

PART 1

Teaching of Evolution and Beliefs

This first part, composed of three chapters, targets religious beliefs and the role of chance in students' acceptance or rejection of the theory of evolution.

The chapter by Hanaa Chalak, Marco Barroca-Paccard and Francis Rouquet revisits the question of conflicts between science and belief among French students in 10th grade class (15-year-olds). Based on the reading of historical texts, the authors invite the reader to differentiate between scientific and religious explanatory registers within the framework of “Non-overlapping Magisteria” and to rework the criteria of demarcation between knowledge and belief for a more operative management of these conflicts. Echoing religious beliefs, the chapter by Magali Coupaud, Julie Gobert, Jérémy Castéra and Alice Delserieys studies students' conceptions of chance in their daily lives and in evolutionary biology. Based on a questionnaire, the study shows that the “probabilistic randomness” conception enables a better understanding of the theory of evolution than the “randomness of fate” conception. The results suggest that there is a plurality of conceptions of chance, discussion of which would facilitate the understanding of evolution. Finally, the chapter by José Luis Wolfs concludes this first part by examining the tensions between science and religious beliefs in their sociocultural dimensions. The author explores the secularized and non-secularized conceptions of science among students in the 12th grade class¹ in French-speaking Belgium, and shows that a process of self-assignment to a religious community seems to play a decisive role in the acceptance of scientific knowledge in general and the theory of evolution in particular.

1. Called *terminale* in the French-speaking context, this is equivalent to 12th grade in the US or year 13 in the UK, with students being 17–18 years of age.

1

Student Positions in Learning about Evolution in Relation to Religious Beliefs and Scientific Knowledge

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1.1. Introduction

In France, the creationist viewpoint seems to be growing. In a 2017 survey¹, it was noted that 31% of respondents aged between 18 and 24 years old said that they agreed with the proposition that “God created Man and the Earth less than 10,000 years ago”, compared to 14% of those over 65 years old (IFOP 2017). This result may seem surprising since the theory of evolution was integrated into Earth and Life Sciences (ELS) lessons during compulsory schooling and most 18–24-year-olds have benefited from it.

The teaching and learning of the theory of evolution encounter difficulties linked, in particular, to the influence of religious beliefs that can sometimes lead students to contest the contents of the theory. Although this questioning of the theory of evolution may seem to be a minority position compared to other countries, such as the United States, it would be wrong to think that this does not constitute an issue for our educational system.

1. Ifop survey on conspiracy, for the Jean-Jaurès Foundation and Conspiracy Watch.

One possible explanation is to consider that students have conceptions that correspond to their idea of the world; however, in a psychoanalysis of knowledge, Bachelard (1938/2011) conjectures that primary representations have the status of opinion and are always wrong in principle. Students do not always differentiate between belief, which can be based on “an intuition, a feeling, an intimate conviction, or on the trust or authority granted to a person (...)” (Wolfs 2013, p. 41), and scientific knowledge, which is based:

on reason, demonstration, proof, that is, on arguments that one must be able to communicate and justify, of which one must be able to give a public account, so that they can be examined, debated and tested by others, and are therefore in principle independent of the status of the authority of the person who states them (Wolfs 2013, p. 41).

Several recent studies have been focused on this problematic situation for teachers trying to analyze various teaching strategies (Hermann 2008; Hildebrand et al. 2008; Aroua et al. 2012; Fortin 2014; Urgelli et al. 2018). However, from the students’ perspective, the issue of distinguishing between religious knowledge and beliefs when learning about evolutionary theory has been less visited by research. The arrival of the new French high school curricula (M.E.N. 2019) seemed to us a good opportunity to set up a study on this distinction at the curriculum level and from the students’ perspective. First, we will present an analysis of the ELS school curricula, and then we will consider the tensions between scientific knowledge and religious beliefs in the context of teaching evolutionary theory and discuss this distinction. We will then look at the relationship between knowledge and beliefs from the point of view of students in the second year of secondary school by considering, in particular, a situation where they give their opinions on fixist explanations constructed by scientists in the 18th century before Darwinian theory had been developed.

