



Writing Fictional Short Stories About the Anthropocene: Effects on Students' Futures Thinking

Nicolas Hervé* and Nathalie Panissal

UMR EFTS, École Nationale Supérieure de Formation de l'Enseignement Agricole, Université de Toulouse, Toulouse, France

This article deals with the identification of some general guidelines for teaching aimed at developing futures thinking about themes of the Anthropocene. For that, we estimate such teaching activities at the intersection of socioscientific issues, environmental education, and futures education. We describe two teaching contexts designed on this principle, and centered on pupils' writing fictional narratives, and analyze the effects on their futures thinking. The results show that it is important to design teaching activities that make it possible to think about the temporalities of processes and phenomena, and to invest in relational responsibilities. In order for the pedagogical activity to take temporalities into account, we propose that the backgrounds of the futures on which the stories take place be built using the scenario method. Writing short stories can also allow for a deeper understanding of relational responsibilities, based more on the framework of capabilities. One perspective is to integrate fictional short stories writing into the repertoire of possible activities to be conducted in an inquiry-based pedagogy about the Anthropocene.

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*Correspondence:

Nicolas Hervé
nicolas.herve@ensfea.fr

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INTRODUCTION

Within a few years, the term “Anthropocene” has become “a vivid yet informal metaphor of global environmental change” (Zalasiewicz et al., 2008, p. 7), even if the concept is not stabilized and the word is controversial. The prospect of human activities being responsible for a geological epochal shift marks a recognition of the extent of the human footprint on the Earth System. The Earth System is being propelled into an unprecedented phase of its geological history, one less conducive to maintaining biological diversity and stable living conditions for humanity.

The Anthropocene thus designates the emergence of a paradoxical era, because although the categories of thought and action of modernity make it possible to describe the biogeophysical evolution of the Earth System very precisely, they are nevertheless incapable of fully evaluating the changes underway and the actions to be undertaken. As Latour (2017) expresses it, “it is not speaking ill of humanity to recall the extent to which we are all ill-equipped—emotionally, intellectually, morally, politically, culturally—to absorb such news” (p. 45).

Even if concerns about the evolution of the Earth System are shared, the social space is permeated by numerous visions of the future and divided on the actions to be taken to face it. Chateauraynaud and Debaz (2017) have shown that actors' reasoning in environmental and sociotechnical controversies is deeply structured by the futures images they are building.

They have identified four patterns in futures images about the Anthropocene that are circulating in society. First of all, there is the collapse scenario, which shows a catastrophic future that has the appearance of the end of the world. There is the technoprophetic scenario, that of a future technological breakthrough, with nanotechnology, artificial intelligence, Martian colonization and geoengineering as avatars. There is the scenario of regulation and policy-making, that of a controlled future, legislated by state or international institutions (in the Conferences of the Parties or at the UN), encouraging or forcing change. Finally, there is the scenario of the transition to sustainability, which is defined by new social and political assemblies, a focus on local experimentations and alternatives, for a systemic change in lifestyles.

To educate in the context of the Anthropocene is necessarily to question the sociotechnical trajectories of modern societies, to address environmental issues, and to evaluate possible and preferable actions with regard to their future consequences. This is why the educational currents of socioscientific issues (SSI), futures education (FE), and certain approaches to environmental education (EE) are currently converging, thus forming part of a critical and political tradition of the schooling of environmental issues (Sauvé, 2011).

In this article, we propose to investigate the characteristics of the futures thinking that French high school pupils use in learning contexts that confront them with the challenges of the Anthropocene. To this end, we are interested in two teaching sequences, whose design choices are based on SSI, FE and EE, and which have led pupils to write fictional short stories. By analyzing their productions, we can identify some guidelines for taking into account the temporalities of the Anthropocene in teaching.

EDUCATING IN THE ANTHROPOCENE, A FOCAL POINT FOR SOCIO-SCIENTIFIC ISSUES, FUTURES EDUCATION, AND ENVIRONMENTAL EDUCATION

Three educational currents seem to be particularly interesting for constructing an educational point of view on the Anthropocene (Figure 1): they have in common the fact that they all consider the environment, science and technology, and the future as political issues that should be studied in school as such.

The SSI movement is a resource for thinking about education in the Anthropocene, as socioscientific, sociotechnical and socio-environmental controversies are seen as opportunities to politicize science education (Bencze, 2017; Simonneaux and Simonneaux, 2017; Sjöström et al., 2017; Bencze et al., 2018, 2020; Amos and Levinson, 2019; Chowdhury et al., 2020). Debating an SSI, mapping a controversy, playing a role-playing game, analyzing media, conducting a socioscientific inquiry are some examples of possible activities to be carried out with pupils. They aim to explore controversial, complex, interdisciplinary and value-laden issues (Sadler, 2011; Zeidler, 2015). They are also ways of getting pupils to consider the uncertainties that run through these issues, both in terms of academic knowledge and

in terms of society and the media (because they are debated in society) (Sadler et al., 2017). The aim is a social transformation through the school sector (Simonneaux, 2014).

