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Science Teaching, Disagreements and Intellectual Autonomy

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Abstract

The central objective of this work is to present the discussion around the objective of science teaching in the light of an epistemological approach, in order to verify how this debate reverberates in the teaching of chemistry. Given this discussion, in which different theses are defended, I argue in favor of the thesis that considers that one of the objectives of science education is the formation of a critical citizen with intellectual autonomy. A critical subject is considered to be one who seeks to discuss the reasons involved in a dispute by submitting them to the sieve of reason. Here, critical-reflective action is essential for the formation of a responsible epistemic agent. And, in this sense, responsibility implies autonomy. Thus, autonomy is understood as a virtue or a quality. When I consider that a student (as an epistemic agent) has a virtue, I want to argue that he has a disposition to be motivated in a certain way and to act in a given way in relevant circumstances, and, furthermore, he is successful in achieving the end of his virtuous motive. To illustrate the idea of autonomy, a central theme in the teaching of chemistry was used as an example: the "disagreement" about the concept of molecular structure. For this, a scenario was proposed in which reflection is important and has epistemic value: the ontological status of molecular structure - reducible or non-reducible to quantum theory? Faced with the views of the authors, it was found that some adopt the reductionist perspective which defends the reconstruction of the concept within the quantum structure of atoms in molecules. Others, while recognizing the conceptual discontinuity between quantum mechanics and molecular chemistry, keep alive the hope for reduction. From an explicitly non-reductionist position, authors conceive molecular structure as an emergent phenomenon. In this scenario, reflection was understood as a performance, an activity from which the agent examines the reasons, the evidence, the content involved, the reliability of his own beliefs and, in the face of proposed disagreement, decides what is epistemically reliable to believe or not. This is a theoretical-reflexive research, for its value and normativity, based on the analysis and review of the literature.

Keywords: Autonomy; Disagreements; Science teaching; Philosophy of chemistry

Introduction

The central objective of this work is to present the discussion around the theme "the purpose of science teaching" in the light of an epistemological approach, in order to verify how this debate reverberates in the teaching of chemistry. This discussion refers to the area of science didactics and has a broad contribution from scientists, educators and philosophers of science [1-9].

In the current discussion scenario, there is a diversity of positions about the goal of science education [3,7] maintain that the goal of science education should be a change in students' beliefs. Others argue that science education should aim primarily at students' understanding of the objects that science proposes (scientific theories, models, laws, postulates, and concepts), as pointed out by Cobern WW , Smith MU and Siegel H, Hoffmann M [2,5,6]. Ferreira TAS, et al. [9] argue that the debate about the goals of science education involves at least a combination of moral and epistemic elements. In addition, they consider understanding and knowledge as primary goals. For Ferreira TAS [8], the goal of science education is the formation of the student's virtuous character.

Given this discussion, in which different theses are defended, the question is: what does a student, considered as an epistemic agent, learn? For Santos WLP and Schnetzler RP [10], the function of teaching chemistry involves developing the ability to make decisions. In this perspective, "the teaching of science should lead the student to experience situations that provide the development of the ability to judge, evaluate and position" (p. 1) [11]. On this aspect, (p. 15) Ferreira TAS [8] argues that "understanding can be qualified as the virtue of a subject that can reflect on its own understanding, taking responsibility for their beliefs formed in light of this reflection".

For Libâneo JC [12], the purpose of education is relevant because it expresses, intentions, well-defined and explicit purposes regarding the development of skills developed by students during their training process (for example, cognitive, physical, affective, aesthetic and ethical) to act as a citizen in society. To reach this point, [13] reflecting on the relationship between intellectual virtues and the preparation for the exercise of citizenship, defends the thesis that considers intellectual virtues as the end of education. In this sense, the author argues:

> P1. If virtues of intellectual character are a primary source of preparing people for the exercise of citizenship and preparation for the exercise of citizenship is an end of education, then virtues of intellectual character should be taken as a primary focus of education.
>
> P2. Virtues of intellectual character are a primary source of preparing people for the exercise of citizenship and preparation for the exercise of citizenship is an end of education.
>
> Therefore, C1. Intellectual virtues should be taken as a primary focus of education (modus ponens, P1, P2). (p. 171) [13].

For the author, intellectual virtues are character traits and cognitive excellences constitutive of the intellectual maturation process of the individual. For Borba AZ [13], such virtues can be understood as a regulating ideal of education from official education documents. "This means that the notion of intellectual virtue provides the field of education with an evaluation standard against which to assess the reasonableness and desirability of curricula, teaching methods, learning tests, etc" (p. 208) [14].

What we see in the debates is that there is no consensus within virtue epistemology about what an intellectual virtue is, as Zagzebski L [15] suggests. However, authors who discuss the importance of virtues in philosophical work agree that intellectual virtues express a given type of cognitive excellence. Among the types of cognitive excellence are cognitive faculty, intellectual talent, and intellectual ability [13,16-19]. It is worth noting that cognitive faculties are not always cognitive excellences. An agent may, for example, not observe well, reason poorly, not have a good memory, make mistakes, and so on.

For Borba AZ [13], the concept of intellectual virtue is the central concept for addressing problems and topics in virtue epistemology. The scope of problems depends on the epistemological program in which the epistemologist wishes to research. To a large extent, virtue epistemology has two distinct directions: the Confiabilist Epistemology of Virtue (linked to the theoretical positions of Ernest Sosa and John Greco), which focuses on cognitive faculties, and the Responsibilist Epistemology of Virtue (linked to the positions of Linda Zagzebski and Jonathan Kvanvig), which focuses on character traits. In this sense, intellectual virtues are character traits linked to the pursuit of distinctly intellectual goods, such as knowledge, understanding, among others[1].

There are at least two virtue theses: the confiabilist and the responsible thesis. They are distinct theses because they deal with different aspects, despite using the same term. On the one hand, for the confiabilists, the concept of intellectual virtue comprises: (a) the concept of intellectual virtue involves cognitive faculties (e.g., memory, perception, and intuition); (b) an epistemic agent is not necessarily

1 On the relation between intellectual virtue and epistemic good, I will deal with this later.

responsible for the possession or operation of intellectual virtues and vices; (c) intellectual virtues (under certain conditions) are trustworthy dispositions (conducive to truth); (d) the value of intellectual virtues is instrumental. On the other hand, for the accountabilists, this same concept is understood as: (a) qualities from habits; (b) an epistemic agent is responsible for the possession or operation of intellectual virtues and vices; (c) only personal qualities;

(d) intellectual virtues have intrinsic value [20]. In this paper, however, the notion of virtue will be understood in only one way: via the accountability perspective.

Since the aim of the research is to consider intellectual autonomy as one of the goals of science education, this work is aligned as a special case of virtue epistemology accountability.

For a Responsibilist, virtues would have little definition based on the content of dispositions (i.e. whether they produce truth or not) and a strong commitment to the way in which relations are established in the community of people acting in groups. It is the epistemic community that establishes the criteria for someone to be considered responsible in a given context. (p. 96-97) [8].

In fact, this is a work that seeks to contribute to the character-based "accountable" virtue epistemology, which is a perspective of epistemology that emphasizes reflection on the virtues of intellectual character, such as curiosity, open-mindedness, intellectual courage, rigor, and above all, autonomy. In dialogue with [8,13,21-23], I present what would come into play in science teaching with the virtue of autonomy. To illustrate a central theme of Chemistry teaching, I will use as an example the "epistemic disagreement" about the concept of molecular structure.

In terms of epistemic disagreement, [4] argument consists in allowing for the possibility that two or more people can reasonably disagree about a given proposition even when they have equivalent evidence (arguments, information, facts) regarding that proposition. In this sense, one of the central problems in the epistemology of disagreement consists in answering the following question: what rational attitude should epistemic pairs take when they both hold different views? Here, disagreement becomes epistemologically interesting because epistemic pairs participate in it, as we will explain later. A priori, it is understood that epistemic parity involves an epistemic symmetry around a given issue, in a way that this happens via equality in terms of cognitive capacity and access to relevant evidence and arguments.

For Baehr J [14], the problem of disagreement is one of the most investigated topics in contemporary social epistemology. In this sense, the subject occupies the expressive agenda of discussion of analytical epistemology, because it has a direct link with a widely discussed and debated topic among philosophers: the epistemic justification. Epistemic justification is linked to the problem of whether an agent can resort to reasons to justify his cognitive states. In the philosophical literature, there are arguments for and against the notion that a cognitive agent has transparent and privileged epistemic access to these cognitive states. Such states address the question of whether or not we have the intellectual ability to list reasons that can justify our beliefs.

Roughly speaking, epistemic justification means that in order for us to regard any state as knowledge, rational arguments must be presented, content in relation to which the subject is conscious and which are conducive to justifying the truth of the belief [24]. Goldman A [25] adds that justification must be understood as a matter of "reasons" rather than causes. Here, belief must be the fruit of inquiry.

In general, justification means that regarding any state as knowledge implies that rational arguments are made. In this sense, the arguments are in favor of the truth of the belief, rather than a mere figment of chance. A rational agent is one who has control over his own beliefs and his actions are guided in the light of these beliefs. In other words, the notion of justification is linked to an agent's ability to judge. It is worth noting that there is a difference between being justified and justifying: "Being justified" is a state, whereas the term "justifying" refers to an action (or activity) that involves the evaluation and reflection on something.

About the notion of autonomy, I believe that its unity is related to something that gives motivation to act and that passes the sieve of judgment. There are situations where the subject in a unity encounters conflict: Drive or adherence? To believe or not to believe? I think that the autonomous subject, can conduct himself to maintain (or not) the beliefs already supported by reasons. Moreover, to believe or not to believe is not the goal, but in terms of the ethics of belief: what is required for us to believe or what sanctions something.

