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The notion of the relationship to knowledge: A theoretical tool for research in science education

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Abstract

This article pursues a dual objective. First, it seeks to present the notion of the relationship to knowledge as a valuable theoretical tool for science education research. Secondly, it aims to illustrate how this notion has been operationalized in recent research conducted in Quebec (Canada) that focuses on teachers‟ and students‟ relationship to knowledge. The first portion of this article presents the notion of the relationship to knowledge, documenting its origins, usefulness and contributions to research in the field of science education. In the second portion, we present four (4) studies recently conducted in Quebec that relied on the notion of the relationship to knowledge to analyze, respectively: 1) postsecondary science students‟ relationships to experts; 2) secondary students‟ epistemological postures and relationship to scientific knowledge; 3) the relationship to knowledge and school of primary and secondary students who repeated a school year; and 4) the relationships to knowledges (in the plural form) of preservice secondary science and social studies teachers. We also present one (1) project, in progress at this time, which is dedicated to the point of view of preservice primary teachers concerning science and science education. By way of conclusion, we set out some main avenues for further research and debate in science education.

Keywords: teacher education, Science Education, scientific literacy, students‟ relationship to knowledge, students‟ relationship to scientific experts, secondary and postsecondary education., primary

Introduction

In Quebec as in several countries throughout the world (Guo, 2007), primary and secondary science education has recently been the focus of major curricular reform (Ministere de 1'Education du Quebec [MEQ], 2001a, 2001b)[1] that has generated interest among policymakers, science educators, science teachers, parents and the general public. In Quebec as elsewhere, the objective of primary and secondary science education is scientific literacy of a kind that facilitates the appropriation of disciplinary concepts, fosters the ability to take part in technoscience-related discussions, and promotes sociopolitical empowerment (Anderson, 2007; Roberts, 2007; Roth & Desautels, 2002). From this perspective, the expectation is, to begin with, that students will develop an informed, in-depth understanding of the nature of science, certain scientific concepts, as well as the research methods specific to science and technology (Fourez, 1997; Ministere de FEducation du Quebec, 2001b). There is the additional expectation that (primary and secondary) science teachers will prepare students to function effectively in the (international, national and local) community by providing them with the appropriate resources and learning situations. The main objectives pursued by science education in Quebec are in line with the comments of Guo (2007) on this matter:

> Students and citizens need to be well prepared for a science- and technology- oriented twenty-first century. Rather than preparing selected elites for science careers, schools now are expected to promote scientific literacy for all students. Science teaching, learning, and assessment are expected to stress [the?] meaningful learning of basic concepts, a better understanding of the nature of science, and communication skills, critical thinking, cooperative learning, and problem-solving. Science curriculum and instruction are expected to have relevance to students' daily lives and deal with social issues (p. 252).

1. The Ministère de l'Éducation du Québec (MÉQ) was created in 1964. During a cabinet shuffle in February 2005, the MÉQ became the Ministère de l'Éducation, du Loisir et du Sport (MELS). (p. 2 of manuscript)

Numerous studies have shed light on the point of view of students and teachers concerning science not only in terms of epistemological postures and conceptions of the nature and social dimension of science but also in terms of the mastery of scientific concepts. These studies show, for example, that secondary students tend to entertain predominantly empiricist and realist conceptions of the nature of science, which hold, on the one hand, that science consists in accurate representations of the world that are obtained through the methodical gathering of empirical data and, on the other hand, that the meticulous observation of reality generally ensures the validity of the resulting knowledge (Driver, Leach, Millar & Scott, 1996; Larochelle & Desautels, 2003). Many students thus appear to ascribe a kind of "ideological immunity" to science and have difficulty conceiving how research might be influenced by social, economic, political and ethical considerations. According to this conception, negotiations, debates and disagreements between researchers are not a part of the regular production of scientific knowledge but instead constitute anomalous behaviour (Driver et al., 1996) that in some instances stems from the partisan interests of certain scientists. In the view of these students, such disagreements are generally beneath consideration and, in all logic, should ultimately disappear. The underlying assumption is that the study of the same given phenomenon by different scientists ought ultimately to lead to the same type of methodical description of the real and thus to the same conclusions (Bader, 2003a).

From an epistemological and social point of view, this conception of science is problematical, for it provides no basis for either understanding the uncertainties that are necessarily a part of any production of scientific knowledge, contemplating the limitations of the knowledge thus produced (Wynne, 1997), or collectively debating the attendant issues of risk management. After all, if science and scientists describe that which is, then there is nothing for it but to go along with the expertise that no doubt states the facts. As noted by Desautels (2002), and as tends to emerge from our research (Bader, 2003a, 2002), such epistemological postures lead to an overestimation of scientific expertise and leave little room for negotiation and counter-argument with experts.

It remains, however, the objective of renewing the school conception of science will make it necessary to identify, early on, students' conceptions, outlooks and postures respecting school science, the nature of science and the social function of science. It is with such considerations in mind that a number of French and

Quebec researchers have taken a keen interest in studying students' relationships to knowledge, an aspect that we will develop in greater depth below.

Respecting the points of view of in-service and preservice teachers, the findings of numerous studies in the field of science education generally come around to the conclusion that science teaching has remained tradition-bound (Lyons, 2006; Rennie, Goodrum & Hackling, 2001). It would thus appear that teachers favour a canonical approach to science teaching that is little conducive to epistemological reflexivity, a capacity that is vital to the process of challenging scientific expertise. In that respect, a number of studies focusing on the epistemological postures of preservice primary teachers have shown that, in keeping with the pattern exhibited by secondary students (Driver et al., 1996) and preservice secondary teachers (Guilbert & Mujawamariya, 2003), preservice primary teachers entertain a number of misconceptions concerning the nature, production and scope of scientific knowledge (recently: Bader, 2008; Tsai, 2007; for a review of the literature, see Abd-El-Khalick & Lederman, 2000). Likewise, the way that in-service and preservice teachers picture disciplinary knowledge and the conditions under which it is produced plays an important role in how they interpret the ins and outs of educational reforms and the choice of teaching approaches (Smith & Southerland, 2007). In awareness of this fact, several studies have attempted to identify the difficulties encountered by teachers who opted for an approach to science education that was designed to initiate students into participating in discussions over sociotechnical controversies (Barnett & Hodson, 2001; Levinson & Turner, 2001; McGinnis & Simmons, 1999; Osborne, Duschl, & Fairbrother, 2003; Pedretti, 2003; Tsai, 2001). As identified by teachers, such difficulties included a lack of self-confidence in terms of facilitating students' learning process and mastering the concepts targeted for study (Blades, 2008), along with the impression that focusing on debates between scientific experts detracted from science's image (Abell & Lederman, 2007; Jones & Carter, 2007).

Other studies have brought out how the epistemological postures of preservice teachers are constructed on the basis of their previous experiences involving the learning of science (Jones & Carter, 2007). Some studies have shown that epistemological postures play a decisive role in this process (Ben Abderrahman, 2000; Jelman, 2002). As analyzed by Jones and Carter (2007), research results also show that teachers who lack confidence respecting science education -

and particularly primary teachers (Tosun, 2000) - tend to neglect science education whereas those who are comfortable with the types of scientific knowledge covered in the curriculum dedicate longer amounts of time to these tasks. Barnett and Hodson (2001) were referring to just this phenomenon when they wrote, "Knowledge that enables teachers to feel more comfortable in the classroom and to enhance their sense of self is likely to be embraced; knowledge that increases anxiety or makes teachers feel inadequate will almost certainly be resisted or rejected" (pp. 431- 432). "

These various research findings warrant reflection, all the more so since the curriculum reform instituted by Quebec's Ministere de 1'Education, du Loisir et du Sport (MELS, or Ministry of Education, Recreation and Sport) has highlighted the notion of the relationship to knowledge when articulating its expectations respecting science teaching/leaming and the training to be provided to teachers concerning these questions. The ministry's recommendations specifically mention that preservice primary teachers should adopt a "freer relationship" toward scientific knowledge and stress the need for university-level teacher trainers to encourage preservice primary and secondary teachers to develop a freer relationship with scientific experts: "This new relationship allows [preservice teachers] to ask questions, exercise judgment and think up new ways to apply expertise in learning tasks requiring the use of ‘scientific' knowledge" (MEQ, 2001a, 2001b)"

As an outgrowth of these various considerations, each of this article's authors has conducted research concerning teachers' and students' relationships to knowledge. Furthermore, the impetus for the present article stems, generally, from a symposium[2] organized in May 2008 by the first two authors and a colleague of theirs concerning the notion of the relationship to knowledge in research in science education and the environment, and particularly from a conference given by Author 3 (in October 2008) concerning the methodological orientations appropriate for studying the relationship to knowledge. The three authors thus felt it would be valuable to disseminate, in the world of English-speaking science education research, the notion of "relationship to knowledge," which is already well known and abundantly used throughout French-speaking world of Europe and Canada (and more specifically Quebec). The outcome, occurring several months later, has been this article, which, in short, we wrote in order to present the notion of the relationship to

2. The complete program of this symposium is available for viewing at xxx (p. 7 of manuscript)

knowledge as well as a number of science education research projects from Quebec - i.e., projects whose problematic or theoretical framework are structured around the notion of the relationship to knowledge.

