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Abstract

The present study analyses decision-making and argumentation by high school students in a debate situation on a socioscientific issue, the use of embryonic stem cells in research and therapy. We tested the influence on the debates of two different contexts. Adolescent students at the high school level in the same grade (mean age 16.4 years) from rural and urban zones of Provence, France participated in three debate sessions. During the first session students listed the background questions they want to ask the expert(s). They were also required to identify one or two major issues that would serve as an outline for the future debate. They then discussed these with the expert(s) during the second session and took note of the answers. During this session, control groups met with a neuroscientist whereas the experimental "contextualized" group met with the same neuroscientist together with a representative of an association of patients suffering from a neurodegenerative disease. Analysis of the students' arguments and decision-making revealed that contextualization introduced dynamism in the students' exchanges: they paid more attention to their peers' arguments and were more motivated to argue their own opinion. However, this type of contextualization may contribute to reinforcing ideology in scientific progress.

Keywords: *debate, socioscientific issue, argumentation, contextualization, expertise, decision-making, human embryonic stem cells.*

Introduction

Meetings between researchers and the public are a significant modality of contemporary science communication. By doing so, researchers express their will to meet lay people, and particularly students, to discuss science and society connections. The debates we study here are an example of such meetings. In formal and informal science education contexts, debate protocols are considered effective strategies to engage people in socioscientific issues. The training of participants in argumentation skills is one of the major challenges of scientific citizenship education. Argumentation is the way individuals make and justify claims and conclusions. In this study, we focused on the consequences of debate contextualization on students' argumentations when they are making a decision on a socioscientific dilemma: the use of human embryonic stem cells.

Socioscientific issues' research: rationale and objectives

This research uses the theoretical framework of socioscientific issue (SSI) didactics that arose from the Sciences – Technologies – Society movement. SSI relative to health, environment and techno-scientific innovations are defined as social dilemmas linked to science about which citizens have to make decisions. Many authors have proposed introduction of SSI in science curricula in order to promote development of responsible scientific citizenship (Zeidler, 1984; Aikenhead, 1986; Driver & al., 2000; Kolstø, 2001). The initial purpose of the movement was to engage students in meaningful learning of "*context knowledge*" in order to help them identify the interdependence between science and society (Sadler & al., 2004). This mission is in line with the goal of enhancement of *scientific literacy* promoted by the American Association for the Advancement of Sciences since the 1990's.

According to Simonneaux (2003), who participated in introducing SSI to French science educators[1], the issue for educationalists is how "*to enable pupils, informed in scientific research methods, its practical applications and its possible implications, to propose and argue decisions in an uncertain context and to participate in debates as citizens*".

Sadler (2004) pointed out that SSI research focuses on four main directions: relationships between the nature of science conceptualizations and socioscientific decision-making, ways of evaluating information regarding SSI, influence of conceptual understanding on reasoning regarding SSI, and socioscientific argumentation (Jimenez-Aleixandre & al., 2000; Simonneaux, 2001; Osborne & al. 2004; Zohar & Nemet, 2002). In this study, we focus on the links between the nature of science conceptualizations and socioscientific decision-making, and on socioscientific argumentation, ie, how individuals make and justify claims and conclusions about a SSI. Debate between peers appears to be a pedagogical strategy for helping students to think about open ended and complex issues and to develop argumentative skills. The present study analyses students' argumentation during a debate situation on a SSI where they were asked to express their personal opinions.

Socioscientific issues and the nature of science

Most of the studies focused on the nature of science conceptualization assume that students' knowledge about science influences their interpretation of knowledge in science (Kolstø, 2000,

[1] In French context, whereas the « *éducations à* » (*education to* health, human reproduction, environment) existed in sciences curricula since 1970's, science and society interlinks were introduced *per se* during the last reform 2000-2001. In this context, the field of research dealing with SSI is called 'didactique des questions socialement vives' and analyses the teaching of 'socially 'acute' questions' (Legardez & Alpe, 2001; Simonneaux & Simonneaux, 2004).