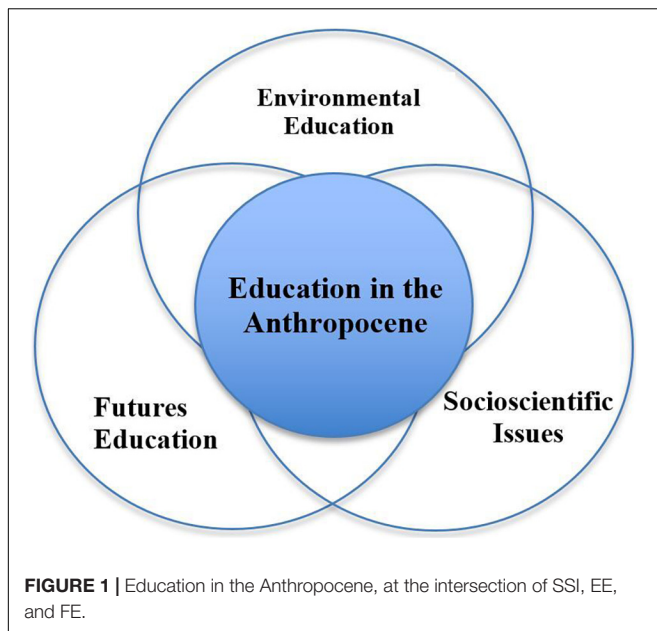
Environmental education is also a key educational research stream for thinking about the Anthropocene. The teaching of science, environmental protection or popular education approaches have played an important role in its development (Sauvé, 2005), in order to enable pupils to build knowledge and attitudes that are environmentally positive (Ojala, 2017). Environmental education constitutes a reservoir of educational practices that make it possible to politicize the challenges of the Anthropocene (Holfelder, 2019; Håkansson et al., 2019), even if its development in the form of education for sustainable development since the 2000s has been criticized for the importance given to the economic dimension to the detriment of the social and environmental dimensions (Jickling and Sterling, 2017; Kopriva, 2020). The themes studied (e.g., disagreements, controversies and conflicts in resource management), the ways of learning (e.g., collective action on a territory or deliberation on issues) and the learning objectives (in terms of knowledge or education for citizenship) all form part of an education in politics (Holfelder, 2019; Slimani et al., 2021).

Futures education is the transposition of practices and knowledge from futures studies (Hicks, 2001), and it is based on the analysis, the construction by the pupils, and the debate of futures images. This educational current considers that the future dimension is often forgotten in education, not questioned, implicit (Gough, 1990; Hicks, 2002). Its explicit integration into the curricula is necessary to promote futures that are responsive to major issues (Milojević, 2005; Hicks, 2012; Pauw, 2015). From the outset, futures education has been associated with issues of education for peace, citizenship and the environment (Gidley and Inayatullah, 2002; Gidley and Hampson, 2005), as well as the risks associated with scientific and technological development (Gidley, 2004; Hicks, 2012). It therefore also constitutes a resource for contemplating the school-based forms of education in the Anthropocene (Holfelder, 2019).

INTEGRATING FUTURE INTO TEACHING TO DEAL WITH SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT AND ENVIRONMENTAL ISSUES

There are a number of arguments to support a link between futures education and science education.

First of all, questioning economic, social and cultural development in Western societies inevitably leads to questioning science and technology because they are at the center of models of development. Many present and future world problems are based on scientific and/or technological foundations. Questioning scientific and technological development is thus one of the objectives of the SSI movement, and one way of approaching it is to focus on the future dimension (Jones et al., 2012; Bunting and Jones, 2015; Branchetti et al., 2018; Levriani et al., 2019, 2021). Researchers argue that science education with a



future perspective provides pupils with the means to examine and problematize their views and concerns about socioscientific issues, including environmental issues (Carter and Smith, 2003; Lloyd and Wallace, 2004). Futures education, integrated into science teaching, thus offers pupils the possibility of evaluating the impact of science and technology on society, constructing ethical dilemmas and exploring possible solutions or actions.

Numerous studies show that scientific and technological elements are very present in the futures images formed by individuals, and that they are often placed in tension with environmental issues (Hicks, 1996; Eckersley, 1999). For example, the quantitative study by Liu and Lin (2018) on students' futures images showed that "(1) students who believe that their preferred environmental futures will happen tend to hold a positive view about technoscience as an influencing factor; (2) students who are more positive about techno-science tend to be less concerned about the environment" (p. 1). Thus, the findings of this study "emphasize the importance of integrating a critical futures perspective into environmental education and science education programmes" (p. 14).

Lastly, teaching approaches that integrate the future dimension are likely to motivate pupils to learn about science, which is at times perceived as arduous (Lloyd and Wallace, 2004). It allows them to construct complex reasoning on problems that make sense to them: "science learning and a critical futures perspective, when used in combination, can assist students to use scientific ideas and processes to address current and emerging problems, and help them to anticipate possible consequences of applying scientific ideas" (p. 164).

