


Article

Understanding Pandemics Such as COVID-19 through the Lenses of the “One Health” Approach

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Abstract: This study aims to contribute to research on systemic thinking in biology education, particularly how to best equip pre-service teachers to introduce health problems such as the COVID-19 pandemic using the “One Health” approach. We attempt to explore to what extent a group of pre-service teachers identify our lifestyle and relationships with nature as factors that contribute to the emergence of future pandemics. The research questions are as follows: (1) *What dimensions of the One Health approach did the students identify as potential causes that can produce and prevent future pandemics such as the COVID-19 disease?* (2) *To what extent did the students show a systemic view aligned to the One Health approach?* The participants were 43 pre-service elementary teachers working on a set of activities about the COVID-19 pandemic, in which they were asked about the potential causes of and ways to prevent future pandemics. Content analysis of individual written responses is applied for addressing the research questions, focusing on the dimensions of the One Health approach and the level of system thinking reflected. Most participants focused on the human dimension and a few mentioned environmental and animal dimensions, which points to the need to integrate the One Health notion into teacher training.

Keywords: One Health; COVID-19 pandemic; health controversies; environmental problems; zoonosis; teachers’ training; primary pre-service teachers



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1. Introduction

Science education faces urgent challenges related to health and environmental problems, as the COVID-19 pandemic has shown. During this pandemic, citizens over the world were called upon to take actions and make responsible decisions to stop the spread of the disease; however, relatively little attention was paid to the environmental factors that contributed to its presence. United Nations (UN) Secretary-General António Guterres recently noted in a message to UNEA5 delegates that “the world’s top environmental body needed to generate global will for action and a transformation of our relationship with nature” [1] (p. 4). The human impact on the environment is increasing the risk of emerging infectious diseases in humans, over 60% of which originate from animals, mainly from wildlife. Plans to reduce the risk of future pandemics need to lessen our impact on the environment, thus critical thinking for taking responsible actions needs to be pursued in health and environmental education.

In response to the COVID-19 pandemic, educators around the world tried to find ways to support their students to develop health literacy and critical thinking in order to understand the disease and avoid the rise of disinformation [2]. However, less initiatives addressed the interactions between nature and health [3], as this study proposes. Lessons from the pandemic can be framed in the One Health concept, meaning that human, animal, and environmental health are interconnected [4]. COVID-19 is an emergent disease, and as such, it can be characterized as a socio-scientific issue (SSI) that demands responsible

citizenship skills [2], as well as a systemic view of the different factors involved in this problem. Equipping students and teachers for these goals requires engaging them in activities that show the complexity of health problems when considered from a One Health perspective. According to Christensen and Fensham, “the urgency and responsibility of including key SSIs that relate to social and environmental health in school science is so great that they cannot be avoided on these grounds” [5] (p. 15).

The One Health approach means that human health cannot be understood without considering the health of other living beings and the environment, which requires the promotion of systemic thinking in science instruction. System thinking implies identifying the different parts or components of the system (first level [6]), and the interrelations between those parts (first level [6]). This study aims to explore how a group of primary pre-service teachers frame the problem of the COVID-19 pandemic; specifically, to what extent they are able to apply a systemic view that recognizes the intersections between environment and human health. The study aims to contribute to research on systemic thinking in biology education research and on how to best equip future teachers for understanding health problems like pandemics from the One Health approach. We attempt to explore to what extent participants identify our current lifestyle and the relationships of human beings with nature as key factors that contribute to the emergence of pandemics and how to prevent them.

The Integration of One Health Approach and Critical Thinking in Health Teaching

Science education curriculums have become increasingly focused on the study of complex systems [7], and the pandemic has shown us the importance of introducing a systemic view when addressing SSIs such as COVID-19.

For centuries, scientists have recognized the close relationship between human, animal, and environmental health [8]. Globalization and the emergence of infectious and zoonotic diseases that cause pandemics put into clear focus the importance of collaboration between scientists, health professionals, and educators from diverse fields. This is the idea behind the One Health approach that this study supports. The term “One Health” is defined as the collaborative effort of multiple disciplines working locally and globally to obtain optimal health for people, animals, and our environment. This concept means that human health and animal health are interdependent and bound to the health of the ecosystems in which they exist.