2004; Ratcliffe & Grace, 2003). This research concerns how students put into practice their conceptions about values and ways of thinking in science. According to Kolstø (2001), we investigate "*content transcending knowledge"*, that is to say "*knowledge or skills and attitudes that do not have their focus on the products of science community.* […] *The focus is shifted from knowledge in science toward knowledge about science*". For Kolstø (2005), essential knowledge about science appears necessary to understand an SSI. The first is that science is not the only aspect to consider when studying an SSI. Financial, ethical, legal, political and social aspects also have to be considered. Because of the interrelatedness of science and society, science cannot be considered neutral. This is an important point to make if we want students to be able to evaluate scientific expertise. Second, science is process based, relying on argumentation and peer criticism. Third, an understanding of the temporary nature of scientific results is necessary in order to debate controversial issues. In order to escape from an absolute relativism, we can distinguish between « core science » and « frontier science », that is between consolidated knowledge and knowledge under construction.

Socioscientific issues and socioscientific argumentation

A majority of studies concerning SSIs focus on students' argumentation skills. Research designs often include debates between peers and individual decision-making about an SSI. Most of the studies reveal the weakness of students' skills in argumentation whatever their age (Khun, 1993). Many studies underline the lack of correlation between science conceptualizations and argumentation skills (Perkins & al., 1991; Sadler & Donnely, 2006).

Several debate situations have been proposed to encourage students' argumentation. For example Simonneaux (2001) compared role-play to debate using an issue in animal transgenesis. She concluded that debate is more efficient than role-play to encourage students' discourses in science. Other studies suggested encouraging students to compare contradictory discourses. Students can integrate and internalize information from media reports and the diversity of the viewpoints expressed (Ratcliffe & Grace, 2003; Simonneaux, 2004; Federico-Agraso & Jiménez-Aleixandre, 2006). Zohar & Nemet's study (2002) also highlights the interest for students to get involved in a time consuming and metacognitive work about argumentation.

We are particularly interested in proposals taking into account the consequences of the debate context on students' argumentation and decision-making. Several authors (Patronis & al. 1999; Kolstø, 2000; Jiménez-Aleixandre & al, 2000) dealing with the inclusions of SSI in science classrooms have pointed out the importance of context for improvement of argumentative skills. The main hypothesis is that personal connections to local, but not global, SSI will improve students' argumentative skills. The majority of these studies dealt with environmental SSI. For example Spanish students debated the *Prestige* oil spill, which hit the Galician coast in 2002 (Jiménez-Aleixandre & al, 2004). However, few studies have addressed contextualization involving interactions with experts in the field, particularly researchers. These studies revealed that this setting does not allow students' opinions about science and scientific knowledge to be transformed (Trabelsi Chalgoumi, 2006; Simonneaux & al., 2005).

In this study, we chose to analyze a controversial health-related SSI and we assessed the effects of contextualization on students' argumentation, by encouraging direct interaction with specialists.

Use of human embryonic stem cells as a socioscientific issue

The use of human embryonic stem cells (hESC) for research or treatment of neurodegenerative diseases is considered an 'acute' socioscientific issue for multiple reasons. In the 1990s neuroscientists proposed the use of embryonic stem cells to generate healthy neurons to replace brain neurons damaged by trauma or compromised by disease, like Parkinson's disease or Huntington chorea. Controversies on how to obtain and store hESC (issues of proliferation and differentiation) and on their therapeutic use (feasibility, therapeutic efficiency, risks for the patient to develop tumors…) exist within the scientific community. The use of the human embryo as a source of totipotent cells is influenced by social representations and value systems due to the fact that isolation of hESC requires embryo destruction and raises the question of the embryo's status. It is therefore highly controversial in society. The benefit-to-risk ratio for patients treated by cell therapy are debated in society and at the time of this study, the ethical framework for therapeutic use of stem cells in France was provided by restrictive legislation on hESC use that was in place at the time (Biomedical Agency)[2]. The last controversial point concerns therapeutic cloning, by which scientists create human embryos through nuclear transfer and extract stem cells for cell therapy, thus avoiding immuno-compatibility problems. Obviously, the large media coverage of the social dilemmas related to hESC use contributes to making this issue 'acute' in the classroom because students are not entirely naïve on the subject. However, teachers often do not believe students will be able to deal with it[3].

