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Exploring Primary Preservice Teachers' Agency and Systems Thinking in the Context of the COVID-19 Pandemic

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The science education curriculum has become increasingly focused on the study of complex systems and on the development of agency so that students make decisions on relevant issues. The current pandemic has underlined the need to look at health from a systemic "One Health" approach, but little is known about the knowledge, skills, attitudes, and actions necessary for individuals to successfully contribute to One Health. This study seeks to contribute to this knowledge, and explores preservice elementary teachers' agency and systems thinking competencies to propose actions for preventing future pandemics from the One Health approach. The participants were 47 preservice elementary teachers working on a set of activities about the COVID-19 pandemic, in which they were asked about ways to prevent future pandemics. Content analysis of individual written responses was applied for addressing the level of systems thinking and the sense of personal and collective responsibility toward the action proposed. Results show that the preservice teachers initially referred mainly to actions in the human health dimension, and that the systems thinking showed a higher level when they made the activity in groups after reading information. Collectively proposed actions showed a lack of agency or individual responsibility compared to individually proposed ones. The implications of the results for science teaching are discussed.

Keywords: agency, COVID-19 pandemic, health education, One Health, environmental problems, preservice elementary teachers, systems thinking

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INTRODUCTION

Science education faces urgent challenges related to health and environmental problems, as the current pandemic shows. During the COVID-19 pandemic, citizens all over the world were called upon to take actions and make responsible decisions to stop the spread of the disease. However, little information was aimed at putting this pandemic in context with the situation of emerging infectious diseases (Jones et al., 2008) or at explaining the factors that may promote its emergence, including environmental ones (World Health Organization [WHO], 2021). 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. 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" (United Nations Environment Programme [UNEP], 2021, p. 4).

Science education should address this issue (Zeyer and Kyburz-Graber, 2012), as it aims to develop critical citizens who make informed decisions about the problems they face. In fact, the experts preparing the PISA assessment program for 2024 (Organisation for Economic Co-operation and Development [OECD], 2020) made a reflection and defined a vision "based on the principle that scientific knowledge and competencies are important and valuable for young people's futures, but that identity outcomes (and the extent to which young people feel meaningfully connected to science, as critical consumers and producers of science in their daily lives) are also crucial for supporting agency and active citizenship in a rapidly changing world" (p. 2). This led the experts to recommend the creation of three new knowledge areas, one of which is 'Socio-environmental Systems and Sustainability' and the addition of two new competencies, 'Using scientific knowledge for decision-making and action' and 'Using probabilistic thinking.' Consequently, science education should enhance students to build scientific knowledge from a systemic view and to develop critical thinking skills for decision-making and responsible actions. Furthermore, it should help to create an identity, to foster values and to promote agency.

Citizens are expected to make decisions and take actions in these complex systems, not only to cope with problems they are facing in the present, but to prevent problems in the future. Science educators have started to incorporate the development of futures thinking, agency and action competence in science education (Levrini et al., 2021). Besides, in response to the COVID-19 pandemic, science educators around the world are working together to find ways to develop health literacy and critical thinking to understand this emergent disease and to avoid the rise of disinformation (Dillon and Avraamidou, 2021; Puig and Evagorou, 2022).

Despite this pandemic showing us the need to understand the links between human health and global environmental change, few studies have addressed the interactions between environmental, animal, and human health or the causes of the increase of pandemics (Lakner et al., 2021). COVID-19 is an emergent disease, and as such it can be characterized as a socio-scientific issue (SSI) that demands not only responsible citizenship skills (Dillon and Avraamidou, 2021), but also a systemic view of the different factors involved in this problem. The factors involved are manifold and condition both the emergence of epidemics and pandemics and their management, and concern all social, cultural, political and ecological spheres. 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 (2012), "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" (p. 15). This study aims to fill this gap by engaging preservice elementary teachers in diverse activities that require to use systems thinking and to develop agency.

Systems Thinking in Health-Related Problems: The One Health Approach

The notions of systems and systems thinking have been defined in a variety of ways, which is reflected in the views of biology educators (Gilissen et al., 2020). 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 (Ben-Zvi-Assaraf and Orion, 2005). On this basis, systems thinking is characterized by, among other things, identifying the different parts or components of the system, their processes or behaviors and the functions or phenomena resulting from these interactions (Ben-Zvi-Assaraf and Orion, 2005; Snapir et al., 2017). Systems thinking has been developed in science education, but mostly applied to natural systems, such as ecosystems (Hmelo-Silver et al., 2017; Mambrey et al., 2022), human body (Snapir et al., 2017), or geological systems (Ben-Zvi-Assaraf and Orion, 2005).

