Chapter 13
Epistemic Beliefs as a Means of Understanding Critical Thinking in a Socioscientific Environmental Debate

Kévin De Checchi, Gabriel Pallarès, Valérie Tartas, and Manuel Bächtold

13.1 Dealing Critically with Unfriendly Epistemic Contexts

Environmental and sustainability issues are of decisive importance for our society. As future citizens, students need to be able to take part in an informed way in debates on environmental socioscientific issues (SSIs) and to think and argue critically. Developing students' critical thinking (CT) about science and its links to societal issues has thus become a major challenge (Hazelkorn et al., 2015). Environmental SSIs are complex (Morin et al., 2017), as students need to combine knowledge from different disciplines with values and other people's opinions, in order to adopt an enlightened position and engage in critical argumentation. Learners also need to deal with knowledge uncertainties (Kampourakis, 2018), as these are a distinctive feature of SSIs. Lastly, students need to be aware of the openness of these issues: there are numerous reasonable answers to an SSI, none of them is self-evident and all must be argued (Oulton et al., 2004).

Students therefore need to be able to problematize, conceptualize, question, analyze, and argue on SSIs. These skills can be developed during the teaching of specific topics and domains, but only if teachers allow sufficient room for argumentation in their teaching (Schwarz & Baker, 2017). Argumentation is a key component of CT (Facione, 2000, 2011), and some authors consider the two to be somewhat similar (Groarke & Tindale, 2013; Kuhn, 2019). Nevertheless, as other authors

K. De Checchi (✉) · G. Pallarès · M. Bächtold
LIRDEF, University of Montpellier and University of Paul-Valéry Montpellier 3, Montpellier, France
e-mail: kevin.de-checchi@umontpellier.fr; gabriel.pallares@univ-reims.fr; manuel.bachtold@montpellier.fr

V. Tartas
CLLE, University of Toulouse, CNRS, Toulouse, France
e-mail: valerie.tartas@univ-tlse2.fr

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(Ennis, 2018) have pointed out, CT is a complex construct that involves not only argumentative skills, but also dispositions to use them. In other words, in order to apply these skills, students must not only master them, but also be disposed to use them (Facione, 2000; Kuhn, 2019).

Several studies have found that students' epistemic beliefs (i.e. their representations of knowledge and knowing) influence their argumentation (Iordanou et al., 2019; Kuhn et al., 2000; Mason & Scirica, 2006; Nussbaum et al., 2008). As SSIs involve various kinds of knowledge and opinions, we assumed that if we wanted to examine epistemic beliefs in this context, we would need to take account of students' representations not only of knowledge, but also of opinions. We expect this investigation to shed light on students' CT skills and dispositions to argue in the context of environmental education. Highlighting these links is important, as it can help teachers improve their teaching strategies for developing students' argumentation and their critical dispositions in relation to environmental SSIs. It would also enable us to ask about the nature of the links between CT and epistemic beliefs in the context of socioscientific argumentation, and more specifically in the context of environmental SSIs.

The main purpose of this chapter is to develop a theoretical framework that could connect CT to epistemic beliefs, defined as representations of both knowledge and opinions. We test this theoretical framework with an empirical study, looking at the arguments produced by six students during debates about environmental SSIs, and transcripts of interviews undertaken to elicit their epistemic beliefs. In the following sections, after setting out our theoretical framework, we describe this empirical study and analyze the two sets of data and their possible interconnections. We then discuss how our study opens up new avenues for developing environmental education and fostering students' critical argumentation on environmental SSIs.

13.2 Towards a Theoretical Framework Connecting Critical Thinking and Epistemic Beliefs

13.2.1 Critical Thinking

CT has been conceived by Ennis (2018) as "judging in a reflective way what to do or what to believe" (p. 136). As this is a rather vague description, CT has been given a variety of definitions, ranging from a very broad set of skills and dispositions to a list of specific behaviors (Ennis, 2011). There is nonetheless a consensus among many authors that there is a strong link between CT and argumentation. For example, each of the six *core critical thinking skills* highlighted by Facione and colleagues in their Delphi project (American Philosophical Association APA, 1990), namely *interpretation*, *inference*, *evaluation*, *explanation*, *analysis* and *self-regulation*, are closely linked to argumentation. By the same token, argumentation scholars often define an ideally *good* argumentation as one that contains *critical discussions* (Van Eemeren

& Grootendorst, 2004) or *critical questions* (Walton, 1989, 1996). This link can also be found in instructional contexts. For instance, Kuhn (2019, p. 147) observed that "inquiry and argument [...] get us closer to empirically identifiable skills or behaviors than does the term critical thinking, while capturing much of what critical thinking is envisioned to encompass." Following Kuhn's methodological concerns, we chose to consider CT through the lens of argumentation in this study, despite considering that CT cannot be reduced to argumentative skills and behaviors.

