FEATURE ARTICLE

A COVID-19 Roadmap to Promote Health Literacy Derived from the Atlas of Science Literacy

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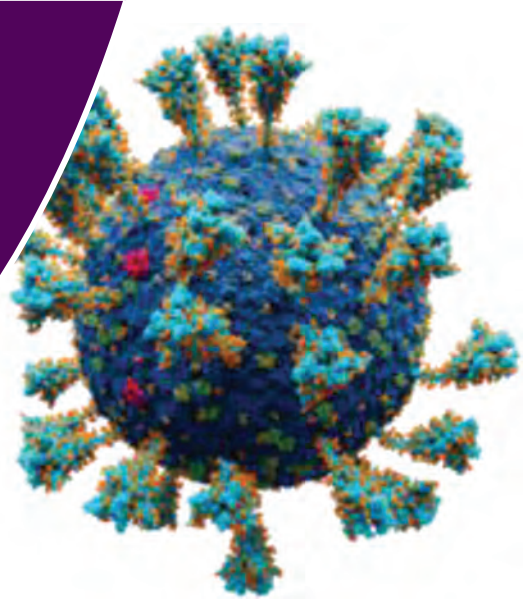

Abstract

Currently, the world needs health-literate citizens who are able to make informed decisions about COVID-19 and other diseases. Here, we propose a COVID-19 roadmap consisting of four commented maps about infection, diagnosis, defense, treatment, and prevention. We built the maps based on those from the Atlas of Science Literacy following a qualitative methodology. Main ideas about health linked to COVID-19 and how they relate to each other can be visualized in the maps in an organized structure and according to K-levels. The maps are accompanied by a text that relates the health ideas to the COVID-19 disease. This tool can be used to promote health education and, ultimately, health literacy through the teaching and learning of COVID-19.

Key Words: *concept maps; COVID-19; science teaching; infection; health literacy.*

○ COVID-19 and the Need for Health Literacy

Currently, the world is facing COVID-19 (Coronavirus Disease) caused by the novel beta coronavirus, the Severe Acute Respiratory Syndrome-Coronavirus-2 (SARS-CoV-2). It was declared a pandemic by the World Health Organization (WHO) on March 11, 2020 (Sun et al., 2020; WHO, 2020a).

Our knowledge of the disease keeps evolving, and so does the information on COVID-19 we are exposed to: vaccines, variants (Alpha, Beta, Delta, and Omicron), hypotheses about its origin, how to combat it, public health measures such as confinements, obligation to use masks, academic planning of the school year, and so on (Olmos Vila, 2020). In this line, WHO alerts about citizen disinformation, which is hindering the health management of the pandemic: "At WHO, we're not just battling the virus; we're also battling the trolls and conspiracy theorists that push misinformation and undermine the outbreak response" (WHO, 2020b).

We propose a roadmap derived from the conceptual strand maps in the Atlas of Science Literacy to promote health education through learning about COVID-19.

We are therefore facing a situation that involves the challenge of being health literate. Especially since it is a new pathogen for which there are still many unknowns, there is a high risk of giving ambiguous information. It is precisely this ambiguity that can lead to a reduction in the level of compliance with prevention and treatment measures even more than when it is admitted that the disease is unknown (Han et al., 2018; Ritov & Baron, 1990). For all these reasons, a critical and responsible citizenship would be the best vaccine to combat and refute the information received (Olmos Vila, 2020) and, that way, help citizens make appropriate decisions.

According to Sørensen et al. (2012), health literacy entails searching, understanding, evaluating, and applying health information with the objective of taking decisions in everyday life to improve the quality of life. Thus, one can expect that a COVID-19-literate individual, among others, is able to be critical of information from the media, develops a functional understanding of the disease, is less panicking, and makes informed decisions (Archila et al., 2021).

Are the citizens health-literate? A large-scale study in the United States described that only 12% of the adult population had competent knowledge in health (Kutner et al., 2006) and the vast majority of teachers of Early Childhood, Primary, and Secondary Education refer to the need for more training in health (Rodríguez & Hernández, 2018). Moreover, sometimes even university teachers in health sciences themselves have an average to deficient level of literacy (Cornock, 2019). In fact, Harrison (2005) suggests that more health education needs to be considered in the context of the school science curriculum.

The American Biology Teacher, Vol. 85, No. 6, pp. 305–313, ISSN 0002-7685, electronic ISSN 1938-4211. DOI: https://doi.org/10.1525/abt.2023.85.6.305.