Questions of research

Our work concerns a comparative assessment of debate situations within two frameworks. We both evaluated the effect of the location of the debates (a cultural science center within a scientific institute) and the effects of the contextualization of the debates (meeting with experts) concerning students' argumentation and decision-making. In the students' argumentation regarding hESC uses, we paid particular attention to knowledge in science and about science.
The test consisted in evaluating the content and quality of students' argumentation in two situations. In the contextualization framework, we tested the effects of the presence of a representative of an association of patients suffering from a neurodegenerative disease, together with a researcher specialized in the topic (contextualized group). In the control framework, students benefited from discussion with only one expert, the researcher (control group).

Methods

Participants

Seven science classes of high school students (107 girls and 89 boys, mean age: 16.4 yrs) from the same grade-level, from French high schools of the Provence Region including urban and

[2] In 2004, during the bioethics law revision, the French government declared a moratorium concerning hESC research. Starting in 2006, research was allowed, for a five-year period, on stem cells of supernumerary embryos from in vitro fertilization or on imported hESC lines. (See http://assemblee-nationale.fr/12/dossiers/bioethique.asp

[3] Without developing media coverage of hESC uses, let us specify that national generalist newspapers (*Le Monde*, *Le Figaro*, *Libération*…) and specialised press (*La Recherche*, *Pour la science*) dealt with this issue about one time a month since 1990s'. According to political or legislative agenda, media coverage can increase (bioethics laws revision, popular consultation as 2005 Italian referendum…). Scientific papers are also relayed by the media as the well known example of first reported nuclear transfer in humans by south Korean researcher Hwang W.S. (Hwang & al., 2004, 2005). See also Jiménez-Aleixandre & Federico-Agraso, (2009).

rural zones, engaged in debate following the protocol described below. They met with seven different scientists and (or not) four representatives of associations. Debates took place in 2005 and 2006, that is to say, during the time in which restrictive legislation on hESC use was in effect.

Protocol of the structured debates

We assigned the theme of the debate to students 4-6 weeks in advance: *Embryonic stem cells and human brain repair.* They were required in a *pre-test* to give their definition of stem cells and to note their immediate questions. Then they had to seek background information and documentation during the 4-6 weeks preceding the debate.

The debate protocol included three successive sessions, each of one hour duration. The first day, students were provided with the entire 3-day protocol, objectives of a debate (to improve argumentative skills and to build a position regarding a SSI) and the elementary rules of a debate. During this first session (Day 1), students listed the background questions they wanted to ask the expert(s). They were also required to identify one or two major issues (questions) that would serve as an outline for the future debate. Then they discussed these questions with the expert(s) during the second session (Day 2) and took note of their answers. The debates occurred during the third session (Day 3) on the question identified in session 1.

We divided each class in two homogenous groups, control and contextualized[4]. The first and third sessions were identical for the two groups. In contrast, the second session differed. Control groups met a neuroscientist whereas the contextualized group met the same neuroscientist together with a representative of an association of patients suffering from a neurodegenerative disease (Parkinson's disease, Multiple sclerosis, Huntington chorea).
After the last session, in a *post-test,* high school students were required once more to give their definition of embryonic stem cells (that may or may not have evolved) and their arguments for or against the use of embryonic stem cells in (1) scientific research and (2) treatment of neurodegenerative diseases. All participants agreed to be video and audio taped. One of us (G. M.) was the moderator and adopted the position of committed impartiality, that is to say he provided his own points of view while encouraging analysis of competing points of view on the controversial issues (Kelly, 1986)[5].

Analysis of the debate content

We first performed a general analysis of pre- and post-tests in order to quantify the decision making regarding hESC uses, the eventual presence of arguments or not in the votes (claims with or without justifications or restrictions) and in particular of scientific knowledge based arguments to explain the votes (Zohar & Nemet, 2002). These were counted, categorized and compared between control and contextualized groups. The general analysis allowed us to identify a classroom (one control group and one contextualized group) in which the group's argued

[4] The science teachers of the class decided the group assignments on the bases of students' facilities to express themselves in task group.

[5] Kelly postulated four positions which teachers might adopt: exclusive neutrality (positivistic approach surrounding sciences product free values truth), exclusive partiality (characterized by the deliberate intention to bring students to adopt a specific point of view), neutral impartiality (characterized by the unrealistic point of view sustaining that moderator should remain neutral and not reveal his own beliefs) and committed impartiality (the moderator, if asked to do so, tells his position on the subject of debate).

decision-making distribution was very close to the distribution when all of the students were quantified. We then performed a detailed qualitative analysis of the discourses of these two selected groups.

