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Viruses, Vaccines and the Public

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Abstract

Current research in virology is changing public conceptions about vaccines and infectious disease. The University of Nebraska State Museum collaborated with research virologists, science writers, artists and learning researchers to create public outreach materials about viruses and infectious disease. The project, funded by the National Institute of Health's SEPA program, developed comics, a book with Carl Zimmer, and other materials and programs. The project launched three kinds of learning research: 1) a survey of Nebraska adults on their opinions about vaccines and infectious disease; 2) a study comparing the mental models of viruses, vaccines and infection from virologists, teachers, and students; and 3) a controlled study 873 high school students randomly assigned to read either a comic or a text-based essay with the same virus information.

Keywords

viruses; microbes; vaccine; museum; outreach; comics

Natural history museums have a primary mission to educate the public about biological diversity and evolutionary history. As specimen-based institutions, most exhibits and programs focus on the macro-world, the remarkable world of nature that is visible to us. Yet floating in the oceans, buried in soil, and living within our bodies are populations that are never seen. They are the most abundant sources of genetic material on Earth, more common than algae or bacteria, or even our own cells. They influence nearly every biological process on the planet yet remain poorly understood by many. These are viruses, tiny organizations of

protein and genetic material with uncanny abilities to highjack living cells. These microscopic yet powerful bits of biology at the cusp of life and non-life present a great challenge for museums. How does one educate the public about something they cannot see?

This article describes a collaboration between a university natural history museum, a virology research center, science writers, artists, and learning researchers, with the goal to educate the public about viruses and infectious disease (Diamond et al. 2015). Funded by the National Institute of Health's Science Education Partnership (SEPA), the World of Viruses materials were designed to be research-based and have maximal impact for both formal and informal education. They have been distributed by publishers and used in school, after-school, museum, and community family programs. Elements were incorporated into exhibits at the University of Nebraska State Museum and into the traveling human microbiome exhibit (Zoo in You) from the Oregon Museum of Natural History. And scientists have taken notice: in the *Journal of Biochemistry and Molecular Biology*, Sirajuddin wrote about our project in his article, "Real Science Gets Inked":

> Conceived as a new way to increase public understanding about viruses and infectious diseases, "World of Viruses" succeeds in being a comic work of art, taking readers on a visual journey across tundra and space and into the ocean and human bloodstream, while personifying the viruses as a series of devious and dangerous characters.
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> (Sirajuddin 2015, 16).

The *World of Viruses* project utilizes humor, art, and science writing to create books, comics, posters, stickers, activities, and other materials that can be used in a variety of educational contexts. All elements of the project are distributed by publishers or are made available at no cost on the project's site: worldofviruses.unl.edu. Our nationally distributed products include Carl Zimmer's book, *A Planet of Viruses* (2nd Ed., 2015), the comic book, *World of Viruses* (Diamond et al. 2012), and the forthcoming book, *Watch Your Mouth!*, by Linda Allison, Rebecca Smith, and Judy Diamond.

What the Public Needs to Know About Viruses

Once thought to be relatively rare, viruses are, in fact, astonishingly common. Current estimates indicate the abundance of viruses in the oceans is on the order of a nomillion, a ten followed by 30 zeros (Suttle 2005). Despite their small size, they can have global influence, affecting the balance of global biogeochemical cycles (Mackinder et al. 2009).

Viruses have considerable and dynamic impacts on human health. In the US influenza still causes thousands of deaths per year (Rolfes et al. 2014). Over 33 million people worldwide currently live with human immunodeficiency virus (HIV), the virus that causes AIDS (Centers for Disease Control and Prevention 2012). Half of all sexually active men and women become infected with human papillomavirus (HPV) at some point in their lives (CDC 2011). HPV is only one of seven viruses responsible for an estimated 10–15% of cancers worldwide (Moore and Chang 2010). Two of these, hepatitis B virus and HPV, can be prevented by vaccination (Enquist 2009), the primary medical defense against viral disease.

