


Knowledge, Belief, and Science Education A Contribution from the Epistemology of Testimony

Tiago Alfredo S. Ferreira¹ · Charbel N. El-Hani²  ·
Waldomiro José da Silva-Filho^{3,4}

© Springer Science+Business Media Dordrecht 2016

Abstract This article intends to show that the defense of “understanding” as one of the major goals of science education can be grounded on an anti-reductionist perspective on testimony as a source of knowledge. To do so, we critically revisit the discussion between Harvey Siegel and Alvin Goldman about the goals of science education, especially where it involves arguments based on the epistemology of testimony. Subsequently, we come back to a discussion between Charbel N. El-Hani and Eduardo Mortimer, on the one hand, and Michael Hoffmann, on the other, striving to strengthen the claim that rather than students’ belief change, understanding should have epistemic priority as a goal of science education. Based on these two lines of discussion, we conclude that the reliance on testimony as a source of knowledge is necessary to the development of a more large and comprehensive scientific understanding by science students.

✉ Charbel N. El-Hani
charbel.elhani@gmail.com

Tiago Alfredo S. Ferreira
tiagothr@gmail.com

Waldomiro José da Silva-Filho
wjsf.ufba@gmail.com; wjsilva@mit.edu

¹ Institute of Psychology, Federal University of Bahia, Brazil, Estrada de São Lázaro, n. 197, Federação, Salvador, BA 40210-730, Brazil

² History, Philosophy, and Biology Teaching Lab (LEFHBio), Institute of Biology, Federal University of Bahia, Brazil, Rua Barão de Jeremoabo, s/n, Ondina, Salvador, BA 40170-115, Brazil

³ Department of Philosophy, Federal University of Bahia, Brazil, Estrada de São Lázaro, n. 197, Federação, Salvador, BA 40210-730, Brazil

⁴ Department of Linguistics and Philosophy, Massachusetts Institute of Technology (MIT), 77 Massachusetts Avenue, Cambridge, MA 02139, USA

1 Introduction

The debate about the goals of science teaching involves at the least a combination of moral and epistemic elements. More than that, it is possible to claim that:

Fruitful and responsible discussions of educational policy inevitably move to the larger philosophic questions that prompt and inform them: those issues are most acutely articulated and examined in moral and political theory, epistemology, and the philosophy of mind (Rorty 1998, p. 1).

Philosophy of education has been reinvigorated by a series of thoughtful works only recently, despite the close relation between philosophical and educational reflections and the recurring presence of issues related to education in philosophical texts along the history of philosophy (Siegel 2005). It is even less common to find in the literature the treatment of specific issues, such as the one concerning the relation between knowledge and belief in science education, which is consequential to cultural issues in science education and, in particular, to multicultural education. This is an important gap, since this relevant discussion cannot advance without closely relating educational and epistemological knowledge. Recently, the literature on science education has dealt with this topic (e.g., Smith and Siegel 2004), but, despite the important contributions already available, we consider that two aspects will play a key role in moving forward this debate: First, instead of providing general epistemological perspectives on the problem only, it is crucial to deepen our understanding by examining the problem under the light of different epistemological theories; second, contemporary approaches to epistemology deserve attention, in their relation to science education and its goals.

While some authors claim that the primary goal of science education should be a *change* in students' *beliefs* (e.g., Alters 1997), others argue that science education should aim primarily at students' understanding of scientific theories, models, concepts (e.g., Cobern 1996).¹ In this article, we aim at showing that the moral and epistemic decision of focusing on understanding as a key goal in science teaching can be grounded on an anti-reductionist proposal about testimony as a source of knowledge. For this purpose, we will discuss some elements of Harvey Siegel's (2005) critique of Alvin Goldman's (1999) view of the goals of science teaching, situated within an epistemology of testimony, and will subsequently analyze Michael Hoffmann's (2007) arguments in his criticism to Charbel El-Hani and Eduardo Mortimer (2007).

2 Goldman on the Goals of Science Education

Goldman makes use of anti-reductionist arguments concerning the epistemic role of testimony to criticize the adoption of "critical thinking" as an essential goal of science education. In turn, Siegel criticizes Goldman's anti-reductionism. This criticism is part of an argument that considers understanding (which includes critical thinking, but does not reduce to it) as an essential goal of science education. Here, we intend to argue that understanding and knowledge can be considered as primary goals of science teaching without abandoning Goldman's arguments about the epistemology of testimony.²

¹ Considering the polysemous nature of the term "understanding," we will limit its usage here to the perspective offered by Smith and Siegel (2004). As explained in more detail in Sect. 5, these authors propose four criteria that should be satisfied if we are to say that one understands a concept or idea: connectedness, sense-making, application, and justification.

² There is a recent debate in epistemology on the distinction between "knowledge" and "understanding" around the idea of "epistemic value" (e.g., Elgin 2006), but we will not discuss this topic here.

Goldman (1999) addresses the goals of science education in an influential work aiming at systematizing the proposal of a social epistemology. Social epistemology can be conceived as covering:

all systematic reflection on the social dimension or nature of cognitive achievements such as knowledge, true belief, justified belief, understanding, or wisdom (Kusch 2011, p. 873).

More specifically, Goldman (1999) asks how individuals can acquire knowledge from their interactions with others. He assumes a weak, deflated meaning for knowledge, which is presented by him as “merely” a true belief. Although it is not entirely out of the correspondence tradition, this view involves elements of a deflationist approach that avoids the criticisms against the proposal of a point-to-point correspondence with objective reality. Goldman’s focus lies rather on social practices that typically lead to truth. These practices are usually involved in argumentation, communication, and testimony (Kusch 2011).

For Goldman (1999), the acquisition of knowledge as true belief is the goal of education. Siegel argues, however, against the epistemic priority of this goal, proposing critical thinking (Siegel 2005) or, more broadly speaking, understanding (Smith and Siegel 2004) as part of the fundamental goals of education. Goldman worries that Siegel’s proposal does not take in due account that much of daily education consists of teachers teaching through statements that are not necessarily backed by reasons and arguments offered in support of them. He claims that teachers expect that their students accept at least part of their statements without other evidence than the teacher’s own testimony. More than a question merely related to the teachers’ wishes, what is at stake is that no one can defend every premise of every argument with further premises without falling into an infinite regress (Goldman 1999, p. 364).

Goldman uses arguments inspired by the epistemology of testimony to justify what he regards as a major value, namely truth as the goal of science education. His criticism to the proposal that critical thinking should be given the same epistemic weight than knowledge as true belief is presented as follows:

I am very sympathetic to some form of critical-thinking approach, but this is not incompatible with veritism. Unlike many critical-thinking advocates (such as Siegel), I do not see critical thinking as an epistemic end in itself. Critical thinking or rational inference is a useful means to the fundamental epistemic end of true belief (Goldman 1999, p. 363).

Thus, critical thinking plays, for Goldman, just an instrumental role in the process through which the student may reach the major goal of science education, namely knowledge as true belief.

In his reply to Goldman, Siegel (2005) uses two argumentative strategies, in which he questions the relations between “truth and thinking” and “testimony and trust” in order to advocate that truth does not have a greater epistemic weight than critical thinking when establishing the goals of science education. In the first strategy, Siegel claims that true belief is not sufficient to the goals of science education. To justify this claim, he argues that if true belief was sufficient, many questionable ways of reaching it would be allowed (e.g., indoctrination and brainwashing). To avoid such questionable means, science teachers should assume as a goal that students not only possess true beliefs, but also critically appraise the reasons that make them true. Then, the argument goes that truth cannot be enough in science education because it is dependent on critical thinking in order to be an acceptable goal. In the second strategy, Siegel builds a criticism of Goldman’s anti-reductionism concerning testimony. This strategy will be the focus of our arguments here.

