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Influence of Human Biology and Health (HBH) Teaching–Learning Process on Students' Conceptions of the COVID-19 Vaccine

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Abstract: The COVID-19 pandemic created the need for universal vaccination. This study aimed to compare university students' (pre-service teachers) conceptions who had already learned the immune system and vaccination topics in the "Human Biology and Health (HBH)" curricular unit with those who had not yet taken part in it. It also intended to verify the influence of secondary school background, perception of one's own health, feeling at risk for COVID-19 and their own experience with it and scientific knowledge related to SARS-CoV-2 vaccination. It was a cross-sectional study with a mixed methodology for data analysis. A questionnaire was applied online to a sample of 102 university students. Results show that students who had already taken the subject on the immune system and vaccination had more acceptable conceptions about the vaccine and wanted to be vaccinated but not in the initial moment of the national vaccination process. The fear of adverse reactions seemed to be the major hesitancy factor. Furthermore, students' argumentation showed that their conceptions progressed towards more socio-scientific reasoning.

Keywords: science education; science literacy; health literacy

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1. Introduction

The SARS-CoV-2 virus caused the COVID-19 pandemic at the end of 2019, with the initial cases identified in Wuhan, China. Its origin remains unclear, but after many epidemiological studies and several hypotheses, introduction between humans through an intermediate host is considered the most likely route [1]. Given the rapid transmission of the virus, the World Health Organization (WHO) has activated the R&D Blueprint, whose strategy was launched in February 2020 and defined two goals: (i) immediate priorities, to accelerate research in order to contribute to containing the epidemic and facilitate optimal care for those affected; and (ii) a mid-long term, to promote global research platforms to prepare for "unforeseen epidemic and encouraging accelerate research, development and equitable access, based on public health needs, to diagnostics, therapeutics and vaccines" [2] (p. 2)

Although some people have reported only mild or moderate symptoms, this new virus proved highly transmissible and lethal, with more than 6 million deaths and approximately 450 million positive cases worldwide [3] in nearly 15 months. Variants Alpha, Gamma and Delta showed higher pathogenicity, whereas Beta and Omicron improved

peoples' immune defence, elevated reinfections and increased transmissibility [4]. According to the European Centre for Disease Prevention and Control (ECDC) [3], Omicron is dominant in transmission and has a reduced impact on severity, but its impact on transmissibility is unclear. This situation required rapid response through vaccination. Despite the WHO's strategy to accelerate research and produce the vaccine, many people are engaged in social movements sharing information that leads to the perception of threats from COVID-19 vaccines, leading to vaccine hesitancy [5]. Such movements have been already observed for other vaccines before COVID-19, making it difficult to attain Sustainable Development Goal (SDG) 3 and its target 3.8 (which aims at vaccines for all) [6], and were largely disseminated in digital media. They have been defined as a set of attitudes ranging from reluctance to refusal of the vaccination, despite the availability of vaccination services [7]. There are several determinants for vaccination hesitancy, including contextual influences and individual and group influences, as well as vaccine and vaccination-specific issues, including the recent novelty of the COVID-19 vaccines and insufficient testing and knowledge [8].

Given the short period to create and release COVID-19 vaccines and some mistrust about vaccines' safety and effectiveness, great discussion and decision-making processes have occurred, accompanied by intense social controversy [9]. Therefore, when this controversy arises in the classroom, one faces socially acute questions (SAQ), where teaching practice needs to combine school knowledge with social realities [10]. On the other hand, contemporary science education aims to prepare citizens to reason about environmental socio-scientific issues impacting their future to promote active participation and the decision-making process, which is a target of SDG 4, quality education and lifelong learning opportunities, promoting knowledge and skills acquisition [6]. Thus, an educational response that prepares students to be active in decision-making processes is the teaching of SAQs [11].

An SAQ has the following characteristics: i) it is acute in society, challenging the social practices of all the interveners in school, reflecting their social representations, being considered an important issue by the society and raising the debate, as well as having media coverage, becoming the school actors familiar with the subject; ii) it is acute in background knowledge, since it promotes debate and controversy among the specialists from disciplinary and professional fields, diverse paradigms from human, social and even exact sciences are in competition, and references based on social, cultural and political practices can result in the background for knowledge to be taught in school; iii) it is an acute question in knowledge taught, becoming all the more "potentially acute" in what is learned in school because it is acute on the other two levels of knowledge (social and background) [10] (p. 25).

SAQ can be linked to socio-scientific issues (SSI). In science education, the latter was introduced as a way of addressing social dilemmas that interact with the scientific domain and have implications in several fields, such as biology, sociology, ethics, politics, economics and the environment [10]. Of this relation between SAQs and SSIs, some authors [12] claim that SSIs are socially controversial or life issues that involve not only scientific topics but also economic, political and ethical aspects and moral dilemmas. These authors further reference that one continuously faces SSIs, namely genetically modified organisms, nanotechnologies and climate changes. In this sense, vaccination for COVID-19 can also be considered both an SAQ and an SSI.

The key elements for the pedagogical practice of SSIs are the following:

(1) Constitute practical applications of scientific knowledge to real-life problems, (2) take place in the intersection of science and society, therefore supporting the idea that science must progress consistently and in accordance with the values and needs of the society in which it is developed and (3) are present in public discussion, often through the media [13] (p. 2).

SSI lessons are a way to promote students' development of scientific literacy and an opportunity to debate and reconstruct the meaning of scientific competence. SSIs in society require a dedicated competence called socio-scientific reasoning (SSR), which includes the skills of complexity, examination, ongoing inquiry and scepticism. Ongoing inquiry focuses on the nature of an SSI as a problem not yet clarified but under permanent research and development, whereas scepticism refers to students' skills to critically analyse the information obtained about an SSI considering the possible bias on the part of the information sources [13]. These two competencies seem very important in the COVID-19 context, with a new vaccine to be produced and the upsetting news about their side effects. In addition to the fact that this pedagogical strategy is explored every year in HBH lessons, in 2020 and within the context of universal vaccination for COVID-19, this strategy was even more relevant.