In the first part of this article, we present the origins of the notion of the relationship to knowledge, the perspectives (psychoanalytical, sociological and didactic) informing its use, and the dimensions covered by this notion (epistemic, identity-related and social). In the second part of this article, we emphasize the relevance and contributions of the relationship to knowledge in science education research, as illustrated by four (4) recent Quebec studies that drew on this notion and by one (1) research project currently being conducted. As readers will no doubt notice, the authors of these studies exhibit a range of research interests and subjects and focus on a diversity of analytical units. Specifically, these studies concern: (1) the relationship of postsecondary students toward scientific experts (Pouliot); (2) the epistemological postures and the relationship to scientific knowledge adopted by 17-year-old students (Bader); (3) the relationship to knowledge of students who repeated a school year (Bader & Therriault); and (4) the relationship of preservice secondary teachers toward scientific knowledge and school knowledge (Therriault). Further, we present a (1) research project in progress concerning the relationship of preservice primary teachers toward scientific knowledge and science education (Pouliot). This diversity serves to illustrate the different ways that the notion of the relationship to knowledge can be used to understand not only the views of preservice teachers concerning their school experience but also their outlooks respecting science teaching and learning. In the conclusion, we propose an assessment of the impact of these studies concerning the relationship to knowledge and sketch out the resulting main avenues ahead for science education.

The Notion of the Relationship to Knowledge: Sociological and Didactic Perspectives

In this section, we present the theoretical notion of the "relationship to knowledge, ” as defined by the adherents of its psychoanalytical, sociological and didactic conceptions. We discuss the origins of this notion as well as the dimensions covered under it.

The "relationship to knowledge'' (in the singular) emerged approximately 40 years ago in such disciplines as psychoanalysis, sociology and anthropology[3]. A certain body of research based on this notion addressed various problems and issues relating to education and learning (Chariot, 2001; Mosconi, 2000, 2008). On the one hand, clinical researchers referring to a psychoanalytical model used the notion of the relationship to knowledge beginning in the 1960s while, on the other hand, sociologists of education working in a critical current also began drawing on this notion in the 1970s. In the 1980s and 1990s, it became the focus of a research problematic and the subject of empirical research (Rochex, 2004).

Table 1 proposes an overview of how the notion of the relationship to knowledge is conceived of according to psychoanalytical, sociological and didactic perspectives. In addition to bringing out the diversity of theoretical frameworks from which this notion takes its inspiration, the table also shows the areas of convergence and divergence occurring between such frameworks. In that respect, it is worth noting that education research involving this notion very often draws on the sociological and didactic perspectives. Table 1 also establishes a link between each of these perspectives and a specific research team: in the case of psychoanalysis, CREF[4] (Centre de Recherche Education et Formation), Universite Faris-X Nanterre, whose founder was Jacky Beillerot; in the case of sociology, the team known as E.SCOL[5] (Education scolarisation), Universite Taris-VIII Saint-Denis, founded in 1987 by Bernard Chariot; and in the field of didactics, the research of IREM[6] (Institut de Recherche sur 1'Enseignement des Mathcmatiqucs). Aix- Marseille, in particular under the supervision of Yves Chevallard using an anthropological approach to knowledge. While the notion of the relationship to knowledge first developed in France and while its main representatives hail from the French-speaking world, it is today widely known and used, generally in French-speaking countries. At the same time, this notion appears only very infrequently in the English-language literature (see: Evrard, Huynen, & Vander Borght-de Bueg- er, 1998; Hausfather, 1998).

3. The historical overview of the notion of the relationship to knowledge developed by Charlot (2003) shows that numerous authors and thinkers, including Socrates, Plato, Descartes, Hegel, Bachelard and Lacan, examined this relationship a long time prior to 1960. (p. 9)

4. (p. 10) CREF “Savoirs et rapport au savoir”: http://www.u-paris10.fr/52124470/0/fiche_cref_%20class=_pagelibre/ (in French only)

5. (p. 10) E.SCOL: http://escol.univ-paris8.fr/rubrique-2.php3?id_rubrique=88)

Table 1. The notion of the relationship to knowledge, viewed from three perspectives: an overview

	Psychoanalytical	Sociological	Didactic
Timeline	From the 1960s to the present time	Beginning in the 1970s and through the 1980s and 1990s	Since the 1990s
Main representatives	Beillerot, Blanchard-Laville and Mosconi	Charlot, Bauthier, Rochex and Jellab	Chevallard, Caillot and Maury
Defining elements	• Clinical approach to the relationship to knowledge (singular) • Refers to the desire to know and not to a specific object of knowledge • Preferred angle of approach: the conscious and the unconscious	• No knowledge without a relationship of the subject to said knowledge (singular) • Refers to a certain relationship to the action of learning • At one and the same time a relationship to the world (epistemic dimension), to oneself (identity-related dimension) and to others (social dimension) • Preferred angle of approach: the individual • Used in education research	• Relationships or rapports to knowledges (plural) • Relationships of individuals or an institution to particular, objects of knowledge related to (school or scientific) disciplines • Preferred angle of approach: knowledge, proper • Used in education research

While both the didactic and sociological approaches lend themselves well to operationalizing the notion of the relationship to knowledge, they also pursue different finalities. From the perspective of didactics, the idea of relationships to knowledges (in the plural form) grew and developed during the 1990s in the field of mathematics education, in which Chevallard (1992, 1996, 2003) stands out as a precursor. Chevallard's approach introduced the idea of the relationship that a subject or an institution maintains with a given object of knowledge. Following from this, there are two types of relationships to knowledge - namely, personal and institutional relationships to an object of knowledge. From this point of view, the personal relationship is, correla- tively, an institutional relationship with the object: the personal relationship is constituted and is modified under the pressure exerted by the institutional relationship to the object.

From the perspective of sociology, the idea of the relationship to knowledge (in the singular) first developed in reaction to the research of sociologists who attempted to explain academic failure (including the drop-out phenomenon) by invoking theories of social reproduction, social origins and sociocultural handicap (Chariot, 1997, 2003; Chariot, Bauthier, & Rochex, 1992; Kalali, 2007).

According to these authors, such theories explain academic failure in terms of lacks, gaps, deficits or deficiencies, all of which amounts to framing this phenomenon in negative terms only. The sociological perspective on the relationship to knowledge instead proposes a "positive interpretation'' of academic success or failure via a grasp of the subject's relationship to knowledge (be this subject a student, teacher, etc.) and of the processes that accompany the structuring of this relationship. According to the sociological approach, academic failure can be viewed as a sequence of events that figure in the learner's personal and academic history. In particular, this research (see Chariot et al., 1992; Jellab, 2001, 2006) shows that the personal history of subjects is not conditioned by social origin.

According to a sociological conception of the notion of the relationship to knowledge, knowledge "only has meaning and value in reference to the relationships that it presupposes and that it produces with the world, oneself and others.” (Chariot, 1997, p. 74 (our translation)). Thus, one of the premises underlying the notion of the relationship to knowledge holds that the process known as "learning” and that consists in appropriating the world and constructing one's self occurs in interactions with others. From this perspective, the relationship to knowledge refers to a rapport (or rapports) with the world and with an individual's learning-centred action. The "world” is not given but is instead constructed by human beings. It consists, among other things, of objects, practices, concepts, institutions, relations, symbols, etc. Students engage in relationships with others in order to learn - which implies, in other words, the actions of a subject. Learning-related action is thus a movement that occurs both within the subject (i.e., falls to the subject) and outside the subject (i.e., requires the actions of others) (Chariot, 1997, 2003). This definition of the relationship to knowledge opens onto three interrelated dimensions: the epistem- ic (relationship with the world and the learning process), the identity-related (relationship with oneself), and the social (relationship with others). The essential characteristics associated with each of these dimensions are set out in Table 2. Although we discuss the epistemic, identity- related and social dimensions separately from one another, it is important to recall the interconnections occurring between them, which contribute significantly to the insights that the notion of the relationship to knowledge proves into individuals' points of views concerning both science and science teaching and learning.

Today, a considerable body of science education research has actively drawn on the relationship to knowledge to document and

analyze difficulties of a cognitive, cultural and epistemological nature. Generally speaking, this research has focused on the types of relationships that teachers and students at various levels of schooling (primary, secondary, junior college and col- lege/university) maintain with a scientific discipline or a specific school subject (Calmettes, 2005; Venturini, 2005) or with well-defined disciplinary content knowledge (e.g., the evolution of species, lightning or volcanism). At the same time, other research has investigated the relationships between students' relationships to knowledge and their conceptions of a particular discipline (Chartrain, 2002), students' relationship to knowledge and the level of conceptual mastery (Albe & Venturini, 2002; Jourdan & Ternse, 2002), or students' relationship to knowledge and their cultural origins (Ben Abderrahman, 2000; Jelman, 2002)[6].

