IDENTIFICATION OF SECONDARY SCIENCE TEACHERS' ALTERNATIVE CONCEPTIONS RELATED TO AVIAN INFLUENZA

How secondary science teachers understand infectious disease and disease transmission has an important impact on the public. This study analyzed the conceptions of ten secondary science teacher participants in the Maps in Medicine Institute. In this paper, we discuss alternative conceptions regarding the flu held by these ten teachers collectively before and after the institute, as well as the role of the institute activities in changing these. Data sources included written assessments before and after the institute and teacher reflections on their learning and the institute activities. The paper concludes with an analysis of how this relates to socioscientific issues and professional development.

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Introduction

Influenza, also called "the flu" is a highly contagious viral infection of the nose, bronchial tubes, and lungs. The threat of influenza is ever-pervasive in our society as our population increases and people become more crowded. While each year results in increasing understanding of this virus, it still remains one of the top killers, striking 10-20 percent of the U.S. population, and leaving approximately 20,000 dead annually. Fatalities are most pervasive among the very young and elderly.

Influenza and the High School Curriculum

The challenge of studying this virus lies with the fact that it is always changing. Influenza hides and develops within a variety of reservoirs, including birds, swine, and humans, and is able to reassort with other strains and undergo random mutations within these reservoirs. The virus's ability to reassort and mutate makes continual study and monitoring a crucial step in the maintenance of public health. The last major pandemic occurred in 1918, killing 50-100 million people worldwide. As flu strains tend to change faster than scientists can keep up with them, the threat of another pandemic continually lurks.

We feel education about influenza is a key to public preparedness and safety. This starts in our schools. We categorize understanding of influenza within four themes. First, teachers and students need to understand what influenza is. At its most basic level, they need to understand that influenza is a virus; at a more advanced level, how a virus infects a cell and reproduces. Next, understanding how our body responds to viruses such as influenza is essential. This includes the concept of flu strains and how antibodies protect our bodies from certain strains. At a more practical level, these concepts can be used to understand how the flu vaccine works, including its strengths and limitations. Third, ecological factors need to be discussed. What are the common hosts of influenza? How is influenza transmitted from one host to another? How can transmission be prevented? Finally, the first three concepts need to be applied to understanding societal impacts of the virus. What steps can we take to keep our community safe from the flu? In the event of a pandemic, how do we evaluate the consequences of quarantining communities, closing schools, and restricting business? In this paper, we discuss how teachers understand these concepts and how they change during a five-day summer institute.

Theoretical Framework

Lens

Our study utilized the socioscientific issues (SSI) framework to give perspective to our research. The SSI framework focuses specifically on empowering students to consider how science-based issues and the decisions made concerning them reflect, in part, the moral principles and qualities of virtue that encompass their own lives, as well as the physical and social world around them (Kolstø, 2001; Sadler, 2004). SSI therefore does not simply serve as a context for learning science, but rather as a distinctly more developed pedagogical strategy (Zeidler, Sadler, Simmons, & Howes, 2004).

Conceptual Framework

This study focused on identifying common alternative conceptions held by secondary science teachers related to influenza and discussing strategies used to address them. By understanding teachers' alternative conceptions and strategies for addressing them, this study will help teachers become better prepared to teach this topic both in content knowledge and pedagogy. Our paper is informed by conceptual theory related to alternative conceptions.

There are five types of scientific alternative conceptions as identified by the National Research Council (1997, p. 28). One alternative conception is that of preconceived notions described by Driver et al. (1994) as popular ideas stemming from everyday life. A second type of alternative conception stems from views from religious or other non-scientific sources. Conceptual misunderstandings are a third alternative conception that addresses faulty models of processes in science. Vernacular misconceptions occur when science ideas are confused with the same term that has another meaning in everyday life, resulting from instructors using analogies and metaphors that are not understood, and thus mischaracterized, by the learner (Chew & Laudbichler, 2003; Clerk & Rutherford, 2000; Duit, 1991; Novak & Gowin, 1984; Wandersee, Mintzes, & Novak, 1994). The fifth alternative conception that informed our study was factual misinterpretation. Factual misinterpretations occur when faulty information is relayed by teachers, parents, texts, or peers (Duit, 1991) and often occur when a learner simply memorizes as opposed to being challenged to contextualize and back their beliefs (Lemberger, Hewson, & Park, 1999).