We consider that SAQs and SSIs are relevant matters to be discussed in the "Human Biology and Health" (HBH) curricular unit of a teacher training course. Therefore, we introduced the vaccination topic in the immune system theme of the HBH unit. This topic was of utmost interest when scientists were trying to deliver a vaccine quickly to control the dissemination of SARS-CoV-2 and to contain the loss of so many human lives. Indeed, we intended to assess how the immune system and vaccination teaching topics contributed to students' scientific knowledge mobilisation for understanding, acceptance and the decision-making process about vaccination.

Therefore, our research question is: how can learning about the immune system and vaccination principles influence the students' conceptions of COVID-19 vaccines? To answer this question, the conceptions of students who had learned these topics in the HBH unit were compared to the conceptions of those who had not yet studied it. Secondly, the influences of some individual factors were also analysed. In this sense, the two null hypotheses were formulated: H0.1 = there are no significant differences in conceptions of COVID-19 vaccines between the students who had or did not have HBH lessons about the immune system; H0.2 = students' secondary school background and other individual factors do not lead to significant differences in their conceptions about COVID-19 vaccines.

2. Methodology

2.1. The Context

The curricular unit "Human Biology and Health" (HBH) is offered in the second year of the initial Basic Education (BE) teacher training course at the University of Minho, in Portugal, having it as one of its objectives to provide the opportunity for students to critically review and debate current key ideas in biology and health. One of the HBH themes is the immune system, which runs during three sessions (one per week) of three hours each. In this theme, the vaccination topic is emphasised. The immune system theme starts with the concepts of innate and adaptive immunity: the human body's barriers and mechanisms of innate immunity are taught in the former, and cellular and humoral immunity are taught in the latter. Thus, the type of cells involved and their functions, more precisely the T lymphocytes and the B lymphocytes, are addressed, as well as their subgroups, functions and mechanisms of action and mutual coordination (activation and suppression). Then, the concepts of antibodies and antigens are explored, with the antigen–antibody bond reference in different molecular structures, making clear that the invading agent (antigen/pathogen) is the one which activates the antibody production. They are mobilised to fight the foreign agent due to their capacity for recognition with molecular complementarity of the light and heavy chains that contain the antigenic determinants. Based on antigenic determinants, the process of activation of antibodies by the antigen is explained, i.e., the mechanism of clonal selection, followed by clonal expansion and differentiation of cells with specific attraction to the antigen that attacked the human organism. Finally, the characteristics of specificity and memory (cellular and humoral memory) are

clarified as the basis of the adaptive immune response; these two characteristics are the basis of the vaccination principle.

Special attention is given to the vaccination process, which is based on the specificity and memory of the immune reaction, producing a primary and secondary immune response: at the first contact with the antigen/pathogen, the body produces a primary response to it, which is characterised by a relatively long lag phase, low antibody production and antibody-producing memory cells; the secondary immune response occurs if the body is exposed to the same pathogen again, which is much faster and producing much higher levels of specific antibodies because the memory cells are at the ready to pump out antibodies against that antigen/pathogen [14]. Therefore, the immune memory will determine the success of the vaccination and prevent illness after reinfection with the same pathogen (or antigen) that has already attacked the organism and been successfully combated by an adaptive immune response [15]. Presentation of contents is always based on discussion and questioning pedagogical strategies, giving students the opportunity to share their ideas in a stimulus of critical thinking. Images are used to elucidate scientific concepts and to provoke cognitive stimulation and reasoning about the themes. To teach and learn about vaccination principles, a graph of primary and secondary antibody response [15] (p. 24) is used. The teacher invites students to explain their interpretations of the antibodies' amount variability and to share known examples, establishing thus a parallel with daily life and orienting them to the understanding of immunological memory.

Following the scientific vaccination principles learning, discussion on social controversy on vaccination was generated in this immune system theme of the HBH curricular unit. As mentioned above, we intended to assess if the immune system theme (including vaccination) contributed or not to students' scientific knowledge mobilisation for understanding, acceptance and the decision-making process about vaccination.

2.2. Materials and Methods

2.2.1. Type of Study and Tool for Data Collection

This work is a cross-sectional, descriptive and correlational study using a mixed methodology for data analysis, with qualitative and quantitative data. A questionnaire was constructed specifically for this research. It was initially constructed by the "Human Biology and Health" teacher (first author) and subsequently validated by another colleague of the same university (last author). Little changes were made, and the questionnaire was prepared to be filled in online. Afterwards, and in order to validate the questionnaire, this was applied to a small group of six students of one similar graduation course of another university nearby, being two of each of the three years of the graduation course of Basic Education.

The questionnaire included open- and closed-ended questions, the first section being about socio demographics (sexes, age, year of the course, secondary school area of studies) and the second about students' conceptions of the COVID-19 pandemic and vaccines. These questions were: the six open-ended questions as follows below (3.2.1 to 3.2.6); and the closed-ended question with the introduction "When the vaccine is available to all in Portugal …" followed by the ten items presented in Table 7 in results section.

The questionnaire was sent to the students using the university Blackboard platform, the most used way for communication and sharing information between teachers and students. The students filled out the questionnaire between 17 and 28 December 2020. This period was just at the time of the beginning of the national vaccination (the elderly population first) that started on 27 December 2020. Thus, the questionnaire was administered precisely during the period when people could not avoid the subject, being closely involved, and so it was a very intense SAQ and SSI matter at the moment of data collection.

2.2.2. Sample

The sample included students from the three years of the graduation course on Basic Education of the University of Minho in Portugal, that is, future preschool and primary school teachers. Most of them were females (only one male in 102 students). The first-year students had not yet taken part in the HBH curricular unit; the second-year students had undergone it two months before data collection; the third-year students had undergone it one year and two months before data collection. More detailed socio-demographic characteristics of the sample will be found in the beginning of the results section. The influence of no formal learning, short-term learning and long-term learning on students' conceptions about vaccination is important to understand how the teaching–learning process modified students' conceptions and if the new scientific conceptions endure over time. It also helps with understanding if students apply their scientific knowledge to daily life.

