are ongoing. Some may also feel that they are the most important issue of our time but they do not override the increase poverty in third world countries and equal right of peoples”. Other more local issues were also identified by some groups as equally or more important. These include including public transport, addressing drought, euthanasia and capital punishment.

The localized experiences of the participants are critical qualifiers in determining the role of government. Even though the student-teachers have expressed strong views about the leadership of government in dealing with climate change, when reasoning about the role of government and what is important, the notion of importance is qualified against the immediate needs of local issues that impact on quality of life.

Community level education can be a focal point of teaching about climate change. By focussing on local happenings, climate change is made more tangible and is part of the local experience and climate change becomes part of the local government and public discourse. The concern about the local, expressed by the student-teachers actually reflects the established link between community efforts at sustainability and addressing climate change (Pruneau et al, 2001). A pedagogy which highlights community based actions on climate change, inclusive of field work and community engagement, would help to consolidate the presence of climate change issue in the everyday.

Addressing climate change is a community issue and cannot be tackled in isolation from the wider public views. Polanyi (2009) points out that the power of science is not as a result of presenting facts, but from how society uses or legitimizes those facts. In other words, he states that what we regard as scientific evidence and how climate change is conceptualized is grounded in democracy and how that evidence is appropriated and used by the public. Climate change pedagogy is about public and education interactions to foster a critical level of public awareness in all levels of citizenry. As education looks towards its communities for educative experiences, a virtuous circle develops in which younger learners are enriched and enrich community.

**Question:** There is no need for carbon intensive economy, people should be educated and living practices need to change.

This question asked the groups to respond to the value of education in changing awareness and behavior. As expected many of the groups stressed the importance of education to change lifestyle and practices within a carbon intensive economy. The sentiments are expressed in one of the groups which states, “People should be aware of their own individual carbon footprint. Further education is required so that people become more knowledgeable and reduce their impact on the environment. Businesses should also take this preventative step”. Another group reasoned that, “We believe education is very important to help create a body of understanding how to look after our environment. Life style changes are part of creating a better environment for people to live in therefore will lead to long term impact on the earth’s environment”. There is a reasoning pattern in which education is regarded as a key component of behavioural change and that as prospective educators are aware of their capacity to influence students.
The pedagogical implications of education specifically targeting behavioural change necessitates that prospective teachers develop a repertoire of understandings of behavioural change theories which they are able to scaffold in the learning processes. In relation to climate change, the work of Fishbein (1993), specifically reasoned action, may form a theoretical underpinning for teachers’ pedagogical development. Fishbein contends that people adopt new behaviours based on their own values and attitudes towards the new behaviours and also taking into account the social expectations around the new behavior. As suggested by Pruneau et al (2001) pedagogical strategies drawing on the theory of reasoned action may involve analyzing media reports and representations of those who demonstrate the desired behavior publicly. The incorporation of media and personal narratives helps to make concrete new behaviours and how they are linked to action around climate change.

In addition, theories based on agency and social action focus on the individual within a social context and theorise how individuals and groups interact. Social action theories focus on strategies aimed at specific actions for improving our world. Agency refers to students’ responsibilities to initiate and negotiate relationships and actions (Jennings and Mills, 2009). Empowering students through positive actions and positive examples of change alleviates the tendency for those seeking climate change to procure nightmarish scenarios of what may happen if action is not taken. While the attempt at shock tactics may be a reaction to inertia around climate change, this can also foster a nihilistic vision of the future and fuel cynicism and futility often felt by young people with respect to climate change and actions (Patchen, 2006). Giddens (2009) sums up the need for positive action thus,

“In combating climate change, we should look to make a Gestalt switch from negative to positive, creating a vision for the future that has a compelling appeal...the focus should be on goals, and the means of reaching them, that citizens can readily understand and accept” (pp.2).

Conclusion

By asking student-teachers a range of questions about climate change, what became evident is the predominant socialized understanding of climate change as the prevalent way that student-teachers reflect and talk about climate change. Rather than seeing this as a deficit in student-teacher knowledge, that is a less than convincing understanding of scientific concepts related to climate change, the line of reasoning was to create an organic pedagogy from this premise.

Underpinning the suggestions for an organic pedagogy is a body of research which asserts the necessity to contextualize and situation socio-scientific problems (Sadler, 2003). The unique issues presented by climate change, not only affirm the socio-scientific contextualization but also necessitate that since each socio-scientific issue is singular and specific, then each needs different ways to address the learning associated
with the issue. Based on this premise, and incorporating the data from the student-teacher research, new teaching strategies have been suggested. These strategies resist the deficit model of teacher training which insists that knowledge content forms the basis of quality teaching, rather the suggested pedagogical strategies embrace the student-teachers’ strengths and attitudes as a basis for teaching about climate change.

Only 65 percent of student-teachers were able to identify the meaning of climate change. However, student-teachers strongly agreed with the authority of scientists to represent fonts of accurate scientific information. In this case, while they may not be able to show their own scientific knowledge, they have capacity to source and value information, which can compensate for their own shortcomings. There is a pragmatic knowledge making at work in which information is not only that which is used to create knowledge but information is also a form of know-how in which students are able to identify those who represent the source of knowledge as anchors for their understanding and opinions.

By assessing how prospective teachers talk about climate change, the study emphasized the dialogic interactions and identified these as critical in teaching about climate change. Incorporating elements of future education, social action and agency theories as well as inquiry based learning are strategies compatible with social and political literacy of student-teachers. The data shows that they are firm believers in the power of education and in critiquing social and political decisions around climate change. The positivity demonstrated by student teachers to question government and economic policy, to show some skepticism about scientific evidence, to understand the systemic relatedness of climate change and other socio-economic issues and to see education and their teaching as a positive source of empowerment and change are important teacher attributes to build upon. Rather than focusing on what student-teachers don’t know, by focusing on what they bring to teaching about climate change, the aim is to harness their attitudes and desires as a way to draw attention and address the paradox of climate change. Finally, the emphasis on social actions presents a way for educators to deal with the paradox.

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