In another work, Mike Smith and Siegel (2004) argue that knowledge and understanding are the primary goals of science education. Their concept of understanding includes critical thinking but does not reduce to the latter. They characterize understanding in terms of four conditions: connectedness, sense-making, application, and justification. Critical thinking is related to justification. By justification, Smith and Siegel (2004, p. 562) mean a coherent appraisal of at least some of the reasons that justify a claim, or, to put it differently, render the claim worthy of belief. Critical thinking, in turn, is described by Siegel (1988, pp. 43–44) as the ability to recognize the importance of reasons and properly assess them. Both in Smith and Siegel (2004) and Siegel (1988), justification and critical thinking are related to a perspective on education in which the student should be capable of recognizing and evaluating at least part of the reasons that give support to a statement.

Siegel characterizes the goal of science education as follows:

On the view of ‘the crucial epistemic aim’ that I favor, education should strive to foster, not (just) true belief, but (also) the skills, abilities and dispositions constitutive of critical thinking, and the rational belief generated and sustained by it (Siegel 2005, p. 347).

Below we maintain that understanding and knowledge can be regarded as primary goals of science teaching, instead of belief change, as one of the authors of the present article previously argued (El-Hani and Mortimer 2007). We will consider, however, the need of revising this argument to some extent, under the light of Hoffmann’s (2007) criticism. In particular, it is necessary to clarify the meanings of “belief” and “belief change.” In the next section, we argue that the proposal of understanding and knowledge as primary goals of science education, shared by Siegel, Smith, Cobern, El-Hani, Mortimer, among other authors, does not require an agreement with Siegel’s reductionist view of the role of testimony as a source of knowledge. That is, we can assume understanding and knowledge as goals of science education in the context of an anti-reductionist view of the epistemic value of testimony.

3 Testimony and Knowledge: Reductionist and Anti-reductionist Views of the Epistemic Value of Testimony

The problem of the role of testimony was already present in a discussion found in David Hume’s works, particularly in the chapter “Of miracles” in his seminal work *An Enquire concerning Human Understanding* (Hume 1748/2007), and, mainly, in Thomas Reid’s works *An Inquiry into the Human Mind on the Principles of Common Sense* (1764/1983) and *Essays on the Intellectual Powers of Man* (1788/1983). However, it was only in the 1960s that the discussion on this topic gained more currency in the philosophical agenda, following the works *Belief*, written by Henry Price (1969), and *Self-knowledge and Self-identity*, by Sydney Shoemaker (1963). The most important hallmark in the revival of the problem of testimony was C. A. J. Coady’s work *Testimony: A Philosophical Study* (1994). Currently, there is a growing amount of works devoted to this topic.

Jennifer Lackey introduces the theme as follows:

Testimony is responsible, either directly or indirectly, for much of what we know, not only about the world around us but also about who we are. Despite its relative historical neglect, recent work in epistemology has seen a growing recognition of the importance and scope of testimonial knowledge. Most of this work has focused on two central questions (...). First, is testimonial knowledge necessarily acquired through transmission from speaker to hearer, or can testimony generate epistemic features in its own right? Second, is justified dependence on testimony fundamentally basic, or is it

ultimately reducible to other epistemic sources, such as perception, memory, and reason? (Lackey 2011, p. 316).

Recently, the discussion on the role of testimony in the formation of our beliefs and in the justification processes that can legitimate the epistemic status of knowledge has gained renewed vigor. Refined arguments have been developed and defended by both authors who regard testimony as a primary source of knowledge (the anti-reductionist position) and authors who accept the possibility of testimony reliability provided that there testimony-independent reasons that attribute credibility to the speaker in a given occasion (the reductionist stance). That is, someone who assumes a reductionist position does not consider testimony as a primary source of knowledge. Before proceeding, however, it is important to bear in mind that the terms “reductionism” and “anti-reductionism” as used in the context of the debates on the epistemology of testimony have no direct bearing on its use in other contexts, as in the philosophy of mind (Lackey and Sosa 2006).

The anti-reductionist perspective, which can be traced back to Thomas Reid, can be formulated as follows:

(...) testimony is a basic source of justification, on an epistemic par with sense perception, memory, inference, and the like (Lackey 2011, p. 319).

In this sense, provided that there are no undefeated defeaters, hearers can be justified in accepting what is said based merely on the speakers’ testimony. With the expression “undefeated defeaters,” we indicate that, if a teacher has in his or her school a reputation of both being theoretically incompetent and showing a tendency to pretend to know many subjects, one should not expect the students to be justified in accepting what is said by this teacher without a deeper inquiry into other evidence for the contents of his or her testimony.

In turn, the reductionist stance, whose historical origins usually go back to David Hume, maintains that even in the absence of undefeated defeaters, the hearer needs other reasons to be justified in accepting the testimony of a speaker. These reasons are typically the outcome of induction:

(...) for instance, hearers observe a general conformity between reports and the corresponding facts and, with the assistance of memory and reason, they inductively infer that certain speakers, contexts, or types of reports are reliable sources of information (Lackey 2011, p. 319).

Regarding education, Goldman (1999) uses anti-reductionist arguments to ground his defense that knowledge, *in the truth-linked sense of* “knowledge” (Goldman 1999, p. 357), is the ultimate goal of science teaching. He argues, thus, that students do not necessarily need to have reasons that are independent of the teachers’ testimony to secure knowledge about a given topic. In a nutshell, this is his argument:

How does this apply to education? As noted, teachers commonly expect students to accept at least some statements that they do not support with evidence. Indeed, teachers (like other people) cannot give reasons for absolutely everything they assert, since reason giving must somewhere come to an end. One cannot defend every premise of every argument with further premises, on pain of infinite regress. To be sure, students might have reasons for trusting a teacher even if the teacher does not state those reasons (Goldman 1999, p. 364).³

³ One might argue that this is not an anti-reductionist argument, as reductionists are not committed to claiming that *S*’s belief that *p* is justified via *T*’s testimony only if *S* has independent reasons for believing that *p* (is true?). Reductionists claim—the argument continues—that in order for *S*’s testimonial belief that *p* to be justified, she must either have reason to trust the sort of testimony that *T* is giving in general or reason to trust *T*’s testimony in this particular case. However, this is already a weakened version of reductionism, appealing to the notion of a “sort” of testimony to counteract the criticisms of the reductionist position. But

Goldman is not merely stating that we can never justify our beliefs *only* through their coherence with other justified beliefs. Besides the fact that students need to rely on the acceptance of testimony to form their beliefs, he is arguing that we routinely rely on testimony to acquire knowledge.

In the context of a debate on the goals of science teaching, Siegel (2005) attacks Goldman's anti-reductionist argument on the role of testimony as a source of knowledge. When proposing that critical thinking does not have only an instrumental role in reaching truth, but should be part of the goals of science teaching, Siegel develops his arguments from a reductionist position concerning testimony, which is in agreement with what Goldman calls the "good reasons approach" (GR). This good reasons approach, which Goldman criticizes, could be based on the following principle:

(GR) A hearer is never justified in believing what a speaker (baldly) asserts unless the hearer has good, independent reasons to trust the speaker on that occasion (Goldman 1999, p. 364).

