CBE—Life Sciences Education
Vol. 8, 62–71, Spring 2009

Article

High School Intervention for Influenza Biology and Epidemics/Pandemics: Impact on Conceptual Understanding among Adolescents

Nancy Dumais,*† and Abdelkrim Hasni†

*Département de Biologie, Faculté des Sciences, Université de Sherbrooke, Sherbrooke, QC, Canada, J1K 2R1; †Centre for Research in Youth, Science Teaching and Learning, Faculté d'Éducation, Université de Sherbrooke, Sherbrooke, QC, Canada, J1K 2R1

Submitted August 11, 2008; Revised October 27, 2008; Accepted November 6, 2008
Monitoring Editor: Debra Tomanek

Understanding real-life issues such as influenza epidemiology may be of particular interest to the development of scientific knowledge and initiation of conceptual changes about viruses and their life cycles for high school students. The goal of this research project was to foster the development of adolescents' conceptual understanding of viruses and influenza biology. Thus, the project included two components: 1) pre- and posttests to determine students' conceptions about influenza biology, epidemics/pandemics, and vaccination; and 2) design an intervention that supports conceptual change to promote improvements in influenza knowledge based on these primary conceptions. Thirty-five female students from a high school biology class participated in a series of instructional activities and pre- and posttest assessments. Results from the pretest indicated that high school students exhibit a limited understanding of concepts related to viruses. Six weeks after an intervention that promoted active learning, results from a posttest showed that conceptions about influenza are more accurately related to the provided scientific knowledge. Although adolescents have nonscientific models to explain influenza biology, we showed that a carefully designed intervention can affect students' knowledge as well as influence the implementation of health education programs in secondary schools.

INTRODUCTION

Influenza is an acute febrile illness that is caused by influenza A or B viruses. It occurs primarily during the winter in temperate climates, and throughout the year in both tropical and subtropical countries. Globally, influenza epidemics result in 3 to 5 million cases of severe illness and approximately 250,000 to 500,000 deaths each year (Rothman *et al.*, 2006). Three pandemics occurred during the past century: the Spanish influenza pandemic in 1918 to 1919, which claimed an estimated 50 million lives, and the Asian (1957) and Hong Kong (1968 to 1969) pandemics, which each resulted in 1 to 2 million deaths (Ayob *et al.*, 2006; Hampson and Mackenzie, 2006). Moreover, influenza is highly contagious and of considerable public health concern because of both the rapidity with which epidemics evolve and their associated rates of morbidity and mortality. In addition to science knowledge, understanding the conceptions that young people have about viruses and influenza in particular may be important for the development of effective school health education programs. In the health sector, the impact of both the depth and organization of biological knowledge has been demonstrated in a range of studies that focused on both adolescents' and lay adults' understanding of the biological basis of health and disease (Sivaramakrishnan and Patel, 1993; Kalichman *et al.*, 2000; Baker *et al.*, 2002; Schillinger *et al.*, 2002).

Teens have access to common sense, or intuitive, theories of scientific knowledge that trigger their reasoning about infectious diseases; however, these intuitive theories are conceptually shallow and marked by important errors (Simonneaux, 2000; Jones and Rua, 2006; Markow, 2006; Martin, 2006). Stud-

DOI: 10.1187/cbe.08–08–0048
Address correspondence to: Nancy Dumais (nancy.dumais@usherbrooke.ca).
Conflict of interest: Nancy Dumais was involved in producing, administering, and assessing the effectiveness of the curriculum.

ies that regard children's physical representations of microorganisms are insightful because these representations can vary between age groups (Naguy, 1953; Jones and Rua, 2006). The use of abstract figures appeared to decrease with age as animal representations increased and microorganisms were seen as harmful to humans (Naguy, 1953). Moreover, a study performed by Jones (Jones and Rua, 2006) showed that medical professionals, teachers, and students held a wide range of conceptions about bacteria and viruses. The authors noted that lower grade teachers as well as their students often combined both spontaneous and formal knowledge when expressing their understanding of microorganisms (Jones and Rua, 2006). Interestingly, this study also showed that the assumed size of a microorganism was attributed to the length of time it took for the body to rid itself of the illness and the degree of illness experienced. In general, students reasoned that a virus was more virulent compared with bacteria and, therefore, it was assumed to be larger in size (Jones and Rua, 2006). Poor hygiene and the use of warrior metaphors are common among adolescents when discussing microorganisms (Vasquez, 1985). In young adults, social dimension of conceptions such as childhood memories and media influences play important roles in the formation of concepts related to microorganisms (René and Guilbert, 1994). In 2000, a study was performed to understand students' conceptions about microorganisms to better evaluate their effects on the understanding of biotechnology (Simonneaux, 2000). The author showed that students' conceptions are conditioned by the status given to diseases, a hygiene-oriented culture, both informal and formal knowledge, personal experiences, socio-cultural mediation, and linguistic confusion (Simonneaux, 2000).

Children begin the knowledge acquisition process by organizing their sensory experiences under the influence of everyday culture and language into a narrow but coherent explanatory framework that may not be based on current scientific theory (Vosniadou and Ioannides, 1998). According to various studies, this constructed knowledge is called nonscientific knowledge, conceptions, or misconceptions (Vosniadou and Ioannides, 1998; Chi and Roscoe, 2002). Studies in science education provide clues and indications to help students acquire scientific concepts and change existing conceptions, a process called conceptual change. The concept of conceptual change varies among theorists; however, most researchers share the goal of student learning. To Vosniadou (Vosniadou, 2002), conceptual change is a process that enables students to gradually synthesize models from their existing explanatory frameworks and is referred to as a progression of mental models. For Chi and Roscoe (Chi and Roscoe, 2002), conceptions are miscategorizations of concepts, and conceptual change results in the repair of these erroneous conceptions. Some authors argue that conceptual change is the reorganization of diverse types of knowledge into complex systems in students' minds (diSessa, 2002), whereas others have a more radical view of conceptual change (Ivarsson *et al.*, 2002). For the latter group, common sense does not serve a purpose in conceptual change because conceptual change is the appropriation of intellectual tools. In science education, conceptual change models influence learning science, teaching science, learning how to teach science, and teaching how to teach science (Vosniadou, 2001). Instructional strategies that promote conceptual change are grouped into three categories: developing cognitive conflict, applying analogies, and facilitating cooperative and shared learning to promote collective discussion of ideas (Limon, 2001).