○ The Atlas of Science Literacy

Health education is directed toward improving health literacy (Nutbeam, 2000). And, among the tools that a K–12 educator can use to promote health education is the Atlas of Science Literacy (American Association for the Advancement of Science [AAAS], 2007). This educational resource contains conceptual maps entitled "Disease" and "Maintaining good health," among others, and mentions names of scientists, which allows students to learn about the nature of science, giving them a context of societal and personal concerns. On the contrary, the Next Generation Science Standards do not include health literacy and they do not even mention vaccines (Zucker & Noyce, 2020).

The conceptual strand maps in the Atlas of Science Literacy are derived from Benchmarks for Science Literacy (AAAS, 1993), which itself is based on Science for All Americans. Educators from all over the world make use of the maps to, among others, design curriculum, plan instruction, develop activities and lessons, and prepare preservice teachers. The atlas are also widely cited in science education literature. Therefore, although the approach has been designed taking into account the American educational system, this tool may be of interest to teachers from other countries. For example, Criado et al. (2014, p. 266) described that the Spanish primary education science curriculum "needs to be explicitly and systematically structured, taking into account its progressive sequencing (in the order of increasing complexity) when passing longitudinally from one cycle to the next" after comparing it with the respective national science education standards in England and the United States. Each map of the Atlas of Science Literacy has a number of goals for student learning (represented by squares and connected by arrows) across different grade levels, from kindergarten to 12th grade. Therefore, most students should be able to achieve a given goal in the proposed grade range. Also, in each map, a strand is labeled as a column to show concepts that follow a path of instruction. That way a visual representation of the progression of ideas is shown.

Here, we propose a roadmap derived from the conceptual strand maps in the Atlas of Science Literacy to promote health education through learning about COVID-19. Benchmarks and relationships among them are included. Educators may use the concept maps for K–12 instruction or any other use of the Atlas of Science Literacy described above. And students may use the maps to retrieve, review, or learn about COVID-19.

○ Methodology

Building the maps was made according to qualitative methods (Elliot, 2018). First, we read through all maps and benchmarks to obtain a general sense of the material. Then, we identified what we considered the most pertinent elements and concepts related to COVID-19 and health based on two COVID-19 glossaries (Government of Canada, 2021; Norton et al., 2021). Researcher triangulation was made by the authors to capture different dimensions of the phenomenon (the three of us are teacher educators, and, individually, we are experts in Health, Biology, and Geology). Discrepancies were discussed until agreement was reached. To continue, we categorized selected elements into five themes according to specialized literature (Botero-Rodríguez et al., 2020; Archila et al., 2021): (i) spread and transmission; (ii) cause and symptoms; (iii) prevention of transmission; (iv) diagnostic, treatment, and fatality; and (v) biological basis to understand the behavior of a pathogenic agent (Table 1).

Then, the ideas related to those themes were searched across the five strand maps from the Atlas of Science Literacy that contained elements or concepts related to COVID-19 (Table 2).

Finally, we built a new map with all selected benchmarks from the atlas following the given connections. In order to make the map easily readable, it was then divided into four maps. Those maps were named as infection, diagnosis and treatment, defense, and prevention. Note that the original writing style of the goals in the Atlas of Science Literacy was kept. In this sense, although the maps include the term "germ," the authors consider that teaching students about germs, rather than pathogens, may contribute to an underdeveloped understanding of the pandemic. Thus, in the dialogue constructed between the generated roadmap and current COVID-19 pandemic, the term "germ" will be avoided and changed to pathogen or virus when needed.

○ Results

In this section, we will detail the health literacy concepts that can be worked at the different stages of K–12 education according to the generated maps: infection (Figure 1), diagnosis and treatment (Figure 2), defense (Figure 3), and prevention (Figure 4). A dialogue is constructed between the generated roadmap and the current COVID-19 pandemic.

From kindergarten to grade 2, children should learn that diseases are caused by pathogens and that they may be spread by people who have them (Infection, Figure 1). In the case of COVID-19, that pathogen is a virus. During the pandemic, handwashing and temperature check routines have been introduced in schools as indicated by the Centers for Disease Control and Prevention (CDC) of the United States Department of Health and Human Services (CDC, 2022). Those measures should be accompanied by understanding that washing one's hands with soap and water reduces the number of pathogens that can get into the body or that can be passed on to other people (Prevention, Figure 4), and that thermometers are used to help figure out whether a person is healthy (Diagnosis, Figure 2). Also, at this stage, children should learn that medicines may help those who do become sick to recover (Treatment, Figure 2) and that vaccinations are used to protect people from getting diseases (Infection, Figure 1). This is in agreement with the CDC recommendation that everyone aged five years and older should get a COVID-19 vaccine to help protect against the disease. Therefore, during these stages, children are introduced to the first notions of diagnosis and treatment, infection, and prevention, and no knowledge in defense is expected of them.