CT can be seen both as a set of skills and as a set of dispositions (Ennis, 2011). As Kuhn (2019, p. 148) noted, researchers currently hold that "critical thinking is at least as much a disposition as it is a skill or ability," as students may have the ability to put forward arguments to explain their opinion, but may not necessarily be disposed to use it. CT dispositions can be seen as the difference between *critical thinking* and *critical thinker*: the former is an activity that can be achieved with the use of specific skills, while the latter is the individual who can decide whether or not to use these CT skills. Accordingly, *dispositions* are linked to willingness to engage in CT. The Delphi project (APA, 1990, p. 6) listed some of the many dispositions of an *ideal critical thinker*. We consider this list relevant but to be viewed with caution, as dispositions are broad and can manifest themselves in a variety of ways in the context of argumentation. For example, in a debate, a student who is *open-minded* and *willing to reconsider* may be inclined to acknowledge that his or her opinion is not self-evident and attempt to argue in favor of it, but may also tend to take another person's opinion into account, try to understand it better, and either challenge it or agree with it.

Another issue is whether students develop all these critical dispositions at the same time. Some dispositions may be easier to develop, if they make more sense to students with regard to the current activity or topic. In the context of environmental SSIs, which is a favorable one for CT practice or development (Simonneaux, 2007), it may be useful to identify which kinds of epistemic beliefs can influence both the development and use of certain critical dispositions. So let us turn now to epistemic beliefs and the most accurate way of defining them.

13.2.2 Epistemic Beliefs

Epistemic beliefs can be defined as "beliefs that might be more or less independent, rather than existing in integrated fashion and developing in a coordinated sequence" (Hofer, 2004, p. 45). This definition implies that "there are multiple dimensions to be considered and these dimensions can be thought of independently, as well as together" (Schommer, 1990, p. 301).

In a developmental approach, Kuhn et al. (2000) identified three stages. At the *absolutist* stage, individuals view knowledge as a certain, objective entity supported by external sources. At the *multiplist* stage, they no longer view knowledge as an objective entity that can be acquired, believing instead that having a given item of knowledge is as a matter of choice. In other words, all individuals have the right to

their opinions, and all opinions have equal value. Finally, at the *evaluativist* stage, knowledge is assumed to contain elements of uncertainty because it is constructed by individuals, but there are objective criteria for evaluating and comparing it, which allow this uncertainty to be reduced. More broadly, the developmental approach considers that all individuals move through the same increasingly elaborated stages that reflect the development of the criteria and/or strategies expressed by students to deal with their awareness of uncertainty (King & Kitchener, 2002).

In a dimensional approach, Hofer and Pintrich (1997) described the content of epistemic beliefs in terms of four dimensions separated into two components. The first component concerns the *nature of knowledge (i.e.* what an individual believes knowledge is) which includes the dimensions *certainty of knowledge* and *simplicity of knowledge*. The second component concerns the *nature of the process of knowing* (i.e. how an individual comes to know), and contains the dimensions *justification for knowing* and *source of knowledge* (Hofer & Pintrich, 1997). Moreover, Chinn et al. (2011) proposed to study epistemic beliefs more comprehensively and argued "for a fine-grained, context-specific analysis" in terms of five dimensions: epistemic aims and epistemic values; the structure of knowledge and other epistemic achievements; the sources and justification of knowledge, and the related epistemic stances; epistemic virtues and vices; and reliable and unreliable processes for achieving epistemic aims.

Context-dependency has been supported by several empirical studies, which have shown that epistemic beliefs vary notably according to the academic discipline (Kuhn et al., 2000) or SSI (e.g. Khishfe et al., 2017). Zeidler et al. (2009) observed, for example, that students may be at different stages of epistemic beliefs, depending on which SSI they are being asked about. In this regard, we chose to focus our attention on epistemic beliefs in the context of argumentation, and more specifically in the context of environmental SSIs.

13.2.3 Epistemic Beliefs and Socioscientific Argumentation

Many studies investigating the influence of epistemic beliefs on argumentation have shown that the more elaborated these are, the better individuals argue (e.g. Kuhn et al., 2000; Mason & Scirica, 2006). More specifically, elaborated epistemic beliefs have been observed to lead to better reasoning (Zeineddin & Abd-El-Khalick, 2010), or more alternative arguments and better coordination of facts and hypotheses (Kuhn, 1991). Nussbaum and Bendixen (2003) also observed epistemic beliefs influence the way students engage in argumentative activities. More precisely these authors pointed out, for example, that students who consider knowledge to be certain and simple state that "arguments were anxiety-promoting" (p. 3) and tend to avoid dealing with them. A correlation has been found between certain dimensions of epistemic beliefs (according to Hofer & Pintrich, 1997) and argumentative skills: *justification from knowing* develops in the same direction as the argumentative quality of written productions (Ferguson & Bråten, 2013; Mason & Scirica, 2006),

while *certainty of knowledge* develops in the opposite direction to willingness to engage in argumentation (Nussbaum & Bendixen, 2003). Moreover, the nature of the topic being discussed influences the way in which students argue: the latter do not argue in the same way if the debate concerns a scientific issue or an SSI (Simonneaux, 2007; Zeidler et al., 2009; Zeineddin & Abd-El-Khalick, 2010). The particular features of the topic under discussion should therefore be taken into account in order to describe epistemic beliefs in a situated way in the context of socioscientific argumentation.