This research investigates the potential of promoting and supporting conceptual understanding of viruses and influenza biology in the context of high school students using a classroom intervention that supports conceptual change. In the first part of this research, we determined adolescents' conceptions and knowledge about both viruses and influenza biology. The identified conceptions and the scientific views were then used to develop learning activities on specific concepts related to virology that fostered students' conceptual development. Six weeks after the intervention, conceptual change was measured and compared with students' preconceptions. We interpret conceptual change as the evolution of students' initial conceptions of viruses and influenza biology to more complex conceptual understanding of these concepts after the intervention. Because the media abundantly discuss influenza, our findings play important roles in the implementation of comprehensive educational programs on influenza and epidemics/pandemics as well as on other topics related to virology or microbiology in secondary schools.

METHODS

Participants

The student participants were from a private school in the Eastern Townships of Québec (Canada). Data were collected on 35 female students in a grade 10 biology class. All student participants had little or no instruction related to viruses or illness either before or during the semester of the study because there are currently no specific guidelines or competencies for students in grade 10 related to instruction about microorganisms and bacteria (Québec, 2003).

Pretest and Posttest

Students' conceptions have been elicited and compared before and after a teaching intervention. The questionnaire consisted of a mix of open-ended and multiple-choice questions (see Supplemental Material A). Three open-ended questions were used to assess student knowledge or conceptions regarding virus and influenza biology as well as the mechanism of infection (e.g., What is a virus? Can you describe the influenza virus? How are influenza viruses infecting specific target cells?). Multiple-choice questions were used to determine students' knowledge about vaccination and the emergence of flu epidemics/pandemics at the cellular level. For this section of the questionnaire, the score constituted the number of items answered accurately: a wrong answer was assigned a score of 0, whereas a correct answer was assigned a score of 1. Pretests were administered 1 wk before the intervention, and the posttests were administered 6 wk after the intervention. For both the pre- and posttest, a period of 10 min was allowed to answer the questionnaire.

Students' responses to the questionnaire were also characterized in terms of model progression (Keselman *et al.*, 2007). We classified students' understanding of influenza biology into three conceptual models: nonscientific, intermediate, and advanced. The models reflect students' understanding of the following concepts: the nature of influenza, the mechanism of influenza infection, epidemic/pandemic progression, and vaccination. Students were assigned to a model if at least two of three concepts were consistent with the model description. The advanced model involved a basic understanding of influenza-relevant biological structures and processes on the cellular level. The intermediate model necessitated the un-

Table 1. Coding guidelines to determine the models of influenza understanding

Type of model	Characteristics: Core concept of influenza virus	Mechanism of infection	Epidemics/pandemics and vaccination
Advanced (understanding of influenza-relevant biological structure and processes on the cellular level) Score = 2	Influenza is a virus with specific cellular-level (structural and functional components)	Influenza is transmitted by air and infects cells located in the respiratory tract	The immune system fails to recognize viral particles that have mutated envelope proteins AND Knowledge of the basis of immunization (vaccine, immunity)
Intermediate (understanding of influenza on systemic, but not on the cellular level) Score = 1	Influenza virus is a biological entity (details of the viral structure or characteristics are not provided)	Influenza is transmitted (details of how and where are not mentioned)	The immune system fails to recognize new viral particles (without structural details) OR Knowledge of the basis of immunization (vaccine, immunity)
Nonscientific (describing influenza using lay concepts of health and disease and/or scientific concepts unknown) Score = 0	Influenza virus is confused with cell or bacteria or illness	No scientific concepts are used	No scientific knowledge on that topic

derstanding of influenza on a systemic level. Finally, the nonscientific model was built around intuitive lay concepts of health and disease. A detailed description of the coding scheme is presented in Table 1. For the analysis, the models were converted into numeric scores as follows: the nonscientific model was assigned a score of 0, the intermediate model was assigned a score of 1, and the advanced model was assigned a score of 2. A researcher who possesses background in virology/immunology performed the coding that was repeated two times to ensure consistency. To better describe students' conceptions about viruses for this particular topic, adolescents' responses were also analyzed by noting common traits and developing categories from the emerging commonalities. The use of appropriate scientific vocabulary was also scrutinized in the students' responses.

Intervention Design and Procedure

To develop the curricular content of the intervention, we used students' pretest conceptions in combination with scientific knowledge about influenza biology. The intervention was performed during an 80-min period, and the curriculum included scientific-led lectures (conferences) and for certain topics, models in large or small groups. After the analysis of students' conceptions in the pretests and identification of concepts for which students demonstrated a weak comprehension, we created models for fundamental concepts such as virus structure, cellular tropism, and influenza epidemics/pandemics. Details of the intervention as well as the mechanisms of conceptual changed used to foster conceptual change are presented in Table 2.

A model is defined as a representation of an object, event, process, or a system (Gilbert *et al.*, 1998a, 1998a, b). For scientists, science teachers, and science learners, models and modeling are essential tools (Coll *et al.*, 2005). Here is a brief description of the models used during the classroom intervention that fostered conceptual change in students:

1. Virus structure: To explain the influenza virus structure, we constructed an analogical model (Harrison and Treagust, 2000a). We selected a limited number of viral components that are essential to the understanding of the mechanisms of antigenic shift and drift (Figure 1). The virus, drawn in green (20-cm diameter), was represented as a circle in which the edge corresponded to the envelope. Eight movable rectangles (3 large, 3 medium, and 2 small) were used as symbols of the segmented RNA genome. We identified the two segments responsible for the production of hemagglutinin and neuraminidase. These envelope proteins (hemagglutinin and neuraminidase) were also present in the analogical model as movable parts. The virus components were drawn in green.
2. Cellular tropism: To explore this particular topic, we used an analogy (Harrison and Treagust, 2000a) to investigate virus attachment and entry into specific cells. To understand the key/lock model, we proposed a game to help students comprehend the principle of virus attachment to a specific cell type. Four students in the classroom were chosen to represent either influenza or HIV, whereas the other students represented different cell types, such as neurons, T lymphocytes, epithelial cells from the respiratory tract, or muscle cells. Each student received a strip of paper that contained either the virus or the cell type with a bicolor code. Then, the four students who represented the viruses "infected" the classroom. In fact, they were looking for the particular color code on cells that corresponded to the color code of their virus. After discussion, we explained the concept of cellular tropism and the importance of influenza virus attachment to epithelial cells of the respiratory tract via hemagglutinin on the virus and sialic acid-containing cellular surface proteins or lipids on the cell.
3. Influenza epidemics: We generated two analogical models of influenza virus as shown in Figure 1 in two different colors: a red virus that infects humans and a green virus that infects ducks. Giant cells of human, duck, and pork were drawn on the blackboard, and infection of the human cell with the red virus and infection of the duck cell with the green virus were simulated. After the simulation, we discussed the possibility of simultaneous infection of pork epithelial respiratory cells with both human and avian viruses. We used the model to show that reassortment of RNA segments could occur in pork, resulting in new viral strains (antigenic drift). Students subsequently explored this concept by rearranging the viral segments in their models. We also discussed the possibility that viruses generate

Table 2. Details of 80-min intervention on virus and influenza biology

Time allowed (min)	Studied concept(s)	Details on the intervention	Teaching strategies that foster conceptual change
10	Virus bacteria cell	We first helped students to define what is a virus, a bacteria and a cell. Our discussion was supported with visual presentation.	Confrontation of students' conceptions of virus, bacteria, and cell with scientific models.
15	Virus structure	Elements of the virus particles were discussed: - Enveloped vs. nonenveloped virus particles - Viral proteins embedded in envelope (glycoproteins) - Genome (DNA or RNA) - Capsids and morphology We then explored the structure of influenza. The lecture was also carried out with visual support.	Utilization of an analogical model for the influenza structure[a] and manipulation of the model by students (1 model/2 students).
15	Cellular tropism	We talked about students' conceptions of tropism and virus entry (without referring to scientific models). Then, students were invited to play a game (analogical model for virus entry[1]). At the end, we defined the scientific model for virus entry and used a visual presentation to describe how influenza enters target cells.	Utilization of an analogical model for tropism and virus entry[a]; the game was played with all the students with discussion throughout. Confrontation of students' conceptions with scientific models for cellular tropism and virus entry.
30	Epidemics/pandemics	We used a mini-lecture with visual support. Then students were grouped and they explored the analogical model for epidemics/pandemics.[a]	Utilization of an analogical model for epidemics/pandemics[a] in groups (6–8 students).
10	Vaccination	For the last section of the intervention, we helped students to make links with the different concepts discussed during the intervention. Since they mastered the concept of vaccination in general (see Table 4), we focused our talk on the principal characteristics of vaccines for influenza.	Confrontation of students' conceptions with scientific models for vaccination.

[a]The analogical models are described in detail in the *Methods* section.

mutated envelope proteins (hemagglutinin and neuraminidase) to affect the immune response (antigenic shift).

RESULTS

Students' Understanding of Influenza Biology: the Nature, the Mechanism of Cellular Infection, Epidemic/Pandemic Progression, and Vaccination

To analyze the students' overall knowledge about influenza, answers on both the pretest and posttest were categorized according to the nonscientific, intermediate, and advanced models (see Table 1) as proposed previously for a study of students' conceptions about HIV/AIDS (Keselman *et al.*, 2007). Before the intervention, most of the students' models were either intermediate (n = 6) or nonscientific (n = 29). Thus, before the intervention, the students' mean score on influenza biology knowledge was relatively low (0.194 ± 0.401; Table 3).

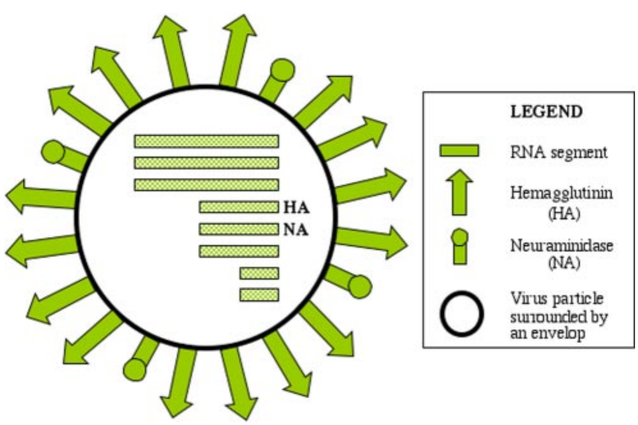

Figure 1. Representation of the analogical model of influenza virus used during the classroom intervention. RNA segments, hemagglutinin, and neuraminase were movable and sticky to the virus particle.

Table 3. Students' mean scores on influenza biology

Pretest	Posttest	P (ANOVA)
Mean = 0.194 SD = 0.401	Mean = 1.306 SD = 0.669	P = 0.000

Note: The range of test scores is 0 to 2.

After the classroom conference, students used more advanced knowledge to explain influenza biology and epidemics [mean score 1.306 ± 0.662; advanced model (n = 14), intermediate model (n = 17), and nonscientific model (n = 4)]. Clearly, the conference and models used during the classroom intervention significantly increased students' knowledge on that specific subject, leading to improved knowledge on core virus concepts as well as on mechanisms of infection.

Students' Conceptions about Viruses and Influenza

Students' conceptions about viruses were measured using open-ended questions, and responses were categorized using keywords. A qualitative examination of students' answers to the question "What is a virus?" in the pretest revealed that adolescents confound concepts such as cell (18.6%), bacteria (17.1%), and illness (15.7%; Figure 2A), as shown by the examples collected from the questionnaires:

> "A virus is a bacterium that attacks the immune system."
> "A virus is a cell that contains bacteria."
> "A virus is an illness that is transmitted by air like influenza."