According to the GR, the justification of one's beliefs should necessarily go beyond trust in testimony in its own right, taking non-testimonial reasons as a ground. The expression "independent reasons" refers to the reduction in testimony to other reasons, such as perception and deduction.

Siegel argues that a critique of GR should maintain that students typically do not have other reasons to believe in their teacher besides the content of the teacher's testimony itself. He stresses, however, that the students typically do have those other reasons⁴:

Students generally have a variety of independent (of testimony) reasons for trusting their teachers: Teachers are in positions of authority; they possess relevant academic credentials; they are treated as experts by their colleagues, administrators, and other adults (including the students' parents); etc. All this is readily observable by students, and provides them with at least some non-testimony-based reasons for trusting their teachers (Siegel 2005, p. 361).

Siegel's argument would be undefeatable if one was claiming that the students' belief in what the teacher says is exclusively due to the content of the testimony of *that teacher, specifically*. However, we should bear in mind that, even though the justification of a large number of scientific and other beliefs takes place through testimony, we cannot reduce the source of reliability to the statements of a single individual. On the contrary, we should appeal to a web of testimonies (Coady 1994). If we state, then, that the teachers' academic credentials, expert status, etc., are themselves reliable because of an intricate web of testimonies, Siegel's argument looks weaker. In other words, the elements regarded as non-testimonial by Siegel are ultimately testimonial if we accept the notion of a web of testimonies.

Footnote 3 continued

this does not represent the reductionist view in a more general sense. Here, we use the following more general notion of reductionism: "In contrast to non-reductionism, reductionists [...] maintain that, in addition to the absence of undefeated defeaters, hearers must also possess non-testimonially based positive reasons in order to be justified in accepting the testimony of speakers (Lackey 2011, p. 319)." The version of reductionism used by Goldman (1999) is compatible with this more general version of reductionism. As our focus lies here on the debate between Goldman and Siegel, we will systematically use the term "reductionism" and derivatives to make reference to this version. Finally, it is important to notice that reductionist arguments about testimony are different from other types of reductionism commonly discussed in philosophy, for instance reductionism as a set of ontological, epistemological, and methodological claims about the relations between different scientific domains (Brigandt and Love 2015).

⁴ Even though the use of the term "never" in the GR enunciation is too strong for Siegel, he clearly assumes in his paper the thesis that the students typically have reasons that are independent from the testimony.

The notion of a “web of testimony” is crucial for the understanding of authority positions, academic credentials, and so forth, and what the peers say also become reliable due to the relations between testimonies within a specific community:

Various people tell him that they are members of the expert bodies and that the bodies really are expert, others tell him that their sons and daughters are being trained by such bodies in some expertise or other, and so on in a complicated web of testimony (Coady 1994, p. 283).

Coady’s argument makes sense under the light of externalism and, more specifically, of its expression in the form of a reliabilist theory of justification. Externalism, both in its reliabilist version (Goldman 2012) and in its semantic version (Brown 2004), advocates that the contents of an individual’s intentional mental states, such as thoughts and beliefs, logically and conceptually depend on the physical and social circumstances that are external to her: If I think or believe that there is water in the glass, this thought of mine depends, on the one hand, on the fact that there is water in the glass, and, on the other, on the fact that I am a member of a linguistic community that uses the words “water”, “glass”, etc., to refer to certain experiential conditions in certain circumstances. In these terms, what determines, at least in part, the contents of our thoughts and beliefs are the relations we maintain with the external world, both social and linguistic. Two elements are indispensable to the perspective of externalism: semantic memory (a certain mastery over the word meanings) and testimony (it is through the others’ words that we acquire mastery over language and have access to information about the empirical and symbolic worlds).⁵

4 Epistemic Externalism and Reliabilism

According to externalism, rationality is not necessarily supported by what the agent can cognitively access. The best and most reliable way of reaching truth does not need to be discriminated and cognitively accessed by the agent itself (Vahid 2011). Reliabilism is the strongest expression of externalism (Goldman 2012). This perspective—as all kinds of externalism—is not centered upon the subject, since it conceives that beliefs are not grounded on what is true to the agent at the moment of the belief state.

The externalism/internalism debate usually takes place in relation to criteria for justifying beliefs (Kornblith 2001). Roughly speaking, internalists maintain that the justification lies in the cognitive agent’s perspective on the world, even though they can substantially diverge about what such perspective would be. Externalists, in turn, claim that elements of justification can be external to the cognitive agent’s perspective (Vahid 2011).

Generally speaking, reliabilism claims that a belief is justified if and only if it is produced or supported by a reliable process that tends to produce more true than false beliefs. Provided that certain canceling conditions⁶ do not obtain, perception, memory, and testimony are reliable. To bring the general reliabilist formulation closer to our current theme, it is necessary to highlight that reliabilism seems to grant an important place to the understanding of scientific theories and models in education, since these theories and models result from procedures that typically generate more truths than falsities. In the face of such a statement, it is important to keep in mind that Goldman and other reliabilist

⁵ Evidently, we can also acquire information about the empirical world through experience, but, yet, a great deal of information we have about the latter comes from testimony.

⁶ A “cancelling condition” is any experienced situation that signals to the individual the imminent possibility of an error in the testimony, for example when he or she receives information that the individual who is providing the testimony was found lying in similar situations.

authors certainly support a fallibilist view about justification and human beliefs, which is not committed to strong realism or any other perspective that avoids the plural and fallible character of human beliefs (Goldman and Olsson 2009).

The point is not necessarily in establishing whether there is or there is no justification, whether the subject knows or does not know. It is also not the case of simply claiming that cognitive processes are socially determined. What is at stake is that the very definitions of knowledge and justification are entirely reformed, entailing that the distinction between belief and knowledge does not refer to the fact that the subject can necessarily discriminate between all the reasons that ground her belief:

(...) It is often assumed that whenever a person has a justified belief, he knows that it is justified and knows what the justification is. It is further assumed that the person can state or explain what his justification is. On this view, a justification is an argument, defense, or set of reasons that can be given in support of a belief. Thus, one studies the nature of justified belief by considering what a person might say if asked to defend, or justify, his belief. I make none of these sorts of assumptions here. I leave it an open question whether, when a belief is justified, the believer knows it is justified. I also leave it an open question whether, when a belief is justified, the believer can state or give a justification for it. I do not even assume that when a belief is justified there is something 'possessed' by the believer which can be called a 'justification' (Goldman 1979/1992, p. 106).

What is assumed by Goldman is that a *justified* belief has this status due to some social processes that make it justified. Nevertheless, these social processes are not necessarily possessed by the subject, but by the social interactions that produce reliable processes.

Goldman (1979/1992) lists a set of requisites that might offer support to beliefs or, alternatively, a set of counterexamples that might cancel those requisites. Among them, a decisive factor is the causal component in the formation and maintenance of beliefs.

Granted that principles of justified belief must make reference to causes of belief, what kinds of causes confer justifiedness? We can gain insight into this problem by reviewing some faulty processes of belief formation, i.e., processes whose belief-outputs would be classed as unjustified. Here are some examples: confused reasoning, wishful thinking, reliance on emotional attachment, mere hunch or guesswork, and hasty generalization (Goldman 1979/1992, p. 113).

What is shared by those processes is their non-reliable character, which follows from the fact that they typically produce mistakes, differently from other processes, such as standard perceptual processes, remembering, good reasoning, and introspection, which are typically reliable, generally producing truths. Thus, Goldman's proposal is that the justifiedness of a belief is a function of the reliability of the processes that cause the belief.