Science education curricula have become increasingly focused on the study of complex systems (Less, 2006), for example those which imply interactions between natural and social systems. The pandemic has shown us the importance of introducing a systemic view when addressing socio-scientific issues such as COVID-19. In a world characterized by uncertainty, individuals will need to think in a more integrated way that avoids premature conclusions and recognizes interdependencies (Organisation for Economic Co-operation and Development [OECD], 2018). Students will need to apply their knowledge and skills in unknown and evolving circumstances, as the current pandemic shows.

The systemic and holistic view is necessary to address issues related to sustainability (United Nations [UN], 2015) and health. Indeed, the Food and Agriculture Organization of the United Nations, World Organisation for Animal Health, World Health Organization [FAO, OIE, WHO], 2019) where they developed the One Health approach, which looks at the environment–animal–human system and specifically at the interactions between the parts of that system, that make that the health of animals, of the environment and of humans be interconnected and interdependent.

For centuries, scientists have recognized the close relationship between human, animal, and environmental health (Hutchins et al., 2014). 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: "To end the triple planetary crisis of climate change, biodiversity loss and pollution that threaten our peace and prosperity, we must understand that human, animal and planetary health go hand in hand. We must do more to promote transformative actions that target the root causes of nature's destruction" (World Health Organization [WHO], 2021). 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.

The One Health approach implies systems thinking, but no studies have been found in the literature review on this topic in a teaching/learning context related to this notion. Perhaps this is because it is a relatively recent term. However, some studies in the context of environmental education and/or Education for Sustainable Development (ESD) have dealt with systems thinking. Authors such as Hofman-Bergholm (2018) advocate introducing systems thinking in education as one of the keys to achieving sustainability: "Perhaps systems thinking, and systems education could be the missing tools needed to develop the holistic thinking required in the work toward a sustainable future." (p. 3). The United Nations Educational, Scientific and Cultural Organization [UNESCO] highlighted the need for developing systems thinking in ESD activities and programs both in the final report of the UN Decade of ESD (2005–2014) (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014) and in the roadmap for 2030 for the future of ESD (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2020). Indeed, several proposals to define the competencies for ESD that educators should have also make explicit reference to systems thinking (Sleurs, 2008; United Nations Economic Commission for Europe [UNECE], 2012). Nevertheless, teacher trainees have shown deficiencies in systems thinking. For instance, in Palmberg et al.'s (2017) study, three quarters of the 424 Nordic teacher trainees showed no evidence of systems thinking when relating species identification, biodiversity, and sustainable development. This study seeks to contribute to empirical research on systems thinking in the context of applying the notion of One Health to propose actions to prevent pandemics like COVID-19.

Action Competence and Agency

Funtowicz and Ravetz (1993) introduced the concept of 'postnormal' science and stated that in the case of socio-environmental systems, which entail high levels of risk and uncertainty, individuals' values are fundamental, not secondary, elements. In this scenario, experts and non-experts have a more balanced power of decision-making, given that there are no definitive solutions endorsed by science. In the face of an increasingly uncertain and complex world, both science education and environmental education can help students embrace the challenges we are confronted with, as the current pandemic shows. The OECD Education 2030 project (Organisation for Economic Co-operation and Development [OECD], 2018) contributes to the UN 2030 Global Goals for Sustainable Development, aiming to ensure the sustainability of people and the planet.

Education has a vital role to play in developing the knowledge, skills, attitudes, and values that enable people to contribute to and benefit from an inclusive and sustainable future. Students need to practice agency and to develop action competence in the science classroom. Agency is a term whose theoretical meaning is often defined too narrowly and unclearly (Oliveira et al., 2013). In this paper, we draw from the definition of agency provided by Levrini et al. (2021), who consider it as the capacity to take responsibility for global challenges, take part in decisions and consciously influence events and circumstances to realize the desired future scenario. Therefore, the notion of agency involves a sense of responsibility to participate in the world and, in so doing, to influence people, circumstances and events for the better.