Inger Andersen, Executive Director of UNEP, observed that if we want to stop the triple planetary crisis of climate change, biodiversity loss, and pollution that threaten our peace and prosperity, we have to understand that human, animal, and planetary health go hand in hand [9]. The goal of One Health is to foster interdisciplinary, interinstitutional, and interprofessional collaboration locally, nationally, and globally to advance the well-being of people, animals, and the environment.

Despite the importance of this notion, we have not found science education studies dealing with this notion in the pandemic context. Studies developed in science education have primarily paid attention to how to prepare students to face misinformation about the pandemic rather than on how to engage students in activities that help them to understand the origin of pandemics and how to prevent future pandemics based on the One Health notion. Several studies have analyzed students’ capacity to critically analyze COVID-19 information spread by social media and scientific arguments related to COVID-19 (e.g., [10,11]). These studies engaged students in the critical evaluation of fake news about the origin of coronavirus and analyzed the arguments provided by them. However, these analyses did not attend to the use of One Health notion in students’ arguments.

A significant issue that has been highlighted during the pandemic is the public need to understand how science works [12]. In the words of this author, “science in the making” has taken center stage in daily public affairs calling for understanding of the methods that scientists use in order to generate new knowledge about the coronavirus. Studies exploring students’ understanding and arguments regarding COVID-19 vaccines have

been developed in our context during this period [10] and point to the need for promoting health literacy in conjunction with critical thinking development. Understanding the notion of One Health requires, as with other multifaceted notions, the capacity to take into account multiple views, thus open-mindedness, which is directly related with CT dispositions [2,13]. Furthermore, we concur with Colucci-Gray and Gray [13], that critical thinking needs to be cultivated in the classroom, but also, as the authors emphasize, so does the “critical consciousness”. This means in the context of the current pandemic to make students aware of their own impact on the environment and the interrelationships between human health and environmental health.

The capacity to take into account multiple views in a One Health approach requires systems thinking, as the One Health approach can be seen as a complex system with multiple interconnected and interacting parts. The notions of systems and systems thinking have been defined in a variety of ways, which is reflected in the views of biology educators [14]. However, there are several factors common to the different definitions. Thus, a system is understood to be made up of several parts that interact interdependently, such that any change in one part affects the others, and with a common goal—the functioning of the system [6]. On this basis, systems thinking is characterized by, among others, identifying the different parts or components of the system, their processes or behaviors and the functions or phenomena resulting from these interactions [6,15]. Our view, then, is that systems thinking and critical thinking are interdependent, as the capacity to consider multiple views is a requisite condition, both in systems thinking [6] and in critical thinking [16,17]. Systems thinking is necessary for addressing the interactions and outputs of those interactions [6], and critical thinking is for the construction of evidence-based justifications [17] to explain the interactions between parts.

Although the One Health approach has featured during the current pandemic as a strategy to address complex problems that are at the interface of human, animal, and environmental health, little effort has been directed at identifying the knowledge, skills, and attitudes necessary for individuals to successfully contribute to One Health efforts, particularly in science education. There is growing interest in how to equip students and teachers with critical thinking and systemic thinking skills in biology education, although we have not found previous research dealing with how to integrate health controversies using the One Health approach, particularly in teachers’ training.

Preparing future teachers for the integration of the One Health approach requires designing activities that engage them in the comprehension and application of this notion in real life contexts, such as COVID-19. Health issues, as infectious diseases, are part of the primary education curriculum on natural sciences in our country. However, the focus at this level of education is on health and hygienic habits to prevent them rather than on understanding their causes and ways to prevent them considering the interactions between human actions/behaviors and the environmental factors. Taking this issue into consideration, this study seeks to improve the knowledge on primary pre-service teachers’ understanding of One Health notion and its application to COVID-19. We seek to make an original contribution to this emergent line of research by addressing these research questions:

- (1) What dimensions of the One Health approach did the students identify as potential causes that can produce and prevent future pandemics, such as COVID-19?
- (2) To what extent did the students show a systemic view aligned to the One Health approach?