These were divided in *sequences* or episodes and underwent three levels of analysis (Simonneaux, 2003). In turn at speaking system, *sequence* is defined as dialogs with high semantic and / or pragmatic consistency (Kerbrat-Orecchioni, 1998). For the first we analyzed the macrostructure of the debates: we identified the themes discussed, their recurrence and those common to both groups. Inductive analysis method was applied, that is we did not use any predefined set of categories for the analysis (Kolstø, 2005). We also quantified the total duration of the debates, the number of turns each student had at speaking, and the number of the moderator's speech acts. This analysis allowed us to characterize the dynamics of the debates and to select specific episodes concerning the human embryo's status for a more accurate comparative analysis.

For the second level we performed a microscopic analysis of the quality of the arguments: we counted claims without justification, simple arguments relying on only one justification, and multiple level strategies involving several justifications that were linearly linked or interrelated, i.e. with counterclaims or rebuttals (Toulmin, 1958; Adam, 1992) and finally the type of arguments used (Breton, 1998).

For the third level, we examined *modalisation*. Modalisation consists in the semantic way used by speakers to reveal their level of adhesion to their arguments. We classified the types of *modalisation* used into four categories, following Bronckart (1996): logic, deontic, appreciative and pragmatic *modalisation*[6]. The grid of analysis was therefore a combination of different grids (Simonneaux, 2003; Federico-Agraso & Jiménez-Aleixandre, 2008) for a more robust analysis.

Results

First we present the macroscopic analysis of the students' (n = 196) decision-makings and written arguments in the post tests, and then the microscopic analysis of the two selected groups' argumentation comparing the control and contextualized sessions of the oral debate.

Macroscopic analysis of the students' decision-making and arguments in their post-tests

More than 75% of the students from the control and contextualized groups voted in their post tests in favor of the use of human ESC in research only as early as 2006. In contrast, 80% of the students from control groups voted in favor of the therapeutic use of hESC, compared to only 60% of the contextualized group. This latter group, compared to the control group, showed an increase in the response "no" and in the "may be" response (figure 1).

Please insert Figure 1 about here

On the whole, weakness of students' skills in argumentation was obvious when they expressed their decision-making during the post-tests. Some decision-making lacked justifications or restrictions, but the arguments given were rarely simple, often relying on many linearly linked

[6] Logical modalisations consist in truth value judgment of formulated opinions (considered as certain, possible, uncertain, probable…). Deontic modalisations consist in formulated opinion appreciation considering social values (socially allowable, unsuitable, necessary, advisable…). Appreciative modalisations are the expression of a more subjective judgment, facts are considered as felicitous, unfortunate, strange… Lastly, pragmatic modalisations refer to someone's responsibility (will, objective, abilities, reasons…).

justifications.
Concerning arguments in favor of hESC uses, they were in order of occurrence:
- The hope "*to cure*", "*to save lives*", was the main argument used by students to justify their vote in favor of the use of hESC for research and therapy (63 occurrences). That category of arguments was twice as much in the contextualized groups (42 occurrences) than in the control ones (21 occurrences). Moreover, students of the contextualized groups expressed more often restrictions that took into account the potential risks of cellular therapy in their argumentation in favor of the use of hESC (14 occurrences vs 11 for students of the control groups). The most prevalent justification was: "*To save lives, we must accept the sacrifice of other lives*"

- The progress and freedom of scientific research was also used as justification. The written arguments were for example: "*This can make the world better*", "*hooray for science and progress*". We found 42 occurrences of that kind of arguments in favor of the use of hESC for scientific research, without significant differences between the control and contextualized groups. Concerning students in favor of the therapeutic use of hESC, arguments for the progress of research were twice as much in the contextualized groups (8 occurrences) than in the control ones (4 occurrences)

- The embryo is not a human being was an argument used 13 times: "*the embryo is a group of cells, [a piece of meat], thus it does not think* ". That kind of arguments was equally used in both groups.