There are different ways of defining intellectual autonomy. The concept of intellectual autonomy is one that can lead to a number of issues if taken to an extreme. For example, (p.225) Fricker E [26], describes an "autonomous knower" based on Descartes and Locke as one who "does not take anyone's word for it, but accepts only what he has discovered for himself, relying only on his own cognitive faculties and investigative and inferential powers." Descartes explicitly defended this ideal and method in his Meditations [27]. Locke likewise rejected "the opinions of other men floating in his brain" as not constituting knowledge [28].

This extreme purism restricts very severely how much one can come to know [26].

The conflict surrounding the notion of intellectual autonomy is whether or not it involves trust in others [26,29-30]. According to Zagzebski L [30], intellectual autonomy is the right or ideal of self-direction in acquiring and maintaining beliefs. For the philosopher, the acquisition or maintenance of beliefs, is the arena in which autonomy is exercised. In this sense, the author argues:

> Since intellectual autonomy is the exercise of self-management in our beliefs, epistemic self-confidence is a necessary condition for intellectual autonomy. I think this point can be generalized. Autonomy requires confidence in the connection between the conscious use of all one's powers - perceptual, epistemic, affective, conative - and success in achieving the basic ends of those powers. Self-confidence is a necessary and critical condition for autonomy and, by the same token, it is a necessary and critical condition for being a self. (p. 259) [30].

Characterizes "a self" as being aware of oneself, including awareness of different mental states, and also beliefs, desires, emotions, sensations, attitudes, judgments, and decisions. For her, a conscious self-reflective person is committed to authority in the realm of belief. Epistemic as well as emotional self-confidence is rational and inevitable. Moreover, epistemic self-confidence is consistent and commits us to trust others, so that some of these others satisfy conditions for epistemic authority [30]. Baehr J [21], supported by the Kantian definition of thinking for oneself, considers that there would be intellectual autonomy and an agency when an agent can defend a belief from the support of reasons, endorsed in a reflexive way. For Baehr J [21], as for Zagzebski L [30], intellectual autonomy occurs based on the defense of a belief, through reasons that are presented to our self.

From another point of view, Roberts RC and Woody WJ [29] supported by an individualistic autonomy, consider that intellectual autonomy as a virtue means that the subject must on his or her own seek to reflect, analyze evidence, and reach his or her own conclusions. This autonomy can be exemplified in the student or researcher who is able to act on his own. From this perspective, the notion of autonomy would be a willingness to use one's reason ''without direction from another" [29].

> Imagine first the person who is self-governing '' all the way down". He is the sole unaided author (or at least the original discoverer) of all the logical rules he uses, all the experimental patterns, all the vocabulary of inquiry, all the guiding questions he addresses - that is, of everything that regulates his intellectual practices. This pattern is not an inheritance. He has discovered for himself the entire factual background that regulates any current investigation, and he has worked out for himself all the explanations that any current investigation presupposes. He is the complete autodidact, having never had a teacher other than himself, with literally no one to thank for his intellectual powers and accomplishments. He has never darkened the door of a university or any other school. He works entirely alone, never consulting colleagues, never listening to criticism from others, never reading what others have written (p. 259) [29].

For Roberts RC and Woody WJ [29], regardless of how the virtue of autonomy has been interpreted, it has been conceived as a proper ability to think for oneself and not be unduly dependent on or influenced by others. In my view, the positions of Roberts RC and Woody WJ [29] seem to be a misunderstanding. I think that we should not consider the extreme and caricatured form of the autonomous subject. Rather, what allows a subject to be autonomous is not isolation, but interactions - with epistemic sources of other people, for example, teachers, researchers, physicists, chemists, and mathematicians as occurs in the educational process. This thinking considers social relations relevant for intellectual autonomy, enabling them [30]. My position is that the notion of intellectual autonomy involves trust in others, being something absolutely necessary.

We are, in a sense, epistemically dependent on each other. For example, much of the knowledge we have comes from the testimony and words of other people. It is hard to see how we could, even ideally, obtain knowledge through our own intellectual efforts, i.e., intuitively, not everyone can be a chemist, a physicist, a mathematician, a historian, a researcher, and so on [30]. The autonomous epistemic agent is the subject who relies on the intellectual work of others in order to achieve epistemic goods.

In a broader sense, autonomy is conceived in this thesis as a virtue or a quality. When I consider an agent to have a virtue, I want to argue that he has a disposition to be motivated in a certain way and to act in a given way in relevant circumstances, and, furthermore, he is successful in achieving the end of his virtuous motive [30]. Virtues can be understood as relatively stable dispositions to think and/or act well, where the disposition is not just a capacity to do something, but a capacity combined with a propensity to do it [20]. That is, virtues are not mere capacities; they involve a motivational component. Here, critical-reflective action is essential for the formation of a responsible epistemic agent. And, in this sense, responsibility implies autonomy.

To illustrate this idea, I use a circumstance in which the "disagreement about the subject: molecular structure - reducible or non-reducible to quantum theory"?.

The problem of molecular structure is widely discussed. In the debates that have taken place, two major groups stand out: (a) the reductionists and (b) the non-reductionists. In general, reductionists hold the view that the concepts of chemistry can be explained by the postulates of physics, especially, by Quantum Theory [31-34]. Here, there are authors who advocate the reconstruction of the concept of molecular structure within the framework of the quantum theory of atoms into molecules. Others, while acknowledging the conceptual discontinuity between quantum mechanics and molecular chemistry, keep alive the hope for future reduction. Currently, the most strongly emphasized reductionist strategy is that represented by the so-called Quantum Theory of Atoms in Molecules (QTAIM), proposed by Bader in the 1990, [35] maintain that the concept of molecular structure seems to find no place in the ontology described by quantum mechanics since it appeals to classical notions such as the position of atomic nuclei or the individuality of electrons. Trindle C [36] also asserts the viability of the question: does the concept of molecular structure survive beyond the Born-Oppenheimer approach? For Kelly T [37], although this approximation is a powerful tool, it is insufficient to think the problem of molecular structure.

Given this scenario, in which two (or more) agents hold different beliefs about the same subject, having access to the same evidence (i.e., arguments, information, and phenomena), and approximately the same abilities (e.g., reasoning ability, reflection, criticality, etc.), what is the most rational attitude the agent should adopt in the face of this disagreement?

(a) Continue to believe what he believed.
(b) Decrease confidence in his own initial belief.
(c) Suspend judgment.

Faced with the available attitudes, there are two possible theses: the conciliationist and the anticonciliationist. In this paper, I will be arguing in favor of the anti-conciliationist thesis and how it is linked to ontological pluralism, bringing contributions to the teaching of science, in particular, to the teaching of chemistry [38-43].

Faced with the available attitudes, there are two possible theses: the conciliationist and the anticonciliationist. In this paper, I will be arguing in favor of the anti-conciliationist thesis and how it is linked to ontological pluralism, bringing contributions to the teaching of science, in particular, to the teaching of chemistry.

The problem is that the discussion about molecular structure (when it happens) runs through the debates within the philosophy of science, especially in the philosophy of physics and the philosophy of chemistry, and is not usually part of the school and university curricula. Although the problem has attracted the attention of several authors, the discussion is far from being resolved. However, this does not mean that there are not good reasons to defend a certain philosophical position or to offer a different way of argumentation to reflect on the problem. In this paper, my goal is to argue in favor of the position that the concept of molecular structure is not reducible to quantum theory for specific reasons. Moreover, I seek to consider that there would be a great benefit for the teaching of science, especially for the teaching of chemistry, to have this dispute as an object of study in terms of intellectual autonomy.

Taking the case of molecular structure, my initial argument consists in considering that, in order to participate in a rational disagreement, we must be intellectually and morally prepared for the nature of this debate. This attitude implies a careful evaluation of the reasons surrounding the problem, being open to (or accepting) the rules of the epistemic game, submitting to the light of reason, and not imposing oneself by force. But, for this, it is necessary that we have a virtue: intellectual autonomy.

From this, I will defend the thesis that considers that one of the goals of science teaching is the formation of a critical agent with intellectual autonomy. Here, a critical subject is one who seeks to discuss the reasons, submitting them to the sieve of reason, that is, the arguments for or against [44]. In this sense:

> The gain can be direct: when the person discards unsatisfactory reasons and finds assurances to believe or disbelieve. It can also be indirect: leading to a more demanding attitude, distrustful of certain statements, yet curiously and open-minded, becoming more able to understand positions different from one's own. This form of disagreement can be found in everyday life as well as in philosophy (p. 117) [44].

Therefore, it is considered that the notion of intellectual or epistemic autonomy, as well as disagreement and reflection, can contribute with answers to the obstacles partially discussed in this master's thesis. Thus, I argue, with [8,21,22] that one of the goals of science teaching is intellectual autonomy. The entire argumentative path of this thesis seeks to explore reasons why the goal of science education should include something like autonomy. The student, in this perspective, is an autonomous, virtuous, critical and reflective agent constructor of knowledge.

The Reflective-Theoretical Method

This work is eminently theoretical-reflexive in nature, for its value and normativity. According to Ferreira TAS, Matos MS [45], theoretical-reflective research is divided into at least three categories: conceptual, theoretical and philosophical research. Conceptual research seeks to investigate a concept. The intention is to assess whether there are (or not) problems in its definition or in the relationship it has with other concepts in the formation of a given theory [46].

Thus, the central concept is molecular structure. My intention is to verify the controversy surrounding the discussion of this concept and how it relates (or not) to the theory in focus: the quantum theory. This study focuses on the following question: molecular structure - reducible or non-reducible to quantum theory? I draw on the argumentation of the concept in order to present a theoretical and critical discussion, guided primarily by the specialized literature of contemporary philosophy, seeking to understand a relationship that I consider fruitful between Social Epistemology and science teaching.

