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GLOBAL WARMING IN SCIENCE CURRICULUM

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Abstract

A design-based research on 12th-grade students' engagement on global warming is reported. An interdisciplinary teaching sequence has been designed within a model of socioscientific controversies ecology. It integrated an initiation to nonviolent communication, expertise of thesis on global warming and a simulation of a citizens' conference. Students identified arguments on the global warming issue in scientific publications or contradictory expertise and questioned scientific knowledge and its social dimension. Contribution of this empirical study to integration of socioscientific issues in the secondary education science curriculum and potential connections between environmental, science and citizenship curricula are discussed.

Keywords: Global warming; science education; curriculum development; interdiciplinary education

1. Introduction

In France, recent school reforms have focused on the development of a "common base of competencies"[†] and on citizenship education. Environmental education is also re-affirmed as a key-element to form future citizens able to live with others, to respect environment and future generations in the framework of sustainable development. Activities dedicated to develop citizenship education and environmental education should be present during all primary and secondary education and all subject matters are asked to contribute to these activities. Curricular organizations proposed by institutional reforms to fulfil those educations (to citizenship and to environment) raise crucial questions for education research.

For instance, in the French middle school curriculum (6th to 9th grades), six "convergence themes" have been introduced on energy, environment and sustainable

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development, climate, statistics, health and security. The educational aims linked to themes of theses stressed the importance to develop scientific literacy necessary to citizens' participation to social stakes and informed, argued and reflexive decision-making. Teachers are asked to "contribute together to learning" about these themes. What can be the curricular organizations for the teaching of such "convergence themes"? Science subject matters teaching? Curricular multidisciplinary or interdisciplinary activities? Extra-curricular activities? In the same vein of Audigier (2000) and Davies (2004) interrogations about citizenship education in light with its neglect in history and contested nature, the potential curriculum of the "convergence themes" can be questioned: to be everywhere, may there be nowhere?

In the French high-school (10^{th} to 12^{th} grades), socioscientific issues have been introduced in science curricula (biotechnology, global warming, energy, water) with the educational aims to develop and exercise citizenship, critical thinking on social problems and awareness of ethical considerations. Social stakes associated to these controversial socioscientific issues should be explicitly addressed in class and activities focused on argumentation and debates are strongly recommended.

Science education research on socioscientific issues has show science teachers difficulties when dealing with SSI in class (Albe & Ruel, 2008; Levinson, 2004; Oulton et *al.*, 2001). Such teaching challenges their representations of science and science teaching, questions the available resources and raises professional dilemmas on a ethical level: for instance how to both respect the individual expressions of opinions of everyone in class and some specific values in a democratic society (Oulton, Dillon & Grace, 2004 have for instance underlined that perfect balance is impossible and in some cases as racism undesirable)? How to practice what teachers consider a "value-free" teaching while in the meantime they are conscious that they hold strong political or ethical positions on the issue?

Socioscientific issues teaching may therefore take various forms between two extremes positions: on one hand, an exploration of scientific concepts involved and its citizenship education aim limited and on another hand, a mean to develop argumentative competencies without connections of scientific controversies. In this educational context, global warming is often considered as offering a privileged theme for both environmental education and a science education contributing to citizenship education as in the recent past it has become a major issue of concern at social, political, economic and scientific levels. In line with the recent reforms, classroom activities on global warming can be located in a science curriculum or considered as interdisciplinary or extra-curricular activities.

On an educational research theoretical viewpoint, global warming can be apprehended as a socioscientific issue and as a model to explore and discuss connections between environmental education and science education. In line with previous approaches such as the STSE research field, the SSI movement offers a way to explore the nature of science and the interdependence of science and society (Sadler, 2004). Moreover, the SSI movement focuses on democratizing science in society (Driver et *al.*, 2000; Kolstø, 2001). It then occupies a

central role in the promotion of scientific literacy (Sadler and Zeidler, 2005) and is aimed to contribute to citizenship education (Oulton, Dillon & Grace, 2004). Another research suggests that properly designed curriculum can improve both science understanding and argumentation (Lewis & Leach, 2006).