The future dimension is considered central to the understanding of strong sustainability of lifestyles, it is also a key parameter for tackling "big problems" such as climate change, the loss of biodiversity, reducing inequality, etc., and it is a way of thinking about transitions and the changes they

entail. Indeed, one goal of futures education is to keep the range of possible futures open (Voros, 2008), to work with pupils on the diversity of possible futures, to fight against the idea of a determined and threatening future, and to provide hope and alternative political projects. This is why futures education is promoted in the critical currents of environmental education (Hicks, 2012; Ojala, 2017; Holfelder, 2019).

Looking ahead to the future, identifying trends of change and their uncertainties, anticipating risks and consequences of decisions and actions, understanding emotions (e.g., hope, fear, or anger) related to the threats of the Anthropocene, imagining solutions or means of action, these are some of the educational objectives linked to the integration of the future dimension in education, and they represent several ways of using futures thinking.

It is because this thinking is essential to respond to the challenges posed by the Anthropocene that it is necessary to explore it further. A better understanding of futures thinking is to consider the means of articulating in action the temporalities of the social and bio-geophysical phenomena of the Earth System. It also means questioning these dynamics in the construction of the futures of the Anthropocene, in connection with scientific and technological development. To do this, it is important to understand the learning situations that enable its development.

FICTIONAL NARRATIVES TO DEVELOP FUTURES THINKING?

Futures Studies techniques inspire futures education, and the scenario method, for example, has been implemented in several educational contexts (Eckersley, 1999; Jones et al., 2012; Bunting and Jones, 2015; Pauw et al., 2018).

We are interested here in the possibilities offered by science fiction (SF), which is considered a "factory of futures images" (Rumpala, 2015). It is because science fiction extends or anticipates through the imagination the consequences of scientific and technological development in the material, social and cultural structures of societies that it has privileged links with futures studies. It thus constitutes a method in its own right. But if science fiction helps to conceptualize, to make certain imaginations come to life or to help understand what they imply, it is above all an artistic and creative expression. Its way of exploring times and alternatives can therefore be a help in making change concrete, accessible and sensitive (Lombardo, 2015).

First and foremost, science fiction narratives participate in the construction and dissemination of futures images, and as such, they can have a type of performative effect in feeding imaginations and preparing for future developments. Michaud (2017) thus makes science fiction an important element in the development of technoscience. He argues that cultural industries (e.g., cinema, literature, videogame) support industrial projects and maintain the desire for their development.

Fictional story writing is also used to raise awareness of environmental or scientific and technological development issues, and to encourage awareness of the need to act. It is seen as a means of influencing decision-making, imagining strategies for

action and anticipating future changes. For example, the NESTA Foundation has funded an anthology of famous authors to warn of the consequences of antibiotic resistance¹, the University of Arizona publishes a collection of SF stories on the consequences of climate change every 2 years², and the Finnish Parliament has launched a short story writing competition open to all, to help identify possible unlikely events with extreme consequences, the so-called “wild cards” or “black swans” (Ahlqvist et al., 2015).

SF therefore refers to the possibility of creating fictional, meaningful worlds, which ultimately constitute simulations of our world, including “by pushing the boundaries” (Rumpala, 2016, p. 60), i.e., imagining endings or new worlds built on other civilizational premises, by investing in long-term issues. It is in this sense that we can speak of SF as a laboratory of thought experiments.

This is why SF productions are sometimes mobilized as material for the study of the relationship between science and society, and constitute research data that allow the social sciences to question the anthropological changes in the evolution of an increasingly technicized world. Miller (2015) goes even further, as she shows that SF works complement impact studies written in a rigorous and technical manner. In fact, by comparing the repertoire of SF and expert reports on two themes, namely nuclear power and artificial intelligence, she notes that certain dimensions (notably social, political and ethical) are not covered by the expert reports and that they are covered in SF. Thus, fiction and science are prolonged, fiction being a way to extrapolate the consequences of scientific results, adding emotions and feelings.

RESEARCH QUESTION

This article is aimed at identifying some general guidelines for developing futures thinking, based on analyzing singular teaching contexts dealing with Anthropocene issues and drawing on SSI, FE and EE trends. For this purpose, we are interested in evaluating and comparing the effect on futures thinking of two teaching contexts centered on the pupils’ writing of fictional narratives. Following a training on SSI, two literature teachers decided to experiment with teaching about a SSI in their respective classrooms. Both wanted to innovate in their teaching, with the objective of developing their students’ argumentative abilities regarding science-society issues. Having them write fictional narratives seemed to them a pedagogical means for articulating abilities related to the expression of language and thought, and abilities to reflect and question about SSI. In this article, we examine the nature of the futures thinking that students mobilize in their narratives.

METHODOLOGY

The work analyzed in this article was taken from two ordinary teaching situations, conducted by two French teachers who were trained in SSI during their initial formative year.