2. Method

The activities were designed and implemented in a course that started in September 2020. At this time, 593,730 cases of COVID-19 and 29,848 deaths were confirmed in Spain, with 28,871,176 cases and 921,801 deaths worldwide [18]. After the first wave of cases in March, measures to restrict the movement of people had been decreed, but were progressively relaxed from May to June. Cases declined, but after the summer, the number

of cases in Spain was on the rise; a second wave was about to arrive and restrictions were reimposed in October 2020. The activities analyzed in this article were carried out in December 2020, when the number of cases was falling after the second wave. In the three months since the start of the course, a further 1,136,845 cases and 17,776 deaths had been confirmed in Spain (39,974,192 cases and 648,503 deaths worldwide) [18].

The participants were 43 pre-service elementary teachers (PETs)—26 females and 17 males—in the fourth year of Primary Education Degree (typically 22 years old) at a Spanish university. During the course, the PETs had participated in a sequence of modelling-based activities about the interactions between the SARS-CoV-2 virus and the human organism, as well as the vaccines that were in preparation to deal with the virus and how they interact with the human body. After completing the sequence, several activities on the origins of epidemics and pandemics were also implemented. Given the pandemic context at the time, exceptional measures to prevent contagion at the university were applied. One such measure dictated that, on the day of the activities, 16 PETs were in the classroom while 27 PETs were at home following the class remotely. From home, through their computer and a platform designed for this purpose, they could see and hear the class, could talk from home (in writing in a chat or by voice) and send the requested work on the spot.

The activities on the origins of epidemics and pandemics lasted a total of three hours and took place over the course of one session. First, they answered an open-ended questionnaire about pandemics. Next, they were provided with further information by means of popular science articles. In groups, they made a conceptual map of the origins of pandemics. For this study, the answers of two questions included in the questionnaire were considered. Both questions were formulated taking into account dimensions of systems thinking and in the context of the One Health approach. The first one, *“In your opinion, what could encourage the emergence of pandemics such as COVID-19?”*, sought to get PETs to situate their thinking in complex cause-and-effect relationships [6,19]. The second, *“What can we do to prevent another pandemic? Describe in your own words the concrete actions we can take”*, placed the question in what Ossimitz [19] argues is one of the most fundamental elements of systems management; namely, thinking about which components of the system are possible subjects of direct change through changing one’s own behavior.

All participants gave informed consent for their answers to be used as research data. All answers have been translated into English.

To address research questions 1 and 2, the contents of the answers to the questions *“In your opinion, what could encourage the emergence of pandemics such as COVID-19?”* and *“What can we do to prevent another pandemic? Describe in your own words the concrete actions we can take”* were analyzed, categorizing them according to the components of the One Health approach to which the PETs referred (first level of systems thinking according to Ben-Zvi-Assaraf and Orion [6]). In addition, the identification of components of the system subject to direct change [19] was considered. To do so, the second author identified the One Health dimensions to which PETs referred in their writings, and, after applying a constant comparison method [20] to the data, emergent categories were established. The first author revised the categories and results. Disagreements were discussed to reach a consensus. In order to address research question 2, critical and complex systems thinking factors were identified. To do so, the identification of the interrelations among the components of the system was characterized (second level of systems thinking according to Ben-Zvi-Assaraf and Orion [6]). The performance of PETs in establishing interrelations between the components was assigned to a level. Levels were established taking into account three criteria derived from systems thinking and critical thinking frameworks: the number of different One Health components, the allusion to dimensions other than the human dimension, and the justification or explanation of the relationship. Thus, the lowest level (level 0) was considered to be only referring to human dimension, level 1 consisted of responses that alluded to other dimension besides the human dimension. This could be done by explicitly referring to causes or actions in various dimensions or by referring to environment or animals when asked about human health related issues. We included

the latter in level 1 because the question was about pandemics such as COVID-19, so it implicitly included a reference to the human dimension, level 2 was set for responses that besides fulfilling the criteria for being in level 1, justified it, justifying the interrelation, making use of skills related to critical thinking.