The theoretical research deals with conceptual categories, but is not restricted to their analysis. For Dittrich A (p. 20) [47], this research is "dedicated to reconstruct theory, concepts, ideas, ideologies, polemics, with a view, in immediate terms, to improving theoretical foundations." Therefore, it requires: conceptual rigor, a more refined analysis, lines of argumentation, and explanatory capacity. Philosophical research deals with the epistemic conditions of a given scientific field, which seeks to reflect on the ethics of the way we conduct (scientific) research and assesses the assumptions on which a given science is based.

> The character of philosophical research is reflexive and its propositions often normative. This means that science can offer a good description of how things are, but it is in the realm of philosophical ethical reflection that we can argue about how things should be. This prescriptive reflection cannot be sufficiently investigated by some empirical expedient, and is therefore philosophical. (p. 22-23) [46].

The normative condition refers to prescriptive reasons, that is, they suggest something about what could be [48]. In this context, philosophical arguments are normative . Evaluating an argument involves looking at the reasons invoked and the way they are organized in the argument. According to Goldman A [49], the structure of a philosophical argument is formed by three conditions: syntactic (logical), semantic (meaningful) and pragmatic (operational). I share their views because I believe, as do these authors, that the tools to evaluate a good philosophical argument are: reason, intuition, relative ability, communication, emotion, and imagination; they underlie and give reasons for what should be ideal. Thus, the guarantee of the argument is based on good reasons to justify it.

Epistemic Disagreements and the Objective of Science Teaching: the case of Chemistry Teaching

There is much discussion on the topic: what is the objective of science teaching? In this section, I briefly introduce the debate [4,6-8,13]. I then expose the problem of disagreement as a topic within the scope of Social Epistemology [4,38,39,50-58,] . It is worth emphasizing that I am not considering that all problems in the teaching of chemistry are objects of disagreement; that would be counterintuitive and anti-Kuhn, i.e., if there are only disagreements we would not have normal science and consequently it could not be taught. My goal is to use the disagreement around the problem of molecular structure to illustrate the idea of autonomy as I will do later.

The Objective of Science Teaching

There is, in fact, a controversy around the objective of teaching Science. For example, Smith MU and Siegel H [5], as well as Goldman A, El-Hani C and Mortimer E [4,6] maintain that knowledge and/or understanding are the central and normative goals of science teaching. Zagzebski L [59], especially, considers that understanding is independent of knowledge. His arguments refer to the perspective that there is no epistemic priority between them.

From another point of view Hoffmann M [7], as well as Alters BJ [3] and Kvanvig J [60], admit belief change as a goal of science education. According to Ferreira TAS (p. 38) [8] the argument of Hoffmann M [7] seems to support the following assumptions:

1. Belief is a condition for knowledge.
2. Acquisition of knowledge underlies the goals of Science Teaching.
3. Acquiring knowledge thus entails acquiring new beliefs, some of which are contrary to previous beliefs.
4. Changing beliefs is a necessity if knowledge is to underlie the goals of Science Teaching.
5. Thus, changing beliefs is at least part of the goals of Science Teaching.

On the perspective defended by Hoffmann M [7], (p. 669) Hoffmann M [6] comment that "a person can understand or master ideas in which he does not believe, so he can use those ideas without taking ownership of them." Furthermore, they consider that knowledge about science does not depend on whether the student can have their beliefs changed about

the content. For Siegel H [56], Hoffmann's position can lead to at least two risks: on the one hand, a certain epistemic relativism; on the other, an absolutist and totalitarian position that intercepts any possibility of dialogue and propagation of social values that promote democracy. Moreover:

> In the classroom, the alternative conceptions brought by the students should be welcomed and respected, but it is up to the teacher to present how the scientific community has dealt and handles the problem that the student is trying to deal with, or has been proposed, regardless of whether he will abandon his alternative conception or not. The science student is there to have a general education that provides him with a basic understanding of the major results achieved by the scientific community, not metaphysical beliefs that do not derive from or promote scientific inquiry. (p. 42-43) [56].

For Siegel H [56], the thesis that, in science teaching, students who have religion (or not) can understand a certain content without having to believe it as true (or totally true) knowledge is supported. Claiming, the author, that the change of belief is not an essential condition for the purpose of science teaching. Other authors such as Cobern WW, El-Hani C and Mortimer E [2,6] argue that the goal of science education is the students' understanding of the objects that science proposes: models, theories, laws, scientific concepts, among others. El-Hani and Mortimer also point out that:

> A primary factor in achieving success in science education as traditionally defined and yet contributing to empowering students is, in fact, to avoid belief change as a goal of science education. Rather, we must focus on understanding scientific ideas, which means that the student must understand the connections between scientific concepts and statements; be able to make sense of them; be able to apply them in 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 justification criterion does not imply that students must believe scientific ideas, but only that they must appreciate the reasons that make those ideas worthy of belief. (p. 679) [6]

Goldman A [4] based on the epistemology of testimony considers that knowledge as a true belief is the ultimate goal of science education. Here, the justification status of a belief refers to the reliability of the processes that cause it (testimony, for example). There are also several authors who seek to discuss the purpose of science teaching via the epistemology of virtues. From this perspective, Grimm S [61] considers that an intellectually virtuous person is one who desires and is committed to the pursuit of goods such as knowledge, truth and understanding. A certain emphasis is also given to the question of knowledge as the ultimate goal of epistemology. Some authors of this conception [8, 62-66] argue about the value of knowledge as epistemic virtue vis-à-vis understanding. Thus, while, on the one hand, the discussion aims at understanding the relation between knowledge and understanding [67], on the other hand, the intention is to point out that understanding has a greater epistemic value than knowledge [66]. Such a discussion refers to the status of understanding as the goal of science education[2].

The problem of Disagreement

There are currently (among many others) three questions in epistemology for the disagreement problem: Q1: Would evidence of a disagreement be a nullifier for our belief?; Q2: If yes to Q1, then how strong would this nullifying reason be?; Q3: If yes to Q1, then under what conditions is this nullifying reason nullifying? [65]. According to Jonathan Matheson, such questions are normative: they are questions that refer to rationality - they concern what an individual is justified in believing, what he (epistemically) should believe in the face of disagreement.

However, not all disagreement is problematic. What interests me at this point is disagreement between epistemic pairs who are rational agents. I understand epistemic pairs as those who have no epistemic advantage over each other, so that they both share the same important evidence for the question and are equally adept at discussing and evaluating this evidence, i.e., they have the same abilities (perception, reflection, intelligence, memory, etc.) to solve the question. In other words, the constitution of epistemic pairs involves two aspects: they share P (sets of evidence), exchange information and engage in extensive and exhaustive discussion (1), and have similar cognitive abilities (2). For example, a genuine disagreement would be: two philosophers of science/chemistry disagree about the correspondence relation between model and reality, that is, whether or not the model corresponds with reality. Both of them are academics, have compatible backgrounds in their respective fields, are intelligent, epistemically responsible, share the same evidence and the same cognitive abilities (epistemic parity), so they are very careful in evaluating the evidence.

Given the above, considering that agents have distinct beliefs and access to the same evidence (arguments, facts,

2 Authors such as [4-6]] make a discussion around the priority of understanding and/or knowledge in relation to the normative perspective of science teaching. These are interfaces between science teaching and epistemology [8].

information, phenomena), so that none of the pairs keeps information to themselves and share approximately the same skills (intellectual resources, reasoning ability, reflection, perception) and intellectual virtues, the question that motivates this section is: what is the most rational attitude an agent should take when faced with a disagreement?

(a) Continue to believe what one believed.
(b) Decrease confidence in one's starting belief.
(c) Suspension of judgment.

By evidence I mean everything that causes the belief or offers to support the belief. That is, belief is always caused by some evidence. In this sense, I think that if we are rational agents we can reflect on the positions of subjects in a disagreement. An epistemic agent not only believes, but has reasons to believe and has abilities that allow him to think about these reasons.

Conciliationism x Anticonciliationism

The disagreement problem can be described as follows: suppose that after a thorough investigation of a topic (e.g., molecular structure - reducible or non-reducible to quantum theory?), two agents considered as epistemic pairs discover that they have distinct beliefs in the face of the same evidence. Agent X comes to the conclusion that B (i.e., that the concept of molecular structure is reducible to quantum theory) and agent Y comes to the conclusion that ~B (i.e., that the concept of molecular structure is not reducible to quantum theory).

Agents X and Y then find that in the face of the same evidence, they both come to opposite conclusions. After the discovery of the disagreement between epistemic pairs, the question is: what is the most rational action to take?

(a) Continue to believe the initial belief.
(b) Reduce the degree of confidence of the belief.
(c) Suspend judgment.

In this case, it is a scenario involving rational epistemic agents and what they should do in the face of disagreement. But why is this a problem in the disagreement literature? According to the epistemology of disagreement, besides the epistemic agents offering arguments that support their own beliefs, the question is whether the disagreement itself is evidence that was not available to both.

In this scenario, we have two distinct theses: the conciliationist and the anti-conciliationist. Both presuppose rationality, intellectual autonomy, intellectual virtues, and are rationally justified positions. Neither of them defend intellectually vicious positions. They are distinct theses because they deal with the problem of disagreement differently.

In view of this, each thesis seeks to explain why its viewpoint is the most rational. This implies that, from the agent's perspective, it is rational both to maintain its starting belief (without changing the degree of trust) and to reconcile it with its peer [38,39,35,52,66,70-73]. For authors like Christensen D [70,71] and Feldman R, Kelly T, Chisholm R [52,72,73], the most rational position in disagreements is to take the conciliationist view. In this view, it is generally held that in cases of disagreements between epistemic peers we should revise the justification of our beliefs, give weight to the view of the opponent in the dispute, reduce somewhat the degree of confidence of the belief or even suspend judgment in a dispute.