In grades 3 through 5, the concept of infection and diagnosis is further developed. By the end of the fifth grade, students should know that if pathogens are able to get inside one's body, it may keep it from working properly (Infection, Figure 1). At this point, the concept of immunity should be introduced so that, although this is not exactly the case for COVID-19, students understood that there are some diseases that human beings can catch only once and after they've recovered, they don't get sick from them again (Infection, Figure 1). Furthermore, the Atlas of Science Literacy points out that students should know that many diseases can be prevented by injecting people with killed or weakened pathogens so that people don't catch the diseases even once (Infection, Figure 1). We should note that this idea does not apply to the mRNA vaccines, which is the case of most of the developed vaccines for COVID-19, and

Table 1. Glossary of elements and concepts related to COVID-19 and health.

Themes	Topic	Words	
Spread and transmission	Pandemic	Epicenter Wave Outbreak Disease control	Positive rate Reproductive rate (Ro) = Basic reproduction number Herd immunity Community immunity
	Epidemic curve	Exponential curve Flattening the curve	Growth curve Curve peak
	Transmission	Contagion Community transmission Local transmission Chain of transmission Fomite transmission Aerosol transmission Droplet transmission	Indirect contact transmission Super-spreader Super-spreading events Patient zero Exposure risk Close contact
Cause and symptoms	Infection	Incubation period Reinfection	Viral load
	Symptoms	Asymptomatic Symptomatic Fever Ageusia Anosmia Fatigue Body aches	Dry cough Dyspnea Abnormal breathing Sever acute respiratory syndrome Aftereffects COVID Long COVID
Prevention of transmission	Hygiene	Hands wash Hydroalcoholic gel Gloves	Mask Personal protective equipment
	Social measures	Confinement Quarantine/isolation Physical distance Border closure	State of emergency Bubble Curfew
	Vaccine	Clinical trial Cold chain	Adverse reaction Anti-vaxer
Diagnostic, treatment, and fatality	Diagnostic	Temperature check Early detection PCR Saliva-based test	Rapid diagnostic test Antigen detection test Antibody detection test/serological test False negative/positive
	Cases	Confirmed case Active case	Recovered case
	Treatment	Retroviral Respirator	Intubation Plasma
	Fatality	Case fatality rate	Death rate
Biological basis	Virus	Coronavirus SARS RNA	Mutation Virus strain/variant
	DNA	DNA	
	Immunity	Antibody IgM IgG	Immune response Antigen
	Zoonosis	Bat	Pangolin

Table 2. Strand maps from the Atlas of Science Literacy analyzed.

Volume	Chapter	Cluster	Map
1	6	Physical Health	Disease Maintaining Good Health
2	6	The Human Organism	Basic Functions
	8	The Designed World	Health Technology
	10	Historical Perspectives	Discovering Germs

that these vaccines are effective tools to prevent severe COVID-19, hospitalization, and death in most cases, but they do not stop the transmission of the virus (Fiolet et al., 2022). However, at this stage, students should learn that, although SARS-CoV-2 is a pathogenic microorganism, most microorganisms do not cause diseases and may be beneficial (Infection, Figure 1).

In relation to diagnosis, the fact that there are normal ranges for body temperature that help to tell when people are sane is introduced at this stage (Diagnosis, Figure 2); this idea can be related to the fever occurring when contracting COVID-19.

Regarding the concept of defense, by the end of the fifth grade, students should know that a healthy body can fight most pathogens that do get inside although some of them can interfere with the body's defenses. For defense against viruses such as SARS-CoV-2, the human body has tears, saliva, and skin to prevent it from getting