No students (0%) were able to provide scientific definitions of a virus in terms of structure and function, and only 13.8% provided a partial explanation of the structural properties of viruses:

> "A virus is something that attacks cells. A virus cannot survive without cells. The virus damages the cell."

Moreover, 22.9% of the students in the classroom were unable to define the concept of virus (the space was left blank in the questionnaire). We classified "other" as any type of response that did not fit in a previous category (11.2%), such as:

> "A virus is something that our body is not accustomed to have."
> "A virus is a harmful structure for the body and the health."

Classroom intervention on the influenza virus led to important conceptual changes as shown by the results obtained in the posttest 6 wk later (Figure 2A and Table 2). Students' definitions of a virus were more accurate and complete according to current scientific knowledge. More than 66% of adolescents were able to provide an accurate description of a virus and to differentiate the concept of a virus from the concept of a cell (0%), bacteria (0%), or illness (2.9%).

> "Viral particles are composed of a genome (DNA or RNA), proteins, and sometimes lipids (envelope). They parasite cells, they are totally dependent of them for production of new virus. Viruses are not bacteria or cells."
> "Viruses are particles that contain a specific range of proteins and genomic material and are parasites of cells. They also have spikes (glycoproteins) that serve for viral entry into the target the cell."
> "Viruses are particles that contain lipids, proteins, and genomic material. They use cells to produce new viral particles."

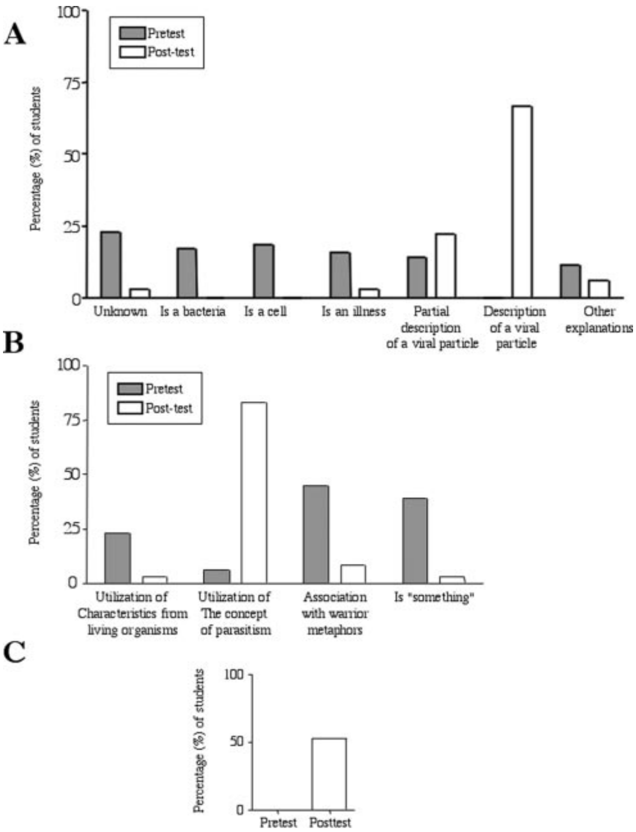

Figure 2. Students' conceptions of viruses and influenza before and after the intervention in the classroom. A, Students' conceptions of a virus. B, Students' utilization of scientific knowledge to describe a virus. C, Students' descriptions of the structure of influenza.

Only 2.9% of students still did not know the definition of a virus, and responses in the "other" category significantly decreased from 11.2% to 5.8%.

We also explored adolescents' conceptions of parasitism and the use of warrior metaphors to describe viruses. As shown in Figure 2B, the classroom intervention considerably decreased the misuse of these concepts. Indeed, before the intervention, 22.9% of students described the virus particles using characteristics of living organisms; this percentage fell to 2.9% after the lecture and activities using analogical models.

> "Viruses are able to divide like cells to proliferate."

The concept of parasitism was almost absent in the pretest (5.8%) but changed significantly (82.9%) after the intervention. It is also interesting to note the use of warrior metaphors to describe virus particles was affected by the intervention (45.0% to 8.3%). During the qualitative analysis of the questionnaire we also noted progress in the use of scientific vocabulary. For example, before the intervention, students (39.0%) were using "something" to describe a viral particle instead of using terms related to virology.

We next determined the students' understanding of influenza virus structure. An open-ended question was used to determine whether students were able to describe the influenza virus structure (Figure 2C). In the pretest, none of the students were able to describe the influenza virus. In contrast, posttest results indicated that 53.1% students had a thorough understanding of influenza. They provided a more appropriate description of the influenza structure: a segmented RNA genome (8 segments), hemagglutinin, and neuraminidase embedded in an envelope composed of lipids that originate from the cells, and, in some responses, other characteristics discussed in the classroom during the intervention.

> "Influenza virus contains eight segments of RNA. It is an enveloped virus (derived from the cell membrane) that has glycoproteins named hemagglutinin (for cellular entry) and neuraminidase. Changed in hemagglutinin and/or neuraminidase cause impairment in the immune response."

The first stage of the virus multiplication cycle is that of attachment when the virus attaches to the potential host cell. The interaction is specific, with the virus attachment proteins (hemagglutinin for influenza) binding to target receptor molecules on the surface of the cell (sialic acid-containing cellular surface proteins or lipids). Having attached to the surface of the cell, the virus must then enter the cell. At the time of the pretest, 80.6% of the students were unable to explain either virus attachment or entry at the cellular level, and 19.4% thought that viruses, including influenza, entered either broken or weaker cells (Figure 3A).

> "Viruses attack cells that have fewer antibodies."
> "Viruses infect cells that are damaged."
> "I think that viruses are trying to take damaged cells because these cells are easier to infect. In damaged cells, the viral proliferation is easier."

On the posttest, students provided more accurate biological explanations of virus entry (Figure 3B): 88.6% mentioned the concept of cellular tropism, 2.8% thought that RNA was responsible for cellular entry, and 8.6% still did not know. Among students who related cellular entry to tropism, 12.7% explained the key/lock concept, 80.6% talked about hemagglutinin and sialic acid-containing cellular surface proteins or lipids, and 6.7% gave relatively good biological explanations that could not be categorized into the previous two categories.