2.2.3. Data Analysis

Data collected online were automatically registered in an Excel file and imported by IBM SPSS (version 27.0) by one author and by Posit R Studio by another for independent data analysis. Then, the results obtained were compared and confirmed. The answers from open-ended questions were categorised and codified to quantify the occurrences of answers' categories, following the content analysis procedures [16]. The content analysis was conducted with QSR International NVivo (version 12.0) for categorisation and extracting results in word clouds. The categorisation process followed a systematic data analysis approach to compare students' groups by counting the occurrence frequencies of significant ideas clustered in categories and subcategories. Each answer to an open-ended question was considered a unit of meaning, and the relevant units of meaning to the research questions were delineated. The process involved four trained authors: three carried out the categorisation independently, as recommended for good validity of the content analysis [17]. Then, two authors checked the lists, eliminated redundancies and wrote the summary.

After the frequencies for category occurrences, the chi-square test was applied to verify any dependency relation between the categories and the individual factors considered for the objectives. Answers from the closed-ended questions (using a Likert scale with four alternatives) were prepared for descriptive and non-parametric statistical tests. The aim was to compare the students' conceptions of the three years of the initial Basic Education (BE) teachers training course and to verify the influence of the other individual factors in these conceptions (secondary school background, perception of own health, feeling at risk for COVID-19 and students' experience with COVID-19). Finally, the students' conceptions concerned with vaccination were firstly explored by the answers obtained to the six open questions, followed by the statistical analysis of the closed-ended question using a Likert scale, including a descriptive and non-parametric analysis. In addition to the deep identification of students' conceptions, this procedure also internally validated the questionnaire, as open-ended and closed-ended questions became complementary.

2.2.4. Ethical Procedures

The ethical procedures were respected according to the code of ethical conduct of the University of Minho for scientific research and the Portuguese legislation for data protection, namely Article 31st of the Law n.º 58/2019 [18]. The questionnaire started with a first question concerned with volunteer and informed consent, which were mandatory to continue to fill in the questionnaire. There was no reward for completing the questionnaire, no identification data were collected, all the students were over 18 years old and none of them had vulnerabilities.

3. Results

3.1. Demographic Characterisation of the Sample

The sample included 102 university students, 101 females and 1 male, aged between 18 and 50, with an average of 20.97 (±5.8) and mode age of 19 (n = 32). Attending the first year of the initial Basic Education teachers training course, there were 51 students (50.0%); in the second year, 34 (33.3%); and in the third year, 17 students (16.7%). Considering the secondary school background or area of studies, the majority (56) were from languages and humanities, 29 from sciences and technologies, 8 from socioeconomic sciences, 7 from professional courses and 2 from visual arts. In terms of perception of their health, as Figure 1 shows, the most frequent problem is only having some seasonal symptoms like colds (37), followed by rarely having health problems (26) and being a fully healthy person (20).

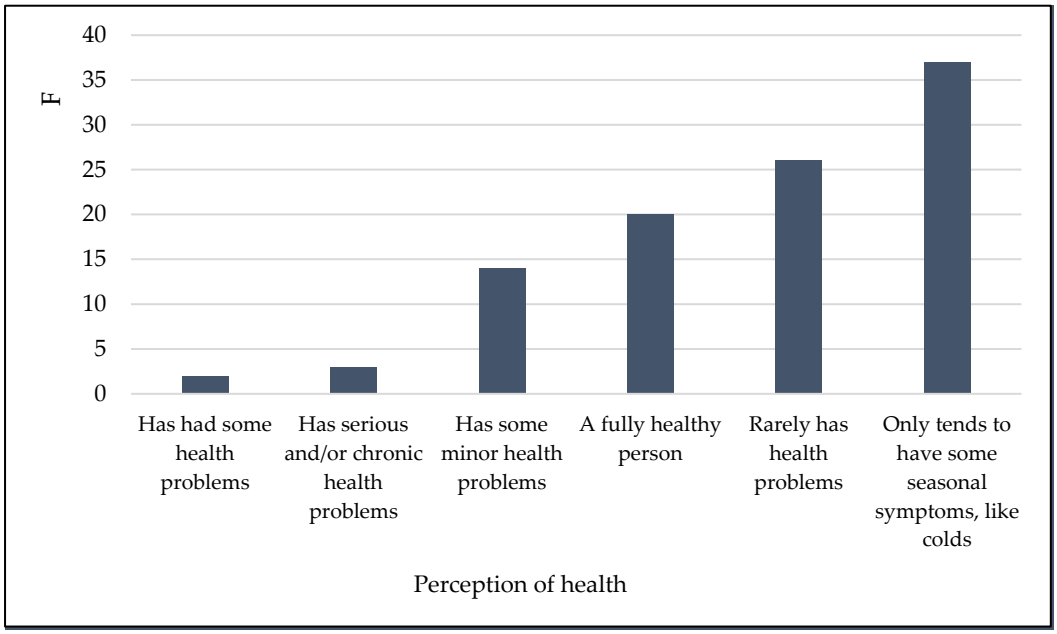

Figure 1. Frequencies of the perceptions of HBH students' health. (F = Frequency).

Regarding if they feel to be a person at risk for COVID-19, only 8 consider they are, and 94 answered no. Concerning the students' experience with COVID-19 at the moment, only 14 had contacted closely with the infection: three were infected themselves, while the others had family members infected.

3.2. Students' Conceptions about COVID-19 Vaccination: Open-Ended Questions

The content analysis results for the six open-ended questions are presented following the order of the questions. The emergent categories for each question are shown in a frequency table and a word cloud.

3.2.1. What Do You Think about Having Vaccines for COVID-19 Already Available?

The analysis of this question reveals the emergence of four categories of answers (Table 1). Nearly half of the sample (48.0%) answered that it is good, fortunately, and it is a hope in the fight against the pandemic. Nevertheless, an important part (29.4%) of students considered that it was too short a time to obtain a vaccine, as it was achieved very quickly, instead of having many scientists working for a long time to create the vaccine. Some students (9.8%) feared the vaccine's side effects, and others (8.8%) were not confident in its efficacy. A few students (3.9%) had no opinion about the subject. Finally, the school background revealed a significant dependency relation ($X^2 = 27.899$; $p = 0.033$), with a higher frequency of the students from languages and humanities in the category "well, good, great" than the others.

Table 1. Categories of students' answers about having vaccines for COVID-19 already available.