¹<https://www.nesta.org.uk/blog/we-need-to-talk-about-antimicrobial-resistance/>

²<https://climateimagination.asu.edu/>

Teaching Contexts

We present here the teaching approaches designed and implemented by the teachers.

Teaching Context 1: The Human–Natural Environment Relationship in Fictional Narratives

This sequence was designed by a literature and philosophy teacher for pupils aged 15 to 16. It is divided into seven sessions. The teacher wanted the students to work on the following problem: how do the literature of ideas and the press invite us to rethink our relationship with nature? By addressing the issue of the relationship between human and nature at the time of the Anthropocene period through written production, she was able to meet the objectives of the curriculum, such as the development of judgment and critical thinking through the study of texts dealing with a controversy, or the analysis of different forms of argumentation. The work is based on fictional literature and requires the students to write a short story.

- Session 1: The aim of this 2-h session is to work on gathering information by studying the reasoning of different actors in their discourse on nature (for example Greta Thunberg’s speech at Cop 24 or extracts from ecological SF short stories).
- Session 2: The argumentative purpose of a story is addressed through the study of *The Man Who Planted Trees* by Jean Giono. This is the story of a shepherd who decides to plant trees to bring the country back to life. At the end of the 2-h session, students are asked to write a 2-pages fictional short story, in the style of Giono, dealing with the relationship of human beings with the natural environment, and reporting on an action beneficial to nature taken by a character the narrator meets.
- Sessions 4–7 help students with their writing—drafting the short story, implementing the argumentative discourse, defending an opinion, building a character to serve the argumentative project.

Teaching Context 2: The Human–Technology Relationship in Fictional Narratives

This sequence was co-constructed by a literature teacher and a physics teacher, and addressed to students aged 14 to 15. It is divided into six specific sessions. The general objective of the sequence is to get students to think about the future of health technology with the development of nanotechnologies. It includes meetings with researchers (a lecture at the school and a visit at the researchers’ lab), science lessons exemplified by the researchers’ activities, and the writing of science fictional stories. We are interested here in the literature course in connection with which the writing activity took place.

- Sessions 1–4: a writing workshop with the literature teacher is set up, which consists of writing outlines of scenarios and snippets of stories.
- Session 5: a bionanotechnology researcher gives a lecture in the classroom, co-hosted by the physics teacher. At the end of this lecture, the pupils are given the task of writing a fictional story at home.

The pupils are assisted with their writing in the various disciplines involved in the educational experiment (technology, biology, physics, chemistry, literature). Each teacher initiates a discussion in their class about these stories in relation to their teaching subject, they address, for example, certain consequences, notably from an ethical point of view, of the possible applications of carbon nanotubes in physics chemistry, information storage in technology, health in biology. The pupils continue and complete their stories at home.

- Session 6: Volunteer pupils read the stories created, and there are interpretative debates based on the stories read (2 h) with the literature teacher.

The Data Collected

The data corpus is made up of the pupils' productions during the two sequences:

For teaching context 1: 16 individual short stories (two to six pages). Only one story was removed because it did not fit the general theme. **Supplementary Appendix 1** lists the themes addressed by the students in their stories. The stories highlight an extraordinary action by an individual confronted with an environmental problem.

For teaching context 2: 12 individual short stories (four to ten pages). These are the ones that were published in a book named *Nanorecits*³. **Supplementary Appendix 2** lists the themes addressed by the students in their stories, which can be grouped into three categories: (1) human enhancement is explored through the downloading of a dead person's human consciousness into a robot (story n°2) (2) geopolitical issues concern power struggles between nations and population control (stories n°6, 8, 9, 12). (3) The theme of nano-health is approached from the perspective of healing, preventive treatment, clinical trials and regeneration (stories n°1, 3, 4, 5, 7, 10, 11).

Framework for Analyzing Data

In order to analyze the mobilization of futures thinking by the students in the fictional stories, we employ a psycho-social model built by Ahvenharju et al. (2018) from a bibliographic synthesis involving various disciplinary backgrounds. According to this model, futures thinking is characterized by five dimensions:

Time perspective is the set of configurations that an individual or a group constructs to situate past, present or future events or situations in time. It can be more or less extended in time (time horizon) or preferably oriented toward the past or the future. It therefore differs between individuals, for example according to their age, living conditions, social status and culture. This dimension also refers to people's understanding of the future consequences of their actions.

Concern for others is an individual's ability to incorporate the well-being of others as a condition for one's own well-being. In this respect, it is in line with the idea of "world consciousness."

³*Nanorecits: un monde imaginaire insoupçonné. Fictions des élèves de la classe 304 du collège de Carbone.* "Nanorecits: an unsuspected imaginary world." Fictions of the students of the class 304 of the college of Carbone. Toulouse: Messages sas, sponsored by les Nouvelles Éditions Loubatières.