In this sense, the following is a general requisite for justification:

If S's believing p at t results from a reliable cognitive belief-forming process (or set of processes), then S's belief in p at t is justified (Goldman 1979/1992, p. 116).

Another important question concerns the fact that an anti-reductionist perspective such as Goldman's does not claim that the subject is, at a given moment, necessarily ignorant of the justification status of her beliefs, but only that she should not necessarily have knowledge about this status. Just as one can know without knowing that one knows, one can have justified beliefs without knowing that they are justified—or how they are justified (Goldman 1999). The focus is on the subject, but the criterion for justification lies in the fact that the belief is the result of a reliable belief-forming process. We can be mistaken in our evaluation of what processes are reliable, but this does not affect the adequacy of the explanation (Goldman 1979/1992).

Reliable processes involved in the justification of beliefs also involve webs of testimonies that are not, by their turn, necessarily justified by independent reasons. When an academic credential, say, a doctoral title, is presented to the student, she will not typically

do the “field work” of verifying if the teacher really did all the courses in her doctoral studies, defended her thesis, and completed all the other steps needed to obtain the title. And even if the student does so, she will have to trust, in the end, the testimony of people who will attest (or not) those facts.

Returning to Siegel’s argument, he also claims that, if the initial argument in relation to authority, academic credentials, and behavior of other teachers, parents, etc., is rejected, there are still other alternatives to fight anti-reductionism:

Consider, as an example, the algebra (or history) student. Let us suppose that on the first day of class the student has no independent reason to trust what her teacher tells her about the subject. But as the class proceeds, every day the student sees the teacher introducing material about which the student is ignorant, hears the teacher’s explanations, observes the teacher answer her (and other students’) questions, sees the teacher speak extemporaneously on tangents that (it is often apparent) were not part of the teacher’s lecture/lesson plan, etc. All this provides the student with testimony-independent (defeasible) reasons for trusting the teacher’s claims with respect to that subject matter (Siegel 2005, p. 362).

Using the reasons put forward by Siegel, we can acknowledge that the observation of a science teacher’s behavior (as well as of the other students) can make the student accept or, for that matter, at some point reject the teacher’s testimony. For instance, she can refuse to accept the latter when she notices that the teacher does not present arguments for defending her claims. Two considerations are relevant in this case:

1. To assume that the observations made by a student, or group of students, can lead to the rejection of the teacher’s testimony does not invalidate the claim that, everything else being equal, along the classroom life testimony is usually a reliable source of knowledge. To put it differently, the falsity of a testimony or the addition of reasons independent from the testimony for the credibility of what the teacher says in specific moments can only take place against a broad background of initial reliance on the web of testimonies that is generated by science and, in this particular case, by school science. This web of testimonies is produced under the influence of what is said by textbooks or by teachers and other actors participating in it.
2. When we claim that observations can lead to the rejection or acceptance of a testimony, we should remember that, as argued by Coady (1973), testimony can also lead to the rejection of observations. This claim is supported by experiments in social psychology (Rodrigues 1998). If we claim that perception can lead us to reject testimony, and, thus, perception would be the more basic source of belief, we will need to consider that testimony can also lead us to reject perception and, thus, testimony can also be taken as such a basic source.

The question at stake reaches beyond the classroom, even though in a manner that directly influences it: Science is not able to advance if the reliance on the testimonies of other scientists in the same community cannot be assured. After all, new knowledge is generated without any scientist necessarily having to do all the basic experiments (and others) in her field of research. One assumes that, say, the data obtained in a series of studies are reliable based on the testimony of whole community (through peer review, citations, etc.) and goes on with the process of scientific knowledge production. In the scientific community too, a web of testimonies attests which methodologies are to be used and what evidence resulting from the use of those methodologies is available, with no need that scientists use all the methodologies described in the papers of a field (or, for that matter, of other fields) and obtain the same evidence before continuing with the work guided by knowledge acquired on the basis of testimonies.

To deny that testimony participates as a primary source (just as deduction, induction, perception) in scientific knowledge production is, in other terms, to deny the possibility of a community producing that knowledge and advancing in understanding the investigated phenomena based on the testimony of others about methods and data that are not necessarily—and typically are not—reproduced by other scientists.

All that said, when we argue that Siegel's criticism to Goldman's argument is not enough to reject anti-reductionism regarding testimony, we do not draw the conclusion that critical thinking—or understanding—is not a goal of science teaching. That is, we can both reject Siegel's criticism of Goldman and agree with what he advocates regarding the goals of science education. The question can be then modified as follows: Can anti-reductionism with respect to testimony as a source of knowledge be compatible with the proposal that critical thinking or understanding is a primary goal of science teaching, just as Goldman states truth is?

It does not seem that there is an a priori incompatibility between anti-reductionism and the proposal of critical thinking and understanding as primary goals of science teaching. But to clarify this statement, we need to consider what Siegel (with Smith) calls understanding. The debate between El-Hani and Mortimer, on the one hand, and Hoffmann, on the other, brings to the fore elements that can help making this notion clear.

5 Belief Change and the Primary Goals of Science Teaching

The discussion about the goals of science teaching involves a key conceptual aspect, which entails the need of clear and precise definitions of the terms used, as well as an essentially pragmatic aspect, marked by the analysis of the ethical and methodological consequences of acknowledging and accepting diverse discourses. From an externalist epistemic perspective, grounded on a view of science that treats it in its connection with sociocultural, political, and anthropological aspects, these two dimensions—conceptual and pragmatic—cannot be conceived in isolation. Even when we are dealing with the conceptual aspect, we cannot neglect its relationship with a social and political positioning that directly reflects in classroom science teaching. It is in this sense that we will analyze the debate between El-Hani and Mortimer (2007), and Hoffmann (2007).

Hoffmann's criticism of El-Hani and Mortimer's proposal of culturally sensitive science education begins by establishing the conceptual parameters of the debate, but, along the argument, makes clear an explicit political positioning concerning the teacher–student relation in the science classroom. With the term “politics,” we mean here a reflection about the procedures for reaching an ethical ideal (Dittrich 2004) and, in this sense, an analysis of Hoffmann's stance about the goals of science teaching cannot avoid reflections indicating the ethical implications of that stance.

Traditionally, it is assumed that the goals of science teaching entail that the student should acquire knowledge. But what does this mean? Is there in this goal the presupposition that the student should change her beliefs about the world? Or is there the possibility of knowledge without belief change? Following Cobern (1996), El-Hani and Mortimer (2007) argue that a person can understand ideas in which she does not believe, i.e., accept as true or valid. She can thus acquire knowledge in the sense of understanding a given claim or idea without changing her beliefs.

Using a practical example, El-Hani and Mortimer refer to a study (Dole et al. 1991, cited by Sinatra et al. 2003) that found no relationship between students' stated belief in

creationism and their ability to understand texts about evolution. They interpret this study as showing that it is possible for a student to understand evolutionary theory without accepting its validity, just as it is possible that a student accept this theory, even though she has limited understanding of it.

The concept of understanding is conceived by them along the lines proposed by Smith and Siegel (2004), as including the following conditions:

1. Connectedness.
2. Sense-making.
3. Application.
4. Justification.

Thus, according to Smith and Siegel, the understanding of something is composed of a coherent connection between ideas, which allows us to make sense of it, and, also, to apply it in academic and non-academic situations. The justification condition, in turn, is deflated in relation to more rationalist proposals, amounting to the subject's capacity of appraising at least some of the reasons that render something worthy of belief.