A revolution in medical treatment began when Edward Jenner demonstrated in 1796 that inoculation with cowpox protects against the far more deadly smallpox (Enquist 2009). But the revolution was slow in taking effect: it took until 1979 for a successful worldwide vaccination effort to eradicate smallpox from the planet. Since the 1970's, however, the number of childhood vaccines developed, available, and recommended in the U.S. has more than tripled, and the prevalence of the associated viral diseases has plummeted (College of Physicians of Philadelphia 2015). Both rubella and polio have been eradicated from the Americas, although there remain pockets of circulation in Asia and other countries, where lack of vaccine compliance continues to threaten the effectiveness of eradication efforts (Papania et al. 2014). Since the introduction of the HPV vaccine in 2006, HPV infections in teen-age girls have decreased by 56% in the United States (Markowitz et al. 2013). Comprehensive vaccination of young adults could prevent 27,000 cases of cervical, oral, and anal cancer in the U.S. annually (CDC 2014).

The study of viruses is interwoven with recent major advances in understanding human biology (Enquist 2009). In 1976, scientists sequenced the first complete viral genome, enabling them to gather evidence of viral diseases from long before the modern era. In 2012 scientists used genetic sequencing techniques to identify a unique hepatitis B virus in a mummified child from 16th Century Korea (Kahila Bar-Gal et al. 2012). Viruses have provided the tools to fuel investigations into genetics and molecular biology, and the steeply rising trajectory in scientific understanding has had widespread influence on medical diagnosis and treatment of infectious disease, allowing scientists to move beyond observation to actually altering aspects of human physiology.

Public Understanding of Viruses

Unfortunately, scientific advances in understanding viruses have had relatively little impact on public understanding. Relevant information is difficult to understand, and it can appear contradictory, as when one researcher's advice is negated by another's (Devroey et al. 2013, Poland and Jacobson 2001). In addition, misinformation about viruses and vaccines is rampant. This false information is persistent, widely spread (Jacobson, Targonski, and Poland 2007), and increasingly hard to counter as more people get their health information from the Internet. Indeed, the Joint Committee on National Health Education Standards (2007) recognized the need to educate the public about virology and infectious disease as a high national priority. Virologists have been particularly forthright in arguing the urgency of this effort:

> The highest purpose of science is the search for a greater understanding of the world around us. In virology, this purpose translates into advances in our understanding of basic biology and improvements in the health of the flora and fauna that inhabit our planet. We cannot shy away from the need to educate the public and our national leaders about the important contributions our field can make
>
> (Enquist 2009, 5302).

The lack of public understanding about viruses has had dire effects. Although vaccinations are known to prevent many kinds of dangerous viral infections, growing numbers of parents are choosing to delay or decline vaccines for their children. Vaccines typically work by inducing "herd immunity," where the reduction of susceptible hosts through vaccination is sufficiently high that viral transmission chains cannot be sustained (Bloom, Marcuse and Mnookin 2014). But when vaccination levels drop too low, person-to person infections can readily spread, resulting in widespread outbreaks of disease. According to the American Academy of Arts & Sciences (2014, 3),

> … vaccines have become victims of their own successes: In the United States, many young parents have never encountered diseases such as polio, measles, rubella, and *Haemophilus influenzae* type b meningitis… For more than forty years, American and European vaccine panics have fueled each other; since the advent of the Internet, these unfounded fears have spread to the far reaches of the globe.

In 1998, press coverage in England about claims linking the Measles, Mumps, and Rubella (MMR) vaccine to bowel disease and autism had the immediate effect of reducing vaccination rates more than 13% (American Academy of Arts & Sciences 2014). Even after those claims were proved fraudulent, many parents still believe there is a link between vaccination and autism (Smith et al. 2008). Changing people's behavior is no simple task: one public health study found that graphically intense pro-vaccine messages can backfire, leading to increased misperceptions and reduced intentions to vaccinate (Nyhan et al. 2014).

Public misconceptions about biology and the relative freedom of individual health choices in the United States can undermine beneficial practices. Public health efforts to create herd immunity through laws requiring vaccinations before children can attend public school have been weakened by states that allow exemptions. The results of under-vaccination have been devastating to communities in which there has been a resurgence of vaccine preventable illnesses (van Punheis et al. 2013).

How People Reason About Viruses and Vaccination

There is broad agreement that progress in the management of infectious diseases requires an informed public. Helping people to make good health decisions and to improve their ability to distinguish scientifically accurate from misguided information is a laudable goal. Our *World of Viruses* project partnered with teams of cognitive and social scientists to investigate how people understand and reason about viruses and vaccines and what kinds of materials are likely to improve public understanding. To inform our project, team members conducted three studies: 1) a Nebraska-based population survey; 2) a set of focused clinical interviews; and 3) a controlled study of the responses of students to our educational comic books.

