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# Museum Monsters and Victorious Viruses: Improving Public Understanding of Emerging Biomedical Research

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## Museum Monsters and Victorious Viruses: Improving Public Understanding of Emerging Biomedical Research

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### Abstract

Although microbes directly impact everyone's health, most people have limited knowledge about them. In this article, we describe a museum and media public education campaign aimed at helping diverse audiences better understand emerging knowledge about microbes and infectious disease. Funded primarily by the Science Education Partnership (SEPA) program of the National Institutes of Health, this campaign involved crosscutting programs designed to extend impacts throughout a broad public audience.

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Collaborations with partners from public media, libraries, science education, the social sciences, and biomedical research centers extended our outreach to local and national audiences of adults and youth. Our campaign developed programs for radio broadcast, schools, libraries, museums, and publishers to ultimately reach over eight million people. In addition, we conducted a series of research studies focused on understanding the mental models that people create of the complex concepts of microbes and infectious disease and on how to engage hard-to-reach adolescents with this science content. These studies furthered our understanding of how people reason about unseen phenomena, the kinds of materials that might intrigue youth who claim little interest in science, and how to begin to combat misinformation pervasive in this field. Our comparisons of expert, teacher, and teen reasoning about microbes revealed their distinct mental models on the topics of infection, vaccination, and immune response. Our investigation of comics confirmed their power to motivate teenagers to want to read more about science. Across all levels of science identity, we found that youth were more engaged with the comics than with comparable essays.

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Together, these findings provide insights into how to educate a diverse public about emerging biomedical research.

All people—not just scientists—need to understand how microbes influence health and the environment. Our bodies harbor more microbes than human cells, and the gut, a center of microbe diversity, contains trillions of bacteria and even more viruses. The balance of helpful and harmful bacteria, viruses, and fungi in our bodies directly influences our health. Although microbes directly impact people's lives, most of us have limited knowledge about them. This is partly because the relevant research is rapidly changing, sometimes contradictory, and often difficult to understand without a biomedical background (American Academy of Arts & Sciences 2014; Poland and Jacobson 2001; Swenson et al. 2010). The need to educate the public about microbes and infectious disease has been recognized as a high national priority (American Academy of Art & Sciences 2014; Joint Committee on National Health Education Standards 2007).

This project builds on the initiative of Oppenheimer (1981) who suggested that improved science learning would result from interaction with different, but complementary, forms of education outreach and media initiatives. Oppenheimer suggested that for any science content area, incorporating multiple outreach programs or media platforms could have synergistic effects, so that each would build on the strengths of the others to increase science education impacts across a broader sector of the public. We thus describe a set of integrated efforts to reach diverse audiences with emerging knowledge on viruses, bacteria and infectious disease. We also studied the impacts of several programs within our broad public education campaign to identify general principles that could be applied to future efforts.

During the past eight years, the University of Nebraska State Museum collaborated with biomedical and social scientists, writers, media producers, artists, educators, and youth to increase public understanding of microbes and infectious disease. Funded primarily by the Science Education Partnership (SEPA) program of the National Institutes of Health (NIH), the museum campaign was created to improve public understanding—while forming partnerships with collaborators who could amplify and deepen the impacts of our programs and products. We had several related goals for the project:

1. We established partnerships to create accurate, publicly accessible resources about microbes and infectious diseases.
2. We focused on developing outreach deliverables that would convey the importance of emerging biomedical research for the wellbeing of diverse people and their communities, thus hoping to empower people to make better decisions about their health.
3. We also wanted to generate interest among the public—especially teenagers—in biomedical careers.

The current article describes the strategies employed for the broader campaign and findings from specific research efforts.

## Understanding Peoples' Reasoning About Viruses

To better understand how people understand microbes and infectious disease, our research partners from Northwestern University conducted in-depth clinical interviews with the project's participants. The team compared three groups with different levels of experience—middle-school students, science teachers, and expert virologists—to assess people's beliefs about microbiological entities and processes. The researchers conducted individual structured interviews that probed a participant's beliefs about eight fundamental concepts related to the microbiological activity of viruses and vaccines:

1. the external appearance of the virus,
2. the external appearance of the host cell,
3. the contents of the virus,
4. the contents of the host cell,
5. the replicated virus,
6. the impact of the virus on the immune system,
7. the immune cell, and
8. vaccination.