2. Theoretical orientations

A theory-oriented initial design on global warming has been developed within the framework of design-based research (Cobb *et al.*, 2003,) within a model of socioscientific controversies ecology (Albe, 2007). According to the design-based research principles, this model is humble, local and contingent, and would be revised along an iterative process (The design-based research collective, 2003).

The model focuses on dispositions to study a socioscientific controversy by three dimensions (Figure 1).

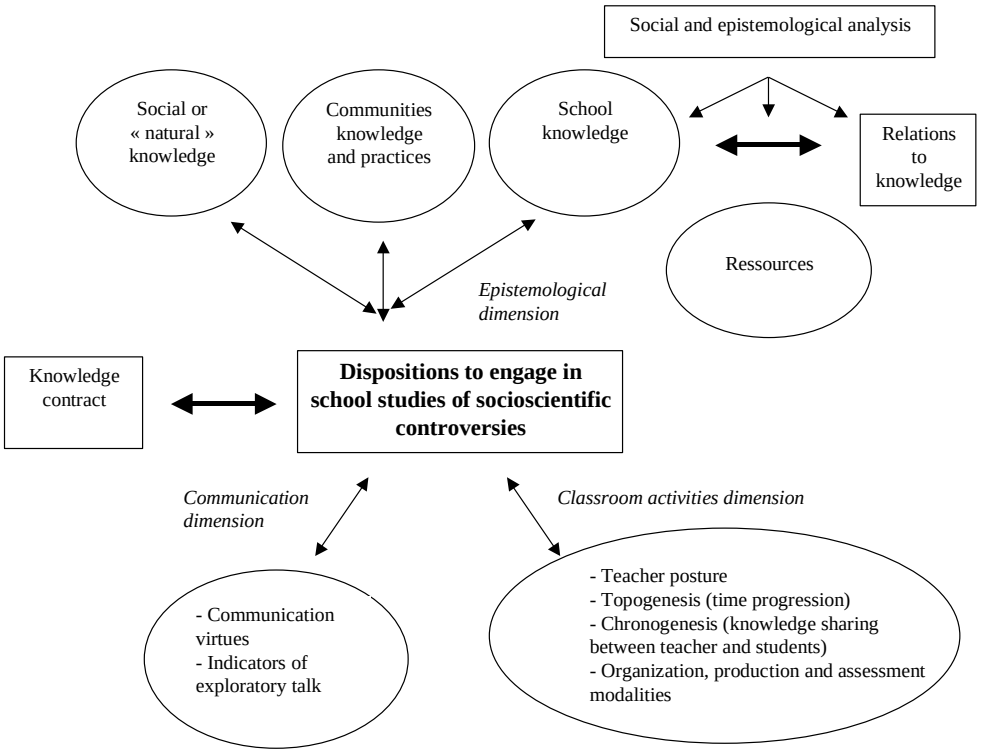

Figure 1: Model of socioscientific controversies ecology

An epistemological dimension accounts for the mobilization of knowledge and practices taken as references when dealing with a socioscientific controversy, as these may be diverse and diversely legitimated by the various social groups involved (scientists, citizens, NGO, journalists, companies, unions, engineers, politicians ...). There is no unique answer that could close the controversy and science cannot provide "the truth". When dealing with socioscientific controversies, where knowledge is "in the making" in communities with different theoretical, methodological, practical, instrumental frameworks, erasing knowledge elaboration processes would prevent potentialities to develop an understanding of such controversies. A social and epistemological analysis of a socioscientific controversy confronts to scientific and technologic enterprise, invites to identify the sociopolitical context of different positions in debate and to explore background and uses of arguments. Such an analysis involves a dimension of critique and, in the interventionist perspective of the model, constitutes a first stage to design teaching activities. It also allows to study, in the analytical perspective of the model, how the diversity of knowledge and practices involved in socioscientific controversies is taken into account in class.