	N	%
Well, good, great	49	48.0%
Too much yield, too fast	30	29.4%
Fear of side effects	10	9.8%
Pessimistic	9	8.8%
No opinion, don't know	4	3.9%
Total	102	100.0%

In some cases, it was difficult to have exclusive categories because students expressed at the same time hope and doubts. For example, an 18-year-old girl in the BE first year said: *I think it's good, but maybe the vaccine was made too quickly, and this can harm us as we can have many side effects*. This answer includes the three first categories (Table 1). Therefore, to keep exclusive categories, answers of this type were classified according to the first sentence or its most substantial part based on the argumentation. The answers' word cloud (Figure 2) shows the results obtained from this first question, where "vaccines", "effects", "good" and "quickly" were the most frequent words.

Figure 2. Word cloud of students' answers about having vaccines for COVID-19 already available.

3.2.2. What Do You Think the Vaccine Contains to Prevent Coronavirus Infection?

More than a third of students (34.3%) think the vaccine contains the virus (in a moderate amount or inactivated) or the virus' genetic material (Table 2). This came from 52.9% of students in the second year, 35.2% in the third year and only 21.3% in the first year. These results indicate the HBH teaching–learning impact was higher immediately after teaching (second year) and lower in long-term teaching (third year); the first year had no HBH teaching, and the correct results were even lower.

Approximately a third of the total students (32.4%) had no idea of the vaccine content (Table 2). Students said that they could have substances (vague concept or alcoholic solutions), chemical components of other vaccines or a mix of several vaccines (11.8%); antibodies (8.8%), being most students (6) in the first year of the BE course, two in the third year and one in the second year; bacteria, other viruses and pathogens (7.8%) were referred to mainly by the first-year students (5). Again, these results revealed the HBH teaching–learning impact on students' conceptions about vaccines.

Table 2. Categories of students' answers about the contents of the COVID-19 vaccine.

	N	%
The virus itself, the genetic material of the virus	35	34.3%
Don't know, no idea	33	32.4%
Substances and chemical components of other vaccines	12	11.8%
Antibodies	9	8.8%
Bacteria, other viruses and pathogens	8	7.8%
No answer	3	2.9%
Mixture of several vaccines	1	1.0%
Antivirus	1	1.0%
Total	102	100.0%

The statistical analysis showed that the feeling of being a person at risk for COVID-19 expressed a significant dependency relation ($X^2 = 17.306$; $p = 0.008$) with the conceptions of vaccine composition, although most students did not feel at risk. Only eight students considered themselves at risk, and half of them thought the vaccine contains the virus or its genetic material.

The word cloud obtained by NVivo software for the answers to this question (Figure 3) confirms that "virus", "know" and "antibodies" were the most frequent ideas, followed by "immune" and "coronavirus". The answer of a 19-year-old girl in the first year of the BE course who studied socioeconomic sciences in secondary school illustrates clearly this conception: *Antibodies that allow our body to fight the virus as soon as we come into contact with it*.

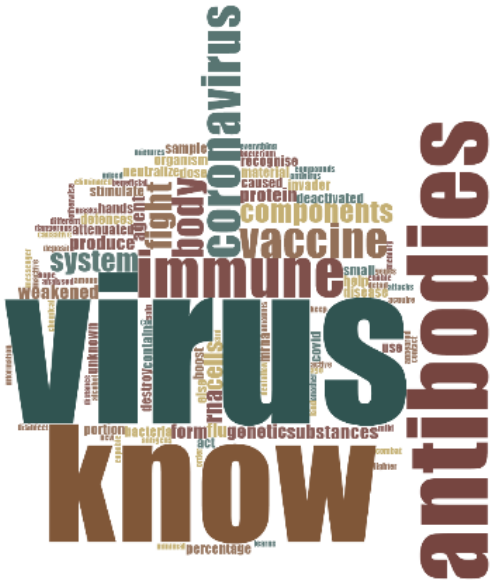

Figure 3. Word cloud of students' answers about the contents of the COVID-19 vaccine.

3.2.3. Who Do You Think Should Be Vaccinated First (in Terms of Social and/or Professional Groups)?

Immediately before the beginning of the vaccination process, the students considered health professionals the priority (23.5%), followed by persons or groups at risk (9.8%) and the elderly (8.8%) (Table 3). Moreover, 9.8% of the students considered both health professionals and elderly groups, and 8.8% the health professionals, the elderly and people at risk simultaneously. An example of these three groups' priority can be seen in the answer of an 18-year-old girl in the first year of the BE course: *The elderly, patients at risk, and*

above all, workers exposed to the virus such as doctors, healthcare assistants, nurses… The relevant idea is that health professionals are not only doctors and nurses but all those working in healthcare services.

Table 3. Categories of students' answers about the priority people for vaccination.

	N	%
Health professionals	24	23.5%
Health professionals and people at risk	18	17.6%
Persons/groups at risk	10	9.8%
Health professionals and elderly	10	9.8%
Health professionals, the elderly and people at risk	9	8.8%
The elderly	9	8.8%
Others	8	7.8%
Formal caregivers and users	6	5.9%
Elderly and people at risk	5	4.9%
All professionals directly exposed	3	2.9%
Total	102	100.0%

The respective word cloud (Figure 4) shows that health professionals occupy the central and major space in the cloud, followed by "elderly", "people" and "risk". In synthesis, students have the conception that those who are more exposed or vulnerable, given their age, socioeconomic or health conditions, are the priorities for vaccination.

Figure 4. Word cloud of students' answers for priorities in vaccination.

3.2.4. What Is Your Opinion about COVID-19 Vaccines Having Appeared from Various Brands?

Table 4 shows that students emphasised economics/competition reasons (28.4%) for vaccines appearing from various brands. In the second place, they pointed out that this diversity can be advantageous (20.6%) to attain more population in a short time and to experiment and confirm the better composition for an ideal vaccine. Other students considered that different vaccines could have different efficacy and cause different reactions in different persons (12.7%), and others revealed uncertainty or doubts about this issue (9.8%). There were some opposing but well-justified ideas, as in the case of this 18-year-old girl attending the first year of the BE course: *On one hand, it may be a business strategy, but on the other hand, it is beneficial to have greater precision of what components the "ideal" vaccine needs in order to be able to neutralise COVID-19 with greater efficacy and precision.*

Table 4. Categories of students' answers about different COVID-19 vaccines from several brands.