The interviewers asked generative questions, i.e., questions that aimed to elicit causal beliefs, and that required participants to elaborate on their thinking. In answering, the participants were required to generate explanations of phenomena that they cannot directly observe, such as virus replication (Chi et al. 1994; Gentner and Stevens 1983; Vosniadou 1994). See Jee et al. (2015) for more details on specific interview questions.

The participants' interview responses were then used to create causal diagrams of participants' *mental models* of microbiological processes—their causal explanations of infection, vaccination, etc. (Jee et al. 2015). The analyses revealed distinctions in the cognitive organization of several concepts, including infection and vaccination. For example, some students and teachers described viral replication in terms of cell division, independent of a host (see Figure 1). Furthermore, almost half of the students held a mental model for vaccination in which the vaccine directly attacks a virus that is present in the body (see Figure 2b), as opposed to stimulating the host's immune system (Figure 2a, the virologists' mental model). These findings have implications for how to communicate about infectious disease to young people (Jee et al. 2015). For example, the findings indicate common gaps in knowledge. Students (and even teachers) seldom mentioned the lock-and-key relationship between a virus and its host, a crucial idea for understanding why different viruses affect the body in different ways. In addition, educational interventions may be more effective when they directly address, and attempt to refine or replace, a student's prior beliefs (e.g., Au et al. 2008; diSessa 2006). Hence, knowing what students think *prior to* instruction is an important first step in designing lessons that will have a lasting impact.

## Museum-Based Educational Campaign

New research on the impacts of microbes on human health and disease is rapidly emerging and challenging to understand for even those with high science literacy. We wanted to provide materials that would inform a broad range of learners and also motivate audiences of youth and adults to feel they could begin to understand these scientific discoveries. We thus worked with artists to design visually appealing materials to attract our target audiences and motivate them to learn more about science. We used storytelling to capture people's interest and, made information personally relevant and accessible in ways that would encourage our audience to independently pursue further learning. Collaboration with our education, science, and research partners greatly enriched our approach. By drawing on the expertise of several collaborators—including media specialists and journalists—we extended the audience beyond museum visitors to a more diverse representation of the population, ultimately reaching over eight million people. Overall, our extensive collaborations extended our SEPA outreach to local and national audiences of adults and youth, reached through radio, schools, libraries, afterschool programs, museums, and the Internet.

We designed our impact studies to align with the opportunities and constraints of each program and deliverable. These efforts examined specific impacts on intended audiences, and they contributed to the answers we found for the larger research questions relevant to informal science education (Diamond, Luke and Uttal 2009). The initial evaluation studies provided important insights on what types of materials would interest youth audiences, how best to disseminate products, and the effects of documentaries on radio listeners. A core assumption of all our projects was that visually dramatic, high quality, enjoyable, and creative storytelling could reach youth who would not otherwise identify with scientists or pay attention to scientific information. Our research on learning focused on understanding the mental models that people create around complex concepts in the science of microbes, and our impact studies examined the effectiveness of the materials in enticing hard-to-reach adolescents to engage with science content.

### Programs for Adults

To reach adults, we enlisted popular science writer and journalist Carl Zimmer to write a series of essays about specific viruses. We approached the University of Chicago Press which agreed to publish the book, *A Planet of Viruses*, and then organize for us a month-long blogging event by Zimmer following the book's publication in April 2012. The book sold over 30 thousand copies in the U.S., has been distributed internationally in five languages, and will be released in 2015 as a new-and-revised edition. For more information and links see <http://worldofviruses.unl.edu/planet-of-viruses>.