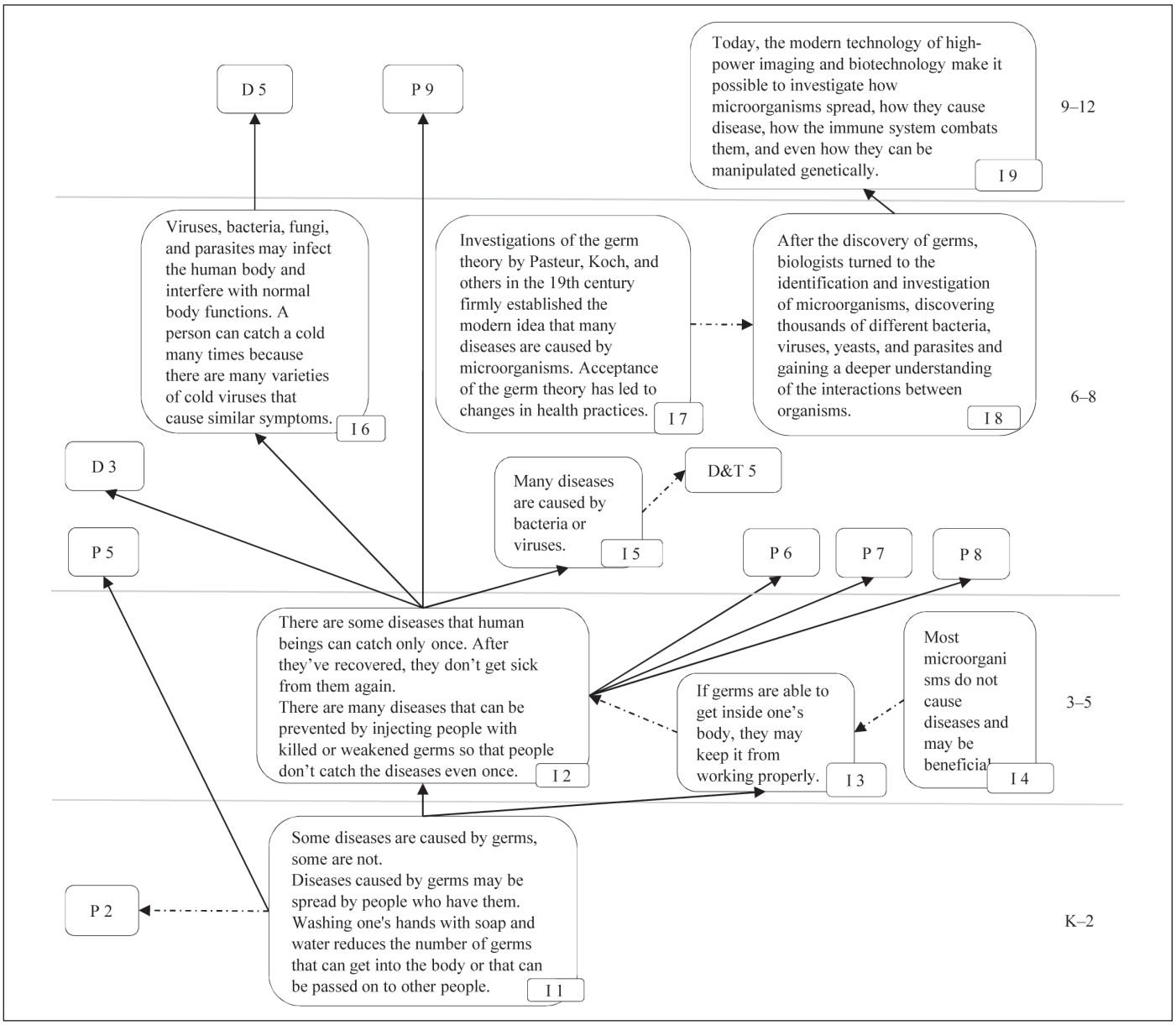

Figure 1. Concept map of Infection (I) showing the goals for student learning across different grade levels, from kindergarten to 12th grade. Squares represent the goals for students' learning as derived from the Atlas of Science Literacy. Continuous arrows represent inter-grade connections and discontinuous arrows represent intra-grade connections. Each idea is identified by the initial of the corresponding map and a number (e.g., I 1). This map is accompanied by a text that relates the health ideas to the COVID-19 disease (see Results).