3. Results

3.1. Dimensions of One Health Approach Identified in Students' Responses

Tables 1 and 2 show the percentage of PETs responding in each category on the causes of pandemics and actions to prevent them, respectively. Two PETs did not respond to the question about causes and eight did not respond to the one about prevention; instead they focused on listing measures to be taken once another pandemic breaks out and not how to prevent its occurrence. Tables 1 and 2 show the percentage of PETs that responded in each category, for each One Health dimension, relative to those that responded to the question asked.

Table 1. Percentage of PET ($n = 41$) identified causes that encourage the emergence of pandemics in each category of the One Health approach dimensions.

| One Health Dimension | Category | Percentage |
|----------------------|--------------------------------|------------|
| Human | Total | 70.1 |
| | Way of life | 41.5 |
| | Social relationships | 24.4 |
| | Hygiene and eating habits | 17.1 |
| | Travelling | 14.6 |
| | Health system deficiencies | 9.8 |
| | Research activity | 9.8 |
| | Lack of a global policy agenda | 2.4 |
| | Not specified | 19.5 |
| Environment | Total | 31.7 |
| | Climate change | 12.2 |
| | Changes in ecosystems | 12.2 |
| | Not specified | 19.5 |
| Animal | Total | 12.2 |
| | Contact with animals | 9.8 |
| | Animal consumption | 4.9 |
| | Animal trade | 2.4 |

Table 2. Percentage of PET (PET ($n = 35$) proposed actions for preventing another pandemic in each category of the One Health approach dimensions.

| One Health Dimension | Category | Percentage |
|----------------------|--|------------|
| Human | Total | 88.6 |
| | Changes in way of life | 62.9 |
| | Improving hygiene and eating habits | 45.7 |
| | Reducing relationships | 31.4 |
| | Progress and investment in science | 48.6 |
| | Investment in health system | 17.1 |
| | Global policy agenda | 5.7 |
| | Education | 2.9 |
| Environment | Total | 34.3 |
| | Protecting nature | 25.7 |
| | Avoiding deforestation and species extinction | 5.7 |
| | Others (renewable energies, diminishing pollution) | 8.6 |
| Animal | Total | 14.3 |
| | Taking care in contact with animals | 8.6 |
| | Controlling hunting and fishing | 2.9 |
| | Avoiding wild animals trade | 2.9 |

As shown in Table 1, most of the PETs (70.1%) pointed to aspects related to the human dimension as causes of pandemics. Most of the categories in Table 2 agree to a high degree with those shown in Table 1 regarding the origin of pandemics, which gives an idea of the level of consistency shown by the students in their answers. Almost half of causes and over 60% of prevention actions alluded to lifestyle aspects such as hygiene and eating habits, travelling, and social relationships, coinciding with the measures put in place by health authorities to curb the spread of the SARS-CoV-2 virus:

“Also, if we increase the number of relationships between people, the virus will have more opportunities to enter our bodies”. [Damasio]

“Lack of sanitary measures can increase the formation of viruses, which means that if there is a lot of dirt and we do not take the necessary measures, more viruses can be created, mutated and transmitted”. [Blanca]

Nearly 10% blamed the origin of pandemics on research activity in laboratories:

“I believe that the emergence of pandemics such as COVID-19 may be encouraged by the research that is increasingly being done today. In fact, there is a lot of laboratory work being done nowadays and there are more chances for errors to occur there”. [Gloria]

In a question not analyzed in this paper, on the origin of SARS-CoV-2, 23.3% of PETs placed it in a laboratory, either intentionally or accidentally. In contrast, research and science activity were seen as necessary by almost half of PETs, who addressed investing in science and conducting research to help advance knowledge as preventive actions against future pandemics.