Agency and action have gained prominence during the current pandemic; however, they have been an object of concern for environmental education for a long time. Several Danish environmental educators (Breiting, 1997; Jensen and Schnack, 1997) called for environmental education being directed toward training for action and considering the conflicts of interest entailed by every environmental problem. In this way, the abilities to think critically, to clarify one's own values, to put oneself in somebody else's shoes, to discern the data on which an argument is based, to decide, and to act in consequence become the fundamental educational objectives to be pursued. Jensen and Schnack (1997) fostered the concept of action competence, associating competence with the ability and desire to be a qualified participant, and emphasizing the intentionality of actions to distinguish them from behaviors, activities, and habits. They counterposed the search for action competence to the search for behavioral change, a primary objective of most current environmental education activities and programs. In behavior-changing activities, educators decide what is the best behavior for the good of the environment, basing their decision on the certainty of scientific analyses, without considering other factors, such as the values of the individuals involved. Researchers (Funtowicz and Ravetz, 1993) and educators (Bonil et al., 2004) concerned by the complexity of scientific issues indicate that if the activity is successful, the participants will demonstrate appropriate behavior, but it is unlikely that they will have developed the competence to act in response to new problems or to jointly construct a sustainable society.

In contrast, in the activities designed to train for action the educational process is more important than the product. From this perspective, the educator should not direct his or her efforts toward achieving a specific change in behavior, but rather he/she should facilitate scenarios that can develop students' abilities in a way that enables them to decide, using their critical thinking skills, what direction change should be taken in a democratic way. The aim, consequently, is to develop "a critical, reflective and participatory approach in which the future adult can cope with environmental problems in a democratic way, instead of prescribing to pupils certain behavioral patterns here and now that we believe contribute to solving current environmental problems" (Mogensen and Mayer, 2005, p. 14).

Building on the OECD 2030 Learning Framework (Organisation for Economic Co-operation and Development [OECD], 2018), we agree that science education should prepare

students to be change agents, which implies that they can have a positive impact on the environment and anticipate the short and long-term consequences of what they do. According to Hodson (2003), action competency requires the mobilization of knowledge, skills, attitudes, and values to meet complex demands. Thus, students should learn how to engage and experience participation in action. Students' consciousness of a problem and the causes is based not only on their opinions and motivation, but also on their views and commitment (Chen and Liu, 2020). Pedagogical strategies for positioning students as agents vary widely with school subject, but are socio-culturally mediated, as Oliveira et al. (2013) pointed out. These authors propose a model of environmental agency in which agency is not strictly inside the mental processes of individuals, rather environmentally protective behavior emerges in students' sociocultural interactions with existing environmental social structures. Furthermore, research in action emphasizes the importance of distinguishing learning *about* action, *through* action, and *from* action. This study attends to the first perspective, although we support that the three can be enhanced. This study seeks to engage students in the process of proposing actions that can help to avoid/prevent future pandemics. We want to make students conscious of their own actions and reflect on the ones that alter positively or negatively human, animal, and environmental health. According to Hodson (2003), substantive knowledge, guided toward action, is crucial to understand the issue underlying a problem and to make informed decisions and arguments. In the context of proposing actions for avoiding future pandemics, we view knowledge on the One Health notion and systems thinking as critical, as explored in the previous section.

The research questions are:

> RQ1. What actions proposed by preservice teachers to avoid future pandemics such as COVID-19 integrate systems thinking? To what extent do individual actions differ from collective actions regarding systems thinking?
>
> RQ2. How do actions proposed by preservice teachers to avoid future pandemics such as COVID-19 reflect a sense of responsibility or agency? To what extent do those proposed collectively differ from those proposed individually?

MATERIALS AND METHODS

Context and Participants

The activities were designed and implemented in a course that started in September 2021. The participants were 47 pre-service elementary teachers – 28 females and 19 males – in the fourth year of their Primary Education Degree (typically undertaken at 22 years old) at a Spanish university. The number of COVID-19 cases was falling, and the majority of the population was vaccinated, although at the beginning of the course the teaching modalities were adapted so that half of the students were at home attending the classes by videoconference. At the time of the implementation of the activities, all students attended classes on site.

The activities on the origins of epidemics and pandemics lasted a total of 3 h and took place over the course of one session. First, preservice teachers answered an open-ended questionnaire about pandemics. Secondly, they were provided with information by means of popular science articles about the emergence of epidemics and the link between environmental problems and zoonosis. In small groups (11 groups, named A–K), they made a conceptual map of the origins of pandemics and proposed actions to avoid future pandemics.