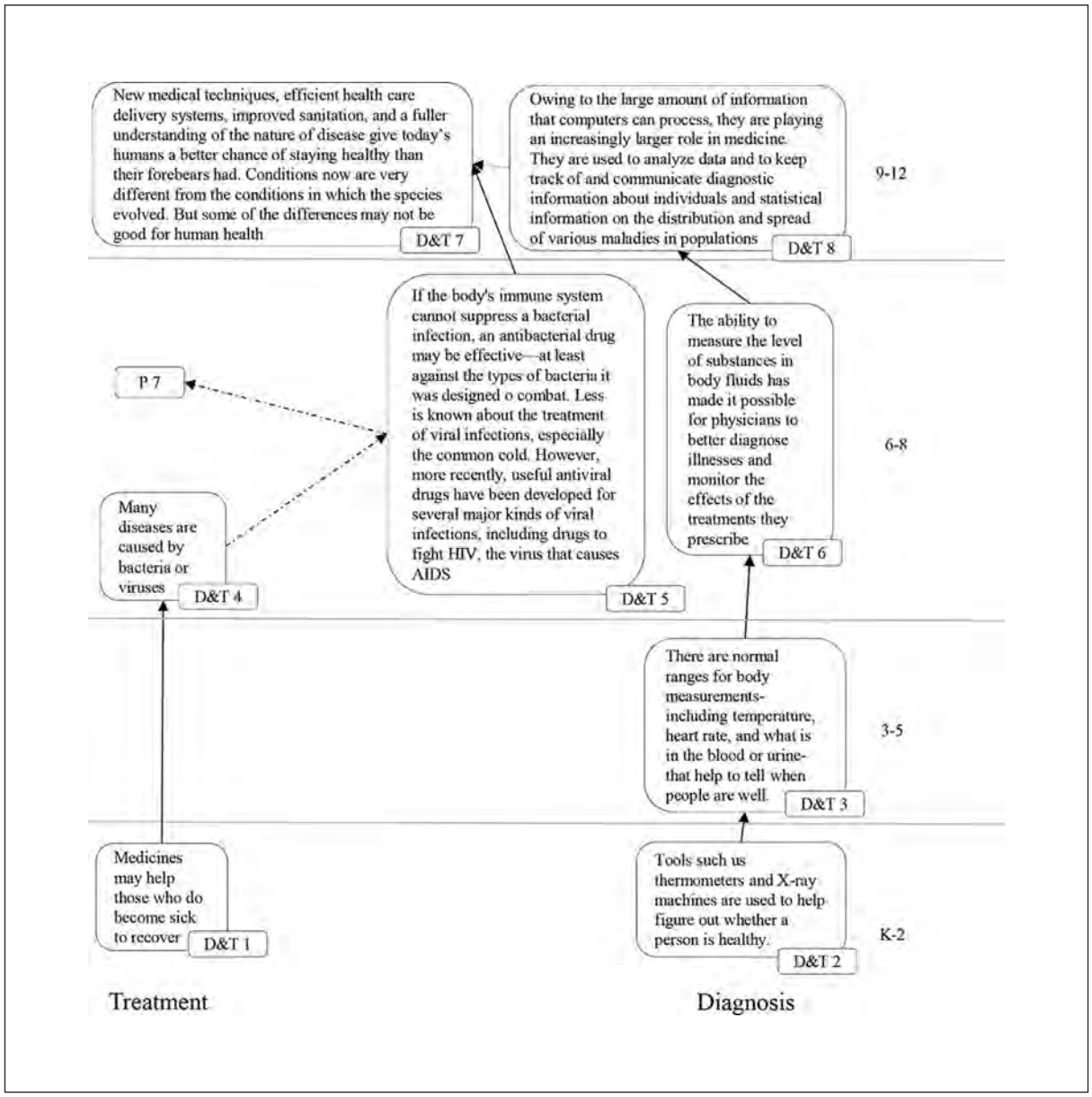

Figure 2. Concept map of Diagnosis and Treatment (D&T) showing the goals for student learning across different grade levels, from kindergarten to 12th grade. Squares represent the goals for students' learning as derived from the Atlas of Science Literacy. Continuous arrows represent inter-grade connections and discontinuous arrows represent intra-grade connections. Each idea is identified by the initial of the corresponding map and a number (e.g., D&T 1). This map is accompanied by a text that relates the health ideas to the COVID-19 disease (see Results).

into the body and special cells to fight it when it gets into the body (Defense, Figure 3).

In grades 6 through 8, the concept of infection is further developed so that a student deepens on various mechanisms and processes related to them. Therefore, by the end of the eighth grade, a student should know that viruses such as SARS-CoV-2, bacteria, fungi, or parasites may infect the human body and interfere with normal body function. Thus, students should begin to differentiate features and classification of organisms. Furthermore, as in the case of colds, a person can catch COVID-19 many times because there are many varieties of SARS-CoV-2 that cause similar symptoms. In fact, in a very short time, students have heard of new variants of the SARS-CoV-2 (Alpha, Beta, Gamma, Delta, and Omicron). The WHO has defined that the SARS-CoV-2 is naturally mutating over time and producing new variants that may affect the virus's properties, such as how easily it spreads, the associated disease severity, or the performance of vaccines, therapeutic medicines, diagnostic tools, or other public health and social measures (WHO, 2022c). Thus, this may be a good time to introduce the concept of mutation and new variants in class.