Links between epistemic beliefs and students' argumentation have been brought to light through the use of interviews or questionnaires within the framework of SSIs (Barzilai & Weinstock, 2015; Kuhn, 1991; Mason & Scirica, 2006). In these studies, the authors presented students' epistemic beliefs as concerning only knowledge. However, the interview questions aimed at eliciting epistemic beliefs about knowledge also focused on opinions: "How sure are you of your view, compared to an expert?" (Kuhn, 1991, p. 175), "Can you say that one opinion is better and one is worse?" (King & Kitchener, 2002). The same is true for students' responses, in which knowledge and points of view were interwoven. For example, in reply to the question "Could someone prove that you were wrong?" (Kuhn, 1991, p. 175), students responded "No, they couldn't prove it [...] because it's my opinion [...]" (p. 181), "I was wrong, but I would probably not change my opinion. It's the result of lifelong personal experience and quite frankly, I think it is right. [...]" (p. 182). The first answer refers to an opinion, and the second answer concerns statistical knowledge that can be given to refute the student's proposal, lending more weight to one opinion than to another based on personal experience. It should be noted that these excerpts can contain different terms, such as *view*, *point of view*, *opinion*, *belief* and *position*. However, these terms are not always defined or explicitly considered in the literature on students' epistemic beliefs. In our research, we took them to be synonymous, and chose to use the term *opinion*. It is also apparent from these few examples that students' responses involved knowledge, opinions, and the connections between the two. This suggests that students may endorse different beliefs about knowledge and about opinions. Even though both kinds of beliefs appear to be expressed in students' responses, the latter have been less studied in the literature and defined as part of the epistemic beliefs to be taken into account in the context of argumentation on SSIs. The description of epistemic beliefs in this context remains restricted to beliefs about knowledge.

13.2.4 Research Questions

Our study aims to achieve a better understanding of the factors at play in high-school students' development of CT on environmental SSIs. In line with other authors (Facione, 2000; Groarke & Tindale, 2013; Kuhn, 2019), we take argumentation to be a major component of CT. More specifically, we assume that CT about environmental SSIs relies on both skills and dispositions to argue on them. As CT

dispositions influence the use of CT skills (Facione, 2000), we chose to specifically study CT dispositions. As pointed out in other studies (Nussbaum et al., 2008; Zeidler et al., 2009), the quality of students' argumentation on SSIs is related to their epistemic beliefs. This leads us to regard epistemic beliefs as a key to understanding how students develop their CT on environmental SSIs. Moreover, as SSIs involve both knowledge and opinions, we investigate epistemic beliefs as representations of knowledge, but also opinions. Based on the literature, we predict that the more elaborated the students' epistemic beliefs are, the more they have developed CT dispositions to argue. Therefore, our research questions are: How precisely are students' epistemic beliefs related to their CT, especially to their dispositions to argue, in the context of environmental SSIs? Which features of their epistemic beliefs about knowledge and opinions are most important in this respect?

We begin exploring our research questions by separately describing the argumentation of six students during an environmental socioscientific debate and their epistemic beliefs on the same topic. We then cross-analyzed our data to show how some features of epistemic beliefs can help us better understand students' critical dispositions to argue.

13.3 Methodology

13.3.1 Context: The AREN Project and the Participants

This study is part of the *Argumentation et Numérique* (AREN) French project (the French word "*numérique*" means "digital"). The purpose of this project is to design an online debate platform (also called AREN) that promotes the development of students' argumentative skills and CT on SSIs, following a design experiment method (Sandoval, 2013). We developed a teaching sequence consisting of three phases: (1) a preparatory phase where students acquire knowledge on the topic; (2) an online debate on an SSI, mediated by the AREN platform; and (3) a synthesis phase, where students undertake a reflective analysis of the quality of the arguments produced during the debate.

The data were collected in two Grade 10 biology classes (mean age: 16 years) in two high schools located in the center of a city from south of France (around 250,000 inhabitants). The first is attended by students from mixed socio-economic backgrounds, and the second by students from middle and low socio-economic backgrounds. We analyzed the productions of six students, three from each class. The sample was composed of four girls (Silène and Hibiscus from the first high school, and Azalée and Crocus from the second high school) and two boys (Jonquille from the first high school and Muguet from the second high school). All original first names have been changed here. All six students were volunteers and were selected with the help of their teachers to reflect varying levels of involvement in class activities. In each class, the teaching sequence was implemented twice during the school year. We examine the second debate, which focused on an environmental SSI, use of renewable energy and/or fossil fuel.

AREN-mediated argumentation has several specific features. Argumentation on the platform is based on a text, which appears on the left side of the screen. Students can debate by posting comments on the right side of the screen. To do it, a student has to select some words, generally a full sentence, in the text or in a peer's comment. This triggers an argumentation pop-up asking the student to reformulate them, give an opinion on this sentence (color-coded: *Tend to agree* in blue/*Tend to disagree* in red/*Do not understand* in grey), and justify this opinion through argumentation. Students are free to fill the *argumentation* box as they wish: the platform induces arguments with a Toulminian structure (Toulmin, 1958), comprising a thesis (here, the opinion) and grounds (in the argumentation box), but this is the only extent to which students' arguments are structured.