“To prevent another pandemic, I think investing in science would be the most important thing. If we knew more about the different viruses and the different ways to treat them, the current scenario would be completely different. Therefore, in order to know more about the above, research is essential, and for that, investment in research should be much higher than it is today”. [Humberto]

Although rare, the allusions to the lack of empathy or common or shared political agendas are of great interest, as they reflect aspects of critical and systemic thinking; in this case, the global political system and inequalities between countries. Here, 2.4% of causes and 5.7% of actions addressed this issue:

“Societal behaviors can encourage the emergence of pandemics such as COVID-19. For me, one characteristic that stands out is the empathy that countries have for each other; if all countries respected each other, the occurrence of pandemics would decrease. On the contrary, being selfish increases the occurrence of pandemics”. [Itziar]

A minority of respondents (Table 1) linked the origin of pandemics to animals or the environment. Only 12.2% mentioned animals when explaining possible causes of pandemics:

“In my opinion, eating raw animals. Because they can transmit many diseases”. [Jazmin]

This low percentage contrasts with the cause of the COVID-19 pandemic, where the majority hypothesis is that it is a zoonosis [21], and with the fact that zoonoses accounted for more than 60% of the emerging infectious diseases of the 335 events studied between 1940 and 2004 [22].

Almost a third of PETs mentioned environmental problems as contributing to the emergence of pandemics either generally or by specifying changes in ecosystems or the problem of climate change:

“In my opinion, climate change can have a major impact on the emergence of new viruses and diseases. After all, changing the climate of our planet in such a

violent way can have serious consequences for ecosystems and the environment and, as a result, lead to natural disasters.” [June]

The percentage of responses in the environment and animal dimensions were slightly higher for actions than for causes. In the case of the actions in the environment and animal dimensions, direct actions, i.e., the identification of system components that one can influence through one’s behavior and thus modify the system [19], were a minority. In fact, only 8.6% of the actions in the environmental component corresponded to direct actions, such as reducing consumption, recycling, using public transport, etc.:

“As I said, I think the reason for pandemics like this is climate change. Therefore, in order to avoid more pandemics, we should encourage actions that do not contribute to climate change. In our case, by using public transport more, that is, by using the car less, or by using second-hand objects, such as clothes, books . . . ” [Fabián]

The rest consisted of non-direct actions, such as avoiding pollution, deforestation or species extinction, promoting the use of renewable energies, switching to sustainable modes of production, or more general proposals such as conserving nature. An example is illustrated below:

“In line with the above, I believe it is essential to take care of the environment, animal, and plant species. Some of the actions we can take include: cutting down fewer trees, controlling fishing and hunting, etc.” [Begoña]

Direct actions related to the animal dimension also accounted for 8.6% of the proposed actions, all of which consisted of taking care when in contact with animals:

“Be very careful with the animals we are in contact with.” [Clara]

There were also other non-direct proposals such as preventing trade in animals and controlling the hunting and fishing of animals.

3.2. Students’ Alignment to One Health Approach

The identification of the interrelations between the dimensions of the One Health approach by PETs when explaining the potential causes of pandemics and actions for prevention is summarized in Table 3.

Table 3. Percentage of PETs’ responses in each level of performance in interrelationship-identification among the dimensions in the One Health approach.

| Level | Types | Causes | Prevention-Actions |
|---------------------------|--------------------------|--------|--------------------|
| 2 Justified interrelation | Total | 7.2 | 2.9 |
| | Human-Environment | 2.4 | |
| | Animal | 4.8 | |
| | Environment | | 2.9 |
| 1 Implicit interrelation | Total | 34.1 | 40.1 |
| | Environment-animal-human | 2.4 | 2.9 |
| | Environment-animal | 0 | 2.9 |
| | Human-environment | 7.4 | 20 |
| | Animal-human | 2.4 | 8.6 |
| | Animal | 2.4 | |
| 0 No interrelation | Environment | 19.5 | 5.7 |
| | Only human | 58.5 | 57.1 |

Most PETs did not identify the interrelationships between the three dimensions (human-environment-animal) as potential causes of future pandemics, which is reflected in the results in level 0 for both responses in Table 3. PETs did not show any awareness about human health being influenced by environment or animal health. Their responses about

causes of pandemics or actions for preventing them were limited to social or individual activities.