> "Because some external proteins of the virus have a shape that can be recognized only by receptors on specific cell types."
> "Viruses are able to detect specific proteins on target cells."

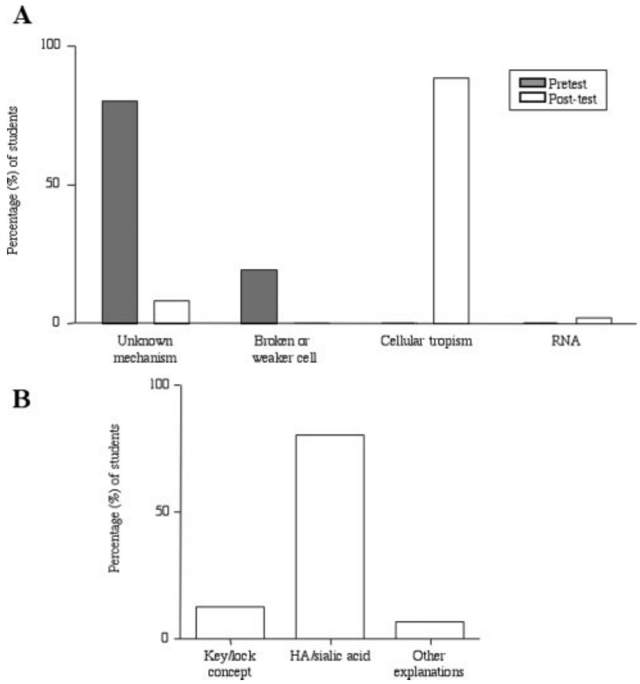

Figure 3. Students' conceptions on virus attachment and entry into the host cell. A, Students' explanations for influenza attachment to the host cell. B, Scientific vocabulary used to describe the attachment in the posttest.

The last part of the questionnaire consisted of multiple-choice questions related to understanding the nature of the influenza vaccine, immunity, and the emergence of influenza with mutated envelope proteins or new strains of influenza. Table 4 summarizes the results obtained for the analysis of the questionnaire. A wrong answer was assigned a score of 0, whereas a correct answer was assigned a score of 1. The first question was written to determine whether high school students were aware of the concept of antigenic shift using the following question: Why is it necessary to get a new flu shot every year? (Correct answer: Mutations may lead to gradual changes in the surface proteins of influenza. Because of these mutations, your immune system will not be able to produce neutralizing antibodies). Significant conceptual changes were obtained after the classroom intervention as demonstrated by the results obtained during the posttest (0.056 ± 0.231 to 0.806 ± 0.401). The same impressive results were obtained for the students' understanding of the concept of antigenic drift characterized by abrupt changes in the surface antigens on the virus that result from genetic reassortment (Question: Can you explain at the cellular level how and why there are influenza pandemics?). The knowledge of the concepts of herd immunity and the percentage of a typical high school population that receives an influenza shot were not well known among the students, and significant improvement was gained after the classroom intervention (0.611 ± 0.494 to 0.944 ± 0.232 and 0.028 ± 0.167 to 0.833 ± 0.378, respectively). On the other hand, the majority of the students knew the composition of the influenza vaccine, and no significant improvement was observed after the

Table 4. Students' mean scores on epidemics/pandemics and vaccination

Knowledge	Test scores (mean ± SD) Pretest	Posttest	P (ANOVA)
Antigenic shift	0.056 ± 0.231	0.806 ± 0.401	0.000
Antigenic drift	0.467 ± 0.178	0.944 ± 0.232	0.000
Herd immunity	0.611 ± 0.494	0.944 ± 0.232	0.000
Composition of influenza vaccine	0.861 ± 0.351	0.972 ± 0.167	0.091
Percentage of a typical population of high school students who get the vaccine	0.028 ± 0.167	0.833 ± 0.378	0.000

Note: The range of test scores is 0 to 1.

intervention (pretest: 0.861 ± 0.351 and posttest: 0.972 ± 0.167).

DISCUSSION

This study highlights the positive impact of a selective classroom intervention on female adolescents' conceptions about viruses in the context of real-life problems. To this end, we first revealed students' conceptions about viruses by a questionnaire administered 1 wk before the intervention. Analysis of the data helped us to recognize that adolescents' conceptions about influenza biology, including comprehension of virus structure, mode of infection at the cellular level, and the nature of new viral strain emergence (epidemics/pandemics), are flawed and are not in agreement with actual scientific knowledge. Conceptions revealed during the pretest provided a valuable diagnostic tool and were the basis of the construction of a specific intervention that used analogical models to foster conceptual changes about viruses. The comparisons of the pre- and posttests regarding influenza-related knowledge revealed the positive impact of the intervention on the induction of conceptual changes about viruses and influenza.

Although the public is exposed to reports from the media or scientific broadcasts about virus outbreaks, such as influenza, severe acute respiratory syndrome (SARS), and HIV/AIDS, adolescents do not master concepts related to viruses and influenza at the scientific level as shown by our study. To acquire new knowledge or deeper understanding of a particular concept, researchers in education have shown that specific teaching strategies are required for conceptualization (Limon, 2001). Thus, important concerns arise as to how to best educate youth in a health education program. Previous synergism between science and health education has been shown to benefit adolescents in the field of HIV/AIDS (Keselman *et al*., 2007). We demonstrated here that the coalescence of health and science learning can foster conceptual changes for the understanding of influenza biology as shown by the changes in the type of model used by the students (Tables 1 and 3). Such areas of practical importance are critical as the foundations for science studies. Moreover, links between health and science education may motivate students to engage in a deeper processing of biological concepts.