Research Tools

For this study, the actions proposed by preservice teachers in two activities were considered, namely the individual answers of one question included in the initial individual questionnaire and the actions proposed by small groups. The question "*What can we do to prevent another pandemic? Describe in your own words the concrete actions we can take*" sought to get preservice teachers to situate their thinking in complex cause-and-effect relationships (Ossimitz, 2000; Ben-Zvi-Assaraf and Orion, 2005) and placed the question in what Ossimitz (2000) 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, which is linked to agency.

All participants gave informed consent for their answers to be used as research data. The names used for preservice teachers are not their real names, but pseudonyms. Preservice teachers with a pseudonym starting with the same letter are from the same group.

Data Analysis

Given the nature of the research questions, the study was mainly based on the interpretative analysis (Erickson, 1986) of data of a qualitative nature. To address RQ1, individual and collective written responses were coded in two categories of systems thinking, according to Ben-Zvi-Assaraf's and Orion's (2005) proposal: (a) Components of the system (One Health dimensions) and (b) Interrelations between the components of the system (One Health dimensions). In this case, the phenomenon would be the increase in epidemics, and the interrelations, the processes of generation and release of new viruses, the processes of transmission of viruses (between animals, between animals and humans, and between humans), and the processes that make increase or decrease of the latter, such as deforestation, the movement of animals, the movement of people, or socio-economic activities, among others. Preservice teachers' answers regarding the establishment of interrelations were assigned to a level, considering the allusion to dimensions other than the human one (that is already implicitly included in the topic of pandemics), and the justification of the relationships between the One Health dimensions. These three levels were established:

> *Level 0*: Includes the responses that only referred to the human dimension, which means that students were not able

to identify environmental and animal as dimensions that need to be considered to prevent future pandemics.

Level 1: Includes the responses that alluded to other dimensions besides the human one. This could be done by explicitly referring to actions in various dimensions or by referring to the environment or animals when asked about human health-related issues. Although these answers did not explain the interactions between the dimensions mentioned, they implicitly interrelated them.

Level 2: Consists of responses that, besides fulfilling the criteria for being in level 1, justified the interrelations between the different dimensions (two dimensions or three) of the One Health notion.

The first author identified the One Health dimensions to which preservice teachers referred in their writings, and, after applying a constant comparison method (Lincoln and Guba, 1985) to the data, emergent categories were established into the dimensions. The second author revised the categories and results. Disagreements were discussed to reach a consensus.

To address RQ2, individual and collective proposed actions were categorized as Indirect actions and Direct actions. Indirect actions are considered actions one cannot take alone, since they depend on others, such as political agendas and institutions, to do so. Direct actions are actions that preservice teachers can carry out themselves, thus they do not depend on others. For instance, to wear a mask, to recycle, to eat less meat. Following Granit-Dgani et al. (2017), two subcategories were identified within this according to the sense of personal and collective responsibility toward the action proposed. For this, attention was on how the writing responses reflected the construal of identity by using the first-person single and/or plural. Thus, the category of direct actions was divided into (a) *direct implicit actions*, which corresponded to actions that did not show participants' explicit awareness of being agents for the action proposed as they did not use the first-person; (b) *direct explicit actions* includes actions proposed by preservice teachers using the first-person, which means that they showed an explicit awareness of being agents for the action.

RESULTS

Integration of Systems Thinking in the Actions Proposed by Preservice Teachers

The analysis of RQ1 *What actions proposed by preservice teachers to avoid future pandemics such as COVID-19 integrate systems thinking? To what extent do individual actions differ from collective actions regarding systems thinking?*, is developed in this section. First, we review data on the types of actions proposed individually and then we compare individual proposals with collective ones.

A total of 111 actions were proposed by preservice teachers in their individual responses: 81 (73%) related to the human dimension, 23 (20.7%) to the environmental dimension, and 7 (6.3%) to the animal one. Indeed, 90.7% of preservice teachers proposed at least one action linked to the human dimension, 27.9% to the environment, and 16.3% to the animal dimension.