Research Questions

We seek to answer two major questions in this study. First, we aim to uncover alternative conceptions related to influenza that our secondary science teachers took into the summer institute and whether and how these changed by the end of the institute. Next, we seek to evaluate the role of professional development activities, those at the summer institute in particular, in helping teachers develop their ideas.

Methods

Participants in this study included 10 secondary science teachers (8 females and 2 males) enrolled in a 1-week institute addressing the history of avian influenza, its identification and mechanism of action, its detection and treatment in animals and humans, tracking its spread, and the nature of a pandemic and how it may be planned for and handled. This institute is part of a five-year cooperative program between high school students and teachers, university faculty, and experts in the community to develop strategies, which include laboratory and mapping activities, designed to make the biological sciences accessible and appealing to high risk students. The institute focused on engaging participants in module activities, enhancing scientific background related to avian influenza, and conducting laboratory exercises that demonstrate how scientists might determine how the influenza virus infects populations and spreads within them.

Data sources included pre- and post-tests containing open-ended and multiple choice questions. We administered the pre-test on the first day of the institute to probe the teachers' alternative conceptions and the post-test on the last day to determine the teachers' understandings at the close of the institute.

Teachers also kept a journal of daily reflections, in which they were encouraged to integrate ideas and apply them to their own classrooms. These were used in evaluating if and how institute activities assisted teachers in developing their ideas.

Both pre- and post-test results, as well as reflections, were categorized two ways. First, test results were categorized by alternative conception based on the NRC's framework. Second, alternative conceptions were categorized into the following subtopics: immunity, molecular, ecology, and society, based on the aspect of influenza being discussed. For example, an alternative conception regarding the body's response to influenza would be classified as "immunity," while an alternative conception regarding hygiene or how we as a society need to respond to a pandemic would be categorized as "society." The assignment to categories was discussed by three researchers and finalized. The original researcher then completed the analysis. The daily reflections were used to give the pre- and post-test context; to gather teachers' opinions on what worked and what did not.

Results—Conceptions Before and After

Immunity

Within the realm of immunity, our participants demonstrated a variety of misunderstandings, which are primarily vernacular and conceptual in nature. First, participants demonstrated a misunderstanding of how influenza strains are named (H_xN_y) and what the letters mean.

Nomenclature

As stated by one teacher, "H stands for highly pathogenic." This response indicates a vernacular alternative conception. While the teacher is able to identify influenza as a pathogen, a false connection between this property and the nomenclature for identifying influenza stains is identified.

Two other teachers have less specific ideas of what the H and N mean. In the words of one teacher, "H tells you the name of the virus;" another states, "H tells you the strain of the virus." While both of these teachers understand that the H and N are used to identify the type of influenza observed, there is still evidence that they do not understand that these letters refer to the hemagglutinin and neuraminidase components of the strain. Here, these teachers seem to understand that the H and N designate the name of the strain while still unaware of what these letters mean. These alternative conceptions can be categorized as vernacular.

Bodily Response to the Flu

All teachers attending this institute generally understood that the flu is a virus. However, with several of the participants, there was no elaboration beyond this, indicating a lack of understanding of how the flu is transmitted and handled by our immune systems. More specific answers were given on the post-test, showing increased understanding of the specifics behind this aspect of the influenza infection.

Flu Vaccination

While several of our participants indicated understanding of what influenza is and basic knowledge of how it infects animals, there was some misunderstanding of how the flu vaccination works to prevent the infection. The primary misunderstanding here was the role of antibodies in our body's defense against this virus. In order to evaluate understanding of the flu vaccine, we used three prompts:

1. How does the flu shot prevent us from getting the flu?
2. Why does the flu shot have to be given every season?
3. How do antibodies to influenza viruses work?

In response to the first prompt, several of the teachers address the fact that the flu vaccine helps the immune system know to attack the virus. While this is true, failure to mention antibodies could indicate that they do not associate this word with the flu vaccine and the body's defense system, potentially indicating a conceptual misunderstanding.

In response to the second prompt, two common responses were that the virus evolves. Some elaborate on this further by mentioning that the virus evolves yearly. Again, these teachers are on the right track. However, there is no mention of the mechanism by which the virus evolves (mutation and reassortment). Additionally, participants stated that influenza changes yearly, which might be categorized as a factual misunderstanding spawned by the media. In reality, influenza is continually evolving and changing.