Taking this notion of understanding into account, El-Hani and Mortimer (2007) maintain a differentiation between understanding and belief, and claim that the primary goal of science teaching lies in reaching the former, not belief change, no matter if we are talking about religious, philosophical, or commonsensical principles. It is precisely the distinction between understanding and belief that is taken as a point of departure in Hoffmann's (2007) criticism. Hoffmann quotes a key passage in their paper:

A primary factor for achieving success in teaching science as traditionally defined and, yet, contribute to empower students is, in fact, to avoid taking change of belief as a goal of science education. We should focus, rather, on understanding of scientific ideas, which means that a student should grasp the connections between scientific concepts and statements; be able to make sense of them; be capable of applying them in the appropriate contexts, not only in academic settings; and properly appreciate what counts as good reasons in the domain of science. It is particularly important that the criterion of justification does not entail that students should believe in scientific ideas, but only that they should appreciate the reasons that make those ideas worthy of belief (El-Hani and Mortimer 2007, p. 679).

Hoffmann begins his criticism by claiming that “without believing that something is the case, there cannot be any knowledge that this is the case.” Then he goes on: “Based on these considerations it does not make any sense to me to give up the goal of ‘belief change’ in education.” In other terms, he claims, “For El-Hani and Mortimer, (...) it is sufficient that students can ‘handle’ scientific knowledge without knowing it in this cognitive sense” (Hoffmann 2007, p. 690).

Hoffmann's argument seems to be logically structured as follows:

1. Belief is a condition for knowledge.
2. Knowledge acquisition is among the basic science teaching goals.
3. To acquire knowledge entails to acquire new beliefs, some of them contrary to previous beliefs.
4. Belief change is a necessity if knowledge is among the basic science teaching goals.
5. Therefore, belief change is at least part of the goals of science teaching.

Even if we assume that Hoffmann's criticism shows fragilities in how El-Hani and Mortimer use the term “belief,” we can claim that his criticism fails mostly because there is a categorical mistake involved in the debate between these authors. It would not be

difficult to assume that El-Hani and Mortimer could state, in a tone of voice,⁷ that belief change is a necessity for the understanding of science and, in another tone of voice, that belief change is not a necessity for the understanding of science.

Our argument has to do with the difference between having beliefs about science and having beliefs in science. The difference between “believe that” and “believe in” in relation to science can be translated into the difference between believing that science describes the world in a certain way (“believe that”) and believing that the scientific description is true (“believe in”). To claim that Paul believes that the scientific claims state *X* is different from claiming that Paul believes those claims to be true (in the latter case, we would say that Paul believes in science).

Hoffmann is right when he says that “without believing that something is the case, there cannot be any knowledge that this is the case,” but fails in that he does not acknowledge that what one claims to be “the case” can be a series of statements about science, and not the very statements of science itself.⁸ The question is: can I have knowledge about certain propositions, even though I do not regard them as knowledge? The answer is clearly in the affirmative. I can deeply know a novelist’s propositions about a given historical fact, and because I deeply know those propositions and also know (through other sources) the historical fact in itself, I can assure that the novelist’s claims are just elements of her fiction, not to be regarded as knowledge of the historical fact.

In sum, the question comes down to whether the goal of science teaching is that students learn what scientific theories or models claim about the world or that they learn about what the world is in fact like, or both. Our position is that the proper goal is that students learn what scientific theories or models claim about the world. Whether they also believe that the world is like the scientific theories or models state (i.e., whether they *believe in* science) is not something to be directly shaped by the teacher, but a position the students can adhere to or not, depending on their own decisions.

It is evident, however, that Smith and Siegel’s proposal is not that the student might regard science as a fiction. In relation to science teaching, their conception of understanding—particularly in the condition “justification”—demands that the student believes that, given the empirical evidence, the scientific explanation provided by the teacher for a phenomenon is the best one. This is clearly a stronger demand than we would ask someone to fulfill if we were to regard her as someone who knows a fictional work. Nevertheless, it does not entail that the student, after appreciating the reasons that justify a scientific interpretation, necessarily needs to believe in it, even though such level of understanding typically leads to belief (everything else being equal).

El-Hani and Mortimer’s (2007) proposal is consistent with the claim that students’ understanding about science, which implies their knowledge about science, does not depend on the students having their beliefs necessarily modified toward the content of scientific propositions. Even though belief change usually follows from understanding, this should not necessarily be the case for both teacher and students in order for them to be regarded as successful in what is expected of them in the classroom. In this sense, the success in reaching the goals of science teaching does not depend on changing students’ belief in science, but on their knowledge/understanding about science. This is how we interpret Smith and Siegel’s (2004, p. 553) statement that:

⁷ The expression “tone of voice” is used by us, following Gilbert Ryle (1949/1984), in order to indicate a specific semantic context. It indicates that the same speaker can use the same word to refer to different existence categories.

⁸ This is the same kind of problem found in the difference between the expressions “teaching science” and “teaching about science.”

where a student evidences a meaningful understanding but still disbelieves, [...] the appropriate goal is for students to believe that the theory in question affords the best current scientific account of the relevant phenomena based on the available empirical evidence.

Hoffmann's argument that El-Hani and Mortimer's proposal leads to a kind of fake-learning faces difficulties such as the following: If a student understands science only through memorizing textbook information and comes to believe in science, we shall claim that she has knowledge, while a student who understands science not only through memorizing texts, but by analyzing its principles and by showing critical thinking, cannot be regarded as having scientific knowledge unless she has also modified her beliefs toward scientific ideas. Critical thinking would then come into tension with knowledge, particularly if the student is in fact led to disbelieve in scientific statements by critically thinking about them, and, say, realizing how the principles underlying them are at odds with her own worldview. This suggests that we are taking the more coherent direction by assuming student understanding and knowledge as the primary goals of science education, to be shaped directly by the teachers in the classroom, instead of belief change.

But let us analyze, once again, Hoffmann's statement that belief change is part of the goals of science education. Expanding on his argument, Hoffmann writes: "As I argued above, the essential idea of believing as well as of knowing is that a person is in a certain cognitive state of accepting something as true" (Hoffmann 2007, p. 690). If we want to examine this claim, the terms at stake should be clarified: What does it mean to accept a scientific proposition as true? Does it mean to substitute scientific beliefs for beliefs at odds with science?

A subject's belief system can be much more complex than one can capture by the simple division between believing in what science says and believing in what religion says (as an example of another belief source). Consider the following example: a biology student, who comes from a family that has a deep-rooted practice of praying to cure diseases, spends 4 years studying scientifically corroborated mechanisms for disease etiologies and treatments and, after that, claims that she believes in science and has modified her prior beliefs, adopting a scientific perspective. And she indeed does more than just saying, never been found again appealing to prayers when she, or close friends and relatives, fall ill. Instead, she repeatedly uses and recommends scientifically validated practices. Suppose, however, that years later she eventually discovers that she is suffering from a very severe and incurable disease. She then calls her parents, and soon the whole family, including her, initiates a series of prayers for her cure. Suppose, also, that in this new stage of her life, the student goes on with her religious practices, defending that they are important means to treat diseases, while she also seriously pursues her engagement in learning life sciences. What should we say then? That she knew and understood science and now she doesn't anymore? Or that she never truly knew and understood science? The situation seems more complex: The previous beliefs were not simply replaced by scientific beliefs, but after learning science, some contexts evoked scientific beliefs to her, while some others evoked religious beliefs. To claim that belief change is a primary goal of science teaching involves a subtle distinction between two possibilities: belief change involves only acquiring new beliefs or also the replacement of previous beliefs? This is not clear in Hoffmann's arguments, and is important to the debate, since the first meaning of belief change seems compatible with the claim that the primary goal of science teaching is understanding and knowledge, whereas the second is not.