Continuing with infection, students should also know about investigations of the germ theory by Pasteur, Koch, and others (19th century), which firmly established that many diseases are caused by microorganisms, and which acceptance led to changes in health practices. After the discovery of germs, biologists turned to the identification and investigation of microorganisms, discovering

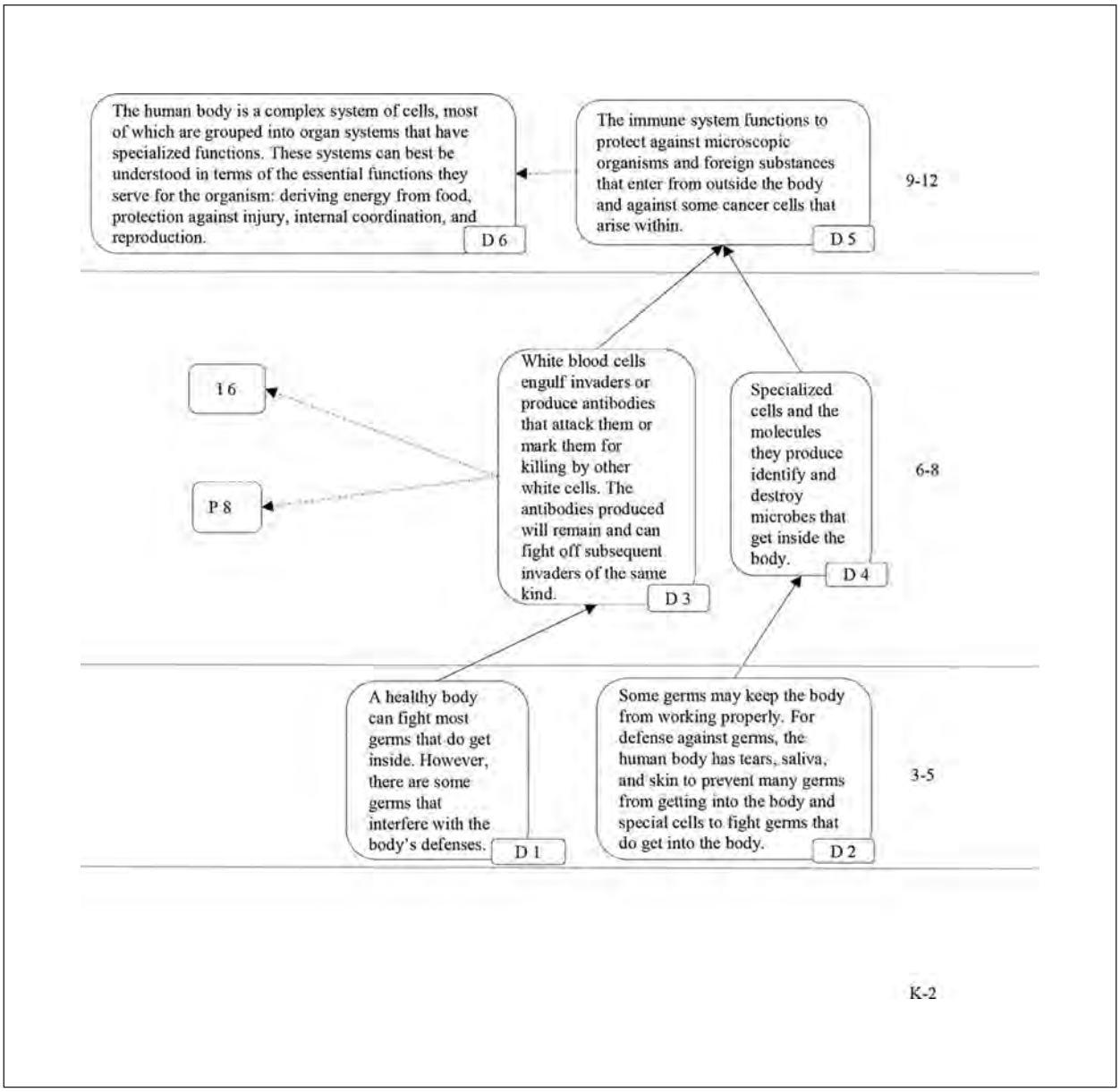

Figure 3. Concept map of Defense (D) showing the goals for student learning across different grade levels, from kindergarten to 12th grade. Squares represent the goals for students' learning as derived from the Atlas of Science Literacy. Continuous arrows represent inter-grade connections and discontinuous arrows represent intra-grade connections. Each idea is identified by the initial of the corresponding map and a number (e.g., D 1). This map is accompanied by a text that relates the health ideas to the COVID-19 disease (see Results).

thousands of different bacteria, viruses, yeasts, and parasites. SARS-CoV-2 is an example of one of those viruses discovered these days.

In addition, Pasteur found that infection by disease organisms caused the body to build up an immunity against subsequent infection by the same organisms. He then produced vaccines that would induce the body to build immunity to a disease without actually causing the disease itself. Therefore, COVID-19 vaccines induce the body to build immunity without actually causing the disease itself (Infection, Figure 1). Thus, at this age, students should not only know that vaccinations are used to protect people from suffering severe COVID-19 but also understand their action mechanism.