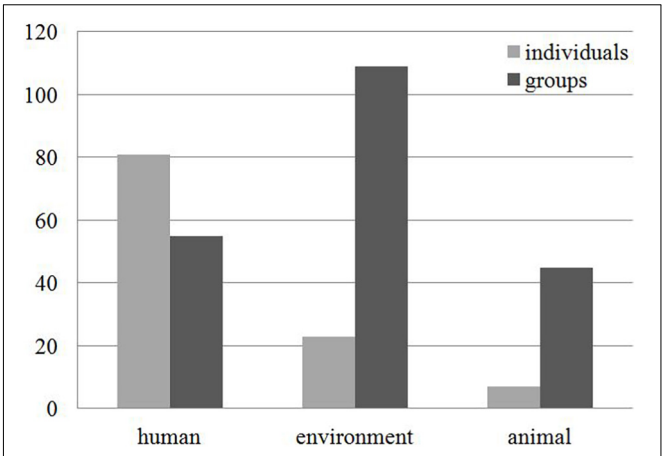

FIGURE 1 | Frequency of actions proposed individually and in groups by preservice teachers to avoid future pandemics, by the corresponding One Health dimension.

The excerpt below shows an example of the human dimension when a student, Jon, appeals to reducing socialization as a measure to avoid another pandemic such as COVID-19.

> "To avoid another pandemic, activities that promote the socialization of people must be reduced (…)." [Jon]

An example of two dimensions, environmental and animal, is reflected in the following response.

> "I believe that not everything is in our hands. Even so, reducing pollution, changing habits (using public transport or bicycles for example), taking care of the landscape and animals, etc. would partly prevent pandemics." [Blanca]

Blanca mentioned diverse factors including taking care of the landscape and animals, which is related to both dimensions. In her answer she referred to these actions as personal actions that can partially prevent pandemics such as COVID-19.

The distribution of individual and collective responses in the One Health dimensions is shown in **Figure 1**.

Actions proposed in small groups were higher in number compared to individual ones; 209 actions were identified. Besides, all groups proposed at least one action in all three dimensions (human, environment, animal). With respect to the consideration of interrelationships among the One Health dimensions, **Table 1** summarizes the results, both for individual and for group proposals.

Level 0. No interrelation: most individual responses were included in this level, since they did not mention other dimensions apart from the human one, implicitly included. We did not identify any group responses at this level. An example of an individual response is the one given by Carmen, which considered globalization and research in laboratories, both in the human dimension:

TABLE 1 | Percentage of individual and group proposals in each level of performance in interrelationship-identification among the dimensions of the One Health approach.

Level	Types	% preservice teachers	% groups
2 Justified interrelation	Total	0	18.2
	Animal	0	18.2
1 Implicit interrelation	Total	32.6	81.8
	Environment–animal–human	9.3	81.8
	Environment–animal	2.3	0
	Environment–human	14	0
	Animal–human	4.7	0
	Animal	0	0
	Environment	2.3	0
0 No interrelation	Only human	62.8	0

> "Reduce globalization, especially in unnecessary global activities. Take more care in research, especially research into diseases." [Carmen]

Level 1. Implicit interrelation: Most individual and group responses are included in this level, although some differences are identified regarding the capacity to integrate the three dimensions of One Health. All group responses mentioned the three dimensions, whereas just a proportion of students were able to do it individually.

The human and the environmental dimensions together are the most frequently mentioned by preservice teachers (14%), as **Table 1** shows. An example is the response of Daniel, who mentioned human dimension actions as experimenting with viruses, or reducing travel between countries, but also considered pollution and natural spaces:

> "Take care of natural spaces, don't pollute so much, reflect on our way of life, don't experiment with viruses. As soon as a new virus appears, stop tourism and relations between countries until it is eradicated." [Daniel]

Individual proposals that mentioned the three dimensions (environment–animal–human) were also present, and some are provided below:

> "I believe that to avoid any kind of pandemic, we have to act more responsibly, observing the consequences of our activities and trying to change them; recycle; use cars that pollute little; carry out awareness campaigns; teach the children who come after us to act responsibly; do not use animals for experiments. In conclusion, we must start taking care of the environment and we can start at home and in our neighborhood. In other words, we can do our bit." [Carol]

> "We need to recycle, and use litter bins; reduce air pollution, and use public transport; implement minimum hygiene measures; more testing of animals, especially wild animals; in case of illness, go to the doctor so as not to infect others; have safety measures in each country and ensure that people comply with them. For example, if masks are compulsory, accept to wear them even if we don't like them." [Irati]

Carol and Irati referred to environmental actions such as recycling, using cars that pollute little or public transport, and actions in the animal dimension such as not using animals in experiments. They also proposed human health measures such as using masks.