As students can react to any part of the text or their peers' comments, argumentation on AREN is not linear, and can take an arborescent structure. It should be noted that there is no guarantee that all the students will actually read all the arguments of the debate, as they may limit themselves to reading only parts of the arguments that are developed in parallel. The reflective synthesis phase, at the end of the teaching sequence, ensures that students have read all the kinds of arguments produced during the debate.

13.3.2 Data Analysis

For our analysis, we first examine the arguments students produced during a debate on environmental SSIs. Second, we describe their epistemic beliefs about knowledge and opinions, based on thematic analysis. Third, we subject the features of both their epistemic beliefs and their argumentative practices to a cross-analysis.

13.3.2.1 Analysis of Students' Argumentation

Assuming that CT is instantiated in argumentation and that argumentation is methodologically the easiest way to evaluate CT (Kuhn, 2019), we chose here to determine students' CT by considering the arguments they produced during debates. To this end, we used a coding scheme developed in the frame of a previous study of the AREN project and applied to analyse about 2500 arguments (Pallarès, 2020) to evaluate the quality of students' socioscientific argumentation. In order to assess CT dispositions in students' argumentation, we link the dispositions listed in APA (1990) to items in the coding scheme. This scheme was based on the view that argumentation is both a dialogical process, in the context of a debate, and a monological process, in relation to students' reasoning (Jiménez-Aleixandre & Erduran, 2007). It was composed of what we called *argumentative moves*. For each of them, we also assessed whether students tried to justify their affirmation, or thesis, for instance using empirical data, examples or personal values.

Concerning CT dispositions, the frequent use of justifications can be linked to the disposition to inquiry, where data are a core component. These argumentative moves, and the precise ways in which they could be related to CT dispositions, are described in Table 13.1, where the last column show examples (underlined) of the argumentative moves, in their context of enunciation. It should be noted that an argument, treated here as the product of an argumentative process (Jiménez-Aleixandre & Erduran, 2007), could contain more than one argumentative move.

We also analyzed the monological aspects of socioscientific argumentation, namely the content of the arguments. We recorded the occurrence of a domain of validity, awareness of uncertainties relative to knowledge, and the socioscientific domains taken into account in the arguments. Each of these indicators, examples for them, and the precise way in which they could be related to CT dispositions, are described in Table 13.2.

13.3.2.2 Analysis of Epistemic Beliefs

The interviews served to elicit students' epistemic beliefs, that is, beliefs about knowledge, opinions and the link between the two. These interviews were conducted after a preparatory phase and before a debate in class. The preparatory phase allowed the students to study definitions and knowledge related to environment in a biology class. They were therefore prepared in terms of knowledge content and knew that they would be debating in a future session on a theme related to what they had studied in biology lessons.

Before the interviews, the researcher explained to students that the aim was not to judge or evaluate what they said, and there were no right or wrong answers. A statement related to the socioscientific theme seen during the preparatory phase: "Human activities that enable economic and social development should not be changed just because they might cause the disappearance of animal or plant species" was then shown to the students, who were asked to express their agreement or disagreement with it. This statement had been previously tested within the AREN project. Each interview lasted about 15 min, was audio-taped and transcribed. We prepared an interview guide featuring nine questions, developed by the first author and their validity discussed with the third and fourth authors. To ensure that the questions were well formulated and understood, the interviews were tested on eight students. Their responses ensured that the questions were well understood and had the potential to elicit students' beliefs about knowledge (Q6 & Q8), opinions (Q2, Q7 & Q9), and the relationship between the two (Q3, Q4 & Q5) (Appendix).

We ran a multistep thematic analysis of the interview transcripts. The first step consisted in describing for each student her or his beliefs about knowledge, opinions, and the link between the two. In the second step, these analyses were compared so as to identify common areas and specific themes. We chose to conduct a thematic analysis first, based on the students' responses, instead of an analysis based on the dimensions established by Hofer and Pintrich (1997) or Chinn et al. (2011). This choice was justified by the fact that we did not know beforehand whether the

Table 13.1 Description of argumentative moves (dialogical aspects of argumentation)

Argumentative moves	Description	Possible links to APA (1990) CT dispositions	Example (translated from French; the relevant parts of the excerpts are underlined)
Concession	Involves the acceptance of another's justification or thesis.	"Flexibility" and "willingness to reconsider" which may concern the thesis or justification one is ready to accept.	Accidents can happen in nuclear power plants (even if it's rare) Nuclear accidents are rare but may be more frequent in the future because nuclear plants grow old
Refutation of the thesis	Counterargumentative move, focused on another's thesis and intended to undermine it.	"Inquiry process," in rebutting with sound data erroneous hypotheses, use of "reasonable criteria," which may be the kind of processes involved when evaluating another's thesis with the aim of refuting it.	I think solar energy is the best, because it does not pollute and is infinite, do not emit greenhouse gas, however we need solar panels and it's expensive Solar energy is not efficient enough, we can't even power a city without another energy
Refutation of the justification	Counterargumentative move aimed at denying a justification put forward by another student.	"Inquiry process," "prudence in making judgments," use of "reasonable criteria," which may be the kind of processes involved when evaluating another's justification with the aim of refuting it.	People's mind is changing, thanks to recycling people care about the planet There's nothing to do with recycling, in any case recycling doesn't prevent millions of people to litter plastic or metallic trash
Nuance	Partial refutation of another's thesis or justification aimed at by pointing out its limitations.	"Fair-mindedness in evaluation," "prudence in making judgments," which may concern another's thesis or justification.	Accidents can happen in nuclear power plants (even if it's rare) Nuclear accidents are rare but may be more frequent in the future because nuclear plants grow old
Development	Intended to complete or extend another student's thesis or justification, by proving further justification or clarification.	"Trustfulness of reason" which may lead to develop another's reasoning expressed in an argument.	[Nuclear accidents] are rare but may be more frequent in the future because nuclear power plants grow oldSo we have to repair them or build new ones