Another dimension of the model concerns classroom activities. Literature has shown constraints for teachers related to the teaching of socioscientific controversies and it has been suggested that teachers may act as consultants, counselors, debate animators… A major element to study dispositions to engage in socioscientific controversies classroom activities therefore concerns teachers' role or posture.

Finally, a communication dimension of the model accounts for students' ideas and discourse confrontations when dealing in class with socioscientific controversies, in reference to the necessary dispositions for discussing a controversial issue proposed by Levinson (2006) with the notion of "Communicative virtues" (Burbules & Rice, 1991, cited in Levinson, 2006) and the notion of « exploratory talk » of Mercer (1996).

3. Interdisciplinary sequence on global warming

The teaching sequence co-elaborated consisted of five teaching sessions and was conducted during the second semester of the 2007-2008 academic year (Table 1).

Table 1: Interdisciplinary teaching sequence on global warming

TEACHING SESSSIONS	DATES	DURATION
1. Initiation to non-violent communication : principles and methods	25th of January 2008	7 H 30
2. Initiation to non-violent communication : practice and debates	29th of January 2008	3 H
3. Film *"An inconvenient truth"* and debate	11th of March 2008	2H
4. Simulation of a citizens conference on global warming	1st of April 2008	2H
5. Analysis session	29th of April 2008	2H

The teaching session integrated an initiation to nonviolent communication, according to our literature review on SSI that showed that when dealing with SSI emotions are involved and conflicts between students may arise. During whole class debates or group works, students often have difficulties in regulating their interactions on a social plane. The two first sessions of the teaching sessions were dedicated to students learning on non-violent principles (Rosemberg, 1999) with focus on listening and empathy, methods with four elements (observation, feeling, need, demand) and practices during debates on themes that were co-decided between students and the interdisciplinary research team (drugs, sport, GMO).

During third session, the film *"An inconvenient truth"* by David Guggenheim with Al Gore was showed to students and followed by a short whole class debate were students discussed the multiple forms of the film (science documentary, political act, ecologist manifesto, self-biography, drama.) and various roles of Al Gore (actor, politician, lonely man, environment specialist, polluting big car driver, friend, father.). Students also stressed the importance to be sensitive to environmental issues and the positive role of the film regarding this aspect.

The fourth session was focused on a simulation of a citizens' conference on global warming. Students were asked to formulate, at the end of the session, four recommendations to politicians concerning energy choices in the context of global warming. This situation was rooted in the French context at the present time of the teaching session, where political decisions related to energy choices were discussed. This corresponded to a choice of the interdisciplinary research team to confront students to authentic issues. Students were asked to

play different roles: two experts had to present the thesis of IEEC on global warming[‡], two experts had to present alternative thesis on climate[§], seven students composed the citizens panel[**] and had to question experts, two non-violent communication regulators[††] had to intervene during discussions to help the development of non-violent interactions and two chairwomen were in charge of note taking and conference synthesis at the end of the session. Roles were attributed to students by the interdisciplinary research team in order to facilitate students' engagement in the activity and argumentation on a documented base rather than on inter-personal relationships. To inform their discussions and prepare the citizens conference, specific documents were provided to students. Citizens-students had to discuss in small group work questions to ask to the two groups of experts. Non-violent communication regulators had to write down the elements of the non-violent communication framework they previously studied. Students playing the role of experts had documents that presented global warming controversy. These documents were constructed by the interdisciplinary research team from a social and epistemological analysis of the issue of global warming in science education research (Albe, 2008) within theoretical and methodological frameworks of science studies (Latour, 2007; Pestre, 2006). Documents respected an ideological balance of the arguments and similar form. In small groups, students studied these documents to prepare their interventions during the simulation of a citizens' conference (15 min). The simulation of the citizens' conference was organized as follows: two experts presented to the whole class the thesis of IEEC on global warming (5 min), two experts presented alternative thesis on climate (5 min) and citizens panel, experts, non-violent communication regulators and chairwomen debated during 15 min. After the debate, students wrote specific reports according to their roles (10 min). Students acting as experts had to write down a summary of the main ideas they presented to the citizens' panel and to precise their sources. Non-violent communication regulators had to write down a summary of their interventions during the debate and to prepare the animation of a collective debriefing on the activity of simulation of citizens' conference.