The third prompt addresses the role of antibodies in our immune systems. This prompt elicited a variety of responses. These included the ideas that antibodies kill virus-infected cells, that they prevent the virus from exiting the cells, and that they physically break apart the virus. These responses indicate misunderstanding of the conceptual model of how antibodies work within our immune systems—a central concept.

Molecular

Pre-test responses and reflections indicated that most of these teachers had some background in biochemistry and genetics, as indicated by their knowledge of the structure and function of proteins. However, these understandings were incomplete, especially as they related to the flu virus.

Protein Folding

The first concept assessed by the pre- and post-tests was why proteins fold to form their secondary and tertiary structures. Two of the teachers seemed to have a good grasp of this before the institute, one mentioning the interaction between the ammonium, carboxyl, and amino acid side groups, and the other addressing the folding that occurs due to some of these side groups being hydrophobic while others are hydrophilic.

Responses outside of those described above ranged from incomplete to nonexistent. Within the incomplete responses, one teacher indicated that proteins fold due to the interaction of amino acids, while another referred to this as, “Interaction between molecules.” These responses indicated incomplete understanding of protein behavior and structure. These teachers understood that proteins are large molecules made of smaller molecular or amino groups. The conceptual misunderstanding lies with how these molecular groups interact in order to create a functional protein, including how they fold as well as the chemical and physical interactions that cause certain proteins to behave the way they do.

Function of Hemagglutinin

The next goal of the pre- and post-tests was to assess the teachers' understandings of how the surface proteins of the influenza virus change in response to its interaction with its host cell. Specifically, the teachers were asked what causes hemagglutinin to change its 3D shape after the influenza virus enters its host cell. Four of the ten teachers correctly stated that hemagglutinin changes its 3D shape in response to the acidic environment within the cell.

As with the previous question about protein folding, incorrect responses to this question ranged from incomplete to nonexistent. The incomplete responses indicated partial conceptual understanding of influenza's adaptation to the intracellular environment. One teacher indicated that hemagglutinin changed due to loss of a small peptide due to proteolytic cleavage. Due to the fact that this was a response to a multiple choice question, it is unclear whether it indicates incomplete conceptual understanding, or whether it was just a guess, indicating similar understanding to the teachers who put forth no guess.

The more popular incorrect answer was that hemagglutinin changes its shape due to its passage across the cell membrane. This response shows these teachers have the idea that the physical interaction between hemagglutinin and the cell membrane changes its shape, showing a conceptual misunderstanding of influenza proteins.

Ecology

Natural Hosts

The pre- and post-tests focused on the vectors carrying the influenza A strains. When asked what the natural hosts of the influenza A strains were, about half the participants chose either swine or humans as opposed to birds, indicating a factual misunderstanding. Since most of what the teachers hear about the flu is in reference to people, it is understandable that some would choose humans as a probable answer. It is less clear, however, why they chose swine, as much of the media attention outside of infection in people is on “bird flu.”

Society

Another important topic addressed by this institute is how influenza relates directly to our society and our lives. What role does the government have in keeping influenza in check? How do we do our part as individuals to minimize the risk to our peers and ourselves? Of the four topic categories, the teachers seemed to have the best grasp of this one, showing very few misunderstandings on both the pre- and post-tests, which addressed concepts such as the goal of pandemic planning, the unintended effects of school closure on citizens, and effective personal hygiene techniques.

The Goal of Pandemic Planning

The first concept we asked the teachers to reflect on was their thoughts on the goal of pandemic planning. On the pretest, one teacher knew that the goal was to spread out the number of people infected over time, as keeping the number of people infected at one time to a low number would halt the spread of the virus. A vast majority of the teachers indicated that the goal of pandemic planning was to eliminate the virulence of the next virus. This answer comes from two conceptual misunderstandings. First, the concept of virulence was defined it as the number of deaths caused by a disease, as opposed to the ratio of number of deaths to number of people infected. Second, they did not fully understand that people may be resistant to infection by a subsequent virus due to antibodies, but this does not affect the virulence of the virus.

One teacher indicated that quarantining a large number of people was an objective of pandemic planning. This comes from a factual misunderstanding of the repercussions such a policy would have in our society, as people would likely refuse to be held against their will.