In addition, there were 23 students who did not justify their vote in favor of hESC uses in the control groups compared to 11 in the contextualized ones. Even if students' skills in argumentation appeared globally weak, the contextualization participated in enhancing students' ability to justify their written opinions and to precise their limits.

Concerning the few students that were against the use of hESC for research or therapy (only 10% of the total), their arguments were more unsophisticated, often with only one justification:
- The embryo is a future human being and its legal status is not clear (12 occurrences). The words "*crime*", "*to kill*", "*to sacrifice*" were used, without significant difference between the control and contextualized groups. Theological or ideological arguments were presented: "*Today society has gotten too far away from the principles of life*", "*I am a neoconservative*", "*We must leave natural selection to make decisions about life and death*".

- The hESC therapy is risky and further research is needed "*before being able to cure, we need research*". That category of arguments was often associated with the one concerning the possibility of alternate therapies, such as those using adult stem cells (16 occurrences of which 10 were from the contextualized groups);
- This could lead to oocyte trading and the commercialization of life (9 occurrences);
- Therapeutic cloning can lead to reproductive cloning (3 occurrences).

In conclusion the majority of students were in favor of the use of hESC for research and in the clinic as early as 2006, although they were fully aware of the potential risks in such treatment of neurodegenerative diseases, as researchers explained them. Concerning nature of sciences, students expressed a strong ideology in favor of the progress of science but they did not clearly understand the differences between fundamental, clinical research and therapeutic

applications. To the extreme, a few students were against research on stem cells but in favor of their therapeutic use.

The meeting with both a researcher and a representative of a patient association (contextualized groups) dampened the above arguments, as the students better understood the risks of the therapeutic use of hESC previously explained by the researcher. This is a paradox as the patients generally lobby for the use of hESC in cellular therapy. Students that met both types of experts (a patient and a researcher) had the opportunity to hear two different viewpoints. This may also explain why their arguments are more complex, and include restrictions and refutations. For the other 50% of contextualized groups, the ideology of the progress of science was probably reinforced by the emotions brought by the meeting with a patient suffering from a neurodegenerative disease. The contextualization radicalized the decision-making.

Microanalysis of the argumentation in control and contextualized sessions

We chose to precisely analyze the control and contextualized groups of a single classroom because the decisions and arguments in post tests were representative of the mean (Figure 1). In the contextualized group, the duration of the discussions between students and the number of turns at speaking were higher that in the control group, where the majority of the feelings expressed did not lead to discussions. Conversely, the number of interventions of the moderator was, proportionately to the debate duration, a little bit lower. This indicates a better involvement of the students in the discussion (Table 1).

Please insert Table 1 about here

Moreover, dividing debates in sequences allowed us to identify common themes to each group (human embryo's status, cellular therapy risks, therapeutic and reproductive cloning) and some specific to one or the other (Table 2). The latter were twice as numerous for the contextualized group. Therefore contextualization introduced dynamism in the exchanges between students, with more attention paid to what the other students are saying and motivation to promote their own opinions.

Please insert Table 2 about here

Comparative analysis of the debates showed that students of the contextualized group were twice more engaged in episodes of argumentation than in simple assertions. This comparative analysis corroborates the findings concerning argued decision-making analysis of the students in the post tests. In the contextualized groups, students were more involved in the debates. Emotion generated by the meeting with a patient suffering from Parkinson disease positioned debates in the complexity of the reality and led students to pay attention to their responsibility when they are debating about hESC uses. Contextualization helped students to develop argumentation skills (reinforced agreements, specifications or restrictions).

Furthermore, contextualization drove many students to diversify their conceptions regarding the nature of science. Faced by the risks of cellular therapy for the patients, many students in the contextualized group considered alternative therapies such as deep brain stimulation or alternative research such as adult stem cell research. In addition, legal (diversity and changes in national legislations) or fiscal (funding systems of research) aspects of science were addressed only during contextualized group debates.

Microanalysis of arguments during debates

We performed a detailed analysis of the microstructure of two episodes (one from a control group and one from a contextualized group) on embryo's status, which is the major issue of the debates. We identified the different strategies of argumentation, the speech acts, the rhetorical moves and the *modalisation* indices in the verbal interactions. We could not draw robust conclusions about the influence of the contextualization on the quality of the oral debates at this analysis scale. Microanalysis of the quality of arguments was inconclusive because it did not detect significant differences between the two groups, as we may be reaching the limits of such a comparative analysis. Indeed, at the other scales of analysis taking into account the whole debates, and not only a single episode, the nature of students' argumentation appeared better in the contextualized groups than in the control ones.