2. Method

In this study, a learning ecology of socioscientific controversial issues is aimed to be documented as a case study to explore the potential interrelations of science education, citizenship education and environmental education.

[‡] Referred as EG1 and EG2 in the results section for "Expert of the international Group" IECC, named "Groupe International d'Experts sur le Climat (GIEC)" in French.

[§] Referred as E1 and E2 in the results section.

[**] Referred as C1 to C7 in the results section.

[††] Referred as NVC1 and NVC2 in the results section.

2.1. Participant (subject) characteristics

In the initial design experiment reported here, a small interdisciplinary research team elaborated and conducted a sequence of teaching sessions with a small number of students (N =15) from 17- to 18- years-old specializing in technologies for agronomy and the environment. The aim is to create a small-scale version of a learning ecology so that it can be studied in depth and detail (Cobb & Steffe, 1983; Steffe & Thompson, 2000).

2.2. Data collection and analysis of the data

The interdisciplinary research team was composed of two teachers-experimenters (one philosophy teacher and one biology teacher), one trainer in non-violent communication and two science education researchers (the authors of this paper). Ongoing relationships with practitioners are sustained by the negotiation of a shared enterprise. Regular debriefing and planning sessions are the forum in which past events are interpreted and prospective events are planned for. These sessions are the sites where the intelligence of the study is generated and communicated (Cobb et al., 2003).

Citizens-students had to write down their four recommendations to politicians regarding energy choices in the context of global warming. Chairwomen wrote a synthesis of the conference. Then citizens presented to the whole class their recommendations (5 min) and a discussion followed on these recommendations, previous students' debate with reports by non-violent communication regulators and synthesis by chairwomen and the whole session with the interdisciplinary research team (20 min).

Last session was focused on analysis on the non-violent communication initiation (40 min), role of citizens regarding scientific and political issues from the case experienced on global warming (40 min), and research project with examples of students' discourse analysis for information and validation (40 min).

The research team assumed responsibility for instruction during classroom experiments (Cobb, 2000; Confrey & Lachance, 2000; Gravemeijer, 1994). Teaching sessions were both aimed as learning activities and data collection.

Data included field notes of the researchers, audio and video tapes of classroom activities (teacher-driven lessons, students group work and debates), and students small group reports and individual notes. All students' debates have been fully transcribed.

Within the framework of the model of socioscientific controversial issues ecology, several analyses were conducted on students' activities during the teaching sequence. Students' debates on global warming during a simulation of a citizens' conference were investigated through the communication dimension of the model within the framework of non-violent communication (Rosemberg, 1999). Students' interventions during debates that rely on one or more of the four elements of non-violent communication (observation,

feeling, need, demand) have been identified in the transcripts. Students' argumentation was also studied by the identification of rhetorical processes developed during debates but cannot be reported here for space reason. The epistemological dimension of the model was also explored. Knowledge students rely on during debates have been identified and classified according to the three "knowledge genres" considered in the model: social or natural knowledge, reference knowledge, school knowledge. Finally, a retrospective analysis, local and contingent to the design, was also conducted on students' activities during the teaching sequence according to the model in order to contribute to document a learning ecology of socioscientific controversial issues.