According to Feldman R, Kelly T, Chisholm R [52,72,73], disagreement shows us that our belief may not be so secure, and that in the context of disagreement, we may have made some mistake in evaluating the evidence. For [52], disagreement is evidence of our fallibility and thus an opportunity for epistemic improvement. In this sense, he considers:

> We live all our lives in a state of epistemic imperfection. Obviously, this is true because the evidence on which we base our beliefs is limited. Somewhat less obviously, we live in states of epistemic imperfection because we do not always respond in the best way to the evidence we have Feldman R (p. 187) [52].

For this author, disagreement is evidence that we are fallible. Our epistemic condition assumes that we give imperfect answers to incomplete evidence, that is, it is part of the rational agent to take into account these sources of imperfection.

From the perspective of moderate conciliationism, a chemist can hold a conciliationist position, in the sense of considering the objections of the epistemic peer and submitting one's own beliefs to review, without necessarily having to suspend judgment or adopt the opponent's position. But what would come into play in the evaluation of the adjustment of the degree of confidence in the belief? For this philosophical perspective, we have: 1 - The confidence that the agent has in the relationship between the evidence and his belief (second order evidence); 2 - The authority he grants to his epistemic peer; 3 - The degree of explanatory and/or practical success of his theory in the community of epistemic peers.

In general, conciliationism, in its strongest conception, the so-called Equal Weight View, considers that we should give equal weight to the opinions of epistemic agents in a rational epistemic disagreement [70]. The point here is that we should give equal weight to the beliefs of epistemic peers. Roughly speaking, this means that we should review the status of the beliefs we form and consider the other's opinion

in the disagreement debate, since both of us as epistemic pairs have a 50% chance of being right about the issue under investigation. That is, according to the previous example, agent X who comes to the conclusion that B, can be as right as agent Y who comes to the conclusion that ~B. If both opinions have equal weight, as indicated by the Equal Weight View, then it is believed that we have no reason to hold either one of them, and in that case we should suspend judgment as in all cases of disagreement between epistemic pairs. This attitude seems unreasonable and could reverberate as a kind of epistemic cowardice as Christensen D [70].

Another problem concerns the gradual loss of self-confidence. If both opinions also have equal weight, then we are in a sense reducing or even weakening the self-confidence we have regarding our own justification. The point here, for example, is that agent X has transparent and privileged access to the formation and justification of his belief, which he does not have relative to agent Y who comes to the conclusion that ~B. Other views are adopted to avoid the objections of this perspective, for example, the Extra Weight View. According to this view, "we should give our own evaluation more weight than the evaluation of those we count as epistemic peers" (p. 485) [70]. However, what we observe is that both Christensen D [70] and Feldman R [52,71,72], hold that the problem of peer disagreement affects justification of agents' beliefs in the dispute.

If on the one hand, the most rational position in disagreements between epistemic pairs is to take the conciliationist view as we have seen in Christensen D [70,71] and Feldman R [52,71,72]. On the other hand, the most rational position is believed to be the anticonciliationist view [35,38,74]. The anticonciliationist says that in the face of a peer disagreement, we should not revise or downgrade confidence in the justification of our original belief, the disagreement itself does not interfere with the justification of the belief, and conciliating would harm both radical skepticism and loss of confidence [35,38,74].

Let's take the initial example from another perspective. If agent Y has properly evaluated the same evidence, arguments, and information relevant to forming his belief that ~B, knowing that agent X has reached an opposite conclusion does not require agent Y to make any revision to his belief. That is, upon discovering that agent X disagrees with agent Y, it would not affect agent Y's rationality to continue believing what he believed. For Lombardi O and Labarca M [39]:

> Rationality consists in responding appropriately to our evidence. But our evidence includes evidence according to which we do not always respond appropriately to our evidence (that is, evidence according to which we are fallible in responding appropriately to our evidence), as well as evidence according to which we are more likely to respond inappropriately when we find ourselves in certain circumstances. (p. 139) [39].

On this basis, Lombardi O, Labarca M [39] adds that an evidence can confirm or deny, in some way, the rationality of what we believe based on the evidence we have. Regarding the question of properly evaluating the evidence with respect to a given issue, Kelly T [38] comments that this consideration is certainly the kind of consideration that is relevant in deciding whether the agent's judgment should be credited with respect to the issue. That is, it is exactly the kind of consideration that is capable of producing asymmetry that would justify privileging one of the two parties in the dispute over the other [38].

Within this context, the attitude that seems to be the most appropriate, reasonable and rational in case of disagreement, is to hold firm to the initial belief. This means that the agent should not reduce the degree of confidence of his belief nor of his justification. Adding to this, knowing that an agent (an epistemic peer) disagrees with our belief that P (e.g., the concept of molecular structure is reducible to quantum theory for specific reasons), does not require us to make any revisions in our belief either. That is, we must always hold firm to our belief both from the first person perspective and in front of a disagreeing peer. In this sense, the author states that:

> Disagreement is not a good reason for skepticism or for changing the original view. In what follows, I will argue for the following thesis: once I have fully scrutinized the available evidence and arguments supporting a question, the mere fact that an epistemic peer radically disagrees with me about how that question should be answered does not weaken my rationality to continue believing it the way I do. Even if I confidently retain my original view in the face of that disagreement, doing so does not constitute a failure of rationality. In fact, confidently retaining the original belief may be the only reasonable response in such circumstances (p. 170) [38].

The point is that for this author, the justification of a given belief is based on first-order evidence (information or reasons). The discovery of a disagreement, on the other hand, would be second-order evidence, and therefore would not affect the justification of that belief at all. In the context of disagreement, what Kelly does is to give priority to first-order reasons over second-order reasons. For him, even if we admit disagreement as a second-order evidence capable of changing the justification of epistemic agents, it would still not be a good reason to change the starting belief. So, in case of disagreement, even after the discovery of an epistemic pair, it is rational to hold firm the same degree

of confidence in the starting belief. If agent Y has properly evaluated the arguments, the information, the evidence, and is justified in holding the belief that ~B, then he has no reason to reconcile his belief with his opponent. It would not be unreasonable for agent Y to continue to believe that ~B, the disagreement itself is not a good reason to reduce the degree of confidence in the starting belief. Another point of the discussion concerns self-confidence. If on the one hand, in the conciliationist view, there is gradual loss of self-confidence; in the anticonciliationist view, the first-person perspective is non-eliminable [68]. We have access to the process of forming our beliefs, but we do not have it in relation to our opponent. In a way, this could give us greater confidence in the belief we form and would be a reason to hold firm to our belief.

Reflection and Disagreements

There is an intense debate in contemporary epistemology about the place of reflection. Some say that it has less value than is thought; others that it has great epistemic value; still others that it has only moral value. For [44], the most common argument that defends the idea that reflection has no epistemic value considers that, through reflection, the formation of second-order beliefs does not affect the attribution of knowledge or improve its reliability. Like these authors, I will remain neutral on this argument.

On this basis, when dealing with non-dialectical contexts, I think it is reasonable to consider that it becomes irrelevant for a person to reflect on a given situation. In contrast, there are relevant cases in which reflection is indispensable, and, moreover, should result in something of great epistemic value. On this point, I agree with (p. 14) [75] when he considers that "a person can discover directly, by reflection, what he is justified in believing at the moment." Such is the case with the disagreement.

About the relevance of reflection, a strong debate about this notion has been outlined in two well-defined positions: the one initiated by Kelly T [28], which considers that reflection would be the act of thinking, doubting, believing, reasoning, knowing that allows access to the idea that could not be obtained directly from things via empirical experience. From another point of view, reflection is understood as a metacognitive performance so that the subject evaluates its own first-order doxastic states (for example, its beliefs and thoughts), and leads to new second-order doxastic states [76]. In this sense, the subject is enabled to judge his own states and act in light of his judgment.

In this section, then, I admit that when a subject reflects he can focus on his cognitive states, so that he can believe something based on reasons or even assume beliefs that are good reasons about the natural world. Some of the main questions considered within this context are: can we produce a discourse that justifies our beliefs? Do we have the intellectual ability to list reasons that can justify our beliefs? Do we have the means to produce a justification that assures us that our beliefs are true? Can our beliefs be justified through reflection? I understand reflection as a performance in which the subject examines evidence, reasons, counter-arguments, positions and contents. In beliefs, believing here refers not only to the belief of something, but to the legitimate right of the subject to believe in something he has reasons to believe, even if reflection is understood as a partial, fragile and imperfect human capacity. In the face of disagreements, a critical subject that seeks to discuss the reasons, submitting them to the sieve of reason (that is, the arguments for or against), is a virtuous subject and has epistemic value.

Epistemic Disagreement around the Teaching of Chemistry

This section aims to identify how the problem of molecular structure is formed within the current discussion scenario. The concept of molecular structure is believed to be central to the chemical style of thinking due to its explanatory and predictive nature. It is also a concept that presents great utility for chemical education due to its representational role and visualization of microscopic phenomena. However, such concept seems to find no place in the ontology described by quantum mechanics, since it appeals to classical notions (such as the position of atomic nuclei or the individuality of electrons). In the face of the debates, two major groups stand out: (a) reductionists and (b) non-reductionists.

When does the problem start?

The problem of ontological reduction has a long tradition both in the history of philosophy and in the history of science. In pre-Socratic philosophy, the search for the reduction of multiplicity to unity was the predominant perspective: the idea of a fundamental thing from which everything is made[3].