1.2. A look at French school curricula

Currently, recent French school curricula insist on the need for students to distinguish between knowledge and beliefs. For example, in ELS, one of the skills mentioned in the introduction to the cycle 4 curricula (for students aged 12–15) is that of “distinguishing between what is a belief or an idea and what constitutes scientific knowledge” (M.E.N 2015, p. 342). However, when we look at how the theory of evolution is presented in these curricula, the reference to beliefs, opinions and debates surprisingly does not appear in the presentation of theme 2, “Living Beings and Their Evolution.” In the examples of situations and activities, teachers are only asked to call upon the history of science so that the student can situate the

evolution of knowledge in a historical and technical context, without any further details or explanations. We can therefore say that these curricula:

do not propose a clear operationalization of the differentiation between belief and science. Fortin (2014, p. 72) already said that “since the curricular objectives are based on a requirement of scientific training for students, the management of religious beliefs in the classroom is not taken into account by the curriculum” and this is visibly the case in the ELS curricula in compulsory education.

The new high school curricula (M.E.N. 2019a) mention that it is also necessary to work on this skill in the 10th grade class. However, as for cycle 4, it is not remobilized in the presentation of the themes to be addressed. Moreover, in the science curriculum for *Première générale* (equivalent to the 11th grade), it specifies that one of the general objectives of the training is to “understand the nature of scientific knowledge and the methods used to develop it. Scientific knowledge is the result of a rational construction. It is distinct from a belief or an opinion. It is based on the analysis of facts extracted from complex reality or produced during experiments. It seeks to explain reality by material causes” (M.E.N. 2019b, p. 2). Here, we see that knowledge and its characteristics are valued, while what differentiates it from beliefs is not presented. Moreover, high school ELS teachers are asked to “participate in the formation of critical thinking” (MEN 2019c, p. 2). A justification is provided in the preamble: “the exercise of critical thinking is particularly necessary in view of the increasing questioning of the contributions of science”. The development of critical thinking would thus enable students to distinguish between what is science and what is religion.

We can see that the scientific dimension is quite present in the school curricula, but there is never any mention of religious beliefs in the case of teaching of the theory of evolution, whereas the emphasis in these school curricula is placed on the distinction between knowledge and beliefs. However, this distinction calls for some vigilance on the part of the teacher, depending on the theoretical framework of problematization (Fabre 2016) in question. The main issue is not only to teach students to distinguish between science and religion, but to develop in them a reflexive and critical posture on science (Matthews 2012), in particular on the complex relationship between science and religion, as we will present in the following sections. Indeed, if the argumentative registers of the religious framework and the scientific framework can be distinguished, the risk is to think that the explanations are not scientific as soon as religion is present and to encourage the “religion/science” dichotomy. It seems to us necessary for students to know how to both distinguish and articulate the language games that interfere in the treatment of the question (Fabre 2016).

1.3. Tensions between scientific knowledge and religious beliefs in the teaching of evolutionary theory

ELS teachers are always confronted with the expression of religious beliefs opposed to the theory of evolution. To remedy this, some try, for example, to set up debates to help students to overcome the opposition between scientific and creationist arguments. Often in these debates, each person sticks to their position without taking both arguments into account (Fortin 2014). This usually results in low pedagogical effectiveness, probably because, according to Fortin (ibid.), the management of students' religious beliefs is not taken into account by the curriculum. Other teachers deal with the issue from a solely scientific perspective, without addressing beliefs, and referring to a neutrality of knowledge and the principle of secularism (Urgelli et al. 2018). However, this stance only distances beliefs, and does not always allow students to differentiate their beliefs from scientific knowledge. For example, the expression of certain religious beliefs to challenge the theory of evolution causes tensions that pose many difficulties for teachers.

From the institutional point of view, we can identify changes in position in certain texts published by the Ministry of National Education, which seem to testify to the complexity of the situation. In 2015, the booklet on secularism advocated avoiding confrontations or comparisons between religious discourse and scientific knowledge, as these two registers are not comparable and therefore not opposable. Grjebine and Bouvet (2015) question this recommendation in an article published in the newspaper *Le Monde*²:

What sense would it make to teach Darwinism in schools to children who would hear creationism praised in their family or their church, their temple or their mosque and would invoke it at school? And so, how can we ask a teacher to explain the theory of evolution, without showing that creationism owes more to irrationality than to science?

Avoidance, proposed in 2015, is no longer mentioned in 2020 in the *vade mecum* on “Secularism at school”³, which recommends remaining firm on the principle that “no question is excluded a priori from scientific and pedagogical questioning (article

2. This article was published on October 26, 2015: https://www.lemonde.fr/idees/article/2015/10/27/l-enseignement-de-la-laicite-doit-maintenir-la-superiorite-de-la-science-sur-la-croyance_4797416_3232.html [Accessed 6 June 2021].