	N	%
Economic/competition	29	28.4%
Advantageous	21	20.6%
No opinion	16	15.7%
Different efficacy	13	12.7%
Normal	11	10.8%
Uncertainty	10	9.8%
No answer	2	2.0%
Total	102	100.0%

In addition to "different" vaccines and a significant number of students without "opinion", the word cloud (Figure 5) highlights the economics aspects: "companies", "economic", "brands", "pharmaceutical" "money" and "profit".

Figure 5. Word cloud of students' answers for different COVID-19 vaccines from various brands.

3.2.5. What Do You Think about the News about Allergic Reactions to the COVID-19 Vaccine?

Most of the sample (55.9%) considered it normal news regarding COVID-19 adverse reactions (Table 5). They justify that it also happens with all the other vaccines, and different individuals will have different reactions, so these are expected reactions. Nevertheless, 18.6% of the students expressed negative ideas about the topic itself, saying "worrying", "frightening", "fear", etc. About the news itself, students expressed ideas of alarming, strange and bad media work. Also, an important percentage of students revealed doubts, confusion and uncertainty (10.8%).

Table 5. Categories of students' answers for news about allergic reactions to the COVID-19 vaccine.

	N	%
Normal	57	55.9%
Worrying	19	18.6%
Uncertainty	11	10.8%
Alarmists	8	7.8%
No opinion	7	6.9%
Total	102	100.0%

The word cloud obtained for the students' answers to this question (Figure 6) emphasises the "normal", "allergic" and "worrying" reactions. For example, this sentence by

a 25-year-old female student in the third year of the BE course refers to normal reactions: *I think it is natural. The injection of the vaccine into the body is the virus itself, and our immune system has to prepare itself to recognise the infectious agent and create defences.* The acquired scientific conceptions about adaptive immune response can be observed in this answer, but she says incorrectly that the "virus itself" is in the vaccine. This student had the HBH curricular unit one year before, where she effectively learned about the immune system response; however, at that time, the COVID-19 vaccine did not exist yet and was not a matter of classroom study.

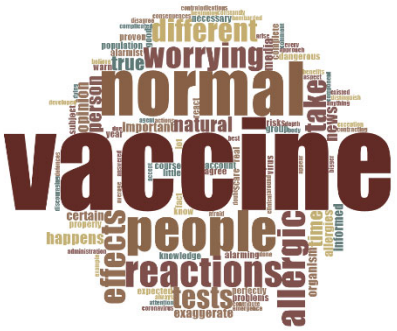

Figure 6. Word cloud of students' answers for news about allergic reactions to the COVID-19 vaccine.

3.2.6. What Do You Think about a 90-year-old Lady Being the First in the UK to Be Vaccinated?

The last open-ended question created six interesting categories, as shown in Table 6. The more frequent answers (41.2%) were related to the higher risk and vulnerabilities of the elderly, as students considered that the intention to vaccinate a 90-year-old lady firstly was to protect her: *due to her advanced age and health history* (girl, 20 years, first year of the BE course) (Table 6). Many students (20.6%) considered the selection of this old woman based on the depreciation of the elderly's life and using them for testing the vaccine. Other responses (15.7%) were related to care and attention to the elderly population. These categories of conceptions are illustrated by these examples, respectively: (i) *Because she is elderly and therefore her immune system is not robust; it could also be that she is someone who is already very old, and if she dies, she has already had a long life* (female, 19 years old, first BE course year); (ii) *With the intention of protecting the elderly* (female, 42 years old, third BE course year).

Table 6. Categories of students' answers for intention to vaccinate a 90-year-old lady first.

	N	%
Higher risk and more vulnerable	42	41.2%
Elderly depreciation and used for testing	21	20.6%
Elderly care and attention	16	15.7%
No opinion	11	10.8%
Example to motivate youngsters	7	6.9%
Publicity	4	3.9%
Economics	1	1.0%
Total	102	100.0%

The word cloud (Figure 7) confirms clearly that the students' conception of risk for the elderly is the predominant argument for the choice of a 90-year-old woman to start the vaccination process. The words "risk", "group" and "person" are central, being surrounded by "elderly" and "vaccine".

Figure 7. Word cloud of students' answers for intention to vaccinate a 90-year-old lady first.

3.3. Students' Conceptions about COVID-19 Vaccination: Closed-Ended Questions

After presenting the students' answers to the six open-ended questions to explore their conceptions about COVID-19 vaccines (see above), this section presents their answers to the ten close-ended questions concerning their views about vaccination and its effects. Note that data collection was performed before the vaccines were available. The descriptive statistics analysis (Table 7) highlights that 78.4% (58 + 22) of these university students wished to be vaccinated but not immediately 55.9% (44 + 13), and 84.3% (38 + 48) were afraid of the vaccine allergic reactions. In addition, 60.8% (53 + 9) had no total confidence in the vaccine for the Portuguese population, 68.6% (51 + 19) did not believe that vaccine would eradicate the virus from the population and 84.3% (63 + 23) were already thinking, at that time, that it would take more than one dose of the vaccine to develop one's immunity.

Table 7. Students' answers about the COVID-19 vaccine and its effects (score frequencies and mean).

	Totally True *	True *	False *	Totally False *	Mean
You do not want to be vaccinated	7	15	58	22	2.93
You are willing to be vaccinated immediately	18	27	44	13	2.51
You are afraid of having an allergic reaction to the vaccine	38	48	15	1	1.79
You think you will have some mild symptoms of COVID-19 after vaccination	9	59	34	0	2.25
If you are not included in the initial vaccination plan, you will try to find a way to be vaccinated even if you have to pay for the vaccine	2	19	52	29	3.06
You believe that the vaccine can develop COVID-19	5	27	58	12	2.75
You have full confidence in the vaccine purchased for Portugal	4	36	53	9	2.66
You believe that the vaccine will eradicate the virus from the population	1	31	51	19	2.86
The vaccine will only make sure that people do not get sick from contracting the virus	3	47	46	6	2.54
Each person only needs to be vaccinated once to develop immunity	2	14	63	23	3.05

* Legend for scores: totally true = 1; true = 2; false = 3; totally false = 4.