Although participants were able to mention the different dimensions individually, they were not able to justify the interrelations between them, as **Table 1** shows. The analysis of collective responses provides similar results; however, some groups did justify the interrelationship when formulating collective actions. For example, Group G when proposing an action linked to animals:

> "Reducing demand for and regulating international trade in live animals, meat and fish products in order to reduce species movements, disease transmission and the development of new pathogen-driver relationships." [Group G]

Students pointed to animal consumption and trade in live animals as potential causes of disease transmission, thus they proposed the reduction and regulation of international trade as measures for preventing future pandemics.

Agency in Actions Proposed by Preservice Teachers

In this section, RQ2 *How do actions proposed by* preservice teachers *to avoid future pandemics such as COVID-19 reflect a sense of responsibility or agency? To what extent do those proposed collectively differ from those proposed individually?* is addressed. Results obtained regarding direct and indirect actions and the integration of agency are first presented, and then individual and group responses are compared in these terms.

The analysis shows that most actions proposed by preservice teachers individually at the beginning of the task were *direct actions*. Particularly, 68.5% were direct actions ($N = 76$) whereas 31.5% ($N = 35$) were *indirect actions*. Considering the examples given above, appealing for controlling experimentation with viruses would be an indirect action, as it is not something they can do themselves, but reducing pollution is a *direct action*, as they can directly contribute to reducing pollution in their day-to-day actions.

Among the *direct actions*, 60% were *direct explicit actions*, since they were formulated using the first person, and the rest were *direct implicit actions*. The following examples illustrate these different types. Jon appealed for reducing socialization activities but Gorka places that same action within his sphere of responsibility.

> "To avoid another pandemic, activities that promote the socialization of people must be reduced (…)." [Jon]

> "At the individual level, we should strictly follow the steps of the scientists, such as avoiding crowds." [Gorka]

Similarly, Belen considered taking care of hygiene, but Gurutze made explicit which everyday actions she could take to maintain hygiene.

"In the same way, it can also be useful to take better care of hygiene and health around the world, both for people and animals." [Belen]

"To avoid a new pandemic, we have to take care of our hygiene first and foremost. That is, we should clean our hands before eating something or after touching something, before putting them to our face, and before putting them to our hands." [Gurutze]

It needs to be highlighted those results are different for each dimension. Regarding the human dimension, more than 2/3 of the actions were *direct actions* (57% of them explicit) and all of them corresponded to pandemic measures dictated by governments to prevent infection by COVID-19 and transmission. It includes wearing a mask (as seen in the Irati example), maintaining hygiene and keeping a safe distance:

"We can do many different activities. On the one hand, we can take care of our habits, especially those related to hygiene. In fact, taking care of cleanliness can stop the spread of viruses like this one." [Borja]

Regarding the environmental dimension, all actions were direct (74% of them explicit) and made reference to recycling (as seen in Carol's and Irati's examples) or taking care of the environment.

In contrast with these results, for the animal dimension, the majority (71%) proposed *indirect actions* and appealed to not carrying out experiments on animals (as in the examples of Carol and Irati). Direct actions (29%), all formulated implicitly, referred to caring for the health of animals, as in the case of Belen.

"In the same way, it can also be useful to take better care of hygiene and health around the world, both for people and animals." [Belen]

When we compare individual proposals to collective proposals some differences are identified. Particularly, in the case of the 209 actions proposed by the groups, 79% were indirect, much more than in the case of individual actions (31.5%). Besides, indirect proposals accounted for the majority in all dimensions (96% in the human dimension, 68% in the environmental dimension and 84% in the animal dimension). Some examples of *indirect actions* proposed by groups are shown below, such as accelerating the energy transition (Group A), facilitating telework (Group C), changing the production of food (Group E), investing in infrastructures (Group G) or giving grants to low-income countries (Group J), all of them outside their field of action:

"Accelerating the energy transition to a carbon-free economy." [Group A]

"Install broadband networks that facilitate telework and telemedicine to help us build a society where we do not accumulate in unhealthy spaces and where income is not related to geography." [Group C]

"Changing the way, we produce food." [Group E]

"Increase investment in animal and health infrastructure, care, information and coordination." [Group G]

TABLE 2 | Percentage of preservice teachers and groups that proposed actions of each type.