(continued)

Table 13.1 (continued)

Argumentative moves	Description	Possible links to APA (1990) CT dispositions	Example (translated from French; the relevant parts of the excerpts are underlined)
New idea	Consists in considering an idea or point of view which was not discussed before during the debate.	"Open-mindedness" and "inquisitiveness," which may concern a new idea or point of view concerning the topic being disputed.	[In a discussion about nuclear waste and what to do with it] Nuclear waste are generally buried deeply

Table 13.2 Description of content of arguments (monological aspects of argumentation)

Content of the arguments	Description	Possible links to APA (1990) CT dispositions	Example (translated from French; the relevant parts of the excerpts are underlined)
Awareness of a domain of validity for assertions	Identification of the cases in which the argument/thesis can be applied or clarification of the degree of trust in the conclusion.	"Fair-mindedness in evaluation" and "prudence in making judgments," which may consists in identifying the degree of trust and the domain of validity.	Yes [nuclear energy] is one of the best energies from a climatic point of view but not a good energy for its local consequences which are terrible
Awareness of the uncertainties	Expression of specific reservations about the certainty of knowledge or showing prudence in considering the development of technologies.	"Prudence in making judgments," "reasonableness in the selection of criteria" to evaluate "results which are as precise as the subject and the circumstances of inquiry permit," what might amount to taking into consideration the uncertainties related to the situation.	For now there is no energy which both respects the environment and sustainable Which is why we need to find energies like this and if it doesn't exist we'll have to use other means!
Socioscientific domains	Domain(s) which are involved in an argument. Eight domains have been identified: Scientific, Technical, Economic, Political, Social, Axiological (values), Sanitary and Environmental.	"Orderliness in complex matters," which can consist in tackling the SSI systematically in all its complexity by considering its different domains.	We have to [*Axiological,* moral imperative] find other energies with similar capacities as nuclear [*Technical* features] but without being dangerous! [risks for *Health* and *Environment*]

dimensions identified in the literature to describe beliefs about knowledge would be equally suitable to describe beliefs about opinions and the links between both. The thematic analysis allowed us to identify four themes: *opinion and knowledge*, *certainty of knowledge*, *certainty of opinion*, and *possibility and means of obtaining a better opinion*. For each theme, we categorized the types of responses given by students. Moreover, in each theme, we distinguished between students' epistemic beliefs according to the richness of their elaboration. Based on King and Kitchener (2002), we judged the relative elaboration of epistemic beliefs on two main criteria: richness of the awareness of uncertainty, and complexity of criteria and/or strategies for obtaining the best opinion available.

13.4 Results Concerning Students' Arguments and Epistemic Beliefs

In this section we first examine the arguments students produced during a debate on environmental SSIs. Second, we describe their epistemic beliefs about knowledge and opinions, based on thematic analysis. Third, we subject the features of both their epistemic beliefs and their argumentative practices to a cross-analysis.

13.4.1 Analysis of Students' Argumentation and Epistemic Beliefs

The results of the analysis of students' argumentation are summarized in Table 13.3. One "argument" is defined as corresponding to one posted comment. It may consist of several argumentative moves or no argumentative move at all (e.g. "I completely agree").

The analysis of students' epistemic beliefs allowed identifying four themes: *opinion and knowledge*, *certainty of knowledge*, *certainty of opinion*, and *possibility and means of obtaining a better opinion*. The main results regarding epistemic beliefs are summarized in Table 13.4.

13.4.2 Cross-Analysis of Argumentation and Features of Epistemic Beliefs

The interviews indicated different profiles of epistemic beliefs among students, based on the four themes (*opinion and knowledge*, *certainty of knowledge*, *certainty of opinion*, and *possibility and means of obtaining the best opinion*). By the same token, concerning argumentation in the socioscientific computer-mediated debate,

Table 13.3 Analysis of students' argumentative moves and content of arguments (numbers in parentheses correspond to the fraction of argumentative moves with a justification)

Argumentativemoves	Azalée	Crocus	Hibiscus	Jonquille	Muguet	Silène
Arguments (Total)	5	8	6	9	12	7
Concessions	2 (1)	2 (0)	2 (0)	0 (0)	1 (0)	0 (0)
Nuances	0 (0)	2 (1)	4 (1)	1 (0)	3 (2)	0 (0)
Refut. thesis	1 (0)	1 (1)	0 (0)	0 (0)	3 (3)	0 (0)
Refut. justif.	1 (1)	0 (0)	0 (0)	0 (0)	1 (1)	1 (1)
Developments	1 (0)	5 (3)	1 (1)	6 (3)	5 (4)	3 (1)
New ideas	1 (0)	0 (0)	1 (1)	2 (1)	1 (0)	1 (0)
Domain of validity	2	0	3	1	3	2
Uncertainties	0	0	1	0	0	3
Socioscientific domains	4 Technical 1 Scientific 1 Environ.	5 Scientific 4 Technical 2 Environ. 2 Health 1 Social 1 Without domain	3 Environ. 3 Social 2 Health 2 Technical 1 Scientific	4 Technical 3 Environ. 2 Health 1 Political 1 Axiological 2 Without domain	7 Technical 5 Environ. 3 Social 1 Scientific	5 Technical 3 Axiological 3 Environ. 2 Health 1 Without domain