3. This is the *vade mecum*, as updated in October 2020: https://cache.media.eduscol.education.fr/file/Valeurs_republicaines/06/8/202010-Vademecum-Laicite-WEB_1338068.pdf [Accessed 6 June 2021].

12 of the Charter of Secularism in Schools)” (p. 47). This *vade mecum* also specifies that teaching distinguishes between beliefs and knowledge based on rationality: “Through its impartiality and objectivity, it protects the freedom of conscience of pupils and teaches them that certainties are constructed” (ibid.). However, this separation of science from religious beliefs is not a consensus among evolutionists. Dawkins (2006), in his book “The God Delusion”, considers that science must intervene and make a pronouncement on the existence of God: “Either he (god) exists or he doesn’t. It is a scientific question; one day we may know the answer and meanwhile we can say something pretty strong about the probability” (ibid., p. 48). Conversely, for Gould (1996), the domains of science and religion should not overlap according to the principle of non-overlapping magisteria (NOMA). This principle of NOMA does not mean that all non-scientific elements should be excluded. It is mainly a matter of separating the explanatory registers so as to better signify the difference between science and religion. Lecointre (2009) thus argues in favor of a discussion in science and philosophy classes, within the framework of scientific rationality, social epistemology and beliefs, to differentiate between evolutionary and creationist arguments. From the perspective of educational researchers, Urgelli (2012) defends the idea “that excluding any consideration of the ideological underpinnings of creationism does not allow students to understand the particularities and significance of scientific answers to the question of the origins of humans and life” (ibid. pp. 167–168). We agree with this position and believe that avoidance is not conducive to the development of students’ critical thinking. On the contrary, from the perspective of building school’s knowledge, the problematic dimension is essential and the place of criticism a necessity.

1.4. The compartmentalization of evolutionary knowledge and religious beliefs

There has been a great deal of interest in the scientific literature regarding possible rejections of certain concepts in evolutionary theory based on religious beliefs (Carette et al. 2013; Wolfs 2013). This work has shown that religious beliefs can potentially be associated with the rejection of evolutionary theory⁴. However, this does not mean that religious people cannot accept evolutionary theory. Pierre Teilhard de Chardin (1881–1955) was both a recognized evolutionist and a Jesuit priest. He was a scientist when he published his discoveries on the synanthrope, and

4. On the other hand, many more scientists do not exhibit religious beliefs. While only 6% of the American public describes itself as atheist or agnostic, 64% of scientists at “elite” American universities fall into these categories (Ecklund 2010). A study by Larson and Witham (1998) also found that 93% of the members of the National Academy of Sciences are agnostic or atheist, and only 7% believe in God.

a theologian when he problematized evolution in a religious way by centering it on humankind and making the divine the Omega point of evolution⁵. From a general point of view, it is necessary to:

[...], avoid confusion: not all believers have opposed Darwinian theory and not all those who have rejected it have done so for religious reasons! Many believing biologists, such as Asa Gray, have accepted the Darwinian theory of evolution. And most biologists who rejected this theory did so for scientific reasons, convinced that natural selection was not a sufficient mechanism to explain evolution [...] (Morange 2016, pp. 222–223).

We can thus be an evolutionist and a believer by distinguishing the two registers of religion and science. “A biologist can certainly be a believer, but scientific normativity forbids him or her evoking a miracle to solve a biological problem” (Fabre 2016, p. 110).

However, from an individual perspective, consideration of evolutionary theory may challenge religious beliefs. Meadows, Doster and Jackson (2000) asked 17 people who were both practicing Christians and science teachers or science education students⁶ about possible conflicts between their personal and professional beliefs. They identify four categories of conflict (Figure 1.1). The first two represent those who intentionally or unintentionally separate their religious beliefs from their learning of evolutionary concepts. The first category is particularly problematic because it may result from a refusal to consider evolutionary theory. Students with fundamentalist beliefs may practice what Cobern (1996) has called “cognitive apartheid”. They would use scientific knowledge so as not to jeopardize their academic success, but would keep their religious beliefs under wraps so as not to challenge their beliefs (Meadows et al. 2000). They are able to resolve inherent conflicts by compartmentalizing their conflicting beliefs.