Table 2. Dimensions of the notion of the relationship to knowledge from a sociological perspective

Dimension	Definition
Epistemic (relationship to the world and to learning)	• Refers to the learning subject's appropriation of representations of the world and of knowledges conveyed at school and generally enshrined in empirical objects (e.g., curricula and textbooks).
Identity-related (relationship to one-self)	• Refers to the individual's history, expectations, goals, values and represen-tations, practices, manner of viewing life and to his/her relationships with others, self-image and the image he/she would like to project. • Concerns the relationship of meaning that is established between the indi-vidual and knowledge.
Social (relationship to others)	• Closely bound up with the identity-related dimension: learning occurs through interaction with others.

The methodological instruments we drew on included "assessments of knowledge" (a term coined by Chariot (1997) and which refers to texts written by students in response to a question about what knowledge is important for them in all that they have learned), semi-structured interviews and written questionnaires. It is worth noting that in the growing body of science education research drawing on the notion of the relationship to knowledge (Maury & Caillot, 2003), several studies were conducted in France and elsewhere in the French-speaking world (Belgium, Tunisia, Quebec, etc.).

6. (p. 13) For a more in-depth presentation of science education research that relied on the notion of the relationship to knowledge, please see Pouliot (2007) and Therriault (2008)

Research Completed or In Progress in Quebec

As was mentioned at the beginning of this article, we will attempt a rather rapid overview of research that has been completed or that is underway in Quebec. The objective is not so much one of engaging in traditional description as one of signalling and illustrating research problematics and conceptual frameworks that have been structured by the notion of the relationship to knowledge.

Completed Research

Preuniversity Students' Relationship to Scientific Experts (Pouliot)

Context and aims of the study

The accelerated development of the technosciences has given rise to a number of controversies (concerning, for example, the use of cellular telephones, the production of genetically modified organisms, and the manipulation of stem cells). For several authors (Callon, Lascoumes & Barthe, 2001; Latour, 2004; Wynne, 2005), managing such controversies, on account of the accompanying risks and uncertainties, compels the participation not only of scientists, industry and government actors but of citizens too. Each is called on, according to his or her specific field of knowledge, to take part in defining the problem at hand and inventorying potential solutions. That being said, if citizens are to take part in discussions effectively, they must believe themselves to be legitimate interlocutors who can, where required, "challenge" the comments of scientific experts and the status of being above the fray (Statut d'exception) that generally attaches to these experts (Aikenhead, 2006; Roth & Lee, 2002; Larochelle & Desautels, 2006).

The present study is part of a broader, three-year project that was funded by the Social Sciences and Humanities Research Council of Canada (SSHRC). Located within the perspective of "technoscientific literacy for praxis" (Roth & Desautels, 2002), this project was designed to enable preuniversity students (i.e., students enrolled at Quebec "cbgeps," roughly the equivalent of North American junior college, or a 12th and 13th year of schooling) to picture themselves

as citizens capable of stating their views on sociotechnical controversies and engaging in political
debates that mobilize knowledge as well as scientists in their capacity as "experts.'' In particular, I focused on students' views concerning the roles and capacities of social actors concerned by current sociotechnical controversies and what, in their opinion, constituted scientific experts (Pouliot, 2007, 2008, 2009, 2010). This study provided some elements of response to the following research question: "What relationship do students maintain toward people whom they consider to be scientific experts, in the context of a 15-week-long investigation of the controversy surrounding the use of cellular telephones?”

Methodology

This project involved the participation, in winter 2004, of two classes (subdivided into small teams of three persons each) of a science course. Each team of three students was paired with another team of three students, thus forming groups of six (6) students altogether. Students worked jointly on elucidating the issues surrounding a sociotechnical controversy on virtual forums (Wikis and chat sites) and through the use of a GNU/Linux operating system. Also, through a process involving interdisciplinary "rationality islands,” that six-member groups (co)developed a representation of the sociotechnical controversy of interest to them. This interdisciplinary approach provides a basis from which to contemplate situations from a broad range of disciplinary angles (Maingain, Dufour, & Fourez, 2002).

I recorded all the spontaneous discursive interactions that occurred between the members of the group; as well, I conducted (and recorded) a series of group interviews. I then worked from the full transcription of the spontaneous interactions and the interviews to produce a discourse analysis (Potter, 1996).

Results and Discussion

The results show that the relationship that students adopt toward people they consider to be scientific experts (specifically, researchers and physicians) is marked by intimidation. Students depicted scientific experts in terms of the competencies and knowledge possessed by the latter; they allowed as to being impressed by the social recognition accruing to some scientific

experts; they viewed an interview with a scientific expert as an impersonal, intimidating relationship during which their discursive and comprehensive capacities will be put to the test; and they repeatedly mentioned the difficulty of challenging the actions or words of a scientific expert (Pouliot, 2007), comparing themselves to children who must place their trust in scientific experts.

> Jimmy: Personally, I'm inclined to trust the researchers as such, but I wonder about the people, the politics around them. (…)
> Remi: It's not easy to see clear [in the situation]. You have to put your trust in them.
> Sophie: In this area, we're like children.
> Jimmy: You're right.
> Sophie: You seek out information, and then you put your trust in them. (IIB 098; 2004-02-10)

The notion of the relationship to knowledge provided a basis for taking into consideration the comments of students concerning not only scientific experts (the latter's roles and capacities) but also the activities which they undertook in order to meet experts, the constraints they encountered, the aspirations they harboured, and their capacities for learning science and understanding the issues associated with the controversy. Within the framework of this research project, the value of operationalizing the notion of the relationship to knowledge stems from the insights afforded into the ways young people picture some of the social actors concerned by the controversy (namely, the "scientific experts'') and how they perceive their relationships with them.

Secondary Students' Relationship to Scientific Knowledge (Bader)

Context and aims of the study

For several years now, my research has focused on secondary students' relationships to scientific knowledge. Following Chariot (1997), this relationship to knowledge can be defined as a "set of relations of meaning, and thus of value, between an individual (or a group) and the processes or products of knowledge" (p. 92 (our translation)), and which thus encompasses epistemic, identity-related and social dimensions, as was defined above.

A number of my projects have brought into play the notion of the relationship to knowledge, focusing on students' epistemological postures and conceptions of science via, in particular, the lines of argument deployed in the context of studying scientific controversies. Initially, as an extension of the work of Desautels (Desautels, 2002) and Desautels and Larochelle (1989), I chose to concentrate on studying the relationships to scientific knowledge of students in their last year of high school, and more specifically concerning the epistemic dimensions, as well as the identity-related and social dimensions, that corresponded to the conceptions of science marshalled by students (Bader, 2003a; 2003b). My desire is to identify the weightier trends that shape the ways that these young people conceive of science, in keeping with a concern for democratizing science education and for moving citizen education in the sciences toward a freer relationship toward this field of expertise (Desautels, 2002). By way of corollary, it is also important to note that the relationship to knowledge is also a relationship to power - that is, a relationship to knowledge to which a certain status of authority has been accorded and that it is more or less legitimate to call into question. By analyzing the relationship of students to scientific knowledge and by taking into consideration the epistemic, identity-related and social dimensions framing this relationship, I have sought to document ways of taking into consideration students' postures with a view to renewing their conception of science. And, as was mentioned in the introduction to this article, a realist, empiricist conception of the technosciences provides little basis on which to contemplate the social dimensions that shape the production of science. Several authors have stressed the importance of including elements of science epistemology and sociology in the classroom and thereby renewing the approaches used to present what the doing of science means (Cunningham & Helm, 1998; Fourez, 2002; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003; Bader, 2004, 2005, 2008). The idea is to enable young people to consider that science is also a matter of arguments, publications, funding searches and ethical concerns. Likewise, a priority has been made of restoring to favour classroom debates about science and their social impacts (Driver, Newton, & Osborne, 2000; Simonneaux, 2004; Albe, 2008). This point is all the more critical in that, as has been brought out by Latour (2004), the public image of science has made it difficult to challenge such knowledge and has, in this process, endowed it with a status of authority and reinforced the conventional overestimation of scientific expertise. From this point of view, it is particularly

worthwhile studying how students in the last year of high school adopt a position on these questions.

With these considerations in mind, I strived to identify the discursive procedures that 17- year-old Canadian students marshalled for interpreting a disagreement between two researchers who did not share the same research priorities where the issue of global warming was concerned. I thus asked small groups of three subjects each to interpret the reasons for the disagreements between these two researchers (Bader, 2003a, 2003b).

Results and Discussion

Identifying the discursive procedures mobilized by these subjects enabled me to describe in detail how their essentially empiricist and realist conception of science shapes their interpretation of the disagreement between the two researchers and leads them to discount out of hand the adoption of positions that run counter to standard conceptions of science and global warming. As the result of this epistemological posture, they had a great deal of difficulty imagining that disagreement could occur between two scientists who studied the same phenomenon. And while, in the course of deliberations, it was possible to question the authority accorded to scientific expertise, as a rule these students ultimately ended up recognizing this authority on a conventional basis - without finding convincing arguments to bolster its legitimacy, however. Certain cultural truisms were summoned to this end, such as the conviction that visual evidence - "observation'' - is a source of cognitive certainty. In addition, those who did not believe in the capacity of science to state the facts and to methodically progress toward the truth were marginalized through processes of ascribing an identity, whereby such subjects ended up being ascribed a dubious personality and suspicious interests. Thus, epistemological posture, ascription of identity and relationship to others are all interconnected whenever students deliberate and adopt positions concerning the possible reasons for disagreement between researchers. Now, the notion of the relationship to knowledge makes it possible to conceptualize and empirically illustrate this interconnectedness.