Fewer PETs showed the second level of systems thinking in their answers [6], which corresponds to identifying the relationships and interrelations between the components. Thus, when asked about human health related pandemics, 34.1% (referring to causes) and 40.1% (referring to prevention actions) linked human health problems to animal and environment health implicitly, respectively. In the next example, it can be seen that Boris, when explaining the causes that can increase pandemics, talked about nature and animals, but did not explain what changes in nature may cause that emergence.

“In this case, it is believed that COVID-19 was caused by an animal, which would be a nature-related reason. Therefore, changes in nature and factors that can cause a pandemic must be monitored and evaluated. Indeed, nature is full of surprises, so observing that is essential. However, infection among people can also lead to the spread of a pandemic”. [Boris]

Similarly, Herminia proposed to care of the planet to prevent pandemics, but did not develop an argument to justify her position.

“To prevent a new pandemic, we should take better care of our planet, i.e., the nature around us. To maintain the balance and prevent the extinction of species, viruses, and bacteria, the different habitats must be taken care of. On the other hand, if a new virus appears that affects humans in this way, countries should isolate themselves better, so as not to spread it”. [Herminia]

Only a few PETs demonstrated more complex thinking when addressing the potential causes and actions for preventing future pandemics and were situated in level 3, as the examples below illustrate. These PETs explained the interrelationships between health factors, they justified the relationship between them by explaining the mechanism. For example, Alazne not only mentioned animals, but also the fact that they have viruses that can be transmitted to humans, providing specific examples on how this happens (through eating or keeping animals with us). Another example is Kevin’s answer. When talking about balance, he justified why balance is important, linking it to the distribution of viruses between the species.

“Although epidemics have existed throughout human history, they now seem to have intensified. Because humans are used to tasting new animals or keeping them. Some animals have viruses that can infect humans and, by eating or keeping them, can transmit these viruses to humans”. [Alazne]

“To prevent another pandemic, we must primarily take care of planet earth, because for there to be a balance between animals, plants, viruses, bacteria and other living things in an ecosystem, it is necessary for habitats to be well preserved and in balance. In these situations, viruses are distributed between species and do not affect humans as directly as in this situation. When nature is changed or destroyed, ecosystems are weakened and the spread of potential pathogens is facilitated”. [Kevin]

4. Discussion and Implications for Health Education

The results of the first research question show that most participants focused in their answers on the human dimension when they were asked about the potential causes and actions to prevent future pandemics such as COVID-19. The other two dimensions (environment and animal dimensions) that form part of the One Health notion, most specifically the animal dimension, were barely mentioned by participants. We have to acknowledge that this research has limitations related to the data available for the analysis of the research questions. In the future, more data sources will be considered, such as interviews or oral debates in which participants may show or not the consideration of the multiple dimensions. Yet, we consider these results remarkable, taking into consideration that the zoonotic origin of SARS-COV-2 is the majoritarian hypothesis suggested by scientists and published by

the media. It seems that the PETs' responses regarding the potential causes of pandemics focus their attention on the factors and measurements adopted by the authorities to contain the spread of the disease among the population: reducing mobility, improving hygiene habits, and limiting social interactions, among others. The few references to animal and environmental dimensions in their responses might be affected by the scarce attention these dimensions received by media (TV, social media, newspapers, etc.) during the pandemic.

Regarding the second research question, we could say that participants showed a very simple vision regarding the pandemic, far from the systems thinking required to apply the One Health notion. According to the levels of systems thinking proposed by Hmelo-Silver and Pfeffer [23], the PETs' performance corresponds to the beginner level. When they were asked to indicate potential causes of future pandemics, more than half of the responses were limited to the human dimension. Hmelo-Silver and Pfeffer [23] categorized low-level systems thinking by novices as thinking focused on structural components, particularly the visible ones, which in the case of our study would correspond to those of the human dimension. Furthermore, even when they linked human health related pandemics to environmental or animal health, they were limited to refer to the components, but they did not refer to the processes and/or mechanisms that related the different dimensions. These results confirm that, as Hmelo-Silver and Pfeffer [23] pointed out, explaining the interrelationships among diverse dimensions, and explaining causal relationships between actions and their consequences, is not an easy task. The fact that participants' performance in systems and critical thinking in a One Health context was so low compared to the results from other studies looking at systems thinking when studying the human body [15], the rock cycle [24], or other geological [6,25] or biological systems [23], suggests that the context of the pandemic was challenging for them. The current pandemic constitutes a complex SSI in which uncertainty persists [4], and misinformation regarding its causes and consequences are easily spread by social media, which might explain these results. According to Dillon and Avraamidou [2], students need to develop the ability to resolve the uncertainty that characterizes these problems, thus we will consider this aspect in future research.