As stated earlier in the discussion, we initially determined conceptions of adolescents about influenza by analyzing results from a questionnaire composed of both open-ended and multiple-choice questions and reanalyzed empirical investigations on students' conceptions about microbiology to design our intervention and learning activities (Naguy, 1953; Vasquez, 1985; René and Guilbert, 1994; Simonneaux, 2000; Jones and Rua, 2006; Markow, 2006; Martin *et al*., 2006). In microbiology education, previous research has been performed primarily to understand conceptions about microbes; few studies have been performed on viruses specifically (Naguy, 1953; Markow, 2006; Martin *et al*., 2006). When conceptualizing bacteria and viruses, students tend to have a negative connotation: Microorganisms are bad and are always associated with illness, which is expected because it is common to hear people saying "I have a virus" rather than naming an illness. In our society, we do not distinguish between the cause of infection and the illness itself, leading to a gap in the understanding of infectious diseases pathogenesis. Negative virus attributes were seen in our study as well as in other studies (Naguy, 1953; Markow, 2006; Martin *et al*., 2006). Several gaps in students' knowledge of viruses were identified using our questionnaire. We noted: 1) confusion about concepts such as cells, bacteria, viruses, and illness; 2) problems understanding the characteristics associated with living versus nonliving organisms; 3) the use of an anthropomorphic view; and 4) a lack of scientific vocabulary (Figures 1 and 2). To our knowledge, this is the first study to determine adolescents' conceptions about influenza and cellular tropism. Currently, articles published in the field of conceptions related to the understanding of a specific virus have focused on HIV/AIDS (Walsh and Bibace, 1991; Robertson and McQueen, 1993; C. Sigelman *et al*., 1993a; Sigelman *et al*., 1993b; Sigelman *et al*., 1993c; Sigelman *et al*., 1995; Kistner *et al*., 1996; Quadagno *et al*., 1997; Sigelman *et al*., 1997; Peltzer *et al*., 1998; Peltzer, 2000, 2001; Peltzer and Promtussananon, 2003; Stansbury and Sierra, 2004; Phaswana-Mafuya and Peltzer, 2005; Peltzer *et al*., 2006; Keselman *et al*., 2007). Additionally, analysis of the questionnaire results revealed that adolescents have no idea about the structure of influenza and the way that it recognizes a specific cell type (in this case, epithelial cells) to infect them (Figure 3). Furthermore, we found that adolescents' knowledge, related to the understanding of immunity and emergence of influenza epidemics/pandemics, was very limited (Table 4). Given that the proposed intervention was aimed at the understanding of influenza biology and epidemics/pandemics, we decided to focus on virus/influenza structure, cellular tropism, and a comprehension of antigenic shift and drift in relation to immunity and vaccination.

Constructing knowledge and making meaningful associations between concepts are challenges for students. However, efforts to change students' already formed belief systems represent a significant challenge for educators; nurturing conceptual change is a key element to promote modification in students' conceptions. As a consequence, the subsequent goal of this study was to design a pedagogical intervention that fostered conceptual changes about influenza conceptions (Table 2). In science education, progress has been made to identify and test instructional methods to facilitate and promote conceptual changes. Although there are competing views, authors agree that conceptual changes occur (Posner, 1982a, b; Mikkila-Erdmann, 2001; Niaz *et al*., 2002; She, 2002, 2004; Niaz and Chacon, 2003; Savinainen *et al*., 2005). Special teaching strategies, assessment techniques, metaphors, analogies, and models often need to be constructed to promote the necessary conditions for conceptual change (Scott *et al*., 1992). Even though we used a lecture-based teaching method in our intervention, the majority of the conference was a discussion about naïve conceptions, models, and analogies of influenza structure and epidemics/pandemics (Table 2). As shown previously by other groups, the opportunity to argue and discuss is necessary to promote conceptual changes and a deeper understanding of complex concepts (Niaz *et al*., 2002; Niaz and Chacon, 2003); we also adopted these strategies for our intervention. Moreover, group work and peer discussions are important ways to enhance students' cognitive and metacognitive thinking skills (Coll *et al*., 2005). Group discussions are very rich situations that produce high-level reasoning that helps students to conceptualize.

When teaching concepts related to large objects, such as the solar system, or objects of very small size, like atoms and molecules, research papers in education have shown the importance of the use of analogies to understand these concepts (Harrison and Treagust, 2000b; Keating *et al*., 2002). Biology, microbiology, and virology are difficult topics to teach because they involve processes that are complex, interrelated, and unobservable at a macroscopic level. Moreover, these processes occur at molecular, cellular, and organismal levels, thus making the explanations of these concepts more difficult. Because viruses are microscopic, we developed an analogical model to explain the structure of the influenza virus as well as of antigenic drift to high school students. Analogical models are communication tools for the teacher but they are also used to explore, describe, and explain scientific and mathematical ideas (Harrison and Treagust, 2000b). Furthermore, analogical models are relevant and interesting for science education; interest is considered part of content knowledge because students will engage in meaningful learning only when they find ideas interesting, relevant, and worthwhile (Pintrich, 1993).

We are aware that our study may have certain limitations. Our findings are localized to a specific topic and a specific situation; the inquiry was performed once at one school during a limited period of time with female participants only and at a private school, which is a very stimulating environment. However, we believe that our intervention and the results gained from this study will influence an improved design of school-based interventions in science and health education. To best educate adolescents on topics related to science and health, we first suggest determining essential concepts from accessory concepts to design specific interventions on a particular topic. Based on our experience, we propose the use of analogical models to foster conceptual changes during an intervention in which participants will have plenty of time and opportunity to manipulate analogical models. Studies have also demonstrated the importance of using simulations, databases, and computational tools as well as activities that imitate the ones performed by scientists in real-life contexts and engage students in learning activities to initiate conceptual changes (DeHaan, 2005). In the planning of interventions, we must avoid situated cognition only (Brown *et al*., 1989), which happens when learners cannot transfer what is learned in an original context to a new situation (Novak, 2002). The quality and the quantity of the knowledge structures built by the learner determine the ability to transfer newly acquired concepts to other situations or contexts (Novak, 2002). Indeed, contextualization is important for conceptual changes, and a new conception needs to be reconstructed several times within different contexts and for extended periods of time to become an effective conceptual framework. In our study, we also showed that after our intervention, students acquired scientific vocabulary related to virology and, in particular, related to influenza biology. However, we cannot pretend that high school students really understand and make sense of scientific vocabulary; therefore, additional study is required to examine this issue.