Table 13.4 Types of student responses by epistemic beliefs theme

Epistemic beliefs theme	Opinion and knowledge	Certainty of knowledge	Certainty of opinion	Possibility and means of obtaining the best opinion
Azalée	Different nature of opinion and knowledge	Source uncertainty	Source uncertainty	Possible if we do some research and ask someone who knows
Crocus	Explicit reference to a link between opinion and knowledge	Source uncertainty	Source uncertainty	Impossible but some opinions are better than others, depending on the arguments
Hibiscus	Explicit reference to a link between opinion and knowledge	Uncertainty related to learning, source uncertainty	Source uncertainty	Impossible but some opinions are better than others, depending on whether we ask a specialist
Jonquille	Explicit reference to a link between opinion and knowledge	Almost certain	Uncertainty owing to the nature of opinion	Impossible right now, but time will tell
Muguet	Different nature of opinion and knowledge	Almost certain	Uncertainty owing to the nature of opinion	Possible if we take the most likely opinions in relation to scientific theory
Silène	Different nature of opinion and knowledge	Almost certain	Source uncertainty	Possible if we ask a specialist

we found various kinds of critical arguments, in terms of argumentative moves. The first theme, *opinion and knowledge*, allowed us to make a clear distinction between two groups of students. This led us to analyze the features of the arguments produced by each group. In order to make sense of the specificities of their respective arguments, we considered the degree of elaboration of students' epistemic beliefs.

The two groups differed on their belief about a link between knowledge and opinions: The students Azalée, Muguet and Silène in Group 1 did not mention any link, whereas the students Crocus, Hibiscus and Jonquille in Group 2 explicitly acknowledged and described a link between knowledge and opinions: Crocus, "your opinion is formed from your knowledge"; Hibiscus, "I will form a opinion based on what I know"; Jonquille, "an opinion is formed from what we have seen, what we have heard" (knowledge being identified here by the student to personal experience). These two groups produced similar numbers of arguments during the debate, 24 arguments for Group 1 and 23 for Group 2. However, they differed on the nature of these arguments. Group 1 produced more diverse argumentative moves, whereas Group 2 seemed to focus mainly on developments and nuances. Moreover, Group 2's arguments featured a better combination of the socioscientific domains than Group 1's.

Looking more closely at the diversity of the argumentative moves produced by Group 1, each of the students in this group produced a refutation of another student's justification, which is a complex critical argumentative move (Sampson & Clark, 2008), especially as these three refutations of justifications were each accompanied by a justification of their own. For example, answering another student's claim "if we stop nuclear power plants before an alternative is found we'll run out of energy" the refutation produced by Azalée was: "there are a lot of different energy sources [refutation of the necessity of finding an alternative], there is not only nuclear, but also solar or photovoltaic energy [justification of this refutation: examples of alternatives which already exist]".

By contrast, only two of the students in Group 2 (Crocus and Hibiscus) produced four or more different kinds of argumentative moves, namely developments, concessions, nuances, and refutation of the thesis (Crocus) and new idea (Hibiscus). Another difference was that the arguments of students in Group 2 were more focused on developments and nuances than on counter-arguments and refutations. For example, Crocus produced an argument combining a concession and a justified nuance (even if it was on erroneous grounds): "Each industry has risks, but nuclear is one of the less lethal energy sources (less than solar or wind)."

Regarding the exploration of SSI complexity, students in Group 2 mostly produced arguments tackling more than one socioscientific dimension, whereas students in Group 1 mostly made arguments tackling only one dimension at a time. The specificity of the domains tackled (e.g., if a student tackled more technical or social matters) did not seem to differ across the two groups of students. For example, Hibiscus produced an argument that simultaneously considered the technical, environmental and social domains: "today there is no BEST energy, namely productive enough [for the needs of our society], cheap, risk-free AND nonpolluting."

For Group 1, we also analyzed the complexity of the criteria and/or strategies expressed by students to obtain the best opinion available and their awareness of uncertainty, in order to determine which epistemic beliefs were more elaborated (King & Kitchener, 2002). Muguet set out not only criteria (e.g., "better from someone who knows") but also a genuine strategy for obtaining the best opinion available: for him, opinions had to be compared with scientific theory to decide which one was the most trustworthy. For Azalée, to obtain the best opinion, it was important to do research and ask a knowledgeable person. We interpret that this process was less elaborated than the one described by Muguet, as it referred more to criteria than to an actual strategy. Silène considered that the best opinion must be one that came from a specialist, and she therefore described the least elaborated way of obtaining the best opinion. Muguet produced more advanced argumentative moves than Azalée and Silène did. Furthermore, Muguet produced more refutations than Azalée, who made more refutations than Silène. Muguet was also the only one of the six students to question another student.