In terms of diagnosis, the Atlas of Science Literacy indicates that students should know that the ability to measure the level of substances in body fluids has made it possible for physicians to better diagnose illnesses and monitor the effects of the treatments they prescribe (Diagnosis, Figure 2). Antigen tests, antibody tests, and PCRs that students have come across in the last years are good examples of this idea.

In relation to treatment, during these grades, students should study the existence of antibacterial drugs designed to combat bacteria and, although less is known about the treatment of viral infections, especially the common cold, more recently, useful antiviral drugs have been developed for several major kinds of viral infections, including drugs to fight COVID-19 (Aslan & Akova, 2021).

Regarding prevention, the students should know that the length and quality of human life are influenced by genes and environmental

factors, including sanitation, diet, medical care, and personal health behaviors. In addition, they should be familiarized with sanitation measures such as the use of sewers, landfills, isolation, and safe food handling that are important in controlling the spread of organisms that cause disease (Prevention, Figure 4). Taking into account that the SARS-CoV-2 is believed to be acquired from zoonotic sources and spread through direct and contact transmission (Umakanthan et al., 2020), this is the moment to remark to the students that improving sanitation to prevent disease has contributed more to saving human life than any advance in medical treatment and that current health practices emphasize sanitation, the safe handling of food and water, the pasteurization of milk, isolation, and aseptic surgical techniques to keep pathogens out of the body; vaccinations to strengthen the body's immune system against subsequent infection by the same kind of microorganisms; and antibiotics and other chemicals and processes to destroy microorganisms (Prevention, Figure 4).

Finally, and concerning defense, students should know that the specialized cells and the molecules they produce identify and destroy microbes that get inside the body. In concrete, white blood cells engulf invaders or produce antibodies that attack them or mark them for killing by other white cells. The antibodies produced will remain and can fight off subsequent invaders of the same kind (Defense, Figure 3). As mentioned earlier,