A number of these 17-year-old students were, however, able to prove themselves critical and made an intelligent use of rhetorical strategies and relevant arguments to defend their position - this though standard convictions generally ended up reactivating

arguments of authority serving to reinforce a submissive attitude toward scientific expertise (Bader, 2003a). Thus, the relationship to knowledge and the relationship to power also stood out as being interconnected.

My analysis suggests that a realist, progressive conception of science does little to facilitate picturing controversies and disagreements between scientists as being an integral part of the production of scientific knowledge. As a result, these students tended to overestimate scientific expertise and to disregard the role of subjectivity and the social and ethical issues that figure in the social production of scientific knowledge. Some students acknowledged, moreover, that school contributes to reinforcing the idea that there cannot be two different interpretations of the same reality on the part of scientists:

> S11: Yeah... Like, I don't know! I feel that researchers, you know, like, I don't know, they're supposed to come to the same conclusion, you know.
>
> S10: That's because they're called researchers.
>
> S11: Well, yeah, for that very reason. It's because they're called researchers. You know, as a rule, according to the categories they teach us at school, you figure they're can't be two versions of the same reality. (Bader, 2003b, p. 192).

In order to combine technoscientific literacy and active citizenship, it would thus appear necessary to update the conception of science mobilized by these young people in order to make sense of and debate questions of science in society - and concerning environmental issues in particular - about which they must take a position and become involved (Bader, 2003a, 2004; 2005). It is from this perspective that I have drawn on research in the sociology of science to shed a different light on what it means to do science in the classroom (Bader & Therriault, 2008).

The Relationship to Knowledge and School (Bader & Therriault)

Context and aims of the study

Some of our most recent research has shed light on what we have agreed to call students' relationship to knowledge and school. In this

work we have studied the academic paths of students, including their success or difficulties, and situate these in relation to students' own views concerning their personal and academic history.

In order to grasp how students involved themselves in their studies and in the learning of disciplinary content knowledge, we brought a contextualized perspective to bear on the outlook of students respecting school subjects. Within the framework of two studies conducted under the sponsorship of our research centre, we characterized the relationship to knowledge and school of students who took part in an after-school citizen engagement and environmental education project in a Quebec City neighbourhood secondary school (Horman, Bader, & Lapointe, 2008), and identified the relationship to knowledge and school among 30 primary and secondary students who had repeated a school year. We present below a few aspects of the latter study to illustrate the potential fruitfulness of a theoretical framework structured around the notion of the relationship to knowledge in the context of studying the conditions of students' academic success.

Theoretical Framework

In this section, we take up the notion of the relationship to knowledge in relation to the study of the relationship to school in terms of a relationship to an institution that governs the modes of teaching and learning. It is a well-known fact that the school institution imposes specific rules, standards and evaluation modes, a delimitation of time and space, a more or less democratic mode of operation, more or less egalitarian authority relationships, periods of silence or listening - all of which shape not only the outlooks of students toward the learning process and their relationship to others but also their personal and social history. In this instance, studying the relationship to knowledge consists in defining the ways in which students become involved in school and school and extracurricular activities, according to the school context at hand as well as the proposed learning situations. This conception of the relationship to knowledge intersects with the comments of Rochex (2004), according to whom "the notion of the relationship to knowledge refe rs to what may be viewed in terms of a relatively stable outlook or a mode of relationship that the subject entertains toward knowledge and which is the outcome of a history that is both personal and social" and that is constructed throughout [students'] entire academic path (our translation).

Furthermore, as an extension of our interest in students' personal and social history in the school context, we also grappled with the question of the characteristics of the particular "school form" (in French: forme scolaire, also referred to in English as the "grammar of school"; Vincent, 1994) in question and with the impacts of this "school form'' on students' relationship to knowledge.

Overview of the Interview Protocol and Results

To examine the relationship to knowledge and school of Quebec City students who repeated a school year, we conducted and analyzed semi-structured interviews (Bader, Doucet, Therriault, & Lapointe, 2008). The interview framework was constructed so as to cover subjects' assessment of elements of the school form as well as the three dimensions of the relationship to knowledge - namely, the epistemic (relationship to the world and to learning), identity-related (relationship toward oneself) and social (relationship to others).

The first interview theme involved a general assessment of the school (primary or secondary) in terms of an institution. Students were queried about their views concerning specific places, significant people with whom they came in contact at school, school regulations, and their relationships with teachers and other students. The goal was to identify the general impression that these students had of the learning institution.

The epistemic dimension refers to the idea of a relationship maintained toward a specific knowledge in terms of an object; it also refers to a more comprehensive relationship to learning that corresponds to a way of involving oneself (or of not involving oneself) in the learning process. An additional focus consists in the reasons underlying a student's decision to become involved or not. In connection with this dimension, students were invited during interviews to indicate their preference regarding certain school subjects and learning activities - and, specifically, their assessment of secondary science courses as compared to other school subjects. Other questions provided them with the opportunity to express themselves concerning the meaning they ascribed to the knowledge being taught. There are grounds for noting that for these repeat secondary students, science, as with the arts and sports, ranked among the school subjects they appeared to appreciate. On the one hand, they were active in these classes and, on the other hand, they considered that science gave them "tangible" knowledge that could be transposed into everyday life.

The identity-related dimension (or the relationship to oneself) refers to students' personal history, self-image, expectations, goals, values and representations, practices, manner of viewing life, as well as the relations they maintain with others (for example, other students, friends and teachers). This dimension is closely bound up with the social dimension (or the relationship to others), since learning is a form of social interaction. At various times during the interviews, students were queried in reference to these two dimensions. Among secondary students, questions concerning their intention of continuing or quitting their studies were added in order to verify how they projected themselves into the future and situated their academic path accordingly. Finally, some questions were put to students concerning their experience of repeating a school year.

Discussion

As was described above, such was the approach we adopted when conducting a study concerning the influence of repeating a school year on the academic success of primary and secondary students and on their relationship to knowledge, by means of gathering elements of their personal and academic history, of their relationship to the world, to learning, to themselves and to others, and of their experience of repeating. We will not elaborate further upon this study within the framework of the present article, which more specifically concerns science education and operationalizing the notion of the relationship to knowledge in this particular field of research. However, we believe it is worth noting that this kind of interpretation of students' outlooks respecting academic learnings provides a useful basis for identifying different types of relationships to school knowledge that to varying degrees attest to the authentic engagement of students in learning activities - a finding that may be worth recalling whenever the question concerns these students' relationship to scientific knowledge in the classroom context.

These considerations respecting distinct relationships to knowledge, which correspond to different manners of contemplating the impact of school knowledges and ascribing meaning to this knowledge (these conceptions being actualized in the various postures and attitudes exhibited by students whenever they are called on to learn), could be combined with the study of certain didactic practices and epistemological postures current in science education, all with a view to clarifying ways of problematizing

students' customary relationships to the learning of science. Such indeed is the objective underlying the research project we are currently undertaking (2008- 2011), which deals with the implement ation of an innovative didactic strategy in science and the study of primary and secondary students ’ relationships to scientific knowledge and the school.

Preservice Secondary Teachers’ Relationships to Knowledges (Therriault)

Context and Aims of the Study

This study was conducted in the context of the current reform of preservice teacher training curricula in Quebec. It inquired into the epistemological beliefs and relationships to knowledges of university-level students who will subsequently become secondary teachers either in science and technology or in history, geography and civics (going under the heading of "social world" in the teacher training program). The proposed directions to be given to teacher training include, in particular, reviewing preservice teachers' beliefs and relationships toward, on the one hand, the scientific knowledge taught at the university level and, on the other hand, the knowledge officially covered in secondary curricula and textbooks (Legendre, 2004; MEQ, 2001a).

Thus, one of the objectives of this study was to identify and then contrast the epistemological beliefs and the relationships to knowledges that preservice science and technology and "social world" teachers bring into play both in their university-level disciplinary courses (biology, chemistry, history or geography) and during their practice teaching in secondary schools (Therriault, 2008).

Theoretical and Analytical Framework

To accomplish the above-mentioned objective, the notions of relationships to knowledges and epistemological beliefs were made use of. In this case, the notion of relationships to knowledges (in the plural form) was approached from a didactic perspective that refers to the relationships or the type of rapport that preservice teachers hold toward knowledge, the latter being conceived of in terms of objects of knowledge that are socially recognized and enshrined in official documents such as textbooks (Maury & Caillot, 2003). The notion of the relationship to knowledge, as operationalized in this

study, also draws on the sociological approach developed by Chariot (1997), an approach that distinguishes between the three dimensions referred to as the epistemic (also called the relationship to the world), identity-related (the relationship to oneself) and the social (the relationship to others).