Regarding Group 2, it was awareness of uncertainty that appeared to be decisive in differentiating between the degrees of elaboration of students' epistemic beliefs. Hibiscus seemed to have the most elaborated epistemic beliefs: "there are things that I know, well maybe it is not true [. . .] with more advanced knowledge [. . .]. So I

think there are some knowledge that are safe, that everybody learns and it's a reality and some others that aren't necessarily. [...] you really need to be specialized in a field to have more advanced knowledge." Crocus seemed to have less elaborated epistemic beliefs than Hibiscus, as she only considered uncertainties about the source of knowledge. Jonquille had even less elaborated epistemic beliefs, as for him, knowledge was always almost certain. Incidentally, Hibiscus's argumentation was more critical than that of Crocus and Jonquille: she produced fewer arguments, but was more focused on nuances (four nuances on six arguments, which is a lot considering that nuancing is a complex critical move), associating them with concessions, and showing considerable awareness of the domain of validity in her arguments (three arguments out of six). Furthermore, Hibiscus tackled more than one socioscientific domain in almost all her arguments (five out of six). Similarly, Crocus's arguments were better than those of Jonquille: her nuances were combined with concessions, she produced a refutation of the thesis, and explored SSI complexity more.

Overall, regarding argumentation and epistemic beliefs, Muguet (Group 1) and Hibiscus (Group 2) were the ones who produced the most critical arguments and who had the most elaborated epistemic beliefs. However, these two students did not argue in the same manner, and their epistemic beliefs differed in one important respect (i.e., expression or not of a link between knowledge and opinions). Muguet was the one who produced the greatest variety of argumentative moves, including justified refutations and questions. We consider that Muguet had the most highly elaborated epistemic beliefs, based on the complexity of the strategy he described for obtaining the best opinion. By contrast, Hibiscus produced a great many nuances and developed arguments related to several domains. We consider that Hibiscus produced the most highly elaborated epistemic beliefs, based on her awareness of uncertainty.

13.5 Discussion and Conclusion

The goal of this study is to highlight links between epistemic beliefs and CT dispositions. As such, our research questions were: How exactly are students' epistemic beliefs related to their CT, and more specifically to their dispositions to argue, in the context of environmental SSIs? Which features of their epistemic beliefs about knowledge and opinions are the most important components in this respect?

In the wake of findings that epistemic beliefs seem to be linked to the way in which students argue, the study provided a new and more fine-grained analysis, offering a mean of defining the relationships between specific features of epistemic beliefs and ways of participating in a computer-mediated discussion on an environmental SSI. Previous studies had found that the more elaborated individuals' epistemic beliefs are, the better they argue (e.g. Kuhn, 1991; Mason & Scirica, 2006). Our study shed further light on this influence. Students may produce arguments

focused more on nuances, or focused more on refutations. Furthermore, it seems that when epistemic beliefs are elaborated, with respects to King and Kitchener's (2002) criteria, students' arguments tend to become more critical, with more nuances (than developments) and more refutations.

Our cross-analysis yields two main results. First, students could be categorized according to whether they ignored the link between knowledge and opinions, or whether they acknowledged and explicitly described it. Indeed, students produced different arguments, depending on whether or not they drew this link: students who ignored it made various argumentative moves and were the only ones to refute justifications, while students who explicitly described this link focused on developments and nuances, and produced more complex arguments from a socioscientific perspective. Second, these specific argumentative features seemed to be related to students' awareness of uncertainties of knowledge and/or their strategy for obtaining the best opinion. The more elaborated students' epistemic beliefs regarding these two aspects, the better they argued. Hibiscus and Muguet, the students with the most elaborated epistemic beliefs, exhibited the most critical argumentation, but in different ways, as Hibiscus saw a link between knowledge and opinions, whereas Muguet did not.

Concerning CT, it should be noted that argumentative moves, be they in the form of nuances or refutations of justifications, can be linked to the same evaluative dispositions, namely *reasonableness of the selection of criteria*, *fair-mindedness in evaluation*, and *prudence in making judgments* (APA, 1990). This is in line with the literature, which indicates that evaluation is a crucial component of critical argumentation (Facione, 2000, 2011; Groarke & Tindale, 2013; Van Eemeren & Grootendorst, 2004; Walton, 1996). Moreover, even if Hibiscus and Muguet differed on their epistemic beliefs, they expressed the same CT dispositions and had the most elaborated epistemic beliefs. It therefore seems that the more elaborated their epistemic beliefs, the more students were disposed to CT. However, the nature of students' epistemic beliefs about the link between knowledge and opinions led them to operationalize these same dispositions in different ways. For instance, by contrast with other students who explicitly drew a link between knowledge and opinions, Hibiscus's arguments contained a high proportion of "nuances" moves. Meanwhile, Muguet's arguments contained a greater variety of argumentative moves and more refutations than those of other students who neglected the link between knowledge and opinions. There were other characteristic features of students' arguments, namely the use of justification for students who ignored the link between knowledge and opinions, and socioscientific complexity for students who explicitly drew such a link. Concerning CT, these features referred to different dispositions, namely *focus in inquiry* (i.e., a set of procedures and criteria appropriate for making reasonable judgments), and *orderliness in complex matters* (i.e., dealing with and organizing complexity in specific issues) (APA, 1990). It seems that when students argue, they are more focused either on inquiry or orderliness, depending on whether they neglect or consider respectively the link between knowledge and opinions.