		% preservice teachers (*N* = 43)	% groups (*N* = 11)
Direct explicit actions	Any dimension	55.8	36.4
	Human	44.2	9.1
	Environment	23.3	36.4
	Animal	0	0
Direct implicit actions	Any dimension	44.2	100
	Human	37.2	9.1
	Environment	11.6	100
	Animal	4.7	63.6
Indirect actions	Any dimension	55.8	100
	Human	48.8	100
	Environment	0	100
	Animal	11.6	100

"Grants to low-income countries to prevent new infections and find solutions to infections such as vaccines, medicines, ..." [Group J]

With respect to direct actions, only 11% were coded as *direct explicit actions,* written in first person.

Table 2 shows the percentage of preservice teachers (initial) and groups (collective, after reading) that proposed actions of each type. Since all types of actions given by each individual or group were counted, the sum is greater than 100.

Table 2 shows that the percentage of preservice teachers in each type was around 50%. Slightly under half of preservice teachers proposed *direct implicit actions*, and just over half proposed indirect actions and *direct explicit actions*. In the case of groups, all groups proposed *indirect actions* and *direct implicit actions* whereas just over one third of the groups proposed *direct explicit actions*, which accounted, as previously mentioned, for 11% of the total of 209 actions.

DISCUSSION

Regarding RQ1, the results of the individual initial actions proposed by participants show that initially referred mainly to actions in the human health dimension. Among these, most preservice teachers mentioned wearing masks, keeping distance, etc. They made reference to the cultural aspects and differences worldwide that actions such as maintaining social distance or changing eating habits imply. Nevertheless, they hardly mentioned actions linked to environmental or animal health. These results are consistent with the guidelines provided by governments to citizens to act against the current pandemic and reflect the low media coverage and studies disseminated to the general population on these dimensions in relation to the emergence of pandemics (Lakner et al., 2021).

It is significant that the results obtained in this study are very similar to the ones obtained 1 year before with another group of preservice teachers from the same university (Puig and Uskola, 2021). Indeed, we could say that they tend to be even

more marked toward the human dimension, showing a very simple vision about the pandemic, compared to the complex systems thinking implied in the One Health notion. Indeed, the preservice teachers performed at a beginner level according to the levels of systems thinking proposed by Hmelo-Silver and Pfeffer (2004), who 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, which corresponded to 73% of the actions proposed initially. Moreover, the 32.6% of preservice teachers that linked human health to environmental or animal health only mentioned the dimension (component) but did not justify the interrelation. Other studies that analyzed systems thinking of students about the human body (Snapir et al., 2017), the rock cycle (Kali et al., 2003), or other geological (Ben-Zvi-Assaraf and Orion, 2005; Baztri et al., 2015) or biological systems (Hmelo-Silver and Pfeffer, 2004), showed better results, which suggests that the context of the pandemic was challenging for participants. Our results are similar, although lower, to those obtained by Palmberg et al. (2017) with preservice teachers. The context, tasks and analysis tools had differences but in sum both studies point to the difficulties shown by pre-service teachers with systems thinking. The report made by United Nations Educational, Scientific and Cultural Organization [UNESCO] (2014) pointed out the challenges of ESD in primary-secondary education and the lack of ESD educator competencies, one of which is systems thinking (Sleurs, 2008; United Nations Educational Scientific Cultural Organization [UNECE], 2012).

The analysis of actions proposed by groups after they have accessed information shows that the groups performed at a higher level than the individuals initially. Thus, all groups included the three dimensions of the One Health notion. They were also able to justify the interactions between them. This reveals that working in small groups and discussing information on the environment, animal and human health improves students' ability to make relationships between them, making it possible to overcome the difficulties inherent in explaining the interrelationships among diverse dimensions, and explaining causal relationships between actions and their consequences (Hmelo-Silver and Pfeffer, 2004). The importance of working in teams for systems thinking was also highlighted by Gray et al. (2014). Nevertheless, the percentage of groups that justified the interrelations was still quite low at the end, which shows that the systems thinking of preservice teachers has much room for improvement in terms of being aware of and explaining the mechanisms and how they lead to the phenomenon.

In relation to RQ2, the actions proposed by preservice teachers to avoid future pandemics such as COVID-19 reflected a sense of responsibility or agency at the beginning of the task before information on COVID-19 was provided. Most of them proposed *direct explicit actions* related with the human and environmental dimensions, but not for the animal dimension, in which a sense of agency did not emerge from their individual responses. They seemed to understand animal actions as measures that do not depend on them, but on others, since they only mentioned experimentation with animals as an activity to avoid future pandemics.