Futures thinking involves a sensitivity to the axiological valence of futures, some of which are valued and desired, while others are rejected or disliked. The question of valued, hierarchical futures is therefore inherent to that of an ethical positioning. The "others" can be humans, animals, plants, etc. The preferred future scenarios are thus often linked to claims of sustainability, ecology or rights for future generations (Thompson, 2017).

Systems perceptions is the ability to think about situations in a comprehensive way, taking into account the relationships between the elements of a situation or the interdependence of systems. As such, the adoption of the synthetic or holistic viewpoint is valued over a purely analytical perspective. It integrates the way an individual perceives, combines and articulates different temporalities, for example those of human and natural phenomena.

Openness to alternatives is the ability of an individual to imagine open possibilities. In this way, it is deeply linked to creativity. It is also critical thinking, as it questions preconceived, prevailing ideas, in particular the idea of a determined and irreversible future. It is also an acceptance of the uncertainties inherent in futures and the consequences of actions, and thus values risk-taking.

Agency beliefs allow people to have a direct control over their actions according to the goals and objectives they have set for themselves. It implies a sense of self-efficacy that makes the individual believe in their ability to act upon the future to achieve their goals. It is also related to the way the future is perceived (open or determined future, optimistic or pessimistic views), and to the attitudes of individuals toward action (passive, active, proactive, etc.).

A content analysis in the form of key words (Krippendorff, 2004) associated with each dimension of futures thinking was used as criteria to categorize the pupils' productions (**Table 1**).

RESULTS

The results of the mobilization of futures thinking are, respectively, described below for each teaching context (human-living relationship, and human-living technologized relationship) according to the criteria outlined in **Table 1**.

Teaching Context 1: The Human–Natural Environment Relationship

Time perspective: We observed that 10 stories (out of 16) do not identify the action of the main character in time, while for the other six writings, this action extends from 5 years (construction of an animal shelter for example) to 20 years (the fight against deforestation). The action takes place in a cumulative manner, by successively adding together micro actions that ultimately give shape to an action that is part of time, without the links between the micro actions having been formalized or argued. Thus, for example, a story about the protection of caribou in Canada involves a number of successive actions, which are not specifically dated, but which add up to 20 years: observation of the animals' behavior, counting in the area, study of their diet,

TABLE 1 | Criteria for identifying futures thinking dimensions in pupils' productions.

Dimensions of futures thinking	Criteria
Time perspective	Presence of chronological markers (dates, etc.) Presence of chronological connectors (after, then, during, etc.) Isolated events or continuous temporal process Causal links between events or processes
Concern for others	Caring, attention to others (human or non-human) Social or emotional connection Continuation or repair of the world
Systems perceptions	Taking into account the multifaceted aspect of a situation Taking into account the relationships between individuals, things and situation Taking into account the overall nature of a situation
Openness to alternatives	Imagination of one or more possible worlds Multiplicity of possibilities envisaged Optimism/pessimism of visions
Agency beliefs	Link between knowledge and empowerment Suggested courses of action Focus on political, economic, etc. powers

construction of a rescue center, which then extends to a center for the protection and study of the ecosystem.

Concern for others: Nine stories (out of 16) focus on efforts to save or care for wild animals living in forests. The other stories focus on a more complex entity, such as the “forest” or the “living environment,” by evoking an interrelation between wildlife, flora and human social activities. This is the case, for example, in the story of the transition to agroecology of a farmer who is working to spread her ideas of “love for the land.” The character whose actions are described in the stories is in most cases a person who lives in isolation from other humans (13 of 16). The production of the stories leads the pupils to question what should be done at the local level.

Systems perceptions: It is in the students' argumentation that we find elements of the systemic dimension, however, they are not elaborated upon. It comes in the form of a questioning of the relationship between human activities and their consequences on the forest or the environment, and constitutes the background against which most of the stories unfold. These contextual elements are most often expressed in the form of catastrophe: deforestation, industrial pollution, intensification of agricultural practices, climate change causing fires, and are described by the pupils as the causes of a decaying environment. This oppressive context is present in all but two of the writings, which show the importance of the natural environment for human health (sylvotherapy) or social resilience (restoration of a village following a storm).

Openness to alternatives: The actions described by the pupils are seen as realistic utopias set against a pessimistic background. Various relationships between human and the environment are thus made possible. Firstly, human action allows “nature to regain its rights.” This idea is expressed in several ways according to the stories: creation of a natural area or a protection center for wildlife, repopulation. They also insist on the sustainable

use of artificial objects (such as recycling, plastic Christmas trees). Finally, some writings show a more integrated social and natural world, especially in terms of land-use planning or shifts in agricultural production methods. However, these utopias are mostly conceived as local alternatives. Only one story tells of the national extension of a transition to agroecology.

Agency beliefs: Students write about different ways of changing the world. Some writings focus on the political dimensions of environmental issues, in the form of collectively organized resistance, sabotage of industrial plants, demonstrations and boycotts of consumer products. Others focus on the economic dimensions, for example, access to property is a way of settling conflicts over land use. It is through the commitment of an individual inhabited by the cause he or she defends that students consider the possibility of taking action. The type of relationship between the person and the narrator, which is mostly found in the stories, is one of mutual aid and transmission of knowledge.