3. Results

Students communication:

From the simulation of citizens' conference transcript, six (out of 252) interventions of non-violent communication regulators have been identified. They focused on the necessity to take into account non-violent communication (I80, NVC1), not intervene when someone else is speaking (I133, NVC2), discuss with all citizens at the address of one expert (I191, I193, I196, I209, NVC1) and used the category of judgment as defined in the observation dimension of the non-violent communication framework (I209, NVC1) in reaction to an expert intervention:

> I205 E1: … [E1 reads the document] « some scientists have indicated the absence of scientific consensus on global warming » well maybe you don't understand me you are the.. nobody lambda […]
>
> I209 NVC1: hey hey mister [to E1] there is judgment on citizens
>
> The two students acting as non-violent communication regulators during the simulation of the citizens' conference also reported this exchange on their written reports elaborated after the debate. They underlined that experts interventions included judgments on citizens and that may indicate an absence of respect. They also reported an exchange where the term "mister freeze" was used that appeared to them as a way for a citizen to ridicule an expert that presented himself as an ice specialist.

Students' knowledge:

Social or natural knowledge:

Students discussed renewable energy issues (wind and water, electric car), costs and profitability, material maintenance (wind turbines, solar devices), limits in production by developing an example of a village electrical supply, impact on landscape

for wind turbines and electrical poles. Students interventions are mainly focused on environmental considerations with care on future generations or French politics in the context of the present time of the teaching session with environment considered as a crucial issue and students evoked the oil ending and the Kyoto protocol:

"Renewable energies as you mentioned before the political elections en France last year well merely a year ago renewable energies as wind turbines solar energy hum recently we saw hum that energy can be provided by by ...wind turbines put under water with currents well every renewable energy and not oil that .. fossil fuels that will come to an end then we will not have any more then it will need anyway it will need to find a solution and hum.. solutions that are hum.. that respect in a way nature (I96, EG1)

Students discussions also focused on economical and political changes that can be consequences of global warming. In reference to the IECC thesis, students stressed that with global warming there is urgency to act and to adapt economies to new energy resources and use. This may cause individual behavior changes, new taxes and a decrease in standard of living.

(I98) EG2 "[…] it cannot be preserved the standard of living of the humble hum we will not be able to.. we cannot guarantee a standard of living as you have today but it is certain that you will have more constraints to respect the environment"

On the opposite and in reference to alternative IECC thesis, students stressed that global warming is a way to decrease standard of living, and that this process is done without democratic debate. Relationships between science and politics are once again raised on this occasion as illustrated in the following quotes:

I155, E1 : here we are ! they want to impose to you some constraints

I156, EG1 : constraints at the material level with wind turbines Mister

I157, E1 : but it is your politicians that give you your money that make them telling that

I158, EG1 : but they don't give us money but…

I159, E1 : but exactly it is a dictatorial system they want…

I160, All [noise]

I161, E1 : …they want you .. they want to settle to you it is exactly that by speaking of ecology and all that to constraint you to a way of life that maybe you don't find to be satisfactory and you hum and here we are

Reference knowledge and practices in scientific communities:

Students' interventions mainly focused on scientific practices and more rarely on scientific knowledge (CO2 confinement in ice, temperature measurements). They discussed scientists income and research funding, science and politics relationships,

scientists research activities, research institutions, nationality and selection of experts, empirical data role, necessity of agreement between scientists. For instance, on two occasions, citizen C2 asked to the students acting as experts opposed to the IEEC thesis about the institutions they work for or the origins of research funding and personal income (I13, I15). Similar questions were addressed by an expert defending alternative IEEC thesis when attributing financial interests to the IECC experts. The former answered by following the idea expressed by citizen C2 with attribution to experts defending alternative IEEC thesis of a financial link with "big polluting companies" and funding by "Mister Bush" (I179, EG1). In reaction, expert E1 refuted in several interventions a link between research funding and results by expressing that he is independent or work "totally without money" (I178, E1). An expert defending IEEC thesis when admitting to have been selected by a government refuted any financial link: "but they don't give us money" (I158, EG1).