In ancient Greece and Rome, atomists such as Leucippus and Democritus were the reductionists par excellence, considering that bodies were composed of indivisible atoms, of distinct sizes and shapes. In Plato's philosophy, principles were understood as non-material. This idea reactivated the ontic priority over other ontic items. In the

3 On this aspect, (p. 2) [35] comment: "Although this early monism was later replaced by an ontic framework based on several material principles, the attempt to reduce the diverse empirical reality to a simpler underlying domain survived in Empedocles and his four elements and in the atomism of Leucipp and Democritus".

Modern Age, the idea of ontic reduction reappears in two perspectives. The first, linked to the relationship between primary qualities, following the philosophical perspectives of Locke and Galileo. The influence of ancient atomism reached the 19th century through John Dalton's modern atomic theory. By the end of the 19th century, their fields of study were conceived in reductionist terms: Boltzmann tried to explain thermal phenomena in gases in terms of classical mechanics; meanwhile, Maxwell worked with analogies, and then used the mechanical models for electromagnetism, although he did not defend its reality, but he reduced light to electromagnetism . In both cases, the underlying ontological assumption was that nature is made of mechanical entities governed by Newtonian physics. This assumption was what justified the strategies directed at explaining the new theories (thermodynamics, electromagnetism) by means of classical mechanics.

Although Chemistry and Physics currently have very close fields of knowledge, in the nineteenth century the interests of these sciences were distinct. Such differences can be identified, for example, by the way classical atomic theory was used in this period [77]. "Atoms were imagined as inelastic particles or inertial points, subject to attractive and repulsive forces that would act both within these particles and in the medium between them" (p.1076) [77]. According to this view, the discrete structure of the microscopic world was used to describe phenomena such as light.

In Chemistry, the notion of atom was linked to the existence of chemical elements that would be composed of particles that could no longer be broken down [78]. In Physics, the notion of the atom began with the dynamic theory of heat. Both sciences had a close relationship between various perspectives, but the problem of this relationship came to manifest itself more strongly in the links between molecular chemistry and quantum theory. The idea of reduction directly affects the concept of molecular structure, and this notion is not merely auxiliary or secondary, but a central concept in chemistry. In other words, "molecular structure is so central to chemical explanation that explaining molecular structure is basically explaining all chemistry." (p.183) [79]

As described here, Chemistry followed a historical development independent from Physics: chemical phenomena were conceived in their own specificity and with their own regularities [78]. However, the great descriptive, predictive and explanatory success of quantum mechanics led to the assumption that chemistry could be reduced completely to physics. This idea spread very quickly and was adopted by different physicists and philosophers of science, and is still being widely addressed by authors such as Wasserman E & Schaefer HF [80] and Dupré J [81].

The Question of Epistemological Reduction

According to the philosophical literature, the term reductionism has different uses. There is no consensus about the typologies of the term. In general, it designates the situation in which one domain of phenomena can be assimilated to another apparently distinct domain [82]. For logical positivist epistemology the "reduction" of propositions was linked to reports of observations. At the beginning of the twentieth century, it was sought to reduce mathematics to logic[4].

In order to propose some considerations about the ontological nature of the problem investigated, I consider [83] concept of epistemological reduction according to which he considers that a reduced theory can be deduced from the fundamental theory plus some necessary definitions. The discussion around this perspective would be more interesting if there existed in science important examples of epistemological reduction from Nagel's perspective. However, this does not seem to be the case [40]. As Primas comments: "there is not a single physically well-founded and non-trivial example for theory reduction" in Nagel's sense (p. 83) [84]. Furthermore: "Even if there were examples of successful application of such a notion of reduction in certain areas of science, there is a broad consensus among philosophers of chemistry that this is not the case in chemistry: the epistemological reduction from chemistry to physics clearly fails" (p. 85) [40].

This view is an eliminativist perspective: since the linguistic items belonging to the reduced theory can be eliminated from scientific discourse, we have no ontological commitment to their references. This implies that if epistemic reduction between two theories is established, one can have good reasons to support ontological reduction [40].

> Therefore, ontological reductionism is a metaphysical thesis that postulates the ontological priority of a certain level of reality, to which the other levels are directly or indirectly reduced. Epistemological reductionism refers, on the contrary, to the logical dependence between scientific theories: one theory can be reduced to another when it can be deduced from it. In this way, epistemological reductionism becomes an epistemological thesis according to which science can (or should) be unified by deducing all scientific theories from a single privileged theory (p. 4) [85].

4 In physics, an example of reduction was that of the laws of gases to laws that consider the shocks between molecules, considering that the laws and phenomena described according to thermodynamics would be explainable in terms of statistical mechanics.

According to Van Brakel J [41], the line of argument most used by philosophers of chemistry in relation to the problem investigated here is the impossibility of epistemological reduction of chemistry to physics. Although the arguments differ among themselves, authors agree in considering that chemical descriptions and concepts cannot be derived from the concepts and laws of physics, as suggested by traditional epistemological reductionism.

On the rejection of the epistemological reduction of chemistry to physics, several philosophers of chemistry maintain that the laws of chemistry cannot be deduced on the basis of the laws of physics, as can central concepts of chemistry such as chemical bonding, molecular chirality, and orbitals. Scerri ER [86] point out that quantitative chemical properties-that is, calculating chemical properties from quantum mechanics-fails, since it requires approximation techniques that can only be justified on the basis of experimental data that, precisely, is intended to be calculated. This is an important argument, but the reductionist defends himself by saying that the scientist's knowledge is limited, so one must appeal to such data.

Conceptual reduction also fails because the very nature of chemical concepts makes this impossible. In turn, Vemulapalli GK, Byerly H [87] point out that epistemological reduction fails even in the simplest cases, since the properties of a chemical system cannot be explained in terms of the properties of physical microcomponents, e.g., equilibrium in non-ideal multiple component systems and non-ideal systems in statistical thermodynamics. They further conclude that: "epistemological reduction fails radically when one attempts to derive the specific chemical explanations from fundamental physics [...] one is only successful in deriving chemical results by assuming chemical data" (p.37) [87].

Molecular Structure: Reducible or Non-Reducible to Quantum Theory?

In this section, I resume the initial discussion around the theme "the goal of science teaching" in order to present how intellectual autonomy and the problem of disagreement can be maintained in this debate. In this sense, I will explain the main argument of this thesis which considers that one of the goals of science education is the formation of a critical agent with intellectual autonomy.

After all, what is the Objective of Teaching Science?

For Smith MU, Siegel H [5] the main goals of science teaching are understanding and knowledge. The relationship between understanding and knowledge would be a kind of epistemic pair, with no epistemic priority between them, that is, understanding is independent of knowledge (and vice versa). For these authors, understanding something is related to the connection between ideas about something and its application in a given context. The notion of understanding must involve four conditions: connectivity, attribution of meaning, application, and justification [8]. Still, the concept of understanding involves critical thinking but is not reducible to it [8]. According to Siegel H [88], critical thinking is linked to the student's ability to know and recognize the relevance of the reasons that can be given when facing a debate. Justification, on the other hand, is admitted as the evaluation of the reasons that support an argument worthy of belief.

In contrast to advocates of critical thinking (such as Siegel), Goldman A [4] comments that he does not view critical thinking as an epistemic end in itself. In this sense, he comments, "Critical thinking or rational inference is a useful means to the epistemic end of true belief" (p. 336) [4]. For the author, critical thinking is an epistemic way to true belief. For Goldman A [4], knowledge as true belief is the goal of science education. Understanding, on the other hand, is the instrument to obtain the truth. This implies that there is no epistemic priority between understanding and knowledge, "but only that they are legitimate fields of interest because they can lead to intrinsic epistemic value (i.e. knowledge as merely true belief)" (p. 14) [8]. "What concerns Goldman is that much of everyday education consists of teachers teaching through statements that are not necessarily grounded in reasons and arguments offered to students. He argues that teachers expect students to accept, at least in part, their statements without evidence other than the teacher's own testimony". (p. 22) [8]

On this point, like Goldman, I also have the same concern. What can we expect the student to learn in science teaching, particularly in chemistry teaching, when they are being taught about the theoretical and conceptual problems that chemistry has? We need more concrete actions that can be taken in science/chemistry teaching and that involve the essential decision-making of the student as suggested by Schnetzler RP [89]. In my view, we need strategies as to how we should work with questions that lead the student to the ability to judge, reflect, evaluate, and analyze what is taught. I believe that teaching through epistemic disagreements is a relevant strategy for teaching to be effective, when it is the case.

About the debate between Zagzebski L [59] and Goldman A [4], it can be seen that Zagzebski L [59] does not agree with the perspective held by [4] on epistemic priority (i.e., by assigning knowledge as true belief to the goal of science education). For Zagzebski L [59], knowledge and understanding would be the goals of science education. The crucial epistemic goal in science education consists

in "striving to promote, not (only) true belief, but (also) the skills, abilities, and dispositions constitutive of critical thinking, and of the rational belief generated and sustained by it" (p. 347) [59].

To a large extent, up to this point, the goals of science teaching assume that the student should have knowledge. The question, however, is: what does this mean? And, after all, what is the difference between understanding and knowledge? According to the epistemology of virtues, understanding is a virtue that has as its characteristics: (1) A skill; (2) This skill refers to the relations between parts and whole, it does not refer to a discrete object; (3) it considers reality in a non-propositional way [62]. Ferreira TAS [8], in discussing the perspectives held by [62], argues that the nature of understanding is tied to a dispositional state - which involves the connection between the parts of a given reality - as well as their connection to the whole. It is argued:

> At less complex levels, only behavioral dispositions are observed, while at more complex levels, elements from three diverse levels (behavioral, phenomenal, and cognitive) are part of this dispositional state. At a high level of complexity, understanding can be qualified as the virtue of a subject who can reflect on his own understanding, taking responsibility for his beliefs formed in light of this reflection. I will argue that understanding is central to the goal of science education from an examination of its epistemic value. (p. 17) [8].