Communication between high school students appeared to be more influenced by psychological and sociological factors (whether they were used to speaking in front of a large audience, whether they were militant for a cause, or familiar with acting as a leader, girl or boy…). This meant that some students (3 out of 15 students of the group) did not participate in the discussion. This does not mean that they did not pay attention to the discussion. In fact, they developed a panel of written arguments in the context of their decision-making, at the end of the third session.

Students had difficulties developing an argumentation while they were speaking. The moderator had to reopen the debate and to regulate it quite often in order to let someone speak, insist that students pay attention to the person speaking, or ask for explanations on what has been said. Often, declarations were imposed without arguments or with very simple ones. The large majority of arguments revealed a low level of adhesion from the speakers. Arguments relying on social or logical values, i.e. with deontic *modalisation,* were the least present. The analysis of the episode of debate on embryo status (Table 3) sheds light on the relationships between scientific knowledge and opinions expressed by students (control group). To elaborate their position on embryo status they used scientific arguments to prepare the audience to receive their opinion in favor of the use of embryonic stem cells. That kind of argument, called a framing argument (*argument de cadrage* in french*)* according to Breton (2003), is often used by students.

Please insert Table 3 about here

Hassen and Corentin (at time 50, 56, 58 and 55, respectively), reduced the embryo to its biological definition (*"a group of cells"* time 50 and time 55), skipping any human dimension (time 56, 58). For Elsa, the embryo is not even alive (time 53). The scientific arguments concerning the absence of nervous system and therefore cognitive functions ("*they do not yet have neurons"* time 50, *"it does not have a nervous system"* 52) were aimed at confirming the non human character of the embryo. They refer to a calendar of development of the central nervous system that they never explain. These definitions of the embryo from a biological point of view only have the ability to make the audience accept its destruction or the use of its cells. And when Hassen introduces the researcher in the discussion (time 50, '*she*' explained) it is as an authoritative argument. Rewording processes reducing the human embryo to his / its cell dimension occur in these kinds of sequences. The implicit purpose is to present the embryo as an object more than a subject and so to legitimize its / his use for research or therapy. Rewording processes concerning the embryo's status appears as a framing argument to make the others accept the human embryo as an object and not as a subject.

Discussion

In the contextualized situation, high school students participated much more in the debate on the possible use of hESC for research and therapy. Meeting a patient suffering from a neurodegenerative disease seemed to have generated emotions, motivation and a sense of responsibility that helped students to better understand the consequences of their votes. According to previous research, the type of contextualization tested in this study (meeting with experts and in particular a representative of an association of patients suffering from a disease) contributed to improve situated cognition by giving a meaning to the debates (Jiménez-Aleixandre & al., 2000, 2004; Kolstø, 2004; Patronis & al, 1999). The diversity of viewpoints, scientific doubts, and uncertainty of the results and risks for patients, became more obvious when debates were in a real-life context. Also, students better recalled their scientific knowledge (ESC proliferation and differentiation, brain plasticity) as if having met with a patient added a new dimension to what they had learned before. Science then became a social activity with legal (the bioethics law and its evolution) and economic (how research is financed) aspects.

The above conclusions should not occlude the fact that concomitant consultation of a scientific researcher and a patient reinforced positivism and the idea that beneficial clinical applications always emerge from basic research. In a recent study Simonneaux and Simonneaux (2008) studied students' reasoning about three controversial SSI characterized by a local contextualization (the reintroduction of wolves in Mercantour and that of bears in Pyrenees in France) and a global one (global warming) and pointed out "the limits of a local contextualization that involves students too much". They observed a lower level of critical analysis and of knowledge appropriation in the case of local issue compared to a global one.