Effects of School Closure

In the event of a pandemic, schools would likely have to be closed. While this would likely prevent the spread of infection by encouraging those infected to stay home, it would also have unintended consequences. Pre- and post-tests indicated no misunderstandings. However, the teachers took several different angles when answering this question. One teacher mentioned that school closure would result in loss of a reliable source for meals for poor students. Several others brought up child care issues. The children would be left home alone while their parents are working, which may result in an increase in delinquency. Others brought up economic issues, including the fact that parents who did not allow their children to stay home alone may have to pay for childcare, and schools would not get money for student attendance. Finally, one teacher mentioned that the loss of part of the school year would possibly result in children getting behind in their education, resulting in long-term economic recession. While the teachers seemed to understand what some of the unintended negative consequences of school closure would be, the goal of the institute was to expand on these understandings, encouraging the teachers to explore the topic more deeply.

Hygiene Techniques

Pre- and post-test data indicate that the teachers understand the role of personal hygiene in preventing the spread of influenza. They were asked to choose an inappropriate hygiene technique for reducing the spread of disease. Of the choices, all of the teachers indicated that sneezing into your hands would not prevent the spread of influenza. Here, they demonstrated the understanding that infected hands will result in our infecting of anything we touch.

Results—How Ideas Developed

Institute Activities—Immunity

Analysis of teachers' reflections showed that models were a key to learning. First, activities emphasized that the function of hemagglutinin is to assist entry into the cell, while the function of neuraminidase is to allow viral particles to exit the infected cell. Second, the hemagglutinin bonds to the sialic acids on our cells. This process was illustrated with a hook-eye model, where the hemagglutinin protein served as the hook; the sialic acid the eye. As a teacher expressed her learning on this topic, "I learned what is necessary for a virus to grow and infect a cell then making it into a 'factory' for the virus to reproduce. I had no idea what the H5N1 was and I can at least recognize that H is the 5th known hema. protein and the 1st known neura. protein, and the fact that a virus is wrapped in a protein coat." This model opened up numerous possibilities for development of conceptual understanding.

This model allowed the teachers to conceptualize how the flu virus attaches to a cell as well as why we are not infected by certain flu viruses. They were able to imagine that certain hemagglutinin "hooks" could fit the sialic acid "eyes" and attach to our cells while others could not. This model was also easily extended to explain the function of antibodies. Antibodies were described as interferers that prevent the hemagglutinin hook from attaching to the sialic acid eye. This seemed to come across as an effective analogy. In the words of one of our teachers, "I learned about the antibodies and just how they stick to the virus so that they block the possibility for the virus to stick to the cell." With the information that our bodies produce antibodies in response to exposure to a virus and how these work, it was easy for teachers to put together how the flu vaccine can prevent us from contracting the virus.

The teachers built upon the experience of the hook-eye model by studying the mechanism of action of antivirals such as Tamiflu, which recognize viral proteins and destroy them, thus preventing viral entry into our cells and reproduction within. This discussion proved both intriguing and informative to the teachers. In the words of one teacher, “We talked about the current drugs that act like the antibodies and block the Neuraminidase so the virus can’t spread. It was also interesting that the drug Tamiflu is the only drug that works at this time.”

In response to the open-ended question on the pre-test, “What causes the flu?” some teachers wrote, “The flu is a virus.” Then throughout the institute, teachers were encouraged to explore many aspects of this question, from the fact that influenza is a virus and must be treated as such to the fact that the virus is transmitted in different ways, from exposure to a crowded environment to poor personal hygiene.

In reflections, teachers also indicated learning that the flu is a virus by addressing how it differs from a bacterium and the implication of this in medical treatment. Discussion of the common misconception that antibiotics such as penicillin can be used to treat influenza was helpful here, as it connected this concept to the lives and wellbeing of themselves, their families, and their students. When this concept was connected to the discussion of flu strains and the H and N proteins, antibodies, and the mechanism of action of the flu vaccine and antivirals, the teachers in this institute were able to acquire a strong background to describe the nature of influenza specifically from a variety of angles.