Teachers in the third and fourth categories recognize the conflict between their beliefs about evolution and religion (Figure 1.1). Teachers in the third category began to question their beliefs on creation as they came to a deeper understanding of

5. The Omega point represents the ultimate point of development of complexity and consciousness towards which the Universe is moving, whereas the “alpha point” corresponds to its creation, according to Teilhard de Chardin.

6. Participants included two university science teachers, one professor and two graduate students in science education, four high school biology teachers, and eight prospective middle or high school science teachers. All but one were from the south-eastern United States and there were 11 females and six males.

evolutionary concepts that was painful and challenging for them. Teachers in the fourth category chose to combine selected evolutionary concepts with the biblical approach to creation through personal theories, a strategy that helped them to manage conflict. They were comfortable teaching general evolutionary principles, but many remained uncomfortable discussing human evolution.

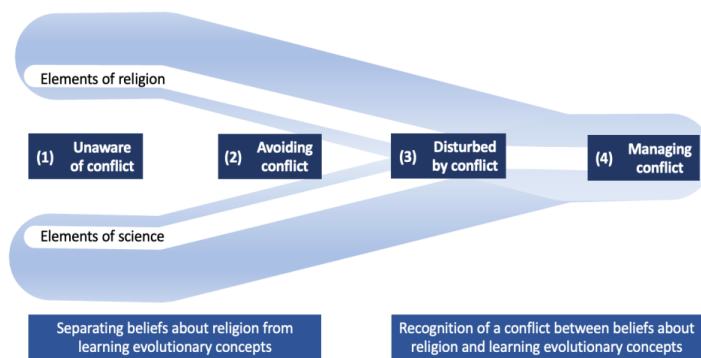


Figure 1.1. Possible categories of conflict among practicing Christian science teachers or science education students (modified from Meadows, Doster and Jackson (2000, p. 106))

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In order to approach the consideration of beliefs with students and to develop a critical reflection on their relationship with science, the history of the progressive construction of the theory of evolution, rich in exchanges between science and religion, seems to us to offer a favorable framework. This is what we have tried to put in place in two 10th grade classes (students being 15–16 years of age) by focusing on the relationship between scientific knowledge and religious beliefs from the students' point of view.

1.5. A case study carried out in two 10th grade classes

We approach the question of the relationship between knowledge and beliefs by specifically studying the productions of students in two 10th grade classes (40 students) who analyze, individually and then in groups⁷, documents presenting

7. The groups formed are heterogeneous in terms of conceptions.

the fixist theory of species⁸ in force in the 18th century. Since the Darwinian theory of evolution, which has already received a lot of media attention, can make students take a position “for” or “against” evolution according to their religious background, we chose the fixist theory so that they could explain why, in their opinion, this theory did or did not seem scientific⁹. We chose a scientific theory from the 18th century, now obsolete, for its historical interest in where science and religion coexisted.

The sheet proposed to the students (Figure 1.2) includes two documents (docs. 1 and 3) and refers to a video (doc. 2). These materials highlight the contributions of the naturalists concerned and indicate the possible links between their work and their religious beliefs.

According to the first document, “the hierarchical classification of animals and plants” proposed by Linnaeus was intended to “reveal God’s plan”.

The second document refers to a video available on the France TV Education website entitled *Avant Darwin: fixisme et transformisme* (“Before Darwin: fixism and transformism”). Students watch only the first part¹⁰ of the video, which presents the fixist theory of species.

The third presents the work of Cuvier who, after studying fossils, showed the disappearance of species in the past and the succession of different faunas in the geological strata. To reconcile his results with the biblical texts (the flood, etc.), he explains the extinctions identified by referring to the intervention of catastrophes and thus becomes a supporter of catastrophism.

The activity is an opportunity for students to work on the distinction between scientific knowledge and religious beliefs. We would like to point out that the productions studied are the result of a session developed within the framework of a research dissertation¹¹ conducted by two trainee teachers in the second year of a

8. According to this theory, species are fixed and do not evolve.

9. Students have not previously had a specific course on fixism, but they have surely heard about it in evolutionary theory classes in college.

10. In this part, Pascal Picq, paleoanthropologist and lecturer at the Collège de France, presents the work of Linnaeus and fixism. This video is no longer available online.