In addition, for most of the students, the place where the debate was organized (a scientific institute), the choice of scientific experts (scientific researchers who were all in favor of the use of ESC in research) probably had an impact on their decision-making. We think that the location reinforced the ideology of progress due to scientific activity that was formulated by students when they declared themselves favorable to cellular therapy, in spite of the risks raised by the researchers. This did not motivate them to challenge science authority and legitimacy as revealed by Federico-Agraso and Jiménez-Aleixandre (2008) concerning students' perception of scientific papers. Moreover, Jiménez-Aleixandre & al. (2000) had previously pointed out that often students give the arguments that teachers were waiting for, in particular for their first debate as in the present study. Science museums or centers for scientific culture may be placed more adapted to debates on SSI (appropriate public spaces for *public use of reason* according to Rasse, 1999). High schools also would be more adapted if the classroom is a democratic place where students can freely express their opinions without any religious pressure.

Weakness of students' skills in argumentation was the other prominent characteristic of the debates. Even if we detected a difference between students' argumentations in contextualized and control groups, both had difficulties in constructing arguments. Students used a small panel of arguments (they rarely mentioned ethical, legal, economic or social aspects of the question) and gave arguments without justification, with authority, or accompanied by simple analogies. Students deeply need to learn the difference between arguments and emotions, to gain ability to construct argumentation to defend their position i.e. to advance a reason for or against, a proposition or course of action. This confirms previous studies pointing out the difficulty of

teaching argumentation (Jiménez-Aleixandre & al., 2000; Kuhn, 1991 ; Sadler, 2004 ; Simonneaux, 2003…). Only long-term efforts seem to give positive results, as proposed by Zohar & Nemet (2002) with a protocol including eleven sequences of work and a specific training to argumentation. Practices such as assessing alternatives, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims are all seen as essential components in constructing scientific arguments (Latour & Woolgar, 1986). So too are scientific controversies and the collective analysis of the different ways a scientific result has been communicated (press release, audio-visual supports, numerical, exhibitions….) (Federico-Agraso & Jiménez-Aleixandre, 2006; Sadler & al., 2004). This is too often neglected in science curricula.

Science is usually "*taught as a nearly unmitigated rhetoric of conclusions in which the current and temporary constructions of scientific knowledge are conveyed as empirical, literal and irrevocable truths*" (Schwab, 1962, p. 24). As pointed out by Simonneaux & al. (2005), frontal transmission of scientific results via conferences given by a researcher to students without any upstream preparation or downstream discussion reinforces the image of the power of science and ideology of progress through science. On the contrary, students deeply need to understand the instability of scientific results as they rarely study epistemology in their curriculum. Also they did not understand how scientific data are produced by researchers, and that they are continuously debated within the scientific community and result from a collective work. The majority of students ignored the difference between basic and applied research and confused basic science with its technological applications. As students are usually keen and enthusiastic to meet researchers, if such meetings are well prepared, it gives them the opportunity to learn more about a subject and understand the instability of scientific results. When debates are thus inserted in a global strategy, students also learn how science is 'produced' in laboratories.

Placed in a socioconstructivist context, science teaching through debates implies trusting students' ability to generate knowledge and to develop scientific expertise that they will use outside classrooms. It implies that teachers used to being the one 'who knows' become facilitators of the collective construction of knowledge. Debates on SSI allow teaching of science within a social context. Learning how to debate appears therefore essential for the future citizens that will have to make scientific and technical choices during their life. To achieve such a goal, each classroom has to be seen as a community that will produce knowledge instead of one that will consume knowledge (Jiménez-Aleixandre & Pereiro-Munoz, 2002). In this perspective, students would choose the question that they want to debate within the framework of the general topics proposed by the teacher. He also proposes that the aim of the debate sessions is that students' argumentation progressively evolves as they integrate new scientific and technical knowledge with societal aspects. Meeting with a diverse group of experts should help them to achieve this goal. This also helps students to identify their own position in an argument.

Are French science teachers trained in a way that would enable them to debate SSI with students? This would require knowledge regarding how science is produced, and an ability to place scientific within historical and social contexts. But initiation to scientific research, and studies of the historical aspects of science and epistemology are absent from their coursework. Lack of opportunities for the practice of argument within science classrooms, and lack of teacher's pedagogical skills in organizing argumentative discourse within the classroom are significant impediments to progress in the field. Structured classroom debates help advance two goals many teachers struggle to achieve with their students: classroom participation beyond the

''usual suspects'' present in every classroom (Oros, 2007) and critical thinking on the scientific claims generated by the plethora of SSI that confront them in their everyday lives.