In addition to the reflections, the post-test data indicated that the institute was effective in helping the teachers overcome their misunderstandings regarding how influenza and our bodies interact. Misunderstandings as the teachers left the institute dealt primarily with the concept of antibodies. One teacher stated that antibodies to influenza viruses work by preventing the virus from exiting the cell. This misunderstanding illustrates the fact that this teacher sought to memorize a phrase describing the function of antibodies as opposed to reasoning through the model. This resulted in the teacher getting it backwards on the post-test.

When describing how the flu shot prevents us from getting the flu, another teacher stated that it allows us to build up immunity before the virus is introduced naturally, while another stated that it helps with our immune response. While these statements are correct, their lack of specificity may indicate that these two teachers have not gained a complete understanding that antibodies are crucial in this process.

Institute Activities—Molecular

At the institute teachers studied the anatomy of the influenza virus and how it changes within cells through interactive lectures, discussions, and analysis of three dimensional plastic models of the virus, which contained models of the RNA, lipid, proton pump, and surface protein components

From post-test data, we concluded that studying the models within an interactive lecture environment was effective in addressing misunderstandings related to how influenza adapts to the intracellular environment. Most of the teachers, during the post-test, correctly stated that hemagglutinin changes its 3D shape in response to the acidic environment within the cell. Those who did not answer this question correctly linked this response in hemagglutinin to the sialic acid receptor. These teachers came into the institute with conceptual misunderstandings and left with a vernacular misunderstanding, mixing up the term, “sialic acid,” which serves as the receptor for hemagglutinin as influenza sticks to the cell, and indicting it as the cause for the acidic cellular environment. Overall, the teachers were able to use this discussion and modeling to learn and build on past understandings. In the words of one teacher,

> Today I learned how plant viruses differ from animal viruses. I am familiar with how single-stranded RNA plant viruses infect their hosts and spread but I am not familiar with how animal viruses particularly influenza works to infect its host and spread. I learned about the two types of protein located on the outside of the virus and I learned what functions these proteins serve.

While the lecture, discussion, and modeling were effective in fostering understanding of how the proteins structures within influenza work, they were relatively ineffective in improving teachers' understandings of protein structure in general. Several of the teachers left this institute continuing to implicate charge and acidity in changing protein structure. Based on the teachers' reflections a major reason for this is that many of the teachers came into this institute with weak backgrounds in biochemistry. One teacher explains her shortcomings: "Since I was not a biology major, I am not familiar with certain processes." Another expresses frustration on the shortcomings of activities presented at the institute:

> The assumption was that all of the teachers had the molecular biology background to perform many of the lab activities. There were not enough explanations of the labs and the interpretation of the results, so that is something that I will have to study more in order to be a comfortable level of understanding.

The parts of this institute pertaining to biochemical concepts were most helpful to the teachers who came into the institute with a strong biology and chemistry background. (However, for those with a weaker background, it perhaps served to make them more metacognitive, as is illustrated by the reflection above.)

Institute Activities—Ecology

The goal of the institute activities related to ecology was to help teachers develop an understanding of the spread of flu via certain vectors. Two activities were helpful for this.

The study of birds as vectors was facilitated with an activity where the teachers participated in a mock study in which they sampled birds in different areas from Alaska to Missouri and mapped the sampling areas using Google Earth. Some of these stations had detected a certain strain of influenza while others did not. Using data on flu strains present as well as swine farm density in the area sampled, the teachers made deductions on the risk of influenza to swine. This activity helped the teachers understand that waterfowl are the primary hosts of influenza while swine and humans can serve as secondary or tertiary hosts. One teacher stated, "I like the idea of utilizing Google Maps, collecting data, analyzing it, etc." This activity was effective in eliminating this misunderstanding, but not perfect, as one teacher identified humans as the natural reservoir for influenza A on the post-test.

Another institute activity involved tracking the spread of influenza by students. This activity was designed to address misunderstandings involving small-scale influenza spread and hygiene. An example of such a misunderstanding is the "five second rule," or the idea that if something touches an infected surface for less than five seconds, then it won't collect enough germs to induce infection. In the words of one of the teachers,

> It was a good visual to show students how easily a virus can be transmitted. It also shows them how many points of contact they have throughout the day, each one of these points of contact being a place or person to which the infection can be transferred.

In the words of another,

> This is a very good activity that will get the students thinking about how diseases are spread. Providing a map and allowing students to plot their pathway would let the students see how their pathways interact with others especially those who were infected with the disease and those that had been exposed to the disease. Using the Glow powder would be an effective way of showing how easily diseases could be spread especially if the infected party is asymptomatic. This would be a good lab to do if we had the necessary supplies.