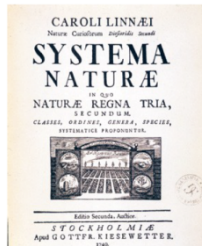
11. The dissertation was conducted under the supervision of Francis Rouquet at the École Supérieure du Professorat et des Écoles (ESPE) in Nantes.

master's degree in Teaching, Education and Training Professions¹² on ELS (Alleau and Bugel 2018).

Instruction 1: (individual work) After having seen the documents on **fixism**, a popular theory in the 18th century, explain how the argument developed in these documents is scientific to you. Why?

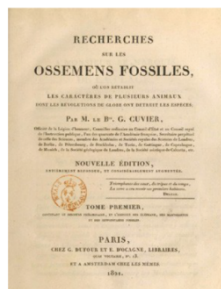
Document 1 – Carl Linnaeus (1707-1778)

Carl Linnaeus was an 18th century Swedish naturalist, who proposed in his book *Systema naturae*, and again in *Species Plantarum* a hierarchical classification of plants and animals. Species are incorporated into a hierarchy of classifying groups including species, genera, orders, classes and kingdoms. By creating order in the diversity of living beings, Linnaeus sought to unveil the purpose of God and show his greatness. In his opinion, species, created by God, were unchangeable; his conception of living beings therefore being profoundly fixist.



Carl Linnaeus, *Systema naturae*
Title page of the 1740 edition. ©
Selva/Leemaage

Document 2 – Video : <http://education.francetv.fr/matiere/sciences-de-la-vie-et-de-la-terre/troisieme/video/avant-darwin-fixisme-et-transformisme>



Georges Cuvier, new edition, Paris, G. Dufouret E. d'Ocagne, 1821-1824, tome 1. Source : BnF

Document 3 – Georges Cuvier (1769-1832)

“Cuvier showed with his study of fossils that species have died out in the past, and that different fauna follow one another in the geological strata. The desire to reconcile these discoveries with biblical texts led him to become a follower of catastrophism, a fixist theory according to which species became extinct on a mass scale following episodes of catastrophe; devastated regions were then repopulated by flora and fauna from elsewhere. In his life time, Cuvier was furiously opposed to his contemporary Lamarck, who subscribed to the new current of ideas on the transformation of species.”

Source of the documents: <http://www.reseau-canope.fr/docsciences/Histoire-d-une-pensee-en-evolution.html>

Instruction 2: (group work) In groups of three or four, compare your points of view and create a new synthetic opinion (on a separate sheet) on the fixist theory to explain how this theory is scientific or not.

Figure 1.2. Documents and instructions distributed to 10th grade students (Alleau and Bugel 2018). The first document discusses Carl Linnaeus, the second Georges Cuvier. The original document was in French but has been translated here into English for the reader

12. *Métiers de l'Enseignement, de l'Éducation et de la Formation* (Teaching, Education and Training Professions).

Based on the information available in the documents, we are interested in whether students can identify:

– on the one hand, elements of the scientific approach of naturalists of the time (observation, comparison and classification of species, study of fossils and different faunas in geological strata);

– on the other hand, whether they point out the links made with religion as non-scientific (seeking to reveal God’s design, reconciling the explanations with biblical texts).

However, it is important to note that the reference to religion in the works of Linnaeus and Cuvier does not obscure the scientific contributions they made at the time, even if these are no longer in agreement with the knowledge accepted today. Moreover, in 1753, Linnaeus established the rules of a binomial nomenclature still used today: “each species is designated by two Latin names, that of the species itself and that of the genus to which it belongs” (Morange 2016, p. 96). The work of Linnaeus and Cuvier presented in the documents should therefore be considered in the context of the time, which was marked by the predominance of religion. What elements do students select from the documents? To what extent can they differentiate between the scientific and religious aspects of the naturalists’ work? What place do they give to the links made with religion?

In the following, we present the results of the qualitative study of the individual and group responses produced by the students of the two 10th grade classes. We identify whether they define the fixist theory as scientific or not, and we analyze the arguments put forward. The analyses carried out allowed us to identify three categories of position. Some students identify only scientific elements or only religious elements, while others identify and discuss both elements at the same time. We study these positions in detail in the following section, illustrating our remarks with students’ statements¹³ and highlighting the arguments put forward. We point out that this analysis is based on what the students wrote when they answered the questions asked and that these statements do not necessarily reflect everything they think about the subject.