Actions proposed by groups were higher than individual ones, but in contrast with them, the majority were *indirect actions* or *direct implicit actions*, which reflects a lack of agency or individual responsibility. These results might be influenced by the information provided, which makes reference to the environment and animal dimensions. Groups did not mention human health measures such as wearing masks, avoiding crowded places and keeping a safe distance, as they previously did individually. Instead they focused attention on the information from the texts provided. Furthermore, it needs to be acknowledged that this information suggested indirect actions since it referred to a higher investment in health infrastructure and changes in economic models that depend on companies and institutions, among other issues. That is, political and economical factors where salient in the information, and it seems that preservice teachers perceived them as external more than internal. Another factor that might explain these differences between individual and group proposals might be the effect of dilution of responsibility and identity when working in groups. Students might think about common responsibilities and identify themselves with the group rather than with their own views. Besides, the student that wrote the final response might have adopted the role of secretary of the group, thus he/she did not transfer their own identity to write in first person. We acknowledge that the use of the first person can be conditioned by such circumstances and that this is a limitation of the study, but we consider that its use denotes a greater personal implication than the use of the third person or impersonal forms (Granit-Dgani et al., 2017).

In summary, the information provided and working in groups helped students to consider more dimensions and to link them; however, the level of responsibility or agency reflected in their answers was low or even absent.

CONCLUSION AND IMPLICATIONS

According to the OECD Framework 2030 (Organisation for Economic Co-operation and Development [OECD], 2018), science education should prepare students to be change agents, which requires equipping teachers for this purpose. This study was carried out within a project about how to best equip pre-service teachers to develop agency and the notion of One Health to address health and environmental problems such as COVID-19.

The analysis of RQ1 allows us to conclude that students were able to integrate and justify the three dimensions of the One Health notion when information was provided and discussed in groups. This means that systems thinking can be promoted under these circumstances. We share the reflections of other authors on the need to change some aspects of teacher education. Rosenkränzer et al. (2017) studied the impact of different interventions for fostering pedagogical content knowledge for teaching systems thinking and their conclusion was that a technically oriented course without didactical aspects seemed to be less effective. They propose a course with mainly didactical content and an intervention with a mix of technical and didactical content. One of the recommendations is introducing activities

that facilitate overcoming the traditional organization of the curriculum in the form of separate academic disciplines (Gray et al., 2014; Hofman-Bergholm, 2018). In addition, activities that require group or teamwork (Gray et al., 2014) should have a strong presence in teacher education, as the results of this and previous research suggests this facilitates systems thinking.

Regarding the presence of agency in students' proposals to avoid future pandemics, it is remarkable that group proposals, after the analysis of information, reveal a lesser sense of agency compared to individual ones at the beginning of the task. To help students to enable agency, educators must attend to the different factors that influence its exercise and learning; for instance, the interactions and relationships among students that help them to progress toward the identification of actions to influence people and circumstances for the better. A concept underlying the OECD Learning Framework (Organisation for Economic Co-operation and Development [OECD], 2018) is "co-agency," defined as the interactive, mutually supportive relationships that help learners to progress toward their valued goals. We consider that the sense of co-agency could be mediated by students' identities, values, and attitudes (e.g., empathy, respect for other opinions and views), so these aspects need to be considered when designing activities that engage students in the development of agency through action proposals.

The results of this study point to the need for designing activities that stimulate students' engagement in co-agency (Reis, 2020) when working in small groups. Developing the sense of co-agency might favor students' engagement in actions to protect human, environment, and animal health. Promoting students' agency requires developing from them a sense of responsibility, as Levrini et al. (2021) proposes.

This paper attends to the first steps of a wider project about primary pre-service teachers' training on health and environmental problems such as COVID-19 from the One Health approach. Research regarding teachers' training for this goal is in progress and it requires different cycles of data collection. The current pandemic of COVID-19 emphasizes the need to incorporate co-agency, which aims to make students take responsibilities on the decisions and actions that affect human, animal, and environmental health.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee for Research on Human Subjects of the UPV/EHU CEISH-UPV/EHU [M10_2021_161 research project, approved 20 May 2021 (138/2021)]. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

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