1. The Population Survey

Questions about vaccines and infectious disease were added to the Nebraska Annual Social Indicators Survey (NASIS), mailed to a random sample of adults. Insights from survey responses helped guide our ongoing educational campaign. Approximately 96.6% of the

children enrolled in kindergarten in Nebraska in 2013–2014 had been vaccinated for MMR, a relatively high rate that is similar to the national average (Seither et al. 2014). Fewer than 2% of Nebraska kindergarteners received exemptions from vaccination, including those for medical as well as religious reasons.

Because of these high vaccination rates, we expected that most Nebraska adults would agree that vaccines are beneficial, and in fact, about three quarters of the sample did agree. There were, however, sizeable numbers of respondents who indicated they did not know the overall impact of vaccines. And although 85% of participants were aware of the value of the measles vaccine, fewer of them knew that people could die from measles, and nearly a third could not say whether or not measles can be fatal. These findings confirmed our initial notions that there were segments of the Nebraska public that are still poorly informed about the benefits of vaccination.

Many once common vaccine-preventable diseases, such as polio, measles, and mumps, are now so rare that many people have never personally encountered them. We wondered whether attitudes about vaccines might have been shaped by this lack of personal experience. If people think that such diseases are unlikely to occur, they may conclude that risks associated with vaccines may be greater than risks of the disease. Among our sample of Nebraskans, fewer than half of the respondents personally knew a victim of polio, and roughly a third knew someone who had had mumps or measles. Almost half of the sample did not know anyone who had experienced any of these diseases. Our survey data indicated that personal knowledge of the dangers of vaccine-preventable diseases increases support for vaccination: knowing someone with measles, mumps, or polio was significantly associated with believing that vaccines result in fewer people getting sick (Bureau of Sociological Research 2014).

2. The Clinical Interviews

A cognitive scientist, Benjamin Jee, led the second study supported by the World of Viruses project. Jee conducted semi-structured interviews of virologists, teachers, and students who participated in our outreach project with the University of Nebraska Medical Center and the Omaha Public Schools. Over two summers, the project team gave educators and students experience with creating videos and radio programs about research in virology (http://worldofviruses.unl.edu/omaha-science-media-project). The clinical interviews allowed a comparison of expert, teacher, and student mental models of infectious disease. There were distinctive mental models of infection, vaccination, and immune response in the three groups (Jee et al. 2015). As expected, the teachers and students lacked the detailed, precise knowledge about viral infection that was evident among the virologists. The study, however, provided striking perspectives on students' misconceptions about vaccination. For example, almost half of the students believed incorrectly that vaccination worked by directly attacking viruses in the body in much the same way that chemotherapy kills cancer cells in the body. These findings helped our project team to target specific misconceptions as we develop educational outreach materials.

3. The Controlled Study

To understand how best to promote learning about viruses and infection, we created comics and essays that presented similar factual information, but used different narrative and graphical techniques, and we then compared their effects on students' knowledge and engagement. A total of 873 students in high school biology classes were randomly assigned to read either a comic or a text-based essay with the same virus information and then to complete a short survey. The results demonstrated no differences between the two formats in knowledge about viruses, but there were differences in degrees of engagement. Youth across all levels of science identity were more engaged by the comics than the essays, and importantly, youth with the lowest science identities were motivated by the comics to read more. These findings demonstrated the power of comics to reach teenagers who might otherwise have little interest in science (Spiegel et al. 2013). This study has informed our strategies for building public understanding and correcting misconceptions about the biology of viruses and vaccination, and it has aided in the creation of appealing materials that explain the scientific concepts that underlie infectious disease.

Conclusion

The rapid advances in virology research demand attentive efforts to help the public understand how viruses influence both health and disease. Increasingly, people are making their own health decisions, and although parents still trust their doctors, they are also seeking more information through diverse media, particularly the Internet (Kennedy et al. 2011). This suggests an even greater need to disseminate accurate and accessible health information through a variety of media channels. Museums have a strategic role to play in creating innovative, research-based outreach campaigns to enhance public understanding of the role viruses play in human health, a key contributor toward enhancing the use of vaccines to prevent infections.

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Biography

Bio Statements

Judy Diamond, Professor and Curator of informal science education, is principal investigator of the NIH-funded World of Viruses and Biology of Human projects.