Hoffmann develops his arguments by considering the case of a student who does not believe in science, but it can be fruitfully expanded to examine what are the putative

implications when a science teacher does not believe in certain scientific theories. Lackey (1999, p. 477) provides us with a useful description:

Suppose that a Catholic elementary school requires that all teachers include sections on evolutionary theory in their science classes and that the teachers conceal their own personal beliefs regarding this subject-matter. Mrs. Smith, a teacher at the school in question, goes to the library, researches this literature from reliable sources, and on this basis develops a set of reliable lecture notes from which she will teach the material to her students. Despite this, however, Mrs. Smith is herself a devout creationist and hence does not believe that evolutionary theory is true, but she none the less follows the requirement to teach the theory to her students.

Given reliable evidence on Mrs. Smith's students successful learning, we can claim that they can obtain knowledge through her testimony, despite the fact that she does not believe in that scientific theory. The case in point is that even though Mrs. Smith does not believe in that theory, she both understands and knows about it and is aware of what is expected of her as a science teacher, a social role that she herself chose.⁹ Can a teacher who does not believe in science be an epistemic causal factor in students' acquisition of scientific knowledge? It is possible to perceive that in this case, the argument of categorical mistake does not apply: Even acknowledging that the teacher can have knowledge of that scientific theory, despite the fact that she does not believe in it, the students may have acquired beliefs *in* science from the teacher's testimony. In conformity with an anti-reductionist perspective in the epistemology of testimony, one can claim that the scope of justification for those students' knowledge (in both senses: a justified belief *about* science and *in* science) does not concern the empirical verification of the scientific statements, but the teacher's testimony about (quite often) what textbooks authors testify about the world.

Even considering that the teacher understands science but does not believe in it, it seems difficult to sustain that the students cannot have acquired scientific knowledge (in a sense that would satisfy Hoffmann's requirements) and, sometimes, that they have even changed their beliefs due to their teacher's testimony. It is unlikely that the primary goal of science education could be conceived as belief change in this case, since the teacher herself does not believe in the scientific theory she is teaching and would hardly assume that goal in her classes. Surely, it might be the case that the students' beliefs change toward a scientific standpoint following the teacher's testimony. However, our focus here does not lie on what might or might not happen, but on the normative dimension of the goals of science teaching.

This scenario can be interestingly extended to relations within science and philosophy:

I take it that similar considerations apply in cases where a Kantian teaches utilitarianism, a dualist teaches physicalism, an atheist teaches Christianity, and so on. If the theory in question is true and a hearer comes to believe it by means of the teacher's testimony, then, I would say, the hearer can acquire knowledge on this basis ... (Lackey 1999, p. 477).

⁹ Certainly, a key problem with religious science teachers is that several of them refuse to teach a given scientific theory, such as evolution, and often do not understand it or know a lot about it. To discuss this issue, however, would lead us away from our main focus in the article. Our view about it, however, is quite simple: to choose to be a science teacher is to choose a given social position, as part of a process of teaching the scientific perspective of the world, and if a teacher does not lend herself to play this expected social role, this will simply mean that she is inadequately placed in that role. Perhaps some people think this is controversial, but we regard it as quite a plain point: to go to the science classroom and refuse to teach a scientific theory (or, for that matter, to teach ideas at odds with scientific theories) is like going to the mass or service of worship pretending to be a priest or pastor and, instead of doing what is expected of oneself, teach a scientific theory such as evolution. Both situations are untenable for precisely the same reasons.

Up to this point, we can say that the conceptual criticism of El-Hani and Mortimer's argument made by Hoffmann points to a gap in it, namely the lack of a clear definition of the term "belief," but at the same time generates more conceptual problems, related to the definition of what would be a "belief change" as a goal of science teaching. We shall now turn to the pragmatic implications of Hoffmann's perspective to the science classroom.

Still considering the case of students who exhibit beliefs at odds with the scientific perspective, Hoffmann establishes a demarcation between what is and what is not scientific knowledge that we can put into suspicion:

... there is no question that the *attempt* to justify knowledge claims is what distinguishes scientific knowledge from other forms of being sure about something (Hoffmann 2007, p. 692, emphasis in the original).

He suggests, thus, that other knowledge systems (religion, art, philosophy, etc.) do not attempt to justify their knowledge claims. But what is justification in this context? Is it limited to the collection of empirical evidence? Or to some other specific practices? It does not seem correct to restrict justification to the empirical backing of statements. In fact, to claim that science attempts to justify its knowledge claims, while other forms of knowledge do not, entails two flaws:

1. Justification is defined based on what science explicitly proposes and, therefore, knowledge in general ends up being reduced to scientific knowledge.
2. It ignores that a great deal of scientific knowledge justification is grounded on the same justification principles found in other forms of knowledge (testimony, memory, etc.).

This way of demarcating between different forms of knowledge has relevant classroom implications, since it legitimates specific teaching practices. Consider, for instance, the following claim:

.. how can a teacher honor those [students'] beliefs more than by treating them as being worthwhile to be criticized and to be improved—based on arguments, not on indoctrination (Hoffmann 2007, p. 694).

At first, this seems to indicate some collaborative attitude between the teacher and the students. However, it also neglects power relationships within the classroom. Subjects who have undergone an educational process to become teachers and have dedicated themselves to think about scientific issues potentially have much more argumentative skills than high school students. Moreover, the very role of the teacher, who uses evaluation instruments that exert a certain power over the students, does not allow the discussion between teachers and students to take place in conditions that are equally favorable to both sides. For instance, a limit for rational debate between teachers and students follows from the fact that teachers will often be unwilling to give up their position (Kolsto and Ratcliffe 2008; Zemplén 2011). This makes the asymmetry between students and teachers in the didactic situation quite clear. Certainly, this kind of asymmetry in the teacher–student relation is not limited to argumentative situations. The teacher most likely exerts some kind of power in the classroom, no matter if she is aware of it or not.

When a science teacher assumes the educational goal of directly shaping or changing her students' beliefs, it will follow that her practice and discourse will tend to show to students that their beliefs are not in an appropriate direction and that science, in turn, offers much better propositions. She will tend to criticize and try to improve students' beliefs based on arguments. There would be no problem with these attitudes and practices *if* the relation between teacher and students in the classroom was free from power relations. But

this is certainly not the case. In the end, the teacher who assumes the goal of belief change will hardly be in a position of someone who honors her students' beliefs. It will be almost unavoidable that she will become an indoctrinator.

One might claim, then, that in El-Hani and Mortimer's proposal, the situation would not be that different. As understanding typically results in belief, as Smith and Siegel (2004) argue, the teacher would still be guiding students' knowledge in certain directions (particularly in the direction of science) when teaching for understanding. But the key point here is that even though it is impossible that the teacher does not influence her students' beliefs, she is not primarily and directly striving to do that. There is no problem in the fact that teaching influences students' beliefs. This cannot be the point, because if it has no effect in students' belief, teaching will not be teaching at all. The true problem emerges when some practices that can easily turn into indoctrination are legitimated because the primary goal of science education is taken to be students' belief change. Science teaching will not generate critical thinking, as a key dimension of understanding, if it degenerates into mere indoctrination. The thesis that understanding is the primary goal of science teaching still needs more systematic reflection, but when compared to the appeal to belief change, it is, in our view, a more meaningful way of conceiving what science education should be about.