13. We present the statements as they were written by the students without spelling corrections.

1.5.1. Study of student statements that exclusively mobilize scientific elements

Seven students mobilize only scientific elements related to the approach taken by the naturalists to position themselves in relation to the fixist theory. They have a dual position with regard to this theory as they think that it is both scientific and not scientific. For Ines, for example, Cuvier's work is scientific because he studied fossils to propose his theory, whereas Linnaeus's work lacks evidence and justification and cannot be considered scientific.

The argumentation developed in this document *is not scientific because there is no proof, no justification*. It is man who has found possible links between living beings in order to classify them into different species. But this is only a proposal and has been contradicted by other theories such as transformism. In doc 3: scientific: *Cuvier made a study of fossils, from that he proposes his own theory*.

Box 1.1. Ines' statement

In the same way, Shannon considers Linnaeus's work to be unscientific because he merely classifies living things into groups, whereas Cuvier's work is scientific, because he studies the fauna and flora of the past with reference to catastrophic events that could lead to the distinction of species.

The argument developed by Carl Linnaeus does not seem scientific because he speaks of a hierarchical classification of classification groups, as there is a periodic classification of chemical elements in physical science, we could believe that it is scientific, *but it is only a classification of species as we could classify anything*.

The Georges Cuvier one seems scientific *because he talks about the past with the fauna and the flora as soon as a species becomes extinct; he talks about a catastrophic event that extinguishes a species but that another one is reborn by its means*.

Finally, the one in the video seems scientific because it says that species should not only be animals that look alike but that, by crossing, form a fertile species (Shannon)

Box 1.2. Shannon's statement

Conversely, Sarah identifies both scientific (species classification and transformations) and non-scientific (unchanging species, catastrophes) elements, without a clear reference to God or biblical texts. This reference is implicit in the words she uses to clarify that the content of document 1 is not scientific.

Document 1: the information given to us is not completely scientific because:
Scientific: *hierarchical classification of plants + animals; species transformation*

Unscientific: *unchanging species; fixed world, fixed species; catastrophes*

Document 2: the information given to us is scientific: extinct species in the past

Box 1.3. Sarah's statement

We can thus note that these students put forward the elements of the scientific approach of the naturalists and do not question their reference to religion, which challenges us. The content of their statements shows that they give primacy to science and do not question the place of religious beliefs in the scientific work of the time.

1.5.2. Study of student statements that mainly mobilize elements related to religion

Two students are clearly opposed to the scientific qualification of the fixist theory, because the scientists of the time brought their religious beliefs into their explanations. In this category, the scientific approach of the naturalists is not taken into account in the arguments.

For Louis, for example, the laws created by God cannot be questioned. He points out the link between the immutability of species admitted by Linnaeus and the impossibility of contradicting religious texts. We can think that this student, even if he does not mention the scientific elements, makes the distinction between religious beliefs and science when he indicates that the laws related to God are not disputed.

Fixism means that there is a relationship with God, the laws were created by God and therefore *we cannot question them; we base ourselves on the words of God = not scientific*

Every fixist theory is linked with religion, always a connection with God

Based on God, *Carl Linnaeus says that species cannot change even if he is not sure, because we should not contradict religious texts.*

Box 1.4. Louis' statement

For Emma, Linnaeus relies on religion and has no proof of what he says. She goes on to say that, from her perspective, science is not needed to prove anything. In this, Emma's position is different from the previous one as regards the distinction between science and religious belief. However, like Louis, her writing does not refer to the elements of the naturalists' scientific approach, which, it should be remembered, cannot be denied despite the intervention of religious beliefs.

Document 1 does not seem to me to be scientific, since *Carl Linnaeus is based on his religion and he has no proof of what he says*. But, from my point of view, there is *no need for science to prove something*.

Box 1.5. Emma's statement

These two students do not choose to call the fixist theory scientific because the work of the naturalists involved is based on religious beliefs. This reference to religion seems to make them forget about the scientific work done. At first glance, we may think that this position distinguishes science and religious beliefs in a general way. But as we have already seen from the study of the productions, this can be different from one student to another.

The group of students, including Emma and Louis, argue that the texts are not scientific because naturalists are influenced by religion and mobilize their religious beliefs. However, they point out that Cuvier conducts research and observations in an attempt to prove that species have become extinct in the past without further clarification.

We believe that *the texts are not scientific because they contain religious beliefs. These texts are influenced by religion*. But in document 3, we can see that Georges Cuvier tried to research to prove that species became extinct in the past by making observations.