Furthermore, epistemic beliefs appear to be more elaborated when students become aware of the uncertainty of knowledge, viewing it as a flawed product that does not reflect reality as it is, but rather an approximation of it (King & Kitchener, 2002; Kuhn et al., 2000). In this regard, it should be noted that, as in the study by Mason et al., (2011), most of our participants seemed primarily focused on the credibility of the source, rather than uncertainties inherent to knowledge itself. This may be explained by the fact that such uncertainties, to be acknowledged, require a developed epistemological view on the nature of knowledge. Our results argue in favor of considering epistemic beliefs not only about knowledge, but also about opinions, as well as the link between them, in order to highlight links with CT in the context of environmental SSIs. This would provide means to investigate precisely how the link between knowledge and opinions drawn by students influences the way they perceive content relating to different SSI domains. For example, depending on their epistemic beliefs, do students perceive arguments relating to the technical and scientific domain as involving only knowledge, and arguments relating to both the social and moral domains as involving only opinions (Kuhn et al., 2000)? The link between epistemic beliefs and CT seems to be a complex one, and needs to be studied with regard to the features of both knowledge and opinions, in order to highlight their influence on students' argumentation. Our cross-analysis focused on two specific aspects of epistemic beliefs: the link between opinion and knowledge, and the elaboration of epistemic beliefs regarding the *certainty of knowledge* and the *possibility and means of obtaining the best opinion*. However, epistemic beliefs can be described from many other aspects (e.g., dimensions proposed by Chinn et al., 2011). Furthermore, the operationalization of critical dispositions appears to differ across contexts: previous studies showed that students' arguments vary according to the SSI being debated (Pallarès, 2020; Pallarès et al., 2020), as well as students' epistemic beliefs (Zeidler et al., 2009). Implementing teaching sequences in the context of other SSIs or in nonsocioscientific debates could yield more detailed data on the link between epistemic beliefs and CT. Finally, it should be noted that our study focuses on computer-mediated argumentation, which may have induced a very different operationalization of CT dispositions from oral argumentations, and further investigation is also needed in that direction.

Despite these limitations and the need for further research, as far as the implications for teaching are concerned, our study highlighted specific epistemic beliefs that should be fostered in environmental education, in order to improve the relevant CT dispositions and thereby students' socioscientific argumentation, making it more critical. This might provide an answer to the problem of students being uncritical of environmental issues that has been identified in previous research (Barthes & Jeziorski, 2012). First, to improve students' critical argumentation, the first set of CT dispositions that need to be fostered are linked to evaluation: *reasonableness of the selection of criteria*, *fair-mindedness in evaluation*, and *prudence in making judgments*. These three dispositions seem to be linked to the critical argumentative moves we observed, notably in students Hibiscus and Muguet. In this regard, one

way of improving CT dispositions may be to develop some aspects of epistemic beliefs related to these critical dispositions. It might be useful for environmental education to foster the sort of epistemic beliefs exhibited by Hibiscus and Muguet, namely the link between knowledge and opinions and either uncertainties (Hibiscus) or the criteria for obtaining the best opinion (Muguet). Before or during a socioscientific debate, teachers could help students ask themselves about the links between knowledge and opinions, the uncertainties of knowledge, and strategies to articulate knowledge and opinions and to deal with these uncertainties. As one of the aims of environmental education is to foster students' CT about SSIs (Morin et al., 2014, 2017; Simonneaux, 2007), this focus on epistemic beliefs would be in line with its objectives.

Second, CT dispositions to *focus in inquiry* and *orderliness in complex matters* also appear important for fostering critical argumentation. Considering that the latter seems to induce a more complex argumentation from a socioscientific perspective, it might be preferable to focus specifically on this in the context of environmental education, which has to deal with complex SSIs. As Leung (2020) pointed out, students who only consider uncertainties about inquiry, and not about the nature of knowledge, may work well when they have to deal with well-established and reliable knowledge. However, this may be more problematic in a context where they have to argue about environmental SSIs, which are complex and uncertain (Morin et al., 2014, 2017).

Overall, this discussion shows that the relationship between students' epistemic beliefs and students' dispositions to argue about environmental SSIs remains a very complex question. However, it also points out that explicitly considering both knowledge and opinions in this respect opens up new avenues that deserve to be explored in future research.

Appendix: Questions of the Interview Guide

- Q1: What do you think about the statement? Do you agree?
- Q2: Would you say your opinion about this subject is certain?
- Q3: Who might have the best opinion on this?
- Q4: How can we obtain the best opinion/least bad opinion?
- Q5: What are the differences and similarities between an opinion and knowledge? What is knowledge?
- Q6: Is knowledge certain or uncertain?
- Q7: In comparison, is an opinion certain or uncertain?
- Q8: Does knowledge change over time?
- Q9: Does an opinion change over time?

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