Teaching Context 2: The Human–Technology Relationship

Time perspective: The long-term temporal dimension is barely addressed in the students' narratives. The short stories on the theme of nanohealth are anchored in the present or near-future and are focused on the search for solutions to treat incurable diseases. The temporal aspect focuses on the process of medical treatment or experimental protocol to develop treatments. The anchoring in the present and the non-questioning of the world mark the narrative on human enhancement, through the downloading of the consciousness of a deceased person into a robot to extend human exchanges beyond death. The stories about geopolitical competition between nations are also rooted in the resolution of present-day conflicts with a very Manichean representation of the protagonists. Here again, time is not questioned, only the victor is glorified. One story, about a researcher who has developed an anti-cancer treatment that allows people to live to be 160, questions life on earth and its temporality, and pushes the reader to question the opportunity to postpone old age and death. In sum, the chronological structure of the narratives is mainly in the present, with rapid time steps.

Concern for others is varied according to the themes of the stories. Thus, geopolitical narratives consider others only through international competition and the goal of world domination. It is a vision of dominance that drives technological research and the arms race. By contrast, the narratives of nanohealth are imbued with this concern for others. They all deal with human vulnerability through disease, clinical trials, care, and the fight against epidemics. Benevolence is therefore emphasized in these stories, which does not prevent the pupils from developing a critical distance from the applications of scientific research on living beings, in particular by addressing the themes of toxicity or the possible misuse of techniques.

Systems perceptions: The students' stories are focused on the character(s) in their narrative. As a result, they do not identify the totality and complexity of the situations and backgrounds in which the stories develop. The narratives

related to nanohealth and human enhancement are confined to the enclosed spaces of the home, laboratory or hospital, and do not mention relationships with the outside world. The perseverance and dedication of researchers or doctors are central themes in the stories. The pupils do not consider the threat of exploitation of the care contract and the dangers of reification of the patient that can arise in increasingly molecularized medicine. They have complete confidence in the practitioners and the new technologies. This state of absolute confidence is not surprising. Indeed, the media discourse on nanohealth means that young people are certainly aware of it, but are focused on its promising effects. The same is true for topics related to geopolitical perspectives, which, as we have already mentioned, are caricatured in a Manichean approach between good and bad, stemming from the ideologies of the Cold War. Geopolitical complexity is not addressed by young people, nor is it included in the school curriculum for this age group.

Openness to alternatives: Optimism emerges from the analysis of the stories. The authors highlight particular qualities such as dedication, self-sacrifice, tenacity, perseverance, kindness and a sense of justice. Even if the outcome of the fictional story is not a happy one (such as the death of a volunteer patient in a clinical trial), it is the confidence in human beings that emerges through the emphasis on the virtues of the heroes of the stories. The future can thus be envisaged with serenity because humans are fundamentally good. Several relationships between humans and technology are thus made possible: the human who sacrifices himself to make technology more efficient, the human who devotes himself to technology to save others, the human who takes irrational risks. For all these students, technology is a means and not an end, it remains a tool to save humanity and improve lives, they do it for the wellbeing of humanity.

Agency beliefs: In their stories, the students show several ways of changing the world. The stories on the theme of nanohealth feature dedicated heroes focused on caring for others (curing diseases, restoring sight, ending a pandemic, finding a drug, improving a diagnosis). These narratives reflect the reliance on experts to change the medical world and continually push the boundaries of pathology. They ignore the collective work of teams and laboratories. The fictions that we have previously described as Manichean reflect a desire for commitment and an optimism in these young adolescents to face up to the adversities of life. When the community is envisaged, it is uniform and subject to a competitive military philosophy. The political dimensions of agentivity are almost absent, with only one story about population control showing this reflection. A young hero, aware of the use of technology to alienate people, investigates the toxicity of products and their use by the government with his sister. He creates a small network of resistant allies thanks to which he will thwart the manipulation and free the oppressed people.

Summary of Results

Results are closely linked to the specificity of each teaching context (architecture of the sequence, work instructions given, etc.). We have summarized them in **Table 2**.

TABLE 2 | Futures thinking in the two teaching contexts.

	The human - natural environment relationship	The human - technology relationship
Time perspective	Little consideration of temporalities	
Concern for others	The environment as a commons	Ambivalence of the human - technology relationship: the vulnerable individual who must be helped—the collective who must be dominated
Systems perceptions	Global dimension present but little explored (setting of the story)	Little explored global dimension, stereotyped technical social spaces
Openness to alternatives	Desirable future in a worrying background	A desirable future marked by trust in human beings and dedication to the service of others and technology
Agency beliefs	Different ways of acting, often individual initiatives	Different ways of acting, guided by the figure of the hero or the expert

DISCUSSION: GUIDELINES FOR THE DEVELOPMENT OF FUTURES THINKING

Thinking About the Temporalities of Processes and Phenomena

The analysis of the temporal dimension in the two teaching contexts shows that the students have difficulties in differentiating the temporalities of the phenomena or situations. Thus, differences in the temporality of tree growth, the rhythms of climate or social change, or innovative technological developments are not distinguished by pupils, nor are those constituting the different actions that are described in the narratives.