Comparing students' conceptions about vaccination by course year, significant statistical differences were only observed for three items (Table 8): (i) willing to be vaccinated immediately (p = 0.008), where second-year students' conceptions differed significantly from first year (Z = −2.846; p = 0.004) and third-year students (Z = −2.402; p = 0.016), being those of the second year who were less willing to be vaccinated immediately; (ii) do not want to be vaccinated (p = 0.032), second-year students' conceptions differed significantly from those of first year (Z = −2.264; p = 0.024) and third-year students (Z = −2.089; p = 0.037), with students of the second year being those who most wanted to be vaccinated; and (iii)

each person only needs to be vaccinated once to develop immunity ($p = 0.025$), in which first-year students' conceptions differ significantly from those of third year ($Z = -2.604$; $p = 0.009$), with first-year students being the ones who most thought it was enough to be vaccinated only once.

Table 8. Significant statistical differences in students' conceptions by course year (Kruskall–Wallis test).

	Course Year	N	Mean Rank	*H*	*p*
You are willing to be vaccinated immediately	1st Year	51	45.65	9.654	0.008
	2nd Year	34	63.66		
	3rd Year	17	44.74		
You do not want to be vaccinated	1st Year	51	55.47	6.869	0.032
	2nd Year	34	41.91		
	3rd Year	17	58.76		
Each person only needs to be vaccinated once to develop immunity	1st Year	51	45.20	7.403	0.025
	2nd Year	34	54.99		
	3rd Year	17	63.44		

Considering the students' secondary school background, it was evident that those from sciences and technologies were more favourable to vaccination than the others (from socioeconomic sciences or languages and humanities) but less willing to try to find a way to be vaccinated even if they had to pay for the vaccine. Significant differences were found for two items (Table 9): (i) to try to find a way to be vaccinated even if they have to pay for the vaccine ($p = 0.022$), with the students from socioeconomic sciences more willing to do it and differing significantly from those of sciences and technologies ($Z = -2.769$; $p = 0.008$) and languages and humanities ($Z = -2.205$; $p = 0.027$); (ii) to believe that the vaccine can develop COVID-19 ($p = 0.017$), with the students from sciences and technologies differing significantly from those who had socioeconomic sciences in secondary school ($Z = -2.199$; $p = 0.028$), as well as from those of languages and humanities ($Z = -2.669$; $p = 0.008$), being students of socioeconomic sciences who trust less that a vaccine can develop the disease.

Table 9. Significant statistical differences in students' conceptions by secondary school background (Kruskall–Wallis test).

	Secondary School Background	N	Mean Rank	*H*	*p*
If you are not included in the initial vaccination plan, you will try to find a way to be vaccinated even if you have to pay for the vaccine	ST	29	59.60	9.657	0.022
	SES	8	27.75		
	LH	56	48.73		
	P	7	52.93		
You believe that the vaccine can develop COVID-19	ST	29	40.09	10.156	0.017
	SES	8	63.44		
	LH	56	55.48		
	P	7	39.00		

Legend: ST = sciences and technologies; SES = socioeconomic sciences; LH = languages and humanities; P = professional course. Note: given the small number of students from visual arts in secondary school (n = 2), it was not possible to include this group in this analysis.

Another factor considered important for this analysis was students' experience with COVID-19. At the moment of data collection, 14 students (13.7%) had experienced close contact with the infection. More precisely, three were themselves infected, and eleven had had family members infected. Nevertheless, this factor did not influence students' conceptions of vaccination. In the same way, the perceptions of their health also did not show an association with students' conceptions about vaccination.

Finally, a significant dependency relation was found between the perceptions of their health and feeling at risk for COVID-19 ($X^2 = 26.643$; $p < 0.001$), meaning that those with a better perception of their health were more confident in not being a risky person for COVID-19.

4. Discussion

The present study showed that students who already studied the university HBH curricular unit had more scientifically acceptable conceptions about the COVID-19 vaccines, indicating that they transposed their learning to the problem and controversy they faced about vaccination. Therefore, this study answered the research question: how can learning about the immune system and vaccination principles influence the students' conceptions of COVID-19 vaccines? And the first null hypothesis, H0.1, is rejected, as significant differences were found.

The sample was almost all female (101 women in 102 students), which generally feels healthy and not at risk for COVID-19, which is expected for young people near their twenties. Few of them (13.7%) had had contact with SARS-CoV-2 at the moment of data collection. Therefore, these sample characteristics can explain the positive point of view and confidence in the vaccine emergence.

Students from the secondary school area of sciences and technologies revealed more acceptable conceptions about the COVID-19 vaccine, indicating the significance of the previous study area. On the other hand, these students were less confident in vaccine benefits at the beginning of the vaccination process compared to students from the socioeconomic sciences or languages and humanities areas, who were more favourable to the rapid effect of the vaccine. This result leads to the rejection of the second null hypothesis, H0.2, since there are significant differences associated with students' secondary school background.

Data from the six open-ended and the closed-ended questions gave interesting, interlinked results, as interpreted below. For the first question of having vaccines for COVID-19 already available, students were divided, with nearly half having a positive view and another half expressing a negative opinion, based on the time to produce the vaccine and the fear of side effects, which are determinants of vaccination hesitance listed by the ECDC [8]. Similar results were found with a university student sample from the USA [19], with 47,5% of students hesitating about the COVID-19 vaccine's effects. Interestingly, in the present study, students who studied languages and humanities in secondary school had a more favourable opinion about taking the vaccine. A possible interpretation for science and technology students being more afraid of vaccine side effects is that they know more about mechanisms of action, microscopic and sub-microscopic dimensions (cellular and molecular) and clinical trial processes. In contrast, socioeconomics or languages and humanities students may be less aware of these technical, scientific details and more concerned about epidemiologic politics and pandemic control for the general population's well-being and thus are more confident in vaccine safety.