6 In Conclusion: Epistemology of Testimony and Epistemic Agency

The reflection about the compatibility between (1) the proposition that the understanding of scientific theories, models, and concepts is a primary goal of science teaching and (2) the critique of reductionism in the epistemology of testimony is embedded into a larger issue in the didactics of science and other knowledge fields: Is it possible to combine in a consistent manner rationality and testimony-based knowledge?

A person is an epistemic agent if she not only believes, but she has reasons to believe and has skills that allow her to think about those reasons. Generally speaking, epistemic agency conditions are not satisfied by making reference to a subject's dispositional capacity to think and believe, or even by referring to the influence that those thoughts and beliefs exert over the explanation of her actions. Besides those abilities, the epistemic agent should also exhibit the capacity of reflection upon such thoughts and beliefs, creating conditions for her actions to be guided by this self-reflective character.

Despite the fact that trust in testimonies has been almost indisputably presented as a participating element in our beliefs, there are still few works that consider the possibility that trust in testimonies could be a necessary condition to ascribe rationality to individuals. Evidently, the claim that trust in testimonies could play a fundamental role in the relation between a subject and her own mental states is even more counterintuitive than the claim that it could be necessary to the elaboration of human understanding.

As Richard Fumerton (2006, p. 81) discusses, the traditional view about human understanding does not attribute to testimony any role in the constitution of rationality:

So the most perspicuous characterization of the traditional internalist's approach to understanding the role of testimony in acquiring justified belief is probably that strictly speaking there is no testimonial inference at all. When we make explicit critical unstated premises, we find that the reasoning that takes account of testimony is just some other familiar sort of deductive or non-deductive reasoning that employs at least one premise describing what other people say.

Admitting that Fumerton is correct in his characterization, the traditional definition of the role of testimony in understanding reduces it to more basic elements, such as induction and deduction. From this perspective, testimony would not have any fundamental role in understanding and rationality, since it would be nothing but a reference to inductive or deductive processes. This traditional formulation is expressed by Fumerton as follows (2006, p. 80):

- “1) Jones said that P in conditions C (where C includes a description of Jones, his qualifications as an authority, and the circumstances under which he made the assertion).
- 2) People who make assertions like P in conditions C are usually saying something true. Therefore,
- 3) P ”

This traditional view is, thus, an example of a reductionist argument, since it states that testimony is reducible to more basic constitutive units of understanding, such as deduction and induction (e.g., Lackey 2006). A reductionist position assures that any reference to testimony as being constitutive of understanding is just a manner of referring to inductive and deductive processes. For the reductionist, therefore, it is necessary to strive for pointing to reasons for the student to trust their teachers who are independent from testimony.

Apparently, both the criteria to understanding put forward by Smith and Siegel (2004) and the broader criteria to ascribe rationality to individuals are intuitively distant from a testimony basis. The latter criteria, for instance, usually refer to the subject’s capacity to know what she thinks and the possibility that this same subject accepts the responsibility for the actions guided by those thoughts. Some arguments, however, escape from this apparently intuitive conclusion. Consider the following case:

Suppose that [...] I find my department chief and the graduate studies program chair discussing alternatives to deliver an exemplar of a thesis [...] to a certain Pedro. As I do not have more classes to give or any other commitment before the evening, I have a car available, and I am inclined to collaborate to the extent that I can, I ask: ‘Where does Pedro live?’ If in that situation somebody asked me ‘Who is Pedro?’, I would hardly have any better answer to offer than saying something like ‘Pedro is the one they are talking about’ (Faria 2006, p. 105).¹⁰

If we assume externalism (in its reliabilist version, e.g., Goldman’s) as a legitimate position, in this case the subject apparently has no capacity to discriminate between the content of his thought and other possible alternatives (Sosa 1991/2000). Considering the information given, a skeptical thinker might claim that the subject cannot have in hands all the relevant information to know what he is thinking, since he cannot establish a conceptual distinction between her cognitive states in relation to relevant situations. In this case, relying on the testimony of others entails that the subject’s capacity to have cognitive access to her reasons to believe is so precarious that he is not capable of knowing who is Pedro, but just that he is the one other people are talking about.

Nevertheless, from a reliabilist externalist perspective, it will be correct to claim that the acquaintance needed to use a proper name may be mediate instead of immediate. If we take mediation into account, the situation in which the subject in the example above is found does not seem as precarious as it seemed at first. The direct implication of the claim that a speaker could have no authority to speak about her own thoughts would be that we could not use in an appropriate manner many of the terms that we use in our everyday utterances. This would be the case because a great deal of the meaning ascriptions to specific terms

¹⁰ The original text is in Portuguese, and the passage has been freely translated into English by the authors of the article. Although Faria is dealing with the epistemic problem of memory in his article, the same example can be used in relation to both memory and testimony.

takes place because of a historical chain of uses of the term, not due to any direct reference. For instance, we can legitimately use the name “Socrates” as we do today because Plato knew Socrates, Aristotle knew Plato, Theophrastus knew Aristotle, in a succession that reaches our times (Geach 1980). The reference to “Pedro” in the example mentioned above can be made, just as in the case of “Socrates,” due to the existence of a web of testimonies that are true, from an anti-reductionist perspective. This does not deny, evidently, the possibility of error, but makes less intuitive to assume that we need extra guarantees for the trust in testimonies to be legitimate or for the testimony to be true unless relevant alternatives appear.

By “relevant alternatives,” we mean any lived situation that signals to the individual the imminent possibility of error in the testimony, for instance, when she receives information that the person who is offering the testimony has been found lying in similar situations. In the absence of relevant alternatives, the web of testimonies of which we are part needs to be assumed as reliable if intersubjective communication is possible. Moreover, without the possibility of such communication, the problem of rationality would not even appear.

If these arguments are valid, the capacity of individuating contents of our own thoughts is also derived from reliance upon the testimonies of others, not from a direct reference to the object of the proposition. Trust in testimonies would be, thus, part of what composes the legitimacy of ascribing to a subject the capacity of being rational or, more specifically, an epistemic agency.

The deflation of the notion of rationality resulting from the insertion of arguments related to memory and testimony brings philosophical reflections about rationality closer to other organized systems of knowledge, such as history and psychology. Moreover, this deflation can be extended to the notions of critical thinking and understanding, and given this deflation, it is possible that critical thinking is not only instrumental (as proposed by Goldman). Understanding and, consequently, critical thinking can be a primary goal of science teaching provided we can ascribe rationality and criticality to a subject who does not necessarily need to present reasons independent from the testimony for her thinking.

The four conditions for understanding put forward by Smith and Siegel can be reached provided that reliance on testimony composes the broad background for the development of the abilities involved in them. In this case, Goldman’s argument of infinite regression does not apply: The student’s capacity of critical thinking does not entail an infinite regression because it can be anchored in statements that are “merely” supported by a web of testimonies. To show the capacity of critical thinking—at least in the deflated sense presented here—does not entail saying that all elements in the student’s thinking need to be justified by reasons that are independent of the others’ testimony. To use the example above, to ascribe to the student the capacity of critical thinking about the Socratic arguments does not presuppose that the very individuation of the term “Socrates” cannot be justified by a web of testimony. For this reason, the thesis advocated here is not limited to a “compatibility” between anti-reductionism and understanding as a major goal of science teaching. Anti-reductionism concerning the role of testimony is taken as a basis for avoiding Goldman’s criticism when entertaining the four conditions for understanding proposed by Smith and Siegel (2004). Against the broad background of reliance on testimony, the infinite regression criticism cannot be even formulated.