The previous position leaded the expert E1 to try to "demonstrate" (I40, I157) an influence from politician on scientist (of the IEEC experts group here):

"A government that's political and politicians make scientists say what they want to, they use the ones they want" (I69, E1).

Several times, students' interventions focused on a description of scientist activity as aimed to "record", "analyze" and "propose solutions", particularly from students-citizens. A student acting as an expert opposed to the IEEC thesis of global warming referred to "field scientists" (I2, E1) as to weight the idea of an authentic and reliable work. He also presented such scientists as ones "that don't have to prove themselves" and that "worry to do research" by opposition as the ones that "only speak" (I244).

School knowledge:

During debate, students relied on the documents elaborated for the teaching sequence about diverse expertise and controversies on global warming, on elements from the film "An inconvenient truth" they saw during the teaching sequence and on science curriculum knowledge. From the documents, students' argumentation based upon empirical data about temperature increase in the global warming thesis and on ice dynamics and Sun influence in the alternative thesis (I2, E1). Other elements from the documents were also used in student's arguments: experts' selection (I194, I199), experts political opinions (I214), IEEC composition (I67, I190, I191), absence of researchers consensus (I207), a case of resignation from an IEEC expert (I210) and the Kyoto ratification process without the USA.

From the film, issues of human impact in greenhouse effect increase (I72, EG1; I85, C1), CO2 measurements and global temperature 0,6°C increase (I1, E1) were discussed by students during the citizens' conference. Students also discussed about renewable

energies (wind and water energy) and their potentials to replace fossil energies (I90, I94, I96, I104, I105, I107, I108, I111, I112, I113, I114) while energy sources distinction between renewable and nonrenewable and energy production by various sources are science curriculum knowledge.

4. Discussion

Students identified arguments on the global warming issue when confronted to scientific publications or contradictory expertise. A result showed that judgment category of the observation dimension of the non-violent communication framework was explicitly used by students during the citizens' conference on global warming. This may indicate that students tried to regulate their interactions on a social plane during the debate. The communication dimension of the model of socioscientific controversy ecology informs here about student's engagement. They studied global warming with a focus on argumentation and knowledge elaboration rather than developed a struggle to "win" the controversy or communication problems. Moreover, within the model of socioscientific controversy ecology, analysis of knowledge students refers to allowed to document relations to knowledge that could be encouraged in the designed teaching sequence. Knowledge students refer to showed that energy choices, standard of living and economic development issues were discussed. The political nature of global warming was identified and debated by students. They considered expertise role, its political use and citizens' position. For some students the idea that solution elaboration would be confined in the hands of experts that are linked to political sphere is viewed as a risk for democracy. Some other students-citizens asked for scientific evidence, scientists' agreement and solutions from experts that may reveal a technocratic use of expertise. Therefore, science and politics relationships were explicitly addressed by students during debate. The designed teaching sequence may contribute to their citizenship education and focuses on the educational potentialities of situations where students are encouraged not to follow others discourse, particularly from the media, and to be able to think by themselves, to (re)empower to participate to decision-making and their world configuration.

Global warming considered as a socioscientific controversy appears to be a good candidate to develop links between science education and environmental education. Several authors have underlined that a science education relevant for citizenship education would be grounded in constructivism with authentic activities used to developed meaning (Tsai, 2002) with a central concern about understanding of what science is (Levinson, 2004). Learning about science requires attention to argument in science, understanding of evidence, contemporary science, and exploring the ethics and values of science (Osborne, 2000). Our results suggest that social dimension of scientific enterprise would be explicitly addressed in class when dealing with socioscientific controversies. Students would benefit knowledge on scientific institutions, publication

practices (Kolstø et al., 2006), underlying interests of scientific developments (Driver, Leach, Millar & Scott, 1996), contexts in which science occurs such as genre, sources of funding and personal prestige or charisma roles (Bingle & Gaskell, 1994). Students should be encouraged to challenge confidence in experts (Norris, 1995). The acceptance of the social nature of knowledge does not imply an inevitable collapse into relativism.