We also collaborated with a public radio group, Soundprint Media Center, Inc., to produce a series of radio documentaries about current research on viruses. Through this partnership, we created eight radio programs that were broadcast through the Soundprint series on National Public Radio to over seven million listeners across the United States. Each program explored issues of human interest while conveying the science behind different viruses and

research efforts of the scientific community. All the radio programs remain archived for continued outreach at <http://worldofviruses.unl.edu/radio> or <http://soundprint.org/virus>.

The radio programs were assessed by an external evaluator who recruited forty subjects using notices on listservs and Craigslist.com (Russell 2012). Participants listened to two twenty-five-minute documentary programs one to three days prior to participating in an hour-long evaluation that included a written open-ended survey and a follow-up focus-group discussion. Findings revealed that listeners learned a range of ideas from the radio programs. In the written survey, some participants characterized what they had learned as surprising: “[I] was really surprised by HPV's ability to replicate...” and “[I] was surprised by how in hog lots, chicken farms, how that is a spreader of the [H1N1] disease.” Another participant commented, “[I] was surprised by the fact that most viruses don't cause illnesses.” A total of 65% of participants in the written survey described at least one additional topic or area they wanted to know more about. Most examples focused on learning more about the science underlying viruses or related diseases. Typical comments were, “I'd be interested to know how this research of serious viruses may be applied to research on common ones like warts, colds, etc.,” “more about the transfer of the viruses via mosquitoes,” “are there any benefits to these viruses?” and “do viruses constitute life?”

Some participants also wanted to know more about the political or social contexts of related research. For example, “I would still be interested in how some religions can still claim that a human being can be protected through prayer,” and “what policies are countries preparing to prevent deadly viruses from spreading?” Many participants were motivated to seek further information upon learning of the impact of viral illnesses on their lives. For instance, “the HPV program really scared me, like I need to learn more about it,” and “I would like to learn more about dengue fever and its prevalence where I work.” In both their written responses to open-ended questions and in focus group discussions, participants were able to accurately describe research techniques presented, and to describe new concepts they had learned from the programs. They also appeared to enjoy the materials; one participant explicitly stated, “I love this program.”

## Using Comics to Engage Youth with Science

A major goal of science education is to nurture the interest of youth—especially of youth from groups underrepresented in the sciences—in pursuing science careers (National Science Board 2006). To this aim, we first consulted with youth librarians because today's modern public libraries—with their teen corners, gaming rooms, and extensive Internet access—are magnets for young people (Pew Internet & American Life Project 2013). Librarians overwhelmingly advised us to develop state-of-the-art comics if we wanted to reach teenagers, particularly those less interested in traditional science-learning materials (see also Harbaugh 2008). Preliminary evidence from previous research confirmed the librarians' suggestions that comics are effective at capturing the attention of youth who are less engaged with science content (Matuk, Diamond, and Uttal 2009), and that comics can prepare youth for deeper understanding of complex science information (e.g. Hosler and Boomer 2011; Tatalovic 2009).

To develop our own comic stories, we partnered with two experienced comic book developers: writer Martin Powell and artist Tom Floyd. Together, we created five graphic novels about viruses: *Phantom Planet* (about HIV), *The Frozen Horror* (Influenza virus), *The Never-Ending Battle* (Ocean viruses), *The Curse of the Treeman* (HPV), and *Confined!* (Foot and Mouth Disease). These five virus stories were also published by the University of Nebraska Press in the compendium, *World of Viruses* (Diamond et al. 2012; see Figure 3). One additional story about gut bacteria and fungi, *Occupied by Microbes!*, was targeted for a younger audience. All of the graphic stories were made into free iPad apps with enhanced features, such as video of the actual scientists depicted in the comic stories, radio programs relating to the virus, virus images that can be opened to look inside, activities to explore different influenza strains or large numbers of ocean viruses, as well as other elements. To find these iPad apps, search the app store for “World of Viruses” or “Occupied”; see Figure 4).

The materials we developed to help middle and high school-aged youth better understand microbes were targeted at those who declare little interest in science, who do not identify with the perceived characteristics of scientists, or who had low achievement in science classes in school. An initial pre-test administered to 126 middle- and high-school students thirteen to sixteen years old showed that the majority of students had a basic grasp of viruses as disease agents, but few could distinguish viruses from cells, or describe the mechanism of vaccines. These results confirmed the need for more information about microbes and that our project materials were targeting the appropriate grade level for the project materials.