Educational implications point to the important of addressing this issue and integrating the One Health notion in biology and health teaching, but also in teacher training, as this study reveals. Participants in this study were able to point to some environmental problems as potential causes of future pandemics, but their answers did not reflect what Colucci-Gray and Gray [13] called "critical consciousness". Most of them were not critical with their own environmental behaviors, and were thus unable to grasp the importance of their actions in caring for the environment and helping to prevent pandemics from this point of view. Future designs should take this into consideration if we want to make students and future teachers aware of their own actions as well as empower them to take responsibility for the protection of the environment and human health.

COVID-19 highlights the relevance of human individual actions, but also indirect actions such as avoiding pollution, loss of biodiversity, species extinction, use of renewal energy, among other measures, that depend on political agendas. Individual actions and real changes depend on shared political agendas. Students need to be informed about the policies and practices that have contributed to the current pandemic and teachers should be prepared to encourage them to question and reconsider these policies using the One Health approach. Critical thinking and systemic thinking for action requires informed critical thinkers able to critically assess indirect actions and engage in decision-making processes based on this approach.

The pandemic is teaching us key lessons about the impact of human activities on the health of the environment and human health. Human health depends on nature's health; therefore, educators and teachers' educators have to make an effort and invest time in their teaching to engage them in activities and actions that help them to cultivate "critical consciousness" and develop "systemic thinking" for dealing with the environmental and health problems we face now and in the future.

The results of this study stimulate the authors to develop further research on how to design activities and to provide students with tools that help them to achieve these goals.

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References

1. United Nations Environment Programme. Available online: <https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/34948/MPN.pdf> (accessed on 20 October 2021).
2. Dillon, J.; Avraamidou, L. Towards a viable response to COVID-19 from the science education community. *J. Act. Sci. Technol. Educ.* **2021**, *11*, 40–45. [[CrossRef](#)]
3. Lakner, Z.; Plasek, B.; Kiss, A.; Soos, S.; Temesi, A. Derailment or turning point? The effect of the COVID-19 pandemic on sustainability-related thinking. *Sustainability* **2021**, *13*, 5506. [[CrossRef](#)]
4. Jiménez Aleixandre, M.P.; Puig, B. Educating critical citizens to face post-truth: The time is now. In *Critical Thinking in Biology and Environmental Education. Facing Challenges in a Post-Truth World*; Puig, B., Jiménez-Aleixandre, M.P., Eds.; Springer: Dordrecht, The Netherlands, 2021.
5. Christensen, C.; Fensham, P.J. Risk, uncertainty and complexity in science education. In *Second International Handbook of Science Education*; Fraser, B.J., Tobin, K.G., McRobbie, C.J., Eds.; Springer: Dordrecht, The Netherlands, 2012; Volume 1, pp. 751–769. [[CrossRef](#)]
6. Ben-Zvi-Assaraf, O.; Orion, N. Development of system thinking skills in the context of Earth system education. *J. Res. Sci. Teach.* **2005**, *42*, 518–560. [[CrossRef](#)]
7. Less, R. Modeling students modeling abilities: The teaching and learning of complex systems in Education. *J. Learn. Sci.* **2006**, *15*, 45–52. [[CrossRef](#)]
8. Hutchins, F.T.; Brown, L.D.; Poulsen, K.P. An anthropological approach to teaching health sciences students cultural competency in a field school program. *Acad. Med.* **2014**, *89*, 251–256. [[CrossRef](#)] [[PubMed](#)]
9. WHO. Available online: <https://www.who.int/news/item/20-05-2021-new-international-expert-panel-to-address-the-emergence-and-spread-of-zoonotic-diseases> (accessed on 20 October 2021).
10. Saribas, D.; Çetinkaya, E. Pre-service teachers' analysis of claims about COVID-19 in an online course. *Sci. Educ.* **2021**, *30*, 235–266. [[CrossRef](#)]
11. Puig, B.; Blanco-Anaya, P.; Pérez-Maceira, J.J. Fake news or real science? Critical thinking to assess information on COVID-19. *Front. Educ.* **2021**, *6*, 646909. [[CrossRef](#)]
12. Erduran, S. Science education and the pandemic, 1 year on. Emergence of new conceptual tools and re-calibration of existing educational approaches. *Sci. Educ.* **2021**, *30*, 201–204. [[CrossRef](#)] [[PubMed](#)]
13. Colucci-Gray, L.; Gray, D. Critical thinking in the flesh: Movement and metaphors in a world in flux. In *Critical Thinking in Biology and Environmental Education. Facing Challenges in a Post-Truth World*; Puig, B., Jiménez-Aleixandre, M.P., Eds.; Springer: Dordrecht, The Netherlands, 2020.
14. Gilissen, M.G.R.; Knippels, M.P.J.; Verhoeff, R.P.; van Joolingen, W.R. Teachers' and educators' perspectives on systems thinking and its implementation in Dutch biology education. *J. Biol. Educ.* **2020**, *54*, 485–496. [[CrossRef](#)]
15. Snapir, Z.; Eberbach, C.; Ben-Zvi-Assaraf, O.; Hmelo-Silver, C.; Tripto, J. Characterising the development of the understanding of human body systems in high-school biology students—A longitudinal study. *Int. J. Sci. Educ.* **2017**, *39*, 2092–2127. [[CrossRef](#)]
16. Lack, C.W.; Rousseau, J. *Critical Thinking, Science, and Pseudoscience*; Springer: New York, NY, USA, 2016.
17. Paul, R.; Elder, L. *Critical Thinking*, 2nd ed.; Pearson Prentice Hall: Upper Saddle River, NJ, USA, 2006.