For Ferreira TAS [8], virtues are more than skills, they are also phenomenal-dispositional states. At this point, he sustains some characteristics:

a) Understanding is not a matter of "all or nothing" but suits the analysis of degrees to which the subject S more or less understands a given structure depending on how much we can attribute behavioral, phenomenal, and cognitive dispositions to it.
b) It is not possible to make a list of actions or experiences that can exhaust the definition of what understanding would be. It is a dispositional stereotype and, therefore, is qualified from manifestations that are typically expected of someone who possesses understanding in a certain context.
c) Understanding has both internalist and externalist elements.
d) Understanding need not be entirely transparent to the subject that possesses it. (p. 72) [8].

Phenomenal-dispositional states involve not only abilities, but a propensity to exercise them in given contexts [90]. The propensity is seen as a motivating element of the agent, that is, the agent not only does something, but is motivated to do it in certain contexts.

Faced with these views, the question is: is it possible to have understanding of something without having knowledge? For Kvanvig J [91]: "Understanding requires, and knowledge does not require, an internal apprehension or appreciation of how the various elements of a body of information are related to each other in terms of explanatory, logical, probabilistic, and other kinds of relations, which coherentists have thought to constitute justification. (p.192-193) [91]. [66], meanwhile, offers cases where knowledge occurs without understanding (and vice versa), pointing out a difference between these two terms. Pritchard D [64], meanwhile, points out that even in Pritchard's examples, what is called understanding is a type of knowledge - namely, knowledge of causes [8].

Around the goal of science teaching, another issue concerns the change of students' beliefs. For El-Hani C and Mortimer E [6], a student may understand or master a subject he does not believe in and, therefore, may use it in science without taking ownership of it. Following this line of thought, even if a college student does not believe that there is only one geometry for the water molecule among so many possible ones, he can use arguments that point to its existence. In this example, it is possible that a student understands the geometry of water, without accepting that such geometry is actually possible to be obtained, that is, its validity.

For El-Hani C and Mortimer E [6], the understanding of theories, models and hypotheses is one of the central goals of science teaching. According to these authors, understanding scientific ideas presupposes that the student is able to appreciate the reasons that make the ideas around something in science worthy of belief. On this perspective, Cobern WW [2] argues that rather than expecting students to learn, that is, to accept as true or valid scientific theories, hypotheses, statements, concepts, and models, science teaching should prioritize the goal of getting students to understand them.

In dialogue with Cobern WW [2] and Smith MU, Siegel H [5,6] point out that an interesting goal for science teaching should be to encourage students to recognize the scientific status of the theories (hence, the models) they are taught. Instead of making them believe in the "truth" of scientific theories, the teacher should promote the view that they provide the best scientific picture of phenomena from both empirical and theoretical consistency. On this aspect, I agree with these authors, because I think that the theories (therefore, models) are not (and should not be) exactly reality, but the best we currently have. To understand the nature of models, is to understand the specificity of language in science, especially the language of chemistry.

In opposition to the perspectives advocated by Cobern WW, Smith MU, El-Hani C [2,5,6] authors such as Alters BJ, Hoffmann M, Kvanvig J [3,7,60], argue that belief change is the goal of science education. For [92], the student cannot accept a theory unless he develops some understanding of it. For Hoffmann M [7] there is no knowledge without beliefs, because belief is the necessary condition for knowledge. Another aspect is to consider that acquiring knowledge implies acquiring new beliefs, so that some of them are contrary to previous beliefs. In this sense, the change of belief is a condition for knowledge to be part of the goals of science teaching.

Although the notion of understanding depends on the philosophical perspective, the idea that this concept can be considered as a virtue (as suggested by the epistemology of virtues), I see it more as a product among the theoretical perspectives presented here. My view of understanding is close to the perspective held by, (p.117) [93]: "it is the result of the epistemic effort to form an understanding of relationships, chains, connections, and, to this end, it can only be transparent to the consciousness of the agent".

Unlike the notion of knowledge, the notion of understanding has a character of transparency so that access and such transparency should not be confused with internalist theories that aim at the justification of knowledge [57,75,93]. That is, understanding has the internalist condition for its realization, something that is not required of knowledge [57,93]. Therefore, the self (i.e., the first-person position) and satisfaction of a quality or intellectual ability of the agent, is an indispensable aspect for the notion of understanding. Dialoguing with [93], philosopher [91] adds that understanding lies in the broad understanding of the world and reality, i.e., the understanding we have broadly of information about the problem of molecular structure. In his view, the notion of understanding is tied to a high degree of coherence and breadth.

When I assume that a student knows in this thesis, I am considering the notion that knowledge is a realization just [93,58] maintain. In this way:

> [...] knowledge is an accomplishment because it is a success obtained through cognitive abilities, so knowledge is an epistemic notion that has more value than a mere belief that is true because of luck, since we value, in the same way, achievements that are the result of other abilities as opposed to achievements by luck or chance. Thus, the epistemic notion of knowledge comes to have a higher value in relation to the other epistemic notions precisely because, unlike the other notions, knowledge is an achievement, it is a competence, it is a type of success obtained because of cognitive abilities (p. 44) [58].

When we consider that the epistemic agent knew something about the disagreement over the molecular structure, this implies that he performed - and was successful in - an investigation about the conditions of the formation of his belief. Now, when we attribute knowledge to the student, what we are doing is recognizing that he is a good source of information, a good informant, and that the information he has about the dispute over the concept of molecular structure is true. When I attribute understanding to the agent, I am considering that understanding is the result of epistemic effort and not of chance or mere luck [93]. The focus in the notion of understanding around the reducibility or not of the molecular structure to quantum theory, are the structural relations between the information captured by the agent as well as, (p. 96) Santos FRL [94] argues: "to understand is to comprehend the variety of such connections". Understanding about disagreement around molecular structure requires a high degree of coherence and breadth of information.

Given the above, it is worth noting that to argue that the goal of teaching is knowledge or understanding does not imply a lack of student autonomy, because autonomy involves trusting the teacher, accepting and agreeing with what he teaches. At this point, the concept of trust becomes relevant as we consider the transmission of knowledge based on the teacher. Accepting testimony as a joint action creates epistemic duties and responsibilities and the eventual success can be considered a genuine achievement at the social level of epistemology [95].

Suppose that in class the university teaching professor properly presents a disagreement. This means that he has told the students that the evidence that is available, allows certain researchers to believe the view that molecular structure is reducible to quantum theory and other researchers to believe that molecular structure is not reducible to quantum theory. In debate, the student can understand the disagreement, without the need to seek further evidence, because an intellectually autonomous student is one who depends on and trusts the intellectual work of the teacher. Thus, an agent can only know the debate and be autonomous.

The thesis that a critical student must evaluate his own beliefs and reasons, being responsible for them, is fully compatible with anticonciliationism in relation to disagreement and with the idea that knowledge and/or understanding is the goal of teaching. On this aspect, I agree with Siegel H [88], because I believe that the evaluation of reasons around a subject is not (and cannot be) static, it demands an initiative to human traditions which also make

up traditions of rationality. For (p. 59) [88]:

> A student of science must learn, among other things, what counts as a good reason for or against some hypothesis, theory, or procedure; how much weight the reason has; and how it compares with other relevant reasons. Science education amounts to initiating the student into the scientific tradition, which, in part, consists of appreciating those criteria in the tradition that govern the evaluation of reasons.

Also, having as assumption that the notion of intellectual autonomy involves trust, then who defends that the goal of teaching is to make the student change beliefs, defends an autonomous environment. From this perspective, I ask: Why couldn't science teaching be this way, since having as a goal the change of students' beliefs is neither incompatible with autonomy nor with anti-conciliationism?

Suppose further that in university teaching, after a chemistry class, where disagreement over the concept of molecular structure was charitably presented by the teacher, the student, autonomously, modifies his belief and becomes convinced that the thesis the teacher defends is correct, thus assuming the same perspective as the teacher. The student has taken this attitude based on his intellectual autonomy. His attitude towards disagreement depended on his epistemic evaluation, on the reflection he made around the debate, and on the attribution of confidence to the teacher.

In this scenario, reflection is a performance, an activity through which the student examines the evidence, the content, the reliability of his own beliefs and, in the face of disagreement, decides what is epistemically reliable to believe. In this sense, reflection has epistemic value. Moreover, reflection is about what the student thinks about the disagreement, not just what he thinks on his own. That is, reflection is (and should be) mutual. In other words, a student who assumes the reducibility of molecular structure to quantum theory must also reflect on the ideas, thoughts, beliefs, and especially the reasons the other holds or what the teacher thinks, and so on. This perspective may lead him to assume a certain attitude; however, after analyzing the arguments, he may reconsider or maintain his position. In this respect, beliefs can be understood as a product of their reflexive endorsement [21]. By reflexively endorsing commitments the student exercises his autonomy.

I believe that there is no conflict with the other objectives of science teaching, and therefore, considering that the objective of teaching is knowledge (as judged by the authors cited in this research), for example, implies affirming that it is a teaching that stimulates autonomy.

The Virtue of Autonomy for Science Teaching

In science teaching, and especially in chemistry teaching, I think that creating conditions for epistemic agents to know the arguments and the positions of the authors around the dispute (molecular structure: reducible or non-reducible to quantum theory?), becomes an important step towards the understanding of the problem evidenced. However, I believe that we have to go beyond this point: the defense in teaching, for a critical, autonomous and virtuous agent. About the notion of autonomy, it is important to clarify that autonomy is a virtue or a quality. An epistemic virtue cannot be considered a performance, but the epistemic performance occurs as a function of virtues. Moreover: "An intellectual virtue is that quality or competence that allows the agent to achieve the primary intellectual goal which is truth and, considering this, virtuous agents are reliable shapers of true beliefs." (p. 166) [93].