As SSI teaching requires a greater understanding of science, it converges to environmental education willing to challenge "conventional views of science [that] are objectivist in nature, equating methodological rigor with the eradication of individual human and collective social values." (Andrew & Robottom, 2001: 777). As environmental education, introduction of SSI can also broaden science education perspective "to consider the elements of the issue that formerly (in conventional science education) might have escaped scrutiny as a result of a methodological predilection for focusing on the "objective facts" of the issue." (Ibid. 778). This implies to take into account several dimensions on a socioscientific controversy: economic, political, social, ethical…

Decision making is often implied in both SSI teaching and environmental education. The educative stake of decision making may converge in the two approaches if it "enables individuals to question rather than accept current practices, to examine current, contestable value positions, and to think critically about accepted practices and social norms." (Ibid. 779). Reaching a consensus in class is not necessary, as for both socioscientific controversies and environmental issues, controversial nature of the issue is at the heart of its emergence and development and should be at the heart of its educational endeavor (Oulton, Dillon & Grace, 2004: 415). What is required is a broad debate, considering multiple perspectives, and recognizing that individuals and groups may hold diverse viewpoints because they refer to different sets of information, worldviews or value systems (Ibid.: 411). Simulation games and role plays may offer relevant classroom activities to achieve decision-making while enabling different viewpoints examination and a (simulated) decision that doesn't have to be consensus or resolution of the issue (unavailable).

In the teaching sequence reported here, focus was more dedicated to examination of scientific, social, economic and political dimensions of the global warming issue than on ethical considerations or value elucidation. It may contribute to citizenship education by a focus on students' political literacy development. Davies (2004) has underlined that science education rarely goes beyond what could be merely a superficial connection with citizenship education. Such attempts may, at times, do little more than provide a limited justification for the continuation of one's own specialist subject area in a way that might be unhelpful to citizenship education (Davies, 2004, p. 1756) […] The understanding of science is the focus; 'citizen' is used as a slogan, or instead of 'person' (Davies, 2004, p. 1757). In such a perspective, citizenship education in science lessons may be no more than a way to motivate in science by use of content about contemporary society. There

may be some who go further and discuss the nature of an appropriate classroom climate so that there is gender equality as science is learned but the focus is not an engagement with citizenship. Davis (2004) recommended to make a clear distinction between 'citizen' and 'person', the former being understood in terms of engagement with public issues (Crick, 2000). Citizenship should be seen as encompassing social and moral responsibility, community involvement and political literacy (Davies, 2004).

The research reported here suggests that specific interventions on socioscientific issues could allow us to broaden science curriculum to include social dimensions, ethical and political perspectives. If the aim of socioscientific controversies integration in science curricula is not to reproduce a version of citizenship education unlikely to challenge the social mechanisms of inequality reproduction (Gamarnikow and Green 2000: 10–111), such a teaching sequence on socioscientific controversy of global warming converge to citizenship education. It may also contribute to an environmental education that would explicitly address in class power relationships and a socially critical approach which raises political issues and challenges the status quo (Fien, 1993; Huckle, 1995).

5. Conclusions

A design-based research on an interdisciplinary teaching sequence on global warming with 12th-grade students has been developed. It suggests that specific interventions on socioscientific issues could allow going beyond emphasizing scientific content and towards the exploration of the nature of society and how one could act within it as a citizen. Research reported here underlines that a greater understanding of science, its impact on contemporary society and ways in which young people and others could exert an influence within a democratic society are central goals if we are to develop SSI in curricula as an effective collaboration between science education, citizenship education and environmental education as eco-philosophical and eco-political. Addition of social/environmental issues to science curricula raises questions of the curricular appropriateness of forms of social critique (Hart, 2002) and re-stresses that education itself is not neutral, but a value-laden, political act.

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This study is a free translation of "socle commun de compétences"

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