This activity helped the teachers understand how easily viruses can be spread was well as the fact that infections such as influenza can be tracked spatially. While alternative conceptions regarding the ease of spread of influenza are likely factual, spread by misinformation such as the "five second rule" delivered by parents and peers, those involving the tracking of flu via pathway mapping are likely conceptual, stemming from the fact that this is not a topic that the teachers have thought a lot about.

Institute activities—Society

One way that societal issues related to influenza were addressed that was highlighted in many of the teachers' reflections was discussions with two real-world experts. One was Dr. Tom, a veterinary expert from the university, and Dr. Greg, a pandemic planner for the state of Missouri. Dr. Tom's presentation involved the role of influenza in animals, including the history and what is done in the lab to test for it. Dr. Greg's presentation included the issues the state must face in the event of a pandemic. Addressing the presentation on pandemic planning, one teacher stated:

> We addressed the ramifications of school closures (childcare expenses, juvenile delinquency, loss of instruction time) as well as the social issues that arise such as lack of food and availability of medication. It would be good to have the student perspective on the whole thing. We talked about the delinquency issues, but I would be curious to know how teenagers think that they would respond.

In the words of another,

> Having Dr. Greg's follow up the lesson with the cold hard data also provided that reinforcement of reality to the issue. I believe that I could do this by developing a power point that demonstrates the history of the diseases and its mutations. I do plan to contact his office to acquire the handouts for students to take home to their families.

Addressing the presentation on influenza in animals by Dr. Tom, a teacher shows she is integrating what she has learned at the institute as a whole: "Much of what Dr. Tom discussed seemed like review but this was a good sign. It means that I am understanding the material." Post-test data indicate that these presentations were very effective in helping the teachers overcome their misunderstandings regarding pandemic planning. Not only were no misunderstandings detected by the post-test, but the responses regarding the issues of school closure were much more specific than those on the pre-test. The teachers showed a lot of excitement about sharing these concepts with their students.

Discussion

We consider a socioscientific issue to be one which has a basis in science and has a potentially large impact on society (i.e. Ratcliffe and Grace, 2003). Socioscientific issues impact all of us, from individual decision making all the way up to formation of public policy. Often, science concepts which are already a part of a school's science curriculum are an adequate basis for exploration of socioscientific issues. However, effective engagement in such issues requires a willingness to explore these science concepts in more depth. Additionally, since people tend to be interested in controversial social issues, a socioscientific approach to the classroom tends to put science into context and increase motivation (Solomon, 1993).

What the reflections on the institute activities have in common is that they showed that the science concepts were framed within issues that are dealt with outside of the realms of school and the classroom. Most of the information school people receive about socioscientific issues comes from the media—TV, newspapers, radio, and the internet. Giving teachers and students the opportunity to explore these topics within the classroom sets up a safe, collaborative environment where they can learn important concepts in the science curriculum while critically evaluating and making sense of the bigger issues they will be dealing with through their working lives.

Working socioscientific issues (SSI) into the classroom empowers students to consider how science-based issues reflect moral principles and elements of virtue that encompass their own lives, as well as the physical and social world around them (Zeidler, Sadler, Simmons, &

Howes, 2004). Zeidler, Sadler, Simmons, & Howes (2004) proposed a conceptual model (Figure 1) identifying four areas of pedagogical importance which serve to tentatively guide the teaching of SSI: (1) nature of science issues, (2) classroom discourse issues, (3) cultural issues, and (4) case-based issues. The authors describe these as "entry points in the science curriculum that can contribute to a student's personal intellectual development and in turn, help to inform pedagogy in science education to promote functional scientific literacy (p. 361)."

The results suggest that the institute helped give the participating teachers a variety of strategies and frameworks for implementing SSI into their classrooms. Active, varied discourse served as a staple for the entire institute. Studying different cultural aspects of decision making and related cases helped make the topic of influenza interesting and relevant to the participating teachers. They as well as their students have natural personal investment in the potential consequences of epidemic-related events and decisions, such as a flu pandemic and whether or not to get a flu shot. In this way, SSI gives an organic, very real support structure to concepts that can seem very tedious and abstract.

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