Considering that the origin of intellectual virtues involves, in particular, intellectual habits [13] and that they include epistemic practices; I think we should offer epistemic practices that lead students to question, evaluate evidence, reason, analyze problems or consider different opinions and reflect on their own beliefs. In other words, because "virtues of an intellectual character demand habits, students will only be able to acquire and strengthen intellectual virtues if they are systematically exposed to a teaching focused on virtuous practice" (p. 214) [13]. In this sense, a virtue can be understood as a disposition to judge, identify, know, understand, or act appropriately. About the dispositional aspect Borba considers that: "An intellectual character trait T of a subject S is an intellectual virtue V only if T is (a) a disposition that motivates or enables S to (b) engage with a characteristic cognitive activity A, (c) cultivated through the habitual exercise of a set of situated epistemic practices, and that (d) optimizes S's success in some generic demand of intellectual life" (p. 70) [13].

The virtue of autonomy is linked to a situated epistemic practice - the practice is embedded in the context of school activity, and in this case, in the teaching of science/chemistry. To the extent that the student reflects on the dispute over whether or not molecular structure is reducible to quantum theory, he can formulate an attitude of belief or reject it, and be responsible for such an attitude. We must cultivate in students intellectually virtuous character traits[5].

5 Let's take another example: "A person can cultivate the cognitive behavior patterns characteristic of intellectual autonomy by habitually exercising reasoning-in which case she is, so to speak, an autonomous reasoner. If, however, she begins to cultivate the same patterns of cognitive behavior characteristic of intellectual autonomy from epistemic practices beyond reasoning-say, in practices such as interpreting and observing-she would be increasing the robustness of the power of her intellectually

Science education, is a field in which we could practice virtues. Here, virtues, practice, and goods go hand in hand. That is, virtues such as autonomy achieve the goods as discussed earlier. I agree with [8], [21] and [22], for autonomy to be achieved by the epistemic agent, other virtues must be part of this process, such as intellectual honesty, intellectual humility, rigor, intellectual courage, among many others. In the teaching of chemistry, I maintain that the notion of intellectual autonomy to discuss the objective of teaching presents some possibilities. The first is to create or offer conditions for students to be able to know; understand and evaluate the arguments of each position in relation to the problem of molecular structure, since it is a very important issue and should be treated and discussed in teaching, since this debate points to the assumption that one science underlies another (or not), and if this is possible. There is indeed an idea of intellectual disagreement (that is, between rational beings) since the notion about the problem will depend on the philosophical current in which it is inserted.

Another contribution is to consider that this dispute can bring a great educational benefit to the teaching of science, in particular, to the teaching of chemistry; especially with regard to teacher training, which also points to the very way we understand the nature of science (i.e., how it is constructed, the debates, the positions around it, among many other aspects.). Reinforcing my perspective, researchers such as [34,79,85,96-99], as well as many others, maintain that topics such as explanation, reductionism, and chemical realism should be part of the curriculum. Another contribution is that reflective performance can promote in students an epistemic virtue, or an intellectual ability to evaluate their own beliefs, thereby achieving a more thoughtful and reasonable intellectual attitude. In teaching, I believe that reflective performance in scenarios of epistemic disagreement can promote in the student an intellectual ability to judge their own beliefs or reasons of their interlocutors. The question here is what justifies the agent in believing that molecular structure is reducible or non-reducible to quantum theory? Roughly speaking, what justifies the agent's beliefs?.

In view of the above, I maintain that the virtue of autonomy can avoid the passive, naive, and backward character of the student in the face of traditional teaching. After all, he is not (and should not be) considered a tabula rasa; on the contrary, we need to educate our students for autonomy: the student needs to be motivated, willing, and prone to exercise certain contexts (as Ferreira, 2015 argues); we need to promote the formation of the student with virtuous qualities (as Baehr, 2014 argues); form a student who can examine evidence, reasons, arguments, counter-arguments, and positions around debates, that is, a student who can directly discover, by reflection, what he is justified to believe (as we saw in Silva Filho, 2013); form a critical student as one who seeks to discuss the reasons around problems; form a student who can be responsible for his own beliefs and attitudes, and so on.

Following this line of thought, I present some possible strategies for thinking the classroom as a space for debate and reflection: (a) Discuss in class with students what a debate is about; (b) Present the debate around the problem of molecular structure by putting questions under discussion for students; (c) Show that there are two different science images to deal with the same phenomenon; (d) Point out the arguments for and against, and let them speak; (e) Stimulate students' critical thinking; (f) The teacher can take a position, present and discuss both sides of the dispute, and so on.

It is also possible to consider, as a front for the debates, some questions (among many others): 1 - Is Chemistry an autonomous science?; 2 - Is there a relation of independence between Chemistry and Physics?; 3 - To what extent can Chemistry explain chemical entities, properties and relations - such as the molecule, chemical bond, orbital or chirality - without the inevitable need for quantum theory? ; 4 - If quantum mechanics were shown to be wrong, would it affect any chemical knowledge about molecules? ; 5 - Which model should we use to explain a covalent bond - classical model (Lewis) or quantum model (valence bond and molecular orbital) ? ; 6 - Beyond the use of the classical or quantum models in chemistry training courses: why do two different scientific explanations (chemistry and physics) compete to explain the same phenomenon?; 7 - Does a molecule have a structure?; 8 - Is the concept of molecular structure relevant to the notion of molecular identity? ; 9 - Molecular structure: reducible or non-reducible to quantum theory?; 10 - Considering the debate around the concept of molecular structure, what do reductionists and non-reductionists say? Thus, I think that these are good reasons why the objective of teaching science should include the formation of critical students with intellectual autonomy.

Autonomy, Anticonciliationism and Science Teaching

Around the molecular structure problem, I argue that the notion of epistemic disagreement [14,44,54] can be incorporated into this problem. In my understanding, it seems clear that there is an epistemic disagreement regarding the molecular structure problem since we find epistemic pairs with distinct beliefs facing the same evidence. Moreover,

autonomous disposition. If, moreover, she were to habitually exercise these practices in numerous different situations, she would increase the robustness of the portability of her intellectually autonomous disposition. Put simply, the thicker the set of situations in which she exercises a virtue, the more robust her portability; the thicker the set of epistemic practices in which she exercises a virtue, the more robust her power" (p. 78-79) [13].

I argue that this problem has a broader scope when we go beyond the special case of epistemic pairs.

I maintain that the discussion surrounding the molecular structure problem involves two major groups: (1) The reductionists and (2) The non-reductionists. Thus, based on the reasons that were deemed relevant to the dispute, table 1 is proposed:

Group 1: The reductionists	Group 2: The non-reductionists
(1) Physicalism: physics as self-sufficient [100].	(1) There is no physically well-founded, non-trivial example for theory reduction in Nagel's sense, and even if there were the reduction would fail [40,84].
(2) Reductionism within a reduction of principles [101].	(2) Properties of a chemical system cannot be explained by physical micro-components [87].
(3) Dependence between macro and micro processes [102]	(3) The Born-Oppenheimer approach is insufficient to think about the problem of structure [37].
(4) Local and partial reductions [34]	94) Impossibility of epistemological reduction [41,87]
(5) The molecular structure can be obtained based on the topological properties of the electron density distribution function of the system [32].	(5) Chemical concepts cannot be derived from the concepts and laws of physics [41]
(6) The hope for future reduction [31]	(6) The equations of state used to estimate the energy of interactions of molecules cannot be deduced from any fundamental theory [41]
(7) The environment brings out the classicality of the chemical structure, e.g. decoherence, etc.	(7) The Schrödinger equation cannot be solved analytically without the use of approximations and models [79,103,104].
(8) The reconstruction of the concept of molecular structure within the framework of the quantum theory of atoms in molecule [32].	(8) Molecular structure as an emergent phenomenon.
(9) "Giving up entirely on the hope of reduction at this stage therefore means giving up entirely on hope" (p. 5) [34].	(9) Ontological Pluralism [40,41,43,105].

Source: own elaboration.
Table 1: The group beliefs surrounding the problem of reducibility to quantum theory.

Considering the beliefs publicly expressed by the members of each group around the problem of molecular structure, and that they possess, strictly speaking, approximately the same intellectual abilities (reflection, reasoning, responsibility, confidence, and intellectual virtues), it seems clear that, in the face of the same evidence (arguments, reasons, and information that the agents claim) there are disagreements between the authors who support the reductionist and non-reductionist positions.
Faced with this dispute, what is the most rational attitude the agent should take in the face of this disagreement?
(a) Continue to believe what he believed.
(b) Decrease confidence in one's starting belief.
(c) Suspend judgment.

When I consider in this paper that the agent must have an "attitude" in disagreement, I am thinking of it within the theoretical perspective defended by Goldman A [4]. The philosopher, when commenting on the attitude in disagreements, uses the term gradation: for him, it is possible for the agent to believe with moderation, with firmness, or with absolute conviction, and so on. In a sense, what Alvin Goldman does with respect to Richard Feldman's perspective is to extend it: attitude disagreement includes opinion disagreement. I maintain that the most rational, responsible, and reasonable action in the face of such disagreement is to be uncompromising: it is to continue to believe and hold firm to the same belief that the concept of molecular structure is not reducible to quantum theory. That is, if I adequately assess the disagreement, as well as the arguments, the information, the evidence, and am justified in holding the belief, then I have no reason to reconcile, alter the degree of confidence of the belief or the justification with an opponent.