Box 1.6. Group C's statement

We can therefore see that, following the group work, the students still consider the intervention of religious beliefs in the same way. However, Cuvier's work is brought to the fore without further explanation and without allowing a change in their position in favor of the fixist theory.

In this category, the students mainly point to elements relating to religion in order to make a statement about the scientific nature of the fixist theory. The link with religion is not envisaged, and the work of the scientists of the time is generally overlooked.

1.5.3. Study of student statements that jointly mobilize scientific and religious elements

Many students (28 students and six groups) take into account both scientific and religious elements to make a unique statement about the scientific nature of the theory and justify their position. Indeed, overall they consider fixism to be scientific because the naturalists followed a scientific approach (classifying, observing, etc.), while it is not because they referred to religion. Evan's statement below illustrates this position.

Doc 1: scientific: *the diversity of life*, classification

Not scientific: *fixism, created by God because it is an inexplicable theory, which is not proven*

Doc 3: scientific: species become extinct en masse following catastrophic episodes (...) moreover transformation of species geological strata

Not scientific: fixist theory, *biblical text*

Video: Buffon: era that can assemble = be of the same species.

Box 1.7. Evan's statement

Scientific reasoning:

Doc1: observation of species and comparison to classify them. Hierarchization of the groups.

Doc 3: observation of fossils and fauna of different species: comparison

Video: establishes species according to similarities but observes that the same species can then have very different forms.

Unscientific reasoning:

Doc 1: but uses this reasoning to support his idea that God intended all this. *He mixes belief and science*. According to him, the species are thus "immutable".

Doc 3: he reconciles his idea with his religious beliefs. He becomes a proponent of catastrophism.

Box 1.8. Eleonore's statement

These students clearly identify the scientists' approach as scientific and point out the non-scientific link with religion. Some, like Éléonore, go further by mentioning the mixture of science and belief in the work of naturalists, which would explain the explanations used (unchanging species, catastrophism).

The members of group B also specify that religion is not a matter of science, but rather of beliefs. For them, the principle of the link between scientific observations and biblical texts is in no way a scientific approach.

The theory of fixism is, on the one hand, scientific. Indeed, it uses scientific approaches such as classification, hierarchization, comparison and observation of concrete elements.

However, on the other hand, it is not scientific because *it involves religion, which is a belief and not a science*. Moreover, Cuvier assumes that there is a link between his observations and the biblical texts, which is not a scientific approach.

Box 1.9. Group B's statement

Scientific fixism or belief?

Fixism is an idea that originated in the 18th century, the Age of Enlightenment, which describes how nature has evolved. For the supporters of fixism, nature, whatever it is, was created by God; each species is present since the beginning in an unchanging way. The primary purpose of fixism is to demonstrate the greatness of God.

I- An argument based on a belief

Fixism is above all a religious idea and no physical or concrete proof is brought to the defense of fixism; only beliefs are expressed. However, the method operated by fixism, consisting of classifying animals in a hierarchy, is a totally scientific approach but classified according to a belief, a religious theory. In conclusion, the approach is scientific but not the information.

II- An idea of the context

If today, the idea of an evolution of species by a divine force is partially outdated, at the time the feeling and beliefs were not the same, and an argument implying necessarily the presence of God was quite valid. In the same way that the information observed geologically and involving major biological crises was adequate for the biblical texts.

Box 1.10. Marius' statement

The statement of Marius (member of group B), below, draws our attention through the nature of the arguments developed. He admits that the approach followed is scientific despite the intervention of religious beliefs. Unlike some students who separately identify what is science and what is religion, this student pushes the thinking a little further. He puts fixism in the context of a time when beliefs were not the same and religious arguments were quite valid.

This reflection seems to us to be an interesting one for the students to construct. It corresponds to what one would expect at the end of argumentative and critical work around the tension between scientific knowledge and religious beliefs, because it is strongly argumentative and critical. It would then be appropriate to bring the other students in the class around to such a reflective process.

The writing of group E also places the intervention of religious beliefs in the context of the time when it was unthinkable to contradict biblical texts.

Lucas, a student in this group, also mentioned the same ideas in his individual statement.

The theory of fixism is based on observations. Whether it is Linnaeus who observes and classifies species, or Cuvier who studies fossils. It is thus based on a scientific approach, since we observe and study facts before deducing something. But it is at the moment of this deduction that religious beliefs intervene. *For, at the time, it would be unthinkable to contradict the biblical texts, for a long time the only sources of knowledge.* The scientists of the time therefore lost the objectivity of their observations with the desire to reconcile their theories with the religious texts. The conclusions drawn from their observations are no longer objective and are influenced by their beliefs. Thus, the theory of fixism is not entirely scientific.