Temporalities are most often thought of in the short term, in the near future, and cannot give impetus to futures thinking as it should be solicited to think about the challenges of the Anthropocene. We can make the hypothesis here of considering them as a specific obstacle for the design of teaching situations. It is then a question of emphasizing a pedagogical support that allows pupils to pay attention to the proper time of the phenomena, processes or living beings, in order to inscribe their reflection in a temporal ecology (Grossin, 1996) that is not reduced to the measured social time of humans.

To do this, building scenarios of the future can be complementary to writing fictional stories. The scenario method consists in imagining the evolution of a system (for example, a socio-technical system such as the social deployment of a technology, or a socio-environmental system such as the development of a city or the transformation of an ecosystem). It is based on the identification and temporal monitoring of key trends and relevant drivers to simulate different changes according to the constraints applied (Amer et al., 2013). Scenario building leads students to explain changes by articulating not only different scales, local or global, individual and collective,

but also different temporalities, because not everything changes at the same speed (Eckersley, 1999; Jones et al., 2012; Bunting and Jones, 2015; Pauw et al., 2018). We therefore propose here a few guidelines for the pedagogical framework of an activity involving the production of fictional narratives. First of all, it seems necessary to us to assume an explicit anchoring of the produced narratives in the sub-genre of near-future science-fiction. Indeed, a characteristic of near-future science fiction is its ability to set fiction in a familiar reality, but different from ours by introducing elements that do not exist (e.g., scientific and technological developments, social events, environmental changes). These fictional elements make possible changes in the forms of socialization even though the background is familiar. This created strangeness permits problematizing societal preoccupations (around nature, technology or science, society). Explicit teaching on the societal or environmental background is therefore important so that a coherent and strange story can develop and incite reflection or debate. One way of getting students to construct this background and its temporalities may be to have them identify the consequences of social, technological or environmental changes by building scenarios, whose evolutionary trends and drivers make it possible to grasp the temporalities at play. The writing of stories can thus be organized in a second step, taking place within the constructed background, and giving to see a more familiar futures image, coherent, and embodied in a narrative.

Our results show that the exercise of writing an anticipation story is relevant to address the themes of the Anthropocene with students. The stories have a familiar air, they can be close to the interests of young people. The writing can thus allow students to pay attention to what is happening now, to build on contemporary events in order to methodically explore what could happen in a more or less distant, but not strictly imaginary, future.

Investing in Relational Responsibilities

The narratives produced by the students, in both teaching contexts, consider vulnerabilities, they highlight the importance of relationships (e.g., human-animal, or human-landscape in teaching context 1; patient-doctor, patient-kin, or military-country in teaching context 2). However, these relationships are most often privatized within the confined space of the story character and his or her adventures, and do not allow for an exploration of responsibility beyond this local relationship. The narratives produced generally involve ethical questioning related to concern for others. It is initiated, for example, when students propose to think of the environment as a commons (in the sense of Ostrom, 1990), or highlight the benevolence of a doctor or researcher triumphing over disease, but it is not pursued through the examination of the relationships between actors, technologies, the links that all actors (human and non-human) can build with each other, and the impacts of these links. Relational responsibilities are not thought of in the service of the social contract that allows the perpetuation of society. The vulnerability of living beings is entrusted to the good will of superheroes, and the ordinary individual is

deprived of his power to act. However, to take care of the environment, and by extension of the living, is to highlight the importance of particular relations and to institute them as the roots of our responsibilities. Indeed, the Anthropocene is not only a way of describing the degradation of natural systems as an effect of the modernization of human societies, it is also a sign of the need to renew the modes of attention between humans, living non-humans, and technology (Haraway, 2016). Therefore, it is about fostering social and cultural transformations that establish new relationships between humans and non-humans.

It is therefore necessary to explicitly invest educational work on relational responsibilities that problematize the impacts on environment and future generations. Nussbaum (2010) suggests building a social imaginary, based on everyday life, to construct moral emotions capable of considering vulnerability and combating feelings of omnipotence and domination. The aim is to stimulate emotional and cognitive reasoning in citizens in order to develop a moral imagination of the suffering of others (human and non-human) and of the relationships of social interdependence. Writing fictional narratives is thus appropriate to engage students in questioning human vulnerability. Nevertheless, our results show that agency beliefs are a weak point in the sequences studied in this article. It is one thing to give learners the opportunity to create ethical reasoning to probe the gray areas that our current perceptive and intellectual capacities are not able to perceive, it is another to develop in them capabilities, predispositions to action. Capability goes beyond competence, it encompasses what the person can do, but also what he or she can achieve in his or her environment. Capability thus implies the possibility that a person has to make choices between several possibilities that are presented to him or her, by judging what is estimable. It is therefore exercising a freedom of choice, the choice itself and the possibility to express this choice. Capabilities thus convey issues of social justice and the good life and could be a source of inspiration for the implementation of curricula for the development of agency beliefs.