In the framework of the present study, the epistemic dimension (relationship to the world) was examined from two angles, the first being the various statuses ascribed to the scientific knowledge figuring in the course plans and the textbooks used in university-level teacher training programs, and the second being the statuses ascribed to knowledge drawn from secondary curricula and textbooks (hence, in relation to practical training). The identity-related dimension (relationship to oneself) was analyzed from the angle of the numerous statuses and roles assumed by students during university-level disciplinary education and practical training. Finally the social dimension (relationship to others) was approached from the angle of the statuses and roles assumed by different actors involved in the disciplinary education and practical training of preservice teachers (e.g., university professors, specialists in a scientific discipline, secondary teachers or students, etc.).

In passing, it should be noted that the notion of epistemological belief (or personal epistemology) refers to the conceptions of preservice teachers concerning the nature of knowledge. This notion has developed in reference to a number of studies conducted in the field of psychology in the United States over the last 40 years (in particular, see: Baxter Magolda, 1987; Belenky, Clinchy, Goldberger, & Tarule, 1986; Hofer, 2000; Perry, 1970, and, more recently, Chai, Khine & Teo, 2006; Yilmaz-Tuzun & Topen, 2008). In point of fact, these studies draw on the work of Piaget relating to conceptual development. More specifically, one of these studies (Hofer, 2000) produced a model for structuring four dimensions of personal epistemology on the basis of two main categories: the nature of knowledge (certainty and simplicity) and the process of knowing (source and reasoning/justification of knowledge) (Hofer & Pintrich, 1997). The first main category refers to a subject's beliefs as to what constitutes knowledge whereas the second concerns the process through which an individual comes to know something. Within the framework of my research project, these dimensions were investigated both quantitatively and qualitatively by means of a questionnaire and individual interviews.

In the study of the relationship to knowledges, the dimensions of personal epistemology (certainty, simplicity, source and reasoning/

justification of knowledge) and the didactic and sociological perspectives were taken into consideration with a view to enriching and exhaustively documenting our understanding of preservice teachers' conceptions of knowledge. According to the main underlying this research, the dimensions covered in the study of relationships to knowledges (epistemic, identity-related and social) can be profitably linked to the analysis of students' epistemological beliefs, particularly since researchers in psychology have dedicated little attention to the identity-related aspect.

Methodology

For the purposes of this article, I will set out the findings stemming from interviews and that specifically concern the study of the relationships to knowledges. However, I will also present the entire methodology thus implemented, on account of how it offers insights into the operationalization of the notion of the relationship to knowledge and provides an illustration of the complementariness of the different modes of data gathering used.

The production of data occurred over two phases. To begin with, a personal epistemology questionnaire based on disciplines (in particular, the "Discipline-Focused Epistemological Belief Items" developed and validated by Hofer, 2000) was adapted and administered among four cohorts of students (N=47) in the two fields concerned (science and technology and "social world"). In this questionnaire, students were prompted to adopt a position in respect of 27 Likert-scaled items. The dimensions (certainty, simplicity, source, and reasoning/justification of knowledge) were in relation to the study of epistemological beliefs. The quantitative data gathered through this questionnaire underwent a range of statistical analyses that are not discussed in this article.[8]

During a second phase, of the 47 respondents total, 12 students who presented contrasting points of view in terms of their epistemological beliefs were asked to take part in an individual Piagetian interview (of a so-called critical type: Perraudeau, 1998, Vermersch, 2006). During the interviews, the subjects were prompted to argue and counter-argue around responses formulated in the epistemology questionnaire. The themes covered in the questionnaire and the interviews were the same, and referred to the four dimensions of personal epistemology (certainty, simplicity, source and reasoning/justification of knowledge), as defined by Hofer (2000). In addition, the questions raised during interviews

covered both the university-level disciplinary or scientific education and practice teaching in schools. The qualitative data drawn from the interviews were then subjected to a thematic analysis (Paillc. 1996) and a frequency count (Huberman & Miles, 2003). Moreover, it was during the phase dedicated to the analysis and interpretation of the interview data that the dimensions related to the study of relationships to knowledges - and, specifically, the epistemic, identity-related and social dimensions - came to the fore.

Results and Discussion

On the basis of an analysis of interview data, there are revealing divergences between the relationships to knowledges that were mobilized by the subjects in relation to the disciplinary and practical aspects of their teacher training. In particular, I note a number of distinctions concerning the epistemic, identity-related and social dimensions of these relationships to knowledges (Chariot, 1997). These dimensions were placed in relation to the source of knowledge - namely, one of the categories covered under the study of epistemological beliefs (Hofer, 2000).

To begin with, the data touched on the types of relationships to knowledges and to the process of knowing (or the epistemic dimension) held by students who took part in the interviews. They evidence a different distribution of responses according to whether the disciplinary and practical aspects of preservice training are involved. In particular, on several occasions, respondents mentioned that knowledge is constructed by students at the university (11 statements) and by practice teachers in the environment where they did their internships (8 statements). However, in connection with practical training, few subjects (3 statements) asserted that secondary students constructed their knowledge through interaction with their classmates and their teacher. Furthermore, in connection with university-level disciplinary courses, the belief according to which scientific knowledge must be gradually grasped or acquired by students stood out more prominently (13 statements). Respondents were also of the view that knowledge is held by an exterior authority - in this case, the secondary teacher - who passes on or transmits this knowledge (7 statements). On this point, one student described the experience he came away with from his first two practice teaching sessions at a secondary school as follows: "I essentially passed on the contents that had been prepared by the teacher (to whom he had been assigned). In actuality, I passed on

paragraphs from the textbook.’’(Subject 08: "social world” - 2nd year of preservice training).

Preservice teachers - be they students enrolled in university-level disciplinary courses or doing their practice teaching in schools - maintain a variety of relationships toward themselves (identity-related dimension). To begin with, it would appear that, most often, they put store by the textbook or the experts (for example, the university professor, considered as a specialist in a scientific discipline, or the high school teacher). Several statements referred to this point and applied to both the disciplinary education (23 statements) and the practical training (19 statements).

> In science, however, it's hard. I mean, I'm not a leading researcher! I can't start being too... I've already done some experiments, but as for starting to challenge certain theories? I'd have to be pretty pretentious! (Subject 45: science and technology - 2nd year)
>
> When you're in front of the class [secondary school level] explaining something, quite often, in your capacity as teacher, you're going to work from the documents you have to hand. (...) I'd be inclined to take the book, if it was necessary to follow the book, and deliver the notions that are in it. (Subject 15: science and technology - 3rd year)

Also respecting the identity-related dimension, during their practice teaching sessions, preservice teachers occasionally permitted themselves to turn critical (13 statements) and to interpret the contents of secondary curricula and textbooks (7 statements). On other occasions, they remained neutral (10 statements) or could act in the capacity of experts (4 statements) - both roles that students very rarely permitted themselves in the framework of their disciplinary courses.

Finally, a number of analytical categories touched on students' relationships toward the various actors involved in teacher training (the social dimension). In the following section, I will focus solely on the various roles and statuses that subjects ascribed to professors specializing in the scientific disciplines taught at the university level and to secondary teachers. On this point, interesting contrasts between the disciplinary and practical aspects of preservice training came to the fore. In particular, student interviewees generally were of the view that university professorresearchers gave different answers to the same question (15 statements): "(...) there is no

unanimous agreement between university professors." (Subject 35: science and technology - 1st year). In contrast, secondary teachers most often gave identical answers to the same question (7 statements). Moreover, the respondents ascribed several other roles to discipline specialists - in particular, that of expert (11 statements). University professors also had to provide explanations about the world (4 statements) and remain neutral (4 statements), even though some students considered them to be biased (4 statements).

In my view, the partial findings outlined above illustrate the value of drawing on the notion of relationships to knowledges for the purpose of studying the beliefs of preservice teachers respecting their discipline of specialization (in this case, the field of science and technology and that of the "social world"). Indeed, the analysis of future teachers' relationships toward knowledge, oneself and others provides a basis on which to investigate a complex object - that of epistemological beliefs - and to enrich this portrait through the study of the epistemic, identity-related and social dimensions. In the context of the present study, the notion of relationships to knowledges can be used to deepen our knowledge of students' conceptions pertaining to their respective fields of training at a time when major structural and epistemological transformations have shaken up the world of teacher training in Quebec. More specifically, the use of this notion serves to bring out a number of contradictions between the disciplinary and practical components of training. In particular, it highlights contrasts between the statuses and roles played by university professors, in their capacity as specialists in a scientific discipline, and those assumed by secondary teachers. In addition, students maintained different types of relationships toward the disciplinary knowledge taught at the university and the knowledge deriving from secondary curricula and textbooks. These relationships refer to widely divergent epistemological postures and tend to vary according to the situations encountered, particularly in the contexts of disciplinary courses and practice teaching sessions. It also appears that the surveyed subjects adopted a submissive attitude toward experts - be these professor-researchers or secondary teachers. Such findings should prompt serious reflection within preservice teacher training programs and among those teacher trainers who strive not only to achieve a better fit between the disciplinary and practical aspects
of preservice teacher training but also to attain a clearer picture of the beliefs relating to the three dimensions analyzed.