Box 1.11. Group E's statement

In these two writings, we can see that the contents are more elaborate and that several elements from the documents are addressed and discussed. This positioning is close to what is expected from the proposed work, where the opposition of scientific and religious registers is overcome by taking into account the historical context in which the analyzed works are situated.

1.6. Discussion of the students' positions

The analysis of the students' statements on the work of the fixist naturalists shows a great diversity of positions on the possibility of whether scientific practice

and religious beliefs can be reconciled. The proposed documents explicitly refer to the religious context used by the scientists, which constitutes a way of working on the relationship between science and belief without explicitly asking about the students' personal beliefs. In this sense, the analyses provide us with indicators of the students' ability to differentiate and discuss what is science and what is religious belief. This didactic strategy is in line with the positions of Lecointre (2009) and Urgelli (2012) who defend the idea that it is necessary to discuss beliefs in science class and avoid excluding them. This would help to develop students' critical thinking skills and to better understand the knowledge constructed by scientists.

In order to decide on the scientific nature of the fixist theory, some students took into account the scientific elements, others the reference to religious beliefs and others both. These positions can be related to the categories of conflict identified by Meadows et al. (2000) (Figure 1.1), even though they were identified among teachers and students, and in a different context. Indeed, the Meadows et al. model (ibid.) provides information on situations of conflict experienced between a personal religious belief and the scientific knowledge to be taught. In our situation, students who identify only elements of the scientific process or only religious elements could fall into the first category of the Meadows et al. model (ibid.), in which a separation is made between learning evolutionary concepts and religious beliefs. However, when both scientific and religious elements are identified and discussed, this would correspond to the second and third categories of this model, where the existence of conflicts between religious beliefs and the learning of concepts is recognized. When this opposition is overcome by taking into account the historical context in which the naturalists' work was produced, the fourth category of the model comes into play, corresponding to management of the conflict. The links between our results and the positions of the evolutionists (the NOMA principle of Gould (1996), and the positions of Dawkins (2006)) seem to us to be more complicated to find, given the particularities of the task of the students. In spite of this, we can consider that the reflection of the students who felt that the religious register "has nothing to do" with the scientific one may be in line with the NOMA principle.

The situation proposed to the students thus seems to allow them to find categories in people who may be experiencing a conflict between their beliefs and scientific knowledge. However, it is based on elements of the history of science and does not highlight the personal conflict that the students may experience. It might have been interesting to analyze the students' proposals in terms of their personal beliefs (religion, atheism, etc.). This research also points out why it is interesting to discuss the question of religion in the construction of scientific knowledge. This is why further study is required to investigate the evolution of the students' thinking after the activity and during the sequence. How do their conceptions evolve? How

did they take charge of the critical sphere? Moreover, the data collection can be reproduced in another class by conducting interviews with a few students selected from the different categories to try to shed more light on their positions.

1.7. Conclusion

We were interested in the position of students in the second year of secondary school in relation to texts that present the approaches and work of certain scientists who adhered to the fixist theory of species in the 18th century. The objective of the proposed activity was to allow students to critically reflect on the relationship between science and religious beliefs in relation to the fixist theory. The qualitative analysis of the individual productions allowed us to show that the students' positions were diverse and varied. These first results show that the distinction between science and religious belief is very delicate for the students. We note that the interweaving of religious considerations and scientific approaches in the work of the 18th-century scientists is not so easy to disentangle. However, the work with this type of text has the merit of allowing difficulties in the demarcation criteria put forward by the students to be identified in order to characterize what is and is not scientific. This can provide guidance for the teacher who wishes students to work on the relationship between science and belief in historical explanations. Moreover, it encourages the formation of critical thinking skills, which are emphasized in the new school curricula, so that students can free themselves from academic conformism or imposed neutrality. Moreover, the great diversity of the types of justifications concerning the possibility of whether or not scientific practice and belief can be reconciled clearly shows the potential for a rich critical discussion on this question. This could be done, in our opinion, through a problematization approach (Fabre 2016) based on holding debates after completing the work with the aim of pushing the students to question and develop a critical reflection on the place of religion in the age of fixism.

1.8. References

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