Those who are more interested and search more for information on science, medicine and health, namely in digital media, tend to be more doubtful about COVID-19 vaccine safety, being that the information quality is a problem rather than its availability [7]. Even healthcare workers accept but have some fear and little confidence in the immunisation scenario, as observed in a multicentric study in France [20]. Similar results were found in the USA before the vaccination began [21], with only 36% of the healthcare workers being willing to be vaccinated as soon as possible.

Compared to the first- and third-year students, the second-year students gave a higher proportion of scientifically correct answers about the vaccine contents. This could be due to the teaching–learning process about vaccination in the HBH curricular unit they had had two months before the data collection and the process of vaccination being, at that time, a very controversial issue. Therefore, it demonstrates the positive influence of the vaccination topic of the HBH curricular unit on students' scientific conceptions and learning. Most students expressing the scientifically incorrect conception that a vaccine is composed of antibodies were from the first year. It is understandable since they had not yet had the HBH curricular unit, reinforcing the positive influence of the teaching–learning process on antibody and antigen concepts. A few students in the second and third years also said vaccines contain antibodies, indicating that they did not acquire the correct scientific conceptions or weakened with time. Scientific conceptions acquisition can interact with intuition, and previous conceptions can be obstacles to conceptual change as well, which involves shifts in the meanings of concepts, accommodation of the new concepts in the explanations and management of the relations between concepts [22].

About half of the students (61) who said they were at risk for COVID-19 believed that vaccine composition is the virus or its genetic material, which explains their fear of being infected by the vaccine. Indeed, 33 feared an allergic reaction to the vaccine and 28 mild symptoms of COVID-19, as the data triangulation between the categorical variables and the closed-ended questions revealed. These misconceptions about vaccines and consequent fears can be seen as vaccination hesitancy determinants, them being of individual or group influences [8]. A recent meta-analysis of 56 studies [23] identified many of the highest risk factors for COVID-19 vaccine hesitancy, such as being a woman under the age of 50, having lower educational attainment, being a non-healthcare-related worker and having no children at home.

For the third question of who should be vaccinated first, students elected health professionals, followed by the elderly and people at risk. The COVID-19 pandemic has presented a dilemma worldwide: with the number of cases exploding and a limited stock of vaccine doses, who should be immunised first? Therefore, each country organised a sequential list of priority groups for national COVID-19 vaccination operationalisation. In general, the criteria were based on WHO principles [24], where the table of priorities starts with the principle of human well-being, the goal of reducing deaths and the burden of disease, electing as priority population groups those at high risk of disease or death (including the elderly and patients with comorbidities) and those at high risk of being infected (where health workers are included). Most countries have opted to start vaccinating frontline health workers [21], in addition to the elderly, as in the UK [25] and Portugal [26], as a group considered to be most at risk. Indeed, the concerns of this study's students align with these worldwide criteria by indicating health professionals, the elderly and patients [24,26] as a priority, considering these three groups as high risk.

The fourth question about vaccines from several brands showed the economic or competition reason as the more frequent category. Most of these answers were from first-year students who had not yet had the HBH curricular unit. Curiously, more students from sciences and technologies and languages and humanities showed this conception, compared to less than half from socioeconomics. Some students seemed hesitant about this issue, showing opposing but well-justified ideas. It can be interpreted as a dilemma and reasonable argumentation, which shows this issue's SAQ and SSI nature. Students' argumentation was based on scientific efforts and economic and business interests.

When students are engaging in SAQs, they engage with socio-scientific reasoning (SSR), which involves reasoning including other fields beyond science, "including values, economics, local and global perspectives governance issues and a variety of stakeholder perspectives" [11] (p. 826). The introduction of SAQs in education involves the development of competencies to argue opinions and to assume positions on social issues, as well as to develop science literacy and students' empowerment about controversial issues [10]. Different arguments can be interpreted based on the six styles of scientific reasoning,

which may vary according to specific historical contexts, although the success of science education can be attributed to cognitive tools, resources and styles of reasoning to argue for several ideas [27]. In this sense, the teaching–learning process promoted students' competencies to argue and take positions about this SAQ (several vaccines for COVID-19) instead of having students without opinions. Given these results, we are still more motivated to promote opportunities to implement a specific program of six styles of reasoning in biology [28].

Regarding the fifth question on the news about allergic reactions to the vaccine, the results of this study show that vaccines are considered safe by students. However, they consider that adverse reactions can occur as with any other vaccine due to scientists' short time to create the first vaccine against COVID-19. It was also observed that, in the opinion of some students, vaccines were developed in record time precisely because of the scientific advances of the last decades, which nowadays allow new technologies to be developed even faster. However, underlying this idea, there is still fear and mistrust on the part of some respondents. This study revealed the predominance of students' positive attitudes towards vaccines, even in the context of growing anti-vaccination discourse.

It is recognised that the vaccine against COVID-19 was developed rapidly by implementing the R&D Blueprint strategy [2] to decrease the number of COVID-19 cases in great expansion worldwide. Currently, the disease has claimed more than 6 million victims, and scientists worldwide have dedicated themselves fully to finding efficient solutions to the problem. The existing vaccines result from different biotechnology processes, but all have been shown to be safe and effective. Furthermore, vaccines, as with any immunobiological product, are renowned for their innumerable inherent advantages in protecting health, despite the potential risks of adverse effects, which, in the vast majority of cases, are rare, mild and controllable [29]. Therefore, the development of vaccines against the new SARS-CoV-2 represents one of the main desires of the world population and represents an extraordinary advance in science.

The vaccination process against COVID-19 brought an air of hope while simultaneously reigniting the debate about the importance of vaccines for disease control and how these immunisers are developed in research centres and laboratories.