Research in Progress

The Relationships to Scientific Knowledge and Science Teaching of Preservice Primary Teachers Enrolled in a Preuniversity Course of Study in Education (Pouliot)

Context and Aims

As a rule, preservice primary teachers enrolled in university level education programs in Quebec have taken few science courses. A great many of them experience difficulty in courses related to science education. This observation accords with the findings of research that show that inservice and preservice primary teachers often harbour misconceptions about scientific contents and notions and about the nature of science (Abell & Smith, 1994; Tsai, 2007). And, as was mentioned in the beginning of this article, there are grounds for surmising that the epistemological postures adopted by preservice primary teachers are, in a way, indicative of the epistemic, identity-related and social dimensions of their relationship to scientific knowledge and science education. With these considerations in mind and, more specifically, with a view to documenting the point of view of preservice primary teachers concerning science and science education, I am currently conducting this research project aimed at documenting and analyzing the relationship(s) of preservice primary teachers toward scientific knowledge and the idea of teaching science.

This project is singular on two counts. For one, it documents the point of view preservice primary teachers enrolled in a preuniversity course of study in education, whereas to my knowledge no research has to date been dedicated to the way students conceive of science education ahead of their university training. Secondly, it takes place within a unique context of collaboration. The "cegep" of which it is a question is the only one in the province of Quebec to offer a college-level course of study in education. This course of study, whose purpose is to achieve a better fit between preuniversity and university training programs in education, was developed within the framework of an exclusive agreement (lasting until August 2010) with the authors' university.

Methodology

In order to develop a profile of the preservice primary teachers' relationships to scientific knowledge and science education, 80 students were invited to produce an individual "assessment of knowledge" (biIans de savoir) (a further 160 students were invited to do so in 2009 and 2010). They also took part in semi-structured group interviews (i.e., 16 interviews with groups of 5 students each).

As was mentioned in the first portion of this article, the methodological tool referred to as an assessment of knowledge consists in a text written by students about their views concerning various subjects relating to school and to the learning process (Chariot et al., 1992). This assessment is produced in response to a specific question and can take a variety of textual forms. In the case of the present study, the individual assessments of knowledge took the form of three-page written texts. In particular, they concerned students' relationships to scientific knowledge and science education and were written in response to a series of questions that covered the three dimensions of the relationship to knowledge (epistemic, identity-related and social): What is science for you? What roles does science play in your everyday life? How did you feel when you took part in science courses in primary school? In secondary school? How do you feel about the idea of teaching science?

In the context of this study, the assessment of knowledge was used primarily for the purpose of identifying what students deem important to mention when asked to articulate their views in writing concerning their relationships to scientific knowledge and the future possibility of teaching science. The assessments of knowledge provided a basis with which to structure the framework of the semi-structured group interviews. These 16 interviews, which lasted from 45 to 60 minutes in length, were designed to provide students with the opportunity to detail their point of view concerning the themes covered in the individual assessments of knowledge.

Results and Discussion

The empirical component of this project began in August 2008. An initial analysis of the data stemming from the assessments of knowledge and the group interviews was performed. In a nut shell, this analysis has brought out that most students: 1) noted that the experience of learning science in secondary school was demanding (with physics and chemistry classes being particularly arduous); 2)

allowed as to be sometimes comfortable with/uncomfortable with the idea of teaching science in primary school; and 3) counted on their cbgep and university study paths to gain familiarity with the scientific knowledge identified in the teacher training program for Quebec schools.

These preliminary findings (along with more in-depth results, forthcoming) are significant, in particular because university-level teacher trainers have very little to go on for imparting an emancipative direction to the training of preservice primary teachers in respect of scientific knowledge and science education. Thus, at the conclusion of this three-year project, the results might well serve to inform decisions concerning the implementation of cbgep-level courses of study in education and to structure university-level science education training in a way that encourages students to (re)think their relationship to scientific knowledge and science education.

End Note

This overview of various operationalizations of the notion of the relationship to knowledge and of research conducted in Quebec on the subject of students' and preservice teachers' relationships to knowledges (of a scientific variety or not) echoes the comments of Abell & Lederman (2007, p. xiii), who have noted that:

> The ultimate purpose of science education research is the improvement of science teaching and learning throughout the world. […]; To achieve the ultimate purpose of improving science teaching and learning, our research must be grounded in the real world of students and teachers and school systems and society. […]; To achieve the ultimate purpose of improving science teaching and learning, we as researchers need to be open to new theoretical frameworks, research methodologies, and strategies […]

To begin with, the great richness of the notion of the relationship to knowledge lies in its ultimately providing a basis, as was mentioned by Rochex (2004), for taking into consideration points of view concerning relational elements connected to a subject's identity, his or her assessment of the nature and meaning of knowledge and his or her experience in the world and at school

whenever he or she takes an interest in the knowledge process. The studies outlined in the
present article specify how the definitions that each of us adopted of this notion were operationalized and open on to ways of renewing teachers' and students' school conceptions of science as well as teaching practices.

Thus the potential impact of the notion of the relationship to knowledge concerns teachers' professional development, on the one hand, and students' science education, on the other hand. In a context of curricular reform and concerning what some perceive to be a crisis of legitimacy of scientific knowledge (and of their producers/representatives), this critically important field warrants particular attention.

For us, the priority is to pursue this work of documentation in order to generate some proposals with which to enrich teacher training, epistemological postures and science education practices, in particular by taking into consideration the epistemic, identity-related and social dimension of relationship(s) to knowledge(s) and to school. The overarching objective continues to be achieving a broader, contextualized understanding of the outlooks of teachers and students regarding learning and science education. Through the various studies presented in this article, it this objective that we have strived to shed light on.

In our view, positing the relevance of studying relationships to knowledge thus appears to open up some promising perspectives, at the crossroads of concerns related to mastering scientific knowledge(s), to students' authentic engagement with school learnings, and the renewal of teaching practices so as to more fully integrate renewed relationships toward scientific knowledge and the teaching of this knowledge. In this area, questions remain that would appear to require further documentation by actors in the international science education community.

Finally, when taken together, our studies concerning the relationship to scientific knowledge and expertise bring out a certain overestimation of the legitimacy of expert discourses - and of scientific discourses in particular - that accords with a relationship to scientific knowledge and expertise under which students and teachers shy away from challenging and debating these discourses. This finding warrants pursuing investigations with a view to proposing avenues for educating students and training teachers so that: 1) these individuals more readily define themselves as competent, critical interlocutors; and 2) in the process of mobilizing

a receptive attitude toward dialogue in relation to expert discourses, they evolve toward a more critical relationship to expert knowledge. These closing remarks point to a set of questions deserving of attention. Indeed, this paper shows that much more discussion and debate regarding students' relationship to scientific knowledge (or its producers) is required. It is our hope, however, that this paper will have helped to trigger such discussions across as broad a range of places and perspectives as possible.

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References

1. Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers' conceptions of nature of science: a critical review of the literature. International Journal of Science Education, 22(7), 665-701.
2. Horman, J. Bader, B. & Lapointe, C. (2008) Pour une culture scolaire de Fengagement communautaire et citoyen. In R. Dellandes (Ed.) La collaboration de 1'ecole, de la famille et de la communaute a 1 'apprentissage. Cahiers Scientifiques de 1'Acfas, 10, 135-150.
3. Abell, S., & Smith, D. C. (1994). What is science? Preservice elementary teachers' conceptions of the nature of science. Inte rnational Journal of Science Education, 16(4), 475-487.
4. Abell, S., & Lederman, N. G. (2007). Handbook of Research on Science Education. New Jersey: Lawrence Erlbaum Associates.
5. Aikenhead, G. S. (2006). Science education for everyday life. New York: Teachers College Press.
6. Albe, V. (2008). Pour une education aux sciences citoyenne. Une analyse sociale et epistemologique des controverses sur les changements climatiques. Aster, 46(x), 45-70.
7. Albe, V., & Venturini, P. (2002). Relations entre la maitrise conceptuelle d'etudiants en electromagnetisme et leurs rapports aux savoirs. In C. Amade-Escot, M. Caillot, C. Garcia-Debanc, P. Jonnaert, G. Kpazai, L. Lafortune, S. Maury & S. Vincent (Eds.), Didactiques et rapports aux savoirs: Actes des

3emes journees d'etudes Franco-Quebecoises des didactiques (S orbonne (France), June 2-3, 2002) (31-45). Laboratoire Education et Apprentissages (E.D.A.): Paris.