In summary, our findings suggest that carefully designed interventions may have a profound impact on the acquisition of biological concepts related to the understanding of influenza biology. Recent research provides evidence that real-world applications influence conceptual changes in science topics among adolescents. For health and science educators who are concerned with the development of a socially relevant biology curriculum, a virology-substantive resource may promote conceptual changes in students.

ACKNOWLEDGMENTS

This study was supported by grants to A.H. from the Natural Sciences and Engineering Research Council of Canada Research in Youth, Science Teaching, and Learning program (Grant no. 319745-2005) and from the Social Sciences and Humanities Research Council (Grant no. 410–2005–152).

REFERENCES

Ayob, A., Selviendran, N., Hampson, A. W., Barr, I. G., Kumarasamy, V., and Chua, K. B. (2006). Outbreak of influenza amongst residential school students in malaysia. Med. J. Malaysia *61*, 168–172.

Baker, D. W., Gazmararian, J. A., Williams, M. V., Scott, T., Parker, R. M., Green, D., Ren, J., and Peel, J. (2002). Functional health literacy and the risk of hospital admission among Medicare managed care enrollees. Am. J. Public Health *92*, 1278–1283.

Brown, A., Collins, A., and Duguid, P. (1989). Situated cognition and the culture of learning. Educ. Researcher, *18*, 32–42.

Chi, M.T.H., and Roscoe, R. D. (2002). The process and challenges of conceptual change. In: Reconsidering Conceptual Change: Issues in Theory and Practice, ed. I. M. L. L. Mason. Dordrecht: Kluwer, 3–27.

Coll, R. K., France, B., and Taylor, I. (2005). The role of models and analogies in science education: Implications from research. Int. J. Sci. Educ. *27*, 183–198.

DeHaan, R. L. (2005). The impending revolution in undergraduate science education. J. Sci. Educ. Tech. *14*, 253–269.

diSessa, A. A. (2002). Why conceptual ecology is a good idea. In: Reconsidering Conceptual Change: Issues in Theory and Practice, ed. I.M.L.L. Mason. Dordrecht: Kluwer, 29–60.

Gilbert, J. K., Boulter, C., and Rutherford, M. (1998a). Models in explanations, part 1, Horses for courses? Int. J. Sci. Educ. *20*, 83–97.

Gilbert, J. K., Boulter, C., and Rutherford, M. (1998b). Models in explanations, part 2, Whose voice? Whose ears? Int. J. Sci. Educ. *20*, 187–203.

Hampson, A. W., and Mackenzie, J. S. (2006). The influenza viruses. Med. J. Aust. *185*, S39–S43.

Harrison, A. G., Treagust, D. F. (2000a). A typology of school science models. Int. J. Sci. Educ. *22*, 1011–1026.

Harrison, A. G., and Treagust, D. F. (2000b). Learning about atoms, molecules, and chemical bonds: a case study of multiple-model use in grade 11 chemistry. Sci. Educ. *84*, 352–381.

Ivarsson, J., Schoultz, J., and Säljö, R. (2002). Map reading versus mind reading: revisiting children's understanding of the shape of the earth. In: Reconsidering Conceptual Change: Issues in Theory and Practice, ed. I. M. L. L. Mason. Dordrecht: Kluwer, 77–99.

Jones, G., and Rua, M. (2006). Conceptions of germs: expert to novice understandings of microorganisms. Elec. J. Sci. Educ. *10*.

Kalichman, S. C., Benotsch, E., Suarez, T., Catz, S., Miller, J., and Rompa, D. (2000). Health literacy and health-related knowledge among persons living with HIV/AIDS. Am. J. Prev. Med. *18*, 325–331.

Keating, T., Barnett, M., Barab, S. A., and Hay, K. E. (2002). The virtual solar system project: developing conceptual understanding of astronomical concepts through building three-dimensional computational models. J. Sci. Educ. Tech. *11*, 261–275.

Keselman, A., Kaufman, D. R., Kramer, S., and Patel, V. L. (2007). Fostering conceptual change and critical reasoning about HIV and AIDS. J. Res. Sci. Teach. *44*, 844–863.

Kistner, J., Eberstein, I. W., Balthazor, M., Castro, R., Foster, K., Osborne, M., Sly, D., and Quadagno, D. (1996). Assessing children's conceptions of AIDS. J. Pediatr. Psychol. *21*, 269–281.

Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: a critical appraisal. Learn. Instruct. *11*, 357–380.

Markow, D. (2006). Common cold to bird flu: youth's misperception of viruses and its potential health impact. Trends Tudes. *5*, 1–4.

Martin, S. (2006). Our take on it. Youth Educ. Res. *5*, 1–3.

Martin, T., Petrosino, A. J., Rivale, S., and Diller, K. R. (2006). The development of adaptive expertise in biotransport. New Dir. Teach. Learn. *108*, 35–47.

Mikkila-Erdmann, M. (2001). Improving conceptual change concerning photosynthesis through text design. Learn. Instruct. *11*, 241–257.

Naguy, M. (1953). The representations of "germs" by children. J. Gen. Psych. *83*, 227–240.

Niaz, M., Aguilera, D., Maza, A., and Liendo, G. (2002). Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure. Sci. Educ. *86*, 505–525.

Niaz, M., and Chacon, E. (2003). A conceptual change teaching strategy to facilitate high school students' understanding of electrochemistry. J. Sci. Educ. Tech. *12*, 129–134.

Novak, J. D. (2002). Meaningful learning: the essential factor for conceptual change in limited or inappropriate propositional hierarchies leading to empowerment of learners. Sci. Educ. *86*, 548–571.

Peltzer, K. (2000). Knowledge and attitudes about HIV/AIDS of a sample of school teachers in South Africa. Psychol. Rep. *87*, 1065–1066.

Peltzer, K. (2001). Perception of illness among secondary school pupils in South Africa: malaria, tuberculosis, HIV/AIDS, and alcoholism. Psychol. Rep. *88*, 847–848.