18. Gobierno de España. Departamento de Seguridad Nacional [Government of Spain. Department of National Security]. Available online: <https://www.dsn.gob.es/es/actualidad/sala-prensa/coronavirus-covid-19-14-septiembre-2020> (accessed on 8 April 2021).
19. Ossimitz, G. Teaching system dynamics and systems thinking in Austria and Germany. In *Sustainability in the Third Millennium, Proceedings of the 18th International Conference of the System Dynamics Society, Bergen, Norway, 6–10 August 2000*; Davidsen, P., Ford, D.N., Mashayekhi, A., Eds.; System Dynamics Society: Littleton, MA, USA, 2000.
20. Lincoln, Y.S.; Guba, E.G. *Naturalistic Inquiry*; SAGE Publications: Newbury Park, CA, USA, 1985.
21. Maxmen, A.; Mallapaty, S. The covid lab-leak hypothesis: What scientists do and don't know. *Nature* **2021**, *594*, 313–315. [[CrossRef](#)]
22. Jones, K.E.; Patel, N.G.; Levy, M.A.; Storeygard, A.; Balk, D.; Gittleman, J.L.; Daszak, P. Global trends in emerging infectious diseases. *Nature* **2008**, *451*, 990–994. [[CrossRef](#)] [[PubMed](#)]
23. Hmelo-Silver, C.E.; Pfeffer, M.G. Comparing expert and novice understanding of a complex system from the perspective of structures, behaviors, and functions. *Cogn. Sci.* **2004**, *28*, 127–138. [[CrossRef](#)]
24. Kali, Y.; Orion, N.; Eylon, B.-S. Effect of knowledge integration activities on students' perception of the Earth's crust as a cyclic system. *J. Res. Sci. Teach.* **2003**, *40*, 545–565. [[CrossRef](#)]
25. Baztri, O.; Ben Zvi Assaraf, O.; Cohen, C.; Orion, N. Understanding the Earth systems: Expressions of dynamic and cyclic thinking among university students. *J. Sci. Educ. Technol.* **2015**, *24*, 761–775. [[CrossRef](#)]