It is true that the science teacher does not need to provide reasons for all elements in her statements. In fact, she does not even need to know all the reasons that support those statements, beyond the testimony of the scientific community. However, this does not prevent her from evaluating at least some of these reasons, while several other reasons are justified only by the web of scientific testimonies. In this deflated sense, to consider critical

thinking as a major goal of science teaching does not entail an infinite regression, or a reductionist perspective about the epistemic role of testimony.

Trust in testimonies can be said to be not only compatible with understanding and critical thinking, but also necessary for the development of these attributes of epistemic agency rationality by science students or any other participant of the social/communicative game.

Acknowledgments We would like to thank Harvey Siegel, Ben McMyler, Michael Hoffmann, and two anonymous reviewers, who made valuable criticisms and comments on a previous version of this article, which greatly contributed to its improvement. We are also thankful to Nei Nunes-Neto, Rosileia Oliveira Almeida, Carlos Augusto Sartori, and Tiegue Vieira Rodrigues for their comments, which also contributed to improving the paper. We are also indebted to two anonymous reviewers who brought important contributions to the final version of the paper. We are thankful to the Brazilian National Council for Scientific and Technological Development (CNPq) for the support to the research who led to this paper, through Grants Nos. 301259/2010-0 (CNEH) and 312567/2013-8 (WJSF). We also thank the Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) for the Research Fellowship No. 002706/2015-06 (TASF).

Conflict of interest The authors declare no conflict of interest.

References

- Alters, B. J. (1997). Should student belief of evolution be a goal? *Reports of the National Center for Science Education*, 17, 15–16.
- Brigandt, I., & Love, A. (2015). Reductionism in biology. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. <http://plato.stanford.edu/archives/fall2015/entries/reduction-biology/>. Accessed 9 June 2016.
- Brown, J. (2004). *Anti-individualism and knowledge*. Cambridge, MA: MIT Press.
- Coady, C. A. J. (1973). Testimony and observation. *American Philosophical Quarterly*, 10, 149–155.
- Coady, C. A. J. (1994). *Testimony: A philosophical study*. New York, NY: Oxford University Press.
- Coburn, W. W. (1996). Worldview theory and conceptual change in science education. *Science Education*, 80, 579–610.
- Dittrich, A. (2004). *Behaviorismo radical, ética e política: aspectos teóricos do compromisso social*. São Carlos, SP: Department of Philosophy, Federal University of São Carlos (Ph.D. thesis).
- Elgin, C. (2006). From knowledge to understanding. In S. Hetherington (Ed.), *Epistemology futures* (pp. 199–215). New York, NY: Oxford University Press.
- El-Hani, C., & Mortimer, E. (2007). Multicultural education, pragmatism, and the goals of science teaching. *Cultural Studies of Science Education*, 2, 657–702.
- Faria, P. A. (2006). Preservação da verdade. *O que nos faz pensar*, 20, 101–126.
- Fumerton, R. (2006). The epistemic role of testimony: Internalist and externalist perspectives. In J. Lackey & E. Sosa (Eds.), *The epistemology of testimony* (pp. 77–92). Oxford: Oxford University Press.
- Geach, P. (1980). *Logic matters*. Berkeley, CA: University of California Press.
- Goldman, A. I. (1979/1992). What is justified belief? In *Liaisons: Philosophy meets the cognitive and social sciences* (pp. 105–126). Cambridge, MA: Bradford.
- Goldman, A. I. (1999). *Knowledge in a social world*. Oxford: Oxford University Press.
- Goldman, A. I. (2012). *Reliabilism and contemporary epistemology*. Oxford: Oxford University Press.
- Goldman, A., & Olsson, E. J. (2009). Reliabilism and the value of knowledge. In A. Haddock, A. Millar, & D. Pritchard (Eds.), *Epistemic value* (pp. 19–41). Oxford: Oxford University Press.
- Hoffmann, M. (2007). Learning without belief-change? *Cultural Studies of Science Education*, 2, 688–694.
- Hume, D. (1748/2007). *An enquire concerning human understanding*. New York, NY: Oxford University Press.
- Kolsto, S. D., & Ratcliffe, M. (2008). Social aspects of argumentation. In S. Erduran & M. P. Jiménez-Aleixandre (Eds.), *Argumentation in science education* (pp. 71–88). Dordrecht: Springer.
- Kornblith, H. (Ed.). (2001). *Epistemology: Internalism and externalism*. Oxford: Blackwell.
- Kusch, M. (2011). Social epistemology. In D. Pritchard & S. Bernecker (Eds.), *The Routledge companion to epistemology* (pp. 873–884). London: Routledge.

- Lackey, J. (1999). Knowledge and transmission. *The Philosophical Quarterly*, 49, 471–490.
- Lackey, J. (2006). Knowing from testimony. *Philosophy Compass*, 5, 432–448.
- Lackey, J. (2011). Testimonial knowledge. In D. Pritchard & S. Bernecker (Eds.), *The Routledge companion to epistemology* (pp. 316–325). London: Routledge.
- Lackey, J., & Sosa, E. (2006). *The epistemology of testimony*. Oxford: Oxford University Press.
- Price, H. H. (1969). *Belief: The Gifford lectures*. New York, NY: Humanities Press.
- Reid, T. (1764/1983). An inquiry into the human mind on the principles of common sense. In R. E. Beanblossom, & K. Lehrer (Eds.), *Inquiry and essays* (pp. 1–125). Indianapolis, IN: Hackett.
- Reid, T. (1788/1983). Essays on the intellectual powers of man. In R. E. Beanblossom, & K. Lehrer (Eds.), *Inquiry and essays* (pp. 127–295). Indianapolis, IN: Hackett.
- Rodrigues, A. (1998). *Psicologia social*. Rio de Janeiro: Vozes.
- Rorty, A. (Ed.). (1998). *Philosophers on education: Historical perspectives*. London: Routledge.
- Ryle, G. (1949/1984). *The concept of mind*. Chicago, IL: University of Chicago Press.
- Shoemaker, S. (1963). *Self-knowledge and self-identity*. Ithaca, NY and London: Cornell University Press.
- Siegel, H. (1988). *Educating reason: Rationality, critical thinking, and education*. New York, NY: Routledge.
- Siegel, H. (2005). Truth, thinking, testimony and trust: Alvin Goldman on epistemology and education. *Philosophy and Phenomenological Research*, 71, 345–366.
- Sinatra, G., Southerland, S. A., McConaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching*, 40, 510–528.
- Smith, M. U., & Siegel, H. (2004). Knowing, believing, and understanding: What goals for science education? *Science & Education*, 13, 553–582.
- Sosa, E. (1991/2000). Reliabilism and intellectual virtue. In A. Guy (Ed.), *Knowledge, Belief, and Character: Readings in Virtue Epistemology* (pp. 19–32). Lanham, Boulder: Rowman & Littlefield.
- Vahid, H. (2011). Externalism/internalism. In D. Pritchard & S. Bernecker (Eds.), *The Routledge companion to epistemology* (pp. 144–155). London: Routledge.
- Zemplén, G. Á. (2011). History of science and argumentation in science education: Joining forces? In P. V. Kokkotas, K. S. Malamitsa, & A. A. Rizaki (Eds.), *Adapting historical knowledge production to the classroom* (pp. 129–140). Rotterdam: Sense Publishers.