8. Anderson, C. W. (2007). Perspectives in Science Learning. In S. K. Abell & N. Lederman (Eds.), Handbook of research on science education (pp. 3-30). London: Lawrence Erlbaum Associates.
9. Bader, B. (2008). Education to climate change. In J. Golson, P. Geoffrey & S. George (Eds.), Encyclopedia of global warming and climate change (p. 354-357). Thousand Oaks, CA : Sage Publications. Collection Sage reference
10. Bader, B., Doucet, N., Therriault, G., & Lapointe, C. (2008). Et ude exploratoire sur I'influence du redoublement scolaire sur la reussite educative: le rapport au savoir et a I'ecole d'eleves ayant redouble au primaire ou au secondaire. Rapport de recherche ä Fintention de la Com
mission scolaire des Premieres-Seigneuries. Centre de recherche et d'intervention sur la reus- site scolaire (CRIRES), Universite Laval.
11. Bader, B. & Therriault, G. (2008). Pertinence de la prise en compte des dimensions sociales des sciences pour renouveler la conception des sciences au primaire : illustration de la position d une future enseignante. Revue des sciences de I'education, 37(1), 163-184.
12. Bader, B. (2005). Rapprochement interdisciplinaire entre une education aux sciences citoyenne et I'education relative a 1'environnement: points de vue de chercheurs et formation des enseignants. Dans L. Sauve, I. Orellana & E. van Steenberghe (Eds.), Education et environnement, un croisement de savoirs. Cahiers scientifiques de 1'ACFAS, 104, 109-119.
13. Bader, B. (2004). Epistemological renewal and environmental education: Contextualizing science. Australian Journal of Environmental Education, 20(2), 13-22.
14. Bader, B. (2002). Idealisation des sciences chez des eleves de 17 ans et voie d'entree pour un rapport renouvele aux savoirs scientifiques [The idealization of science by 17-year-old students and a gateway for a renewed relationship to scientific knowledge]. In Didactiques et rapports aux savoirs (pp. 77-91). Paris: Universite Rene Descartes-Sorbonne.

15. Bader, B. (2003a). Interpretation d une controverse scientifique : strategies argumentatives d'adolescentes et d'adolescents quebecois. Revue canadienne de I 'enseignement des sciences, des mathematiques et des technologies, 3(3), 231-250.
16. Bader, B. (2003b). Controverse scientifique et expression rhetorique de croyances sur les sciences. Dans L. Lafortune, C. Deaudelin, P.A. Doudin & D. Martin (dirs.), Conceptions, croyances et representations en maths, sciences et technologies (p. 175-197). Montreal: Presses de l'Universite du Quebec.
17. Bader, B. (2008). Education. In J. Golson, P. Geoffrey, & S. George (Eds.), Encyclopedia of global warming and climate change (pp. 354-357). Thousand Oaks, CA: Sage
18. Barnett, J., & Hodson, D. (2001). Pedagogical context knowledge: Toward a fuller understanding of what good science teachers know. Science Education, 85(4), 426-453.
19. Baxter Magolda, M. B. (1987). The affective dimension of learning: Faculty-student relationships that enhance intellectual development. College Student Journal, 21, 46-58.
20. Belenky, M. F, Clinchy, B., Goldberger, N, & Tarule, J. M. (1986). Women's ways of knowing. The development of self, voice, and mind. New York: Basic Books.
21. Ben Abderrahman, M.-L. (2000). Pertinence et limites de la notion de "rapport au savoir" en didactique des sciences. In A. Chabchoub (Ed.), Rapports aux savoirs et apprentissage des sciences (187-194). Actes du 5 e Colloque international de didactique et d'epistemologie des sciences, Sfax (Tunisia).
22. Blades, D. (2008). Science content knowledge confidence of pre-service teacher candidates. Paper presented at the Canadian Society for the Studies of Education, Annual Conference, UBC, June 1.
23. Callon, M., Lascoumes, P., & Barthe, Y. (2001). Agir dans un monde incertain. Essai sur la democratie technique [Acting in an uncertain world; An essay on technical democracy]. Paris: Senil.
24. Calmettes, B. (2005). Representations et rapports aux savoirs de candidate au Capes de physique- chimie. Didaskalia, 26, 33-55.

25. Chai, C. S., Rhine, M. S., & Teo, T. (2006). Epistemological beliefs on teaching and learning: a survey among pre-service teachers in Singapore. Educational Media International, 43(4), 285- 298.
26. Chariot, B., Bautier, E., & Rochex, J.-Y. (1992). Ecole et savoir dans les banlieues et ailleurs. Paris: Armand Colin.
27. Chariot, B. (1997). Du rapport au savoir. Elements pour une theorie. Paris: Anthropos.
28. Chariot, B. (2001). La notion de rapport au savoir: points d'ancrage theorique et fondements anthropologiques. In B. Chariot (Ed.), Les jeunes et le savoir. Perspectives internationales (5-24). Paris: Anthropos.
29. Chariot, B. (2003). La problematique du rapport au savoir. In S. Maury & M. Caillot (Eds.), Rapport au savoir et didactiques (33-50). Paris: Eabort.
30. Chariot, B. Bauthier, E., & Rochex, J.-Y. (1992). Ecole et savoirs dans les banlieues et ailleurs. Paris: Armand Colin.
31. Chartrain, J.-L. (2002). Rapport au savoir et apprentissages scientifiques: quelle methodologie pour analyser le type de Rapport au savoir des eleves? In C. Amade-Escot et al. (Eds.), D idactiques et rapports aux savoirs: Actes des 3emes journees d 'etudes Franco-Quebecoises des didactiques (Sorbonne (France), dune 2-3, 2002) (16-30). Laboratoire Education et Apprentissages (E.D.A.): Paris.
32. Chevallard, Y. (1992). Concepts fondamentaux de la didactique: perspectives apportees par une approche anthropologique. Re cherches en didactique des m a them al iques, 12(1), 73-112.
33. Chevallard, Y. (1996). Concepts fondamentaux de la didactique: perspectives apportees par une approche anthropologique. In J. Brun (Ed.), Didactique des mathematiques (145-196). Lausanne (Switzerland): Delachaux etNiestle.
34. Chevallard, Y. (2003). Approche anthropologique du rapport au savoir et didactique des mathematiques. In S. Maury and M. Caillot (Eds.), Rapport au savoir et didactiques (81- 104). Paris: Fabert.
35. Cunningham, C.M., & Helm, J. (1998). Sociology of science as a means to a more authentic, inclusive science education. Journal of Research in Science Teaching, 35(5), 483-499.

36. Desautels, J. (2002). Rapport au savoir/ pouvoir en technosciences. In Didactiques et rapports aux savoirs (pp. 92-104). 3ernes journees d'etudes Franco-Quebecoises des didactiques, Paris: Universite Rene Descartes - Sorbonne.
37. Desautels, J. & Larochelle, M. (1989). Autour de I'idee de science, itineraires cognitifs d'etudiants et d'etudiantes. Sainte-Foy, Quebec: Les Presses de I'Universite Laval/Brussels: De Boeck- Wesmael.
38. Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. Science Education, 84(3), 287-312.
39. Driver, R., Leach, J., Millar, R., & Scott, P. (1996). Young people's images of science. Buckingham, UK: Open University Press.
40. Evrard, T., Huynen, A.-M., & Vander Borght-de Bueger, C. (1998). Relationships to knowledge in science classrooms. In H. Bayrhuber & F. Brinkman (Eds.), Actes du colloque de TEuropean researchers in didactik of biology: "What, Why, Flow?" (301-310). IPN-Materialien.
41. Fourez, G. (1997). Scientific and technological literacy as a social practice. Social Studies of Science, 27(6), 903-936.
42. Fourez, G. (2002). La construction des sciences. Les logiques des inventions scientifiques. 4th edition. Brussels: De Boeck.
43. Guilbert, L., & Mujawamariya, D. (2003). Les representations de future enseignants et enseignantes de sciences ä propos des scientifiques et de leurs täches. In L. Lafortune, C. Deaudelin, P.-A. Doudin, & D. Martin (refereed group), Conceptions, Croyances et Representations en Maths, Sciences et Technos (pp. 199-235). Quebec: PUQ, Collection Education/Recherche.
44. Guo, C.-J., (2007). Issues in science learning: An international perspective. In S. Abell & N. G. Lederman (Eds.), Handbook of science education (227-256). New Jersey: Lawrence Erlbaum Associates.
45. Hausfather, S. (1998). Changing students' relationships to knowledge in a theme-study classroom. Journal of Research in Childhood Education, 13(1), 33-47.
46. Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. Contemporary Educational Psychology, 25, 378-405.

47. Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. Review of Educational Research, 67(1), 1-34.
48. Huberman, A. M., & Miles, B. M. (2003). Analyse des donnees qualitatives. Brussels: De Boeck. [Originally published in English as Qualitative Data Analysis: An Expanded Sourcebook. Thousand Oaks (California): SAGE Publications, Inc. 1994].
49. Jellab, A. (2001). Le sens des savoirs chez les eleves de lycee professionnel: une approche sociologique. L komme et la societe, 139 (Jan.- Mar.), 83-102.
50. Jellab, A. (2006). Debater dans Tenseignement secondaire. Quel rapport aux savoirs chez les professeurs stagiaires? Paris: L'Hannattan.
51. Jehnan, Y. (2002). Le rapport aux objets de savoir coniine critere de differenciation entre apprenants: cas de la foudre. C ahierspedagogiques, 277, 2-14.
52. Jones, M. G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell & N. G. Lederman (Eds.), Handbook of Research on Science Education (pp. 1067-1104). New Jersey: Lawrence Erlbaum Associates.
53. Jourdan, I., & Terrisse, A. (2002). Evolution du rapport au savoir des etudiants et professionnalisa- tion: le cas de la formation initiale en EPS ä 1TUFM de Toulouse, entre premiere et deuxieme annee. In C. Amade-Escot et al. (Eds.), Di dactiques et rapports aux savoirs: Actes des 3e"'“ journees d 'etudes Franco-Quebecoises des didactiques (Sorbonne (France), June 2-3, 2002) (169-181). Laboratoire Education et Apprentissages (E.D.A.): Paris.
54. Kalali, F. (2007). Rapport au savoir: bilan sur la place du sujet dans les differents travaux. Text presented at the symposium “Rapports au (x) savoir (s): du concept aux usages” on the occasion of the Congres international Actualite de la Recherche en Education et en Formation (AREF) 2007, Strasbourg.
55. Larochelle, M., & Desautels, J. (2003). Descriptions estudiantines de la nature et de la fabrication des savoirs scientifiques. In L. Lafortune, C. Deaudelin, P.-A. Doudin, & D. Martin (Eds.), Conceptions, croyances et representations en maths, sciences et technos (pp. 149-174). Sainte-Foy, Quebec: Presses de l'Universite du Quebec.

56. Larochelle, M., & Desautels, J. (2006). L'education aux sciences et le croisement des expertises. In A. Legardez & L. Simonneaux, L 'ecole a I 'epreuve de I 'actualite, enseigner les questions vives (pp. 61-77). Paris: ESF Editeur.
57. Latour, B. (2004). Politics of nature: How to bring the sciences into democracy. Cambridge, MA: Harvard University Press.
58. Legendre, M.-F. (2004). Approches construct!vistes et nouvelles orientations curriculaires: d'un curriculum fonde sur 1'approche par objectifs a un curriculum axe sur le developpement de competences. In P. Jonnaert & D. Masciotra (Eds.), Constructivisme: Choix contemporains. Hommage a Ernst von Glasersfeld (51-92). Sainte-Foy, Quebec: Presses de l'Universite du Quebec.
59. Levinson, R., & Turner, S. (2001). Valuable lessons: engaging with the social context of science in schools. London: The Wellcome Trust.
60. Lyons, T. (2006). Different countries, same science classes: Students' experiences of school science in their own words. Int ernational Journal of Science Education, 28(6), 591-613.
61. Maingain, A., Dufour, B., & Fourez, G. (2002). Approches didactiques de I'interdisciplinarite. Brussels: De Boeck Universite.
62. Maury, S., & Caillot, M. (2003). Rapport au savoir et didactiques. Paris: Fabert.
63. McGinnis, J. R., & Simmons, P. (1999). Teachers' perspectives of teaching science-technology- society in local cultures: A socio-cultural analysis. Science Education, 83(2), 179-211.
64. Ministere de l'Education [MEQ], (2001a). La formation a Tenseignement. Les orientations, les competences professionnelles. Government of Quebec. 252 pages. [Also published in English as Teacher Training : Orientations, Professional Competencies]
65. Ministere de l'Education [MEQ]. (2001b). Programme de formation de Tecole quebecoise. Government of Quebec. 362 pages.
66. Mosconi, N. (2000). Pour une clinique du rapport au savoir a fondation anthropologique. In N. Mosconi, J. Beillerot & C. Blanchard-Laville (Eds.), Formes et formations du rapport au savoir (59-116). Paris: L'Hannattan.

67. Mosconi, N. (2008, September). Rapport au savoir: approche socio-clinique. Account of the conference presented during the Seminaire IUFM de Bourgogne "Rapport aux savoirs," September 23, Dijon (France).
68. Osborne, J., Collins, S., Ratcliffe, M., Millar, R. & Duschl, R. (2003). What ' Idcas-about-scicncc' should be taught in school science? A Delphi study of the expert community. Journal of Research in Science Teaching, 40(7), 692-770.
69. Osborne, J., Duschl, R., & Fairbrother, B. (2003). Breaking the mould? Teaching science for public understanding: Lessons from the classroom. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.
70. Paille, P. (1996). De Fanalyse qualitative en general et de Fanalyse thematique en particulier. Revue de Tassociation pour la recherche qualitative, 15, 179-194.
71. Pedretti, E. (2003). Teaching Science, Technology, Society and Environment (STSE) education. In D.
72. Zeidler (Ed.), The role of moral reasoning on socioscientific issues and discourse in science education (pp. 219-239). Boston: Kluwer Academic.
73. Perraudeau, M. (1998). Echanger pour apprendre. L 'entretien critique. Paris: Armand Colin.
74. Perry, W. G. (1970). Forms of intellectual and ethical development in the college years. A scheme. New York: Holt, Rinehart and Winston.
75. Potter, J. (1996). Representing reality: Discourse, rhetoric and social construction. London: Sage.
76. Pouliot, C. (2007). Apprehension d'une controverse sociotechnique et rapport aux experts scientifiques: une etude de cas. [Students' apprehension of a sociotechnical controversy and their relationship to scientific experts: A case study]. Unpublished doctoral dissertation, Universite Laval, Quebec, Canada.
77. Pouliot, C. (2008). Students' inventory of social actors concerned by the controversy surrounding cellular telephones: A case study. Science Education, 92, 543-559.
78. Pouliot, C. (2009). Using the Deficit Model, Public Debate Model and Co-production of Knowledge Models to Interpret

Points of View of Students Concerning Citizens' Participation in Socioscientific Issues. International Journal of Environmental and Science Education, 4, 49-73.

79. Pouliot, C. (2010, in press). Post-secondary Students' Relationship to People They consider to be Scientific Experts. R esearch in Science Education.
80. Rennie, L. J., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: Results of a national study. Research in Science Education, 31(4), 455-498.
81. Roberts, D. A. (2007). Scientific Literacy/Science Literacy. In S. K. Abell and N. G. Lederman (Eds.), Elandbook of research on science education (729-780). London: Lawrence Erlbaum Associates.
82. Rochex, J.-Y. (2004). La notion de rapport au savoir: convergence et debats theoriques. Pratiques psychologiques, 10, 93-106.
83. Roth, W.-M. & Desautels, J. (2002). Science Education as/for Sociopolitical Action: Charting the Landscape. In W.-M. Roth & J. Desautels (Eds.), Science Education as/for Sociopolitical Action (pp. 1-16). New York: P. Lang.
84. Roth, W.-M., & Lee, S. H. (2002). Scientific literacy as collective praxis. Public Understanding of Science, 11(1), 33-56.
85. Simonneaux, L. (2004). Classroom Debates on Biotechnology. T hemes in education, 5(1), 31-52.
86. Smith, L. K., & Southerland, S. A. (2007). Reforming practice or modifying reforms? Elementary teachers' response to the tools of reform. Journal of Research in Science Teaching, 44(3), 396-423.
87. Therriault, G. (2008). Postures epistemologiques que developpent des etudiants des profits sciences et technologies et univers social au cours de leur formation initiale a Tenseignement
secondaire: une analyse de leurs croyances et de leurs rapports aux savoirs. Unpublished doctoral thesis, Universite du Quebec a Rimouski, Universite du Quebec a Montreal, Quebec.
88. Therriault, G., Harvey, L. & Jonnaert, P. (accepted). Croyances epistemologiques de future enseignants du secondaire des profils sciences et technologies et univers social: des differences entre les profils et une evolution au coin’s de la formation initiale. Mesure et evaluation en education.

89. Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. School Science and Mathematics, 100(7), 374-379.
90. Tsai, C.-C. (2001). A science teacher's reflection and knowledge growth about STS instruction after actual implementation. Sci ence Education, 86(1), 23-41.
91. Tsai, C.-C. (2007). Teachers' scientific epistemological views: The coherence with instruction and students' views. Science Education, 91(2), 222-243.
92. Venturini, P. (2005). Rapports ideal-typiques a la physique d'eleves de 1'enseignement secondaire.
93. Didaskalia, 26, 9-32.
94. Vermersch, P. (2006). I. 'entretien d'explicitation. Nouvelle edition enrichie d'un glossaire. Paris: ESF editeur.
95. Vincent, G. (1994). L 'education prisomwre de la forme scolaire? Scolarisation et socialisation dans les societes industrielles, Lyon: Presses Universitaires de Lyon.
96. Wynne, B. (1997). Controverses, indeterminations et contröle social de la technologic. Lemons du nucleaire et de quelques autres cas du Royaume-Uni. In O. Godard (Ed..), Le principe de prëcaиiioп dans la conduite des affaires humaines (pp. 149-178). Paris: Fondation maison des sciences de 1'homme et Institut national de la recherche agronomique.
97. Wynne, B. (2005). Reflexing complexity, post-genomic knowledge and reductionist return in public science. Theory, Culture & Society, 22(5), 67-94.
98. Yilmaz-Tuzun, O., & Topen, M. S. (2008). Relationships among preservice science teachers' epistemological beliefs, epistemological world views, and self-efficacy beliefs. Internati onal Journal of Science Education, 30(1), 65-85.