Conclusion

Meeting with researchers appears to be a positive experience for students debating a socioscientific issue, which increases their knowledge of science and the nature of science. Concerning health-related issues, their meeting with patient association representatives gives more meaning to their knowledge, providing a connection between science and their everyday lives. To make the most of these meetings, students must be prepared to put actors and discourse into perspective, and to evaluate the plurality of viewpoints with the necessary critical distance.

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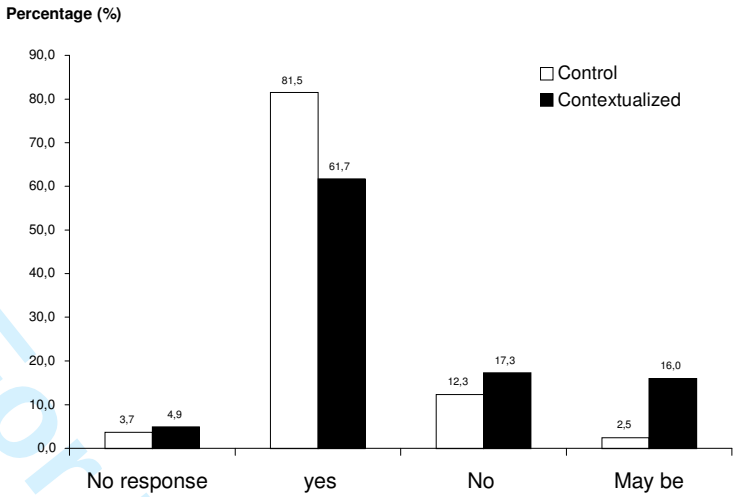

Figure 1: Diagram showing the votes of high school students in response to the question « Are you in favor of the therapeutic use of human embryonic stem cells (for human brain repair) starting in 2005 and thereafter? » (n = 196)

Table 1: Quantification of the exchanges in the two groups

	Control	Contextualized
Duration (minutes)	33	45
Number of turns speaking	145	298
Number of turns speaking/min	4.39	6.62
Number of times the moderator intervened	45	61

Table 2 : The different themes discussed in the control and/or contextualized group

	Themes
Themes common to the control and contextualized group	The embryo status, its therapeutic use The risks of grafting human ESC Abortion Viewpoint of patients, scientists, ordinary people Therapeutic cloning and its links to reproductive cloning
Themes specific to the control group	Science must go on The opportunity of the debate, the social legitimacy of adolescents compared to legislators The ethic committees and their roles
Themes specific to the contextualized group	Alternate therapies (deep brain stimulation) The different laws about the use of ESC for research in different countries Animal models (Parkinson) The neuroscientist and his work The patient suffering from Parkinson's disease, his symptoms, his everyday personal and social life Problems linked to a referendum (example of abortion) The cost of research The possible use of adult stem cells instead of embryonic ones

Table 3: Arguments given during a debate episode on the embryo status

Speaker 00 :10 :20	Oral sentences	Speech acts Argumentation
50 Hassen	[…] As to ethical problems, she explained that when they get the embryos they are just a group of cells, they do not yet have neurons, they are not human beings.	Confused knowledge about the embryo status Simple argument (with authority)
51 Moderator	Do you all agree?	Reopening of the debate
52 Denis	it does not have a nervous system (he thinks), it is not a human being	Agreement with addition of knowledge
53 Elsa	We cannot say that it is alive, it becomes alive only later?	Non justified agreement
54 Victor	It depends on religion, this a religious and ethical question / it has nothing to do with science/ it is a human embryo that could become a human being if we left it to grow / it's not something totally alive / it's alive but	Objection based on scientific knowledge of the definition of the embryo status
55 Corentin	The embryo has no shape since it is just a group of cells / it does not speak, it does not eat, it is unconscious of what it is	Simple argument (de cadrage)
56 Hassen	We can't say that it is human just because it is made of cells	Same argument as 6 minutes before
57 Victor	Scientifically speaking, it is not more developed than a bacteria, or just a little more	Agreement reinforced
58 Hassen	than an animal.	Agreement reinforced