For the sixth and last open-ended question, students considered the health high risk as the main argumentation for initiating vaccination in an older woman in the UK. In third place was the category related to the care and attention to the elderly. In this sense and adding also the small percentage of those who justify the decision as an example to motivate young people, we observe that the majority (more than 60%) of students believe in a positive intention of the policy makers. However, an important percentage of students were not confident in this option, since more than 20% understood the decision based on the depreciation of the lives of the elderly and their use to test the vaccine, considering an attempt to test it with less grief in case of death. As is well known, with advancing age immunity decreases; consequently, elderly people are more susceptible to infectious diseases, and vaccination is the best way to benefit older people [30]. For the 37 older people in the UK (ages 70–89) who followed up after the second immunisation, it was verified that the protection reduced in 3 to 20 weeks, so a third boost was required to keep their immunity to SARS-CoV-2, which also provided benefits against several variants [31]. In addition to the greater immunological weakness, the higher prevalence of chronic diseases substantially raises the risk of dying for the elderly compared to other age groups [32]. To reduce mortality and the need to give visibility to the particularities of elderly care, vaccination against COVID-19 has been made feasible and prioritised for this age group in several countries, following WHO orientations [24], vaccination being understood worldwide as the fundamental strategy to promote and protect the health of the elderly. In our students' conceptions, elderly people were included in the priority groups, and the choice to vaccinate a 90-year-old woman first was positively understood with the primary objective of protecting life and avoiding deaths, which is the most important outcome of any disease.

Other students' opinions referred to the example and incentive for younger people to adhere to vaccination and also related to economic and advertising aspects. Beyond a health issue, the vaccine becomes a subject permeated by the geopolitical and economic interests of different nations, industries and interest groups. Wider retrospective research collecting data between 2015 and 2019 from 149 countries [33] indicates an increase in vaccine confidence. However, European and Asian countries revealed less confidence, partly due to the anti-vaccine movements in France and Poland [33]. This study reports more opinions about children's immunisation, but the authors conclude that the COVID-19 pandemic emergence can be a valuable situation to see where more work is needed for better confidence in vaccines for saving lives. The protection of the elderly must be guaranteed by humanised and quality healthcare, as well as by positive influences. Interestingly, our students, pre-service teachers, have shown themselves to be sensitive to the needs of this most vulnerable group.

At the moment of vaccination emergence in Portugal, the students feared allergic reactions and intended to be vaccinated, though not immediately. Fear of adverse effects associated with vaccine hesitancy among university students was also found in a study with a bigger sample (n = 840) in Mexico City, also during early vaccination implementation [34].

The second-year students were those more interested in being vaccinated, but simultaneously, they did not want to be vaccinated immediately (in the beginning of the vaccination process). This can be interpreted based on the recently acquired knowledge about the vaccine action mechanisms at the HBH curricular unit, in addition to alarming media information and strong social controversy related to the short time to obtain the vaccine [9]. Nevertheless, several factors can influence vaccine acceptance and hesitancy, including academic background, socioeconomic context, beliefs and others [34]. In contrast to the second-year students, those of the first year thought that it would be enough to be vaccinated only once. So, this is evidence of the positive effect of the HBH lessons about immune defence during the second year. Thus, these students who had already learnt the vaccination principles revealed knowledge about the primary and secondary immune response [15], understanding the need for contact with the antigen more than once to develop protection.

Furthermore, the students coming from the secondary school science and technology area were more favourable to vaccination, which is understandable due to their previously acquired scientific knowledge. However, they were frightened of the vaccine side effects and did not want to be vaccinated immediately. Therefore, it can be interpreted as a scientific reason and argumentative competency, based on more detailed and deepened knowledge balancing the benefits and risks of the vaccine, bringing their scientific reasoning for their life and decisions. Indeed, it is the case to think that this issue of COVID-19 vaccination addresses the nature of SSIs as a problem that is not very clearly defined and is under constant investigation and development. The "skepticism is related to the students' ability to critically analyse the facts or information that are provided about an SSI considering the possible bias towards the sources of the information" [13] (p. 5).

This interpretation is reinforced by the results of students coming from the secondary school socioeconomic sciences area, who were most willing to pay for the vaccine and trusted less that the vaccine could develop COVID-19, which means they were not mobilising scientific knowledge for their decisions.

Not many studies were found in searching for specific literature on students' conceptions of COVID-19 vaccination. Only some studies about other general university students' conceptions, more specifically biological sciences students, about the immune system and vaccination were found in Brazil [35–37] and Spain [38]. However, no studies were found on Basic Education university students who are in the process of their initial training to be preschool, primary and/or elementary school teachers, concerning conceptions about the COVID-19 vaccine. Therefore, this study is innovative and contributes to

understanding the argumentation of a part of the population: Basic Education (BE) university students.

In this way, our research contributes to some sustainable development goals [6], namely: goal 3, "ensure healthy lives and promote well-being for all at all ages", focusing more on 3.8, discussing essentially the access to safe and effective healthcare services and vaccines for all; goal 4, having in mind equitable quality education, more precisely for 4.4.—increasing the number of young people with relevant skills—and for 4.7 on knowledge and skills acquisition for promotion of sustainable development and lifestyles.

5. Conclusions

This research shows the importance of the HBH curricular unit's teaching–learning process for students understanding vaccination principles and actions, which is essential in the emergence of a pandemic. Indeed, the scientific conceptions are more robust immediately after the lessons (second-year students), fading with time (third-year students), although the most important concepts, namely antibodies, antigens, vaccination principles and primary and secondary responses, were still present one year after the HBH curricular unit. In addition, the study showed that not only the HBH curricular unit but also the previous secondary school background in science and technologies contributed to building scientific conceptions. The great hesitancy factor seems to be the fear of vaccine adverse effects. Furthermore, the HBH course unit showed to be very appropriate for discussing SAQs and promoting teaching–learning sessions based on the SSIs and SSR. Several other controversial health and environmental issues keep emerging, and we intend to deepen the effects of the teaching–learning process on the students of the initial teachers' training regarding knowledge acquisition increase, conceptions progress and promotion of reasoning competencies for better health and sustainability. For future research, we intend to apply the six styles of reasoning, as mentioned above.

Limitations: The results obtained elucidate about the effect of our human biology and health lessons on students' conceptions about COVID-19 vaccination, an SAQ and an SSR. Nevertheless, they are limited to our population and our context. Instead of our sample being near to the dimension of our population, the sample size is also a limitation, as well as the fact that the sample consisted almost entirely of girls. Moreover, the topic studied cannot be reproduced because the research had to be conducted at that precise moment of the emergence of a new vaccine for this new specific virus.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study since the first question was about consent, and it was compulsory to continue to fill in the questionnaire.

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