Peltzer, K., Cherian, L., and Cherian, V. I. (1998). AIDS awareness of secondary school pupils in the northern province of South Africa. Psychol. Rep. *83*, 955–958.

Peltzer, K., Mngqundaniso, N., and Petros, G. (2006). HIV/AIDS/STI/TB knowledge, beliefs and practices of traditional healers in Kwazulu-Natal, South Africa. AIDS Care *18*, 608–613.

Peltzer, K., and Promtussananon, S. (2003). Black South African children's understanding of health and illness: colds, chicken pox, broken arms and AIDS. Child Care Health Dev. *29*, 385–393.

Phaswana-Mafuya, N., and Peltzer, K. (2005). Perceived HIV/AIDS impact among staff in tertiary institutions in the Eastern Cape, South Africa. Sahara J. *2*, 277–285.

Pintrich, P. R. (1993). Beyond cold conceptual change: the role of motivational beliefs and classroom contextual factors in the process of conceptual change. Rev. Educ. Res. *63*, 167–199.

Posner, G. J. (1982a). Accommodation of a scientific conception: Toward a theory of conceptual change. Sci. Educ. *66*, 211–227.

Posner, G. J. (1982b). Cognitive science and a conceptual change epistemology: a new approach to curricular research. J. Curr. Theor. *4*, 106–126.

Quadagno, D., Eberstein, I. W., Foster, K., Sittig, J. E., Sly, D. F., and Kistner, J. A. (1997). Magic Johnson and children's conceptions of AIDS. AIDS Educ. Prev. *9*, 359–372.

Québec, G. d. (2003). Programme de formation de l'école québécoise. Enseignement secondaire, 1er cycle. Québec: Ministère de l'éducation.

René, E., and Guilbert, L. (1994). Les représentations du concept de microbe: Un construit social incontournable? Didaskalia *3*, 43–60.

Robertson, B. J., and McQueen, D. V. (1993). Conceptions and misconceptions about transmission of HIV/AIDS among the Scottish general public, 1988–1992. Health Bull. (Edinb.) *51*, 310–319.

Rothman, R. E., Hsieh, Y. H., and Yang, S. (2006). Communicable respiratory threats in the ED: Tuberculosis, influenza, SARS, and other aerosolized infections. Emerg. Med. Clin. North Am. *24*, 989–1017.

Savinainen, A., Scott, P., and Viiri, J. (2005). Using a bridging representation and social interactions to foster conceptual change: designing and evaluating an instructional sequence for Newton's third law. Sci. Educ. *89*, 175–195.

Schillinger, D., Grumbach, K., Piette, J., Wang, F., Osmond, D., Daher, C., Palacios, J., Sullivan, G. D., and Bindman, A. B. (2002). Association of health literacy with diabetes outcomes. J. Am. Med. Assoc. *288*, 475–482.

Scott, P., Asoko, H. M., and Driver, R. (1992). Teaching for conceptual change: a review of strategies. In: Research in Physics Learning: Theoretical Issues and Empirical Studies, ed. R. Duit, F. Goldberg, H. Niedderer. Proceedings of an international workshop at University of Bremen, Germany. 310–329.

She, H.-C. (2002). Concepts of a higher hierarchical level require more dual situated learning events for conceptual change: a study of air pressure and buoyancy. Int. J. Sci. Educ. *24*, 981–996.

She, H.-C. (2004). Fostering radical conceptual change through dual-situated learning model. J. Res. Sci. Teach. *41*, 142–164.

Sigelman, C., Maddock, A., Epstein, J., and Carpenter, W. (1993a). Age differences in understanding of disease causality: AIDS, colds, and cancer. Child Dev. *64*, 272–284.

Sigelman, C. K., Alfeld-Liro, C., Lewin, C. B., Derenowski, E. B., and Woods, T. (1997). The role of germs and viruses in children's theories of AIDS (or, AIDS are not Band-Aids). Health Educ. Behav. *24*, 191–200.

Sigelman, C. K., Derenowski, E. B., Mullaney, H. A., and Siders, A. T. (1993b). Parents' contributions to knowledge and attitudes regarding AIDS. J. Pediatr. Psychol. *18*, 221–235.

Sigelman, C. K., Miller, A. B., and Derenowski, E. B. (1993c). Do you believe in magic? The impact of "Magic" Johnson on adolescents' AIDS knowledge and attitudes. AIDS Educ. Prev. *5*, 153–161.

Sigelman, C. K., Mukai, T., Woods, T., and Alfeld, C. (1995). Parents' contributions to children's knowledge and attitudes regarding AIDS: another look. J. Pediatr. Psychol. *20*, 61–77.

Simonneaux, L. (2000). A study of pupils' conceptions and reasoning in connection with "microbes," as a contribution to research in biotechnology education. Int. J. Sci. Educ. *22*, 619–644.

Sivaramakrishnan, M., and Patel, V. L. (1993). Reasoning about childhood nutritional deficiencies by mothers in rural India: a cognitive analysis. Soc. Sci. Med. *37*, 937–952.

Stansbury, J. P., and Sierra, M. (2004). Risks, stigma and Honduran Garifuna conceptions of HIV/AIDS. Soc. Sci. Med. *59*, 457–471.

Vasquez, E. (1985). Les représentations des enfants sur les microbes. Feuilles D'Épistémologie appliquée et de didactique des sciences. *7*, 31–36.

Vosniadou, S. (2001). Conceptual change research and the teaching of science. In: Research in Science Education-Past, Present, and Future, ed. H. Behrendt *et al.* Dordrecht: Kluwer Academic Publishers, 177–188.

Vosniadou, S. (2002). On the nature of naïve physics. In: Reconsidering Conceptual Change: Issues in Theory and Practice, ed. I. M. L. L. Mason, Dordrecht: Kluwer, 61–76.

Vosniadou, S., and Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. Int. J. Sci. Educ. *20*, 1213–1230.

Walsh, M. E., and Bibace, R. (1991). Children's conceptions of AIDS: a developmental analysis. J. Pediatr. Psychol. *16*, 273–285.