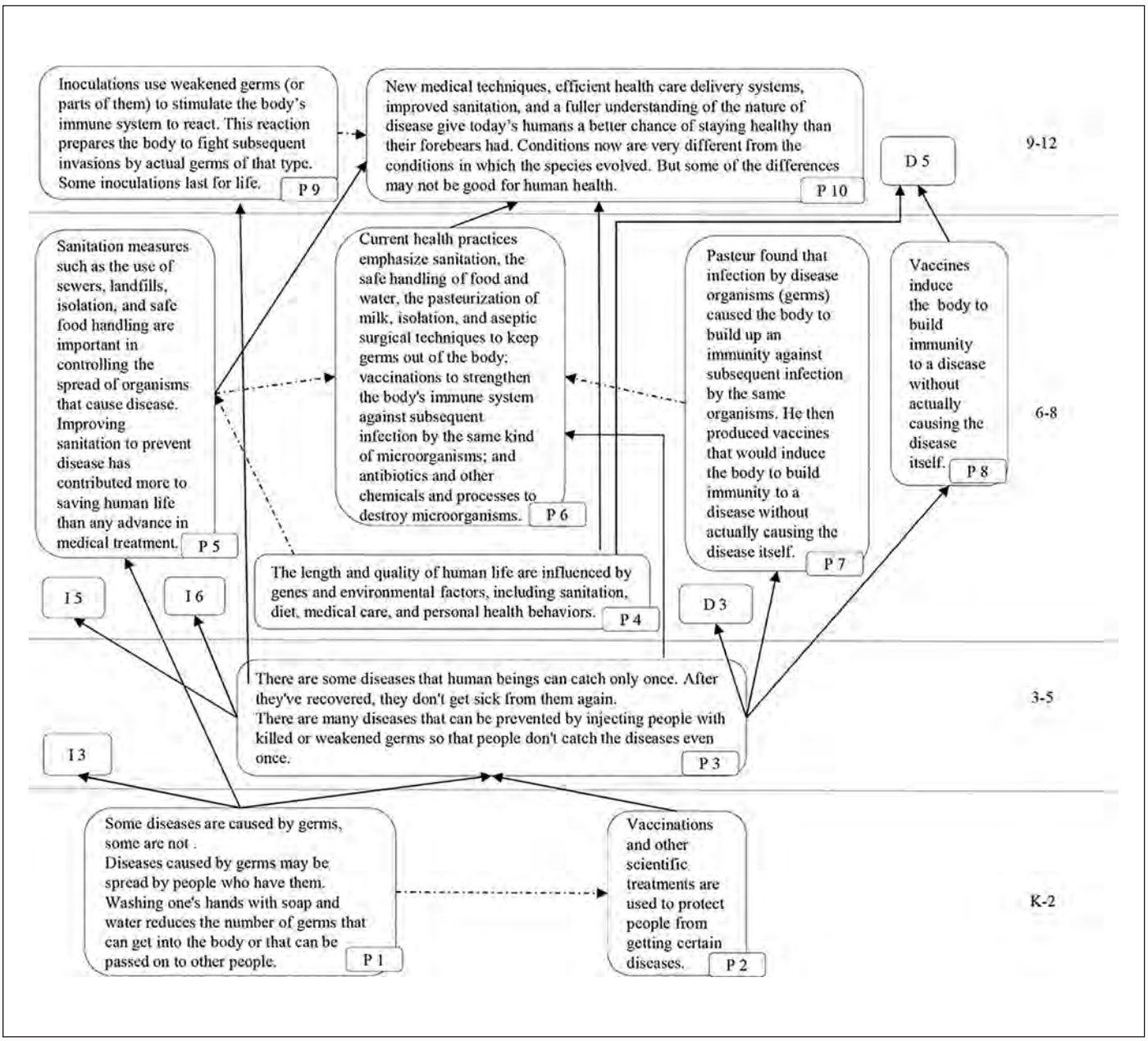

Figure 4. Concept map of Prevention (P) showing the goals for student learning across different grade levels, from kindergarten to 12th grade. Squares represent the goals for students' learning as derived from the Atlas of Science Literacy. Continuous arrows represent inter-grade connections and discontinuous arrows represent intra-grade connections. Each idea is identified by the initial of the corresponding map and a number (e.g., P 1). This map is accompanied by a text that relates the health ideas to the COVID-19 disease (see Results).

students are now familiarized with antigen tests and antibody tests; therefore, in grades 6 through 8, they should understand why these substances are present in the blood after suffering from COVID-19.

Students should finish middle school knowing that the immune system functions to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within. Continuing with infection, students should fully understand the action mechanism of the new vaccines for COVID-19, which have been developed from weakened viruses, parts of them, or genetic sequences to stimulate the body's immune system to react and this reaction prepares the body to fight subsequent invasions. In addition, it is time to introduce that some vaccine responses last for life, although more research is needed to be able to affirm if this could be the case for COVID-19 (Infection, Figure 1).

On the other hand, at this age, students should be introduced to modern technology of high-power imaging and biotechnology that makes it possible to investigate how microorganisms spread, how they cause disease, how the immune system combats them, and even how they can be manipulated genetically (Infection, Figure 1).

In the same line, and related to diagnosis and treatment, students should notice that new medical techniques, efficient health care delivery systems, improved sanitation, and a fuller understanding of the nature of disease give today's humans a better chance of staying healthy than their forebears had. Conditions now are very different from the conditions in which the species evolved (Diagnosis and Treatment, Figure 2). Moreover, owing to the large amount of information that computers can process, they are used to analyze data and to keep track of and communicate diagnostic information about individuals and statistical information on the distribution and spread of various maladies in populations. This is something that we have seen daily on the news, where data are constantly updated, and the tracking that health services around the world have made.

Finally, and in terms of defense, by the end of middle school, students should know that the human body is a complex system of cells, most of which are grouped into organ systems that have specialized functions. These systems can best be understood in terms of the essential functions they serve for the organism: deriving energy from food, protection against injury, internal coordination, and reproduction. If they relate this systemic idea to the COVID-19, they should understand that the immune system functions to protect against the SARS-CoV-2 that enters from outside the body (Defense, Figure 3).

In conclusion, the emergence of the COVID-19 in our lives serves as a framework for learning a context of ideas around every main concept related to the subject in a roadmap to health literacy. These maps can be a valuable tool for educators, who may use them for K–12 (5–18 years old) health literacy instruction using the COVID-19 as a societal and personal context. Future pandemic diseases (including new mutations of COVID-19) could also fit in the given maps after a slight remapping. Similarly, teacher educators may use the maps as a guide for the learning progressions in health literacy. Students, too, may find the maps useful, as concept maps help students clarify their knowledge and sort and classify new information by establishing priorities (Novak, 2010). In this sense, Artayasa et al. (2021) have recently described that inquiry learning accompanied by concept map-making favors higher scientific literacy than conventional learning. Curriculum planners may also benefit from these maps, especially those international curricula (e.g., Spain) where ideas are not explicitly and systematically structured in the order of increasing complexity when passing longitudinally from one cycle to the next (Criado et al., 2014). Overall, the maps are a framework for inspiring educators, students, and others to use COVID-19 to learn and/or teach about health.

○ Acknowledgment

Project PID2022-137010OB-I00 funded by MCIN/AEI /10.13039/501100011033 / FEDER, UE GIU21/031

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