Nussbaum (2000) proposes a base of ten capabilities as the foundation of a just society: life (being able to lead a life of normal length), bodily health (being able to be healthy), bodily integrity (being able to move around, being protected), senses, imagination and thought (being able to use one's senses, to imagine, to think, to be informed), emotions (being able to attach, to love, to associate), practical reason (being able to form a conception of the good and to participate in a critical reflection on the organization of one's life), affiliation (being able to live with and toward others, having the social bases of self-respect), relations with other species, play (being able to laugh, play, have fun), and control over one's environment (political: being able to participate politically, material: being able to own, have a job). These capabilities are a reserve of power to act from which each person can draw according to the circumstances, and we believe they can serve as a reference point for examining the narratives of a future world through the imagination. In concrete terms, this means structuring the narratives around one or more capabilities, which constitute

dimensions that the students must explore. In the same way that the scenario method relies on trends and drivers to produce futures images, the capabilities could serve as key elements to be mobilized in futures images that stories present. To do this, building a fictional narrative could involve, for example, describing the forms of attachment that the characters have with each other, the forms of attention that they develop toward living beings or technology, the emotions that they express, or the forms of collective organization necessary to solve an environmental or socioscientific problem. It is thus a question of integrating into the pedagogical scenario a reasoning on a society of power to act, and of denouncing the attempts of reification of the living and the logics of domination, in order to envisage different ways of extending the possibilities of right action for individuals and collectives.

It is in fact a whole work of politicization that it is necessary to organize so that the students' narratives can provide opportunities to reflect on the means of collective action for change, and thus to encourage agency beliefs. The posture of author that is proposed to the students allows for fictional explorations that feed the construction of a futures thinking. The act of writing allows students to question what is important, what matters, for themselves and for others. In this sense, writing contributes to the moral development of the subject.

CONCLUSION

Our study shows that futures are perceived as worrisome by students and that their ability to change the world seems limited to them. Agency beliefs are low, many students seem to place their hopes in singular individuals or "superheroes."

The two teaching contexts presented are stemming from ordinary teaching practices, they were not conceived to develop futures thinking as we defined it from the model of Ahvenharju et al. (2018), but they have the interest to problematize the relations of the human being with the living and the technology by the writing of fictional narratives. It is therefore conceivable that the combination of different rationalities offers the possibility of opening up to different ways of thinking, acting and feeling about issues in the Anthropocene. Two guidelines for the design of teaching devices have been identified: the attention to be paid to the temporalities of processes and phenomena, and to consider responsibilities as relational. In order for the temporalities of the phenomena to be taken into account more in the fictional narratives, we recommend that the writing work be done after having built evolutionary scenarios (for example in the manner of Jones et al., 2012). In order for relational responsibilities to be explored, we suggest structuring the narratives around Nussbaum's capabilities; the students should then put into their narratives and question the quality of humans' life in the imagined futures.

Our study allowed us to show the feasibility of teaching context focused on the development of futures thinking, in connection with SSI and EE, and to understand some of their effects. Our results therefore allow us to consider these

teaching contexts as being able to be integrated into the inquiry approach advocated in SSI pedagogy (Simonneaux et al., 2017; Amos and Levinson, 2019). Indeed, the inquiry pedagogical process proposed by Simonneaux et al. (2017) consists in putting students in a position to problematize and explore socioscientific issues. To this end, the inquiry is conceived as an iterative, interdisciplinary process, consisting of several stages: the gathering of information, the taking into account of the subjectivity of the investigators, the analysis of the information, the testing and selection of solutions, the proposal, and even the implementation of solutions and actions. The integration of didactic devices aiming at the development of futures thinking can thus make it possible to enrich the process of inquiry, which until now has been studied rather from the point of view of systemic and critical thinking. From this perspective, the writing of fictional narratives is interesting, but more research is needed to understand how it can be articulated with other pedagogical approaches (such as the scenario method) and how it can contribute to developing the agentivity of individuals and groups in the Anthropocene context. The two markers identified in this article can therefore also constitute points of vigilance for teachers, both in their conception of teaching-learning situations and in the pedagogical support of students' inquiry.

Complexity is at the heart of futures thinking, it is not only a capacity to anticipate the probable, but also to project oneself in time, to simulate the possible temporal effects of actions, to feel the articulation present-past-future, which leads to questioning all the participations of the actors, the sharing of responsibilities and interdependencies. As such, futures thinking is constitutive of a political thought, necessary for education in the Anthropocene.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

NH and NP wrote sections of the manuscript. Both authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2022.842252/full#supplementary-material>

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