Julia McQuillan, Professor and Chair of Sociology, collaborates on research designed to enhance health.

Amy N. Spiegel, Research Associate Professor, conducts evaluation of formal and informal math and science education projects (K-16).

Patricia Wonch Hill is a Research Assistant Professor in Sociology with expertise in the sociology of health and research methods.

Rebecca Smith, biochemist turned scientist-educator, works on science learning inside and outside the classroom in the San Francisco Bay Area.

John West, Research Associate Professor, is a virologist who studies interactions between HIV and KSHV and the immune system in Africa.

Charles Wood, Director of the Nebraska Center for Virology and Lewis Lehr/3M University Professor, is a virologist with expertise on HIV and associated infections.

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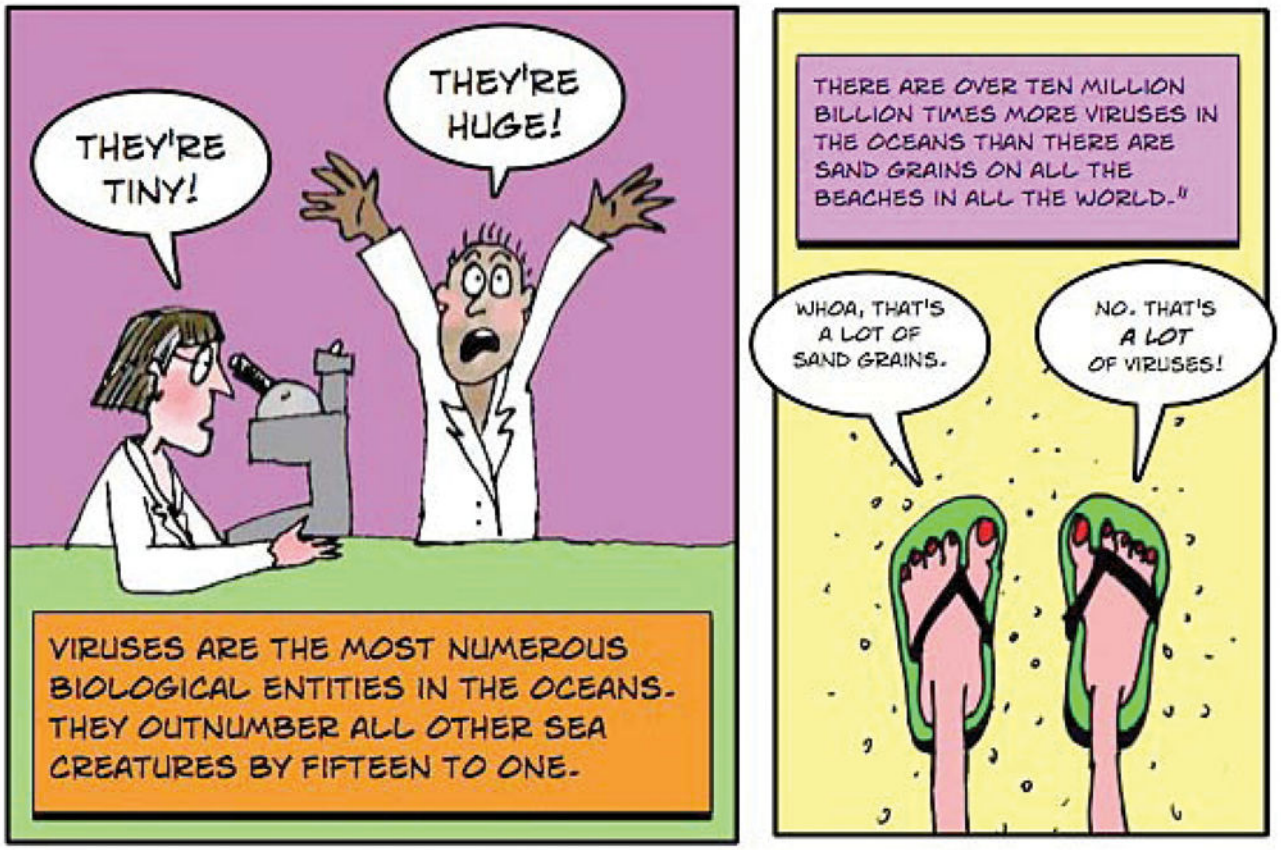

Figure 1.
Cartoon about ocean viruses by Linda Allison for the World of Viruses NIH-SEPA project.