In this perspective, being justified implies that I have reasons to believe. When I talk about reason or reasons in this thesis, my view is close to the perspective advocated by Grimm S [93]: almost always I am dealing with a capacity or an ability of the epistemic agent to evaluate, judge, consider, ponder, critique its own reasons in the face of epistemic

disagreement around the molecular structure, and somehow conduct itself in light of these evaluations, considerations, ponderings and critiques, thus achieving a more flexible, thoughtful and reasonable intellectual attitude.

From this, I think that the correct thesis for the disputation is the anticonciliationist one, because I see that it is the most rational action, presupposes intellectual autonomy, virtues, and does not advocate intellectually vicious positions. I maintain that the thesis is justified for specific reasons: (1) The properties of a chemical system cannot be explained by physical microcomponents [87]; (2) The Born-Oppenheimer approach is insufficient to think the problem of structure [37]; (3) Impossibility of epistemological reduction [41,87]; (4) Chemical concepts cannot be derived from the concepts and laws of physics [41]; (5) The equations of state used to estimate the energy of interactions of molecules cannot be deduced from any fundamental theory [41]; (6) The Schrödinger equation cannot be solved analytically without the use of approximations and models [79,103,104]; (7) Molecular structure as an emergent phenomenon that, although irreducible to quantum mechanics, depends ontologically on the underlying quantum domain. Furthermore, I argue, as does [106], that chemical explanations and models are part of the specificity of the chemical level, and therefore autonomous from other sciences, in particular Physics. Chemistry is distinctly an autonomous science, especially in terms of epistemological and ontological aspects.

How would disagreement, however, affect science teaching? If a teacher presents a disagreement in the classroom, does his/her position (of being conciliationist or anticonciliationist) make a difference? Considering the ontological pluralist perspective, that is, that there is no privileged description between classical molecular chemistry and quantum theory for the concept of molecular structure, and that both ontic realms can coexist to the extent that each of them is constituted by corresponding conceptual schemes, I maintain that the theoretical gain for science teaching would be to show students - from university education - that we have two different images of science to deal with the same problem. The choice between such descriptions will depend on the factors relevant to each situation or on the interest that drives the teacher in each particular case.

I propose that teachers should help students understand the exuberance of plurality of viewpoints of scientific explanations, not as confusion, but to help them penetrate the complexity of the problem context. That is, the same concept (molecular structure) can have both a physical description and a chemical description, even if they are far apart. However, neither description should be privileged over the other [43]. For Van Brakel J [42], if there is no privileged description, both chemical and quantum mechanical concepts are "powerful and illuminating metaphors". In dialogue with this author, I think we should also be tolerant enough to leave the same ontological space for both descriptions. This argument suggests that chemical entities, properties and relations such as molecule, orbital, molecular structure or chemical bonding - need not refer to any item of physics to acquire ontological legitimacy [40,41,96,107], that is, its objective existence is independent of its reduction or emergence with respect to supposedly more basic entities, properties, and relations, but the fact that it is described by a discipline such as chemistry, whose predictive success and transformative capacity no one would currently doubt. Within a pluralist realism, such items exist independently in every ontology constituted as such.

I believe, that all these are good reasons to hold firm the belief of non-reduction for the dispute. Finally, I believe that the concept of molecular structure serves well to think about the coexistence of two different scientific explanations, regardless of their incompatibility for the same phenomenon.

Conclusion and Future Perspectives

This paper addressed the topic: "The purpose of teaching Science" in the light of an epistemological approach. Given the context, in which different theses are defended, I argued in favor of the thesis, considering that one of the objectives of science teaching is the formation of a critical citizen with intellectual autonomy. To illustrate a central theme of Chemistry teaching, the disagreement about the concept of molecular structure was used as an example. I argued that in order to be able to participate in an epistemic disagreement, we must be intellectually and morally prepared for the debate, in order to avoid a rash attitude. This attitude implies that we must carefully and thoroughly evaluate the assertions (thought actions), reasons, and objections surrounding the reducibility or otherwise of molecular structure to quantum theory.

As can be seen, the origin of the disagreement about the interpretation of the concept of molecular structure is formed at the emergence of quantum mechanics in the field of chemistry. More specifically, when we discuss the links between molecular chemistry and quantum theory. According to classical molecular chemistry, molecules have a structure, that is, they are sets of atoms with defined arrangements in space and held together by chemical bonds. However, such a concept seems to find no place in the ontology described by quantum mechanics, since it appeals to classical notions such as the position of atomic nuclei, both of which are strongly challenged in the quantum context.

In science teaching, especially in chemistry teaching, a central aspect, defended here, was to consider that students

should learn not only about the current debate, but also, and especially, something about the nature of science. I argued that the autonomous student has the character of evaluative judgment; what determines the act in science/chemistry teaching should be their choice, not the belief we should impose on the intellect as is usually the case in science/chemistry teaching today. I believe that in teaching chemistry, the presentation and discussion of the problem of molecular structure can lead university students to understand the nature of the relationship between chemistry and physics, as well as the discussion around reduction. I believe that this would already be a great gain for science teaching: to recognize that around the idea of molecular structure there are two distinct scientific images in front of the debate.

In general, this dispute could lead science education in more fruitful directions. For university teaching, the understanding around the relationship between chemistry and physics would point to the need for knowledge of an earlier discussion: the question of neglect - why one of the most productive sciences of the 20th century was neglected. This examination points to the primacy achieved by physics in the philosophy of science. A relevant point, because we could reflect together with the students on reasons that culminated in the historical neglect of the philosophy of chemistry in the philosophy of science. I believe that the approach between Philosophy of Chemistry and Chemistry Education could bring benefits. Among them, how reflections about the nature of the chemical thinking style can contribute to conceptual-theoretical learning. Moreover, such a relationship can help teachers in training and teacher trainers in understanding and clarifying basic problems of chemical education linked to the ontological and epistemological dimensions.

Another point to consider is that in teacher education, the relationship between philosophy and teaching could develop a deeper epistemological conception of chemistry. A major contribution to university teaching would be the need for greater inclusion of the philosophies of chemistry and science within the training of chemistry teachers. The possibility of analyzing the problem from a historical perspective of the proposed models would be welcome for science teaching. And, in this sense, to present models, their uses, applications, explanatory difficulties and limitations, and to highlight that each one of them has its importance in the historical context.

In short, I maintained that the result of such philosophical work is not truth or a theory (hence, a model) regarding the problem investigated, but something like autonomy. Such an attitude implies that the agent can examine the problem, be more careful, more disciplined, less arrogant, more attentive to arguments, objections, counter-examples, be open-minded, and so on. In my view, a virtuous agent should not be entitled to take an argument only without considering the contrary. In this sense, it is argued that approaching autonomy as an intellectual virtue aligns with critical-reflective thinking, both of which are fundamental if we are to cultivate the rationality of agents.

It is relevant to point out, a subject who examines his own beliefs, his reasons, does not mean that, in the end, his effort will be successful, or that there will be clarity about what is being investigated or that the reasons will become evident. While I recognize that things may, in the end, remain unclear, I think that reflecting critically on one's own beliefs, regardless of the outcome, is something positive and valuable for science teaching, for scientific practice, and for teacher education.

Criticality refers to the virtuous agent, his valuable attitude of belief in the face of disagreement: a more demanding attitude, suspicious of given statements, becoming able to understand the reasons and the distinct positions around the problem. Such an attitude consisted in holding firm to the starting belief regarding the question: molecular structure - reducible or non-reducible to quantum theory? Therefore, we can have: the belief that [molecular structure is not reducible to quantum theory for specific reasons], or the thought that [quantum theory does not explain the problem of molecular structure]. So one can speak of the semantic content or meaning of the agent's belief, thought, and so on. As point out, when we believe, we almost always believe something or think something. In terms of beliefs, believing refers not only to the belief of something, but the legitimate right of the agent to believe what he has reason to believe[108-114].

Therefore, this work is a rational effort that sought to defend approaches that were considered relevant between Social Epistemology and Science/Chemistry Teaching, in order to defend a precious goal: the formation of an epistemic agent with intellectual autonomy. Finally, it sought to argue that such approaches can also help students and teachers to distinguish in a careful, disciplined and moderate way between knowing, understanding, believing and the attitude of belief that one can take in something related to science.

To this end, we explored a case of epistemic justification in which the agent can reach conclusions not only on his own. It also sought to think about a possible way of adopting beliefs in science teaching. Supported by social epistemology, I argued that the belief of one agent can somehow interfere directly or indirectly with the belief of another. I believe that this work has contributed to other fronts of investigation: How are intellectual virtues actually born? When do we start or become virtuous agents? What would be the causes involved? Is it possible to always be virtuous or not? What

makes a virtue different from a value? What pathways can be used for epistemic agents to become virtuous? What other problems are relevant for teacher education in science/ chemistry? For the last question, it is worth investigating an agenda of problems: the concept of the atomic orbital, chemical bonding, chirality, the foundations of the periodic table; models and explanations in chemistry and their links to chemical education, and so on. Keeping myself open to dialogue with people who are interested in understanding the nature of the problem agreed upon here, that is, how it is formed within the community, how it is solved (if there is a solution at all), how to act in the face of debate, how to carefully examine the positions around it, is an attitude that can lead to epistemic and moral gains.

I end the article by highlighting that the problems investigated are objects of discussions that have occurred in recent years in ongoing debates in the analyzed fields. However, the objective of this work was not to offer a definitive solution to any of the debates, but to propose a line of argument for the problems investigated, which I believe, supported by the theoretical references, to be a fruitful path for the teaching of science and, in particular, for the teaching of chemistry.

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