To investigate the impacts of the comics, we assessed whether comics were as good as or better than conventional essays for engaging youth in science. The essays were written by Ann Downer-Hazel, a professional children's science writer, and were based on exactly same science content as the comics. We split a group of youths in high school biology classes (N= 873) randomly into two groups. Each was given a plain envelope containing, for one group, a comic, and for the other, an essay. Both groups also received a written survey to complete after reading the science materials.

We found that those who were given the essays and those who were given the comics were not appreciably different on the post-survey in terms of their knowledge of, attitudes about the importance of, or interest in, viruses or their role in infectious disease (Spiegel et al. 2013). Consistent with prior research, the insights of our librarian collaborators and the youth who participated in the focus groups, the teens in the comic group were significantly more likely to want to read further similar materials than those in the essay group. We interpret this finding as indicating higher engagement with the science content among the comic compared to the essay group.

To identify youth who do not usually engage with science, we developed a measure of “science identity.” We hoped to differentiate youth who do not think of themselves as a “science kind of person” from those who do. Latent class analysis of the science identity measure indicated four categories of science identity: low, moderately low, moderately high, and high. The comics inspired more interest in the subject than the essays at every level of science identity, but the effect was significantly more pronounced among youth in the lower



identity categories than in the higher ones. We therefore conclude that comics on science topics can be an effective means of engaging hard-to-reach youth with content and be as effective in communicating science knowledge as essays. For more information, see Spiegel et al. (2013).

## Using Media to Help Educators and Students Understand Biomedical Research

As part of our campaign to educate the public about microbes and infectious disease, we developed an immersive experience that would help teachers of Nebraska's largest public school district, Omaha Public Schools, to rethink how they presented these topics to their students. Today's science teachers are being called upon to provide their students with current science content, and to teach in innovative ways (National Science Board 2014). Research suggests that participation in high-quality professional development can change teacher attitudes, behaviors, and instructional practices; these changes can result in increased student performance (Elmore 2002; Garet et al. 2001; Hawley and Valli 2001). With additional funds from a foundation associated with the Omaha Public Schools, we extended our public education campaign to include professional development for science teachers. Through the *Omaha Science Media Project*, we offered teachers and students a two-week immersion experiences at virology research laboratories at the Nebraska Center for Virology and the University of Nebraska Medical Center (Diamond et al. 2011).

The Omaha teachers and students learned about virology research by becoming science communicators. To accomplish this, we collaborated with our local PBS station Nebraska Public Television, the University of Nebraska School of Journalism, and Soundprint Media, Inc. Teams of teachers, students, and journalists were assigned to virology research laboratories to create video or radio programs about their laboratory experiences. These programs then served as learning tools that were incorporated into classroom science programs throughout Omaha Public Schools. Over the course of two years, thirty-eight teachers and fifty-seven students participated (see <http://worldofviruses.unl.edu/omaha-science-media-project> for more information about the project).

The workshop goals and activities were aligned with the Omaha Public Schools science standards and the National Science Education Standards (National Research Council 1996). Results of the evaluation indicate that the Omaha Science Media workshop empowered teachers to develop media activities with science concepts they identified as challenging for students (Spiegel 2010). One seventh- and eighth-grade science teacher recalled, "I want to continue to marry storytelling and media from a student perspective. I think owning the experience pushes them to think differently about science." Another seventh- and eighth-grade teacher mentioned,

One of the things that happened when we use video is that introverted students became empowered ... This media project shows the potential of capturing *all* students' attention—not just the traditionally "top" students—and then providing them with possible career direction in the fields of health, medicine, science and other related fields.

As a result of their experiences, Omaha Science Media Project teachers continued to use their new journalism skills to teach innovative science lessons. They helped students to become not only science media consumers, but also science media creators, responsible for making science relevant to their peers. In addition, a professional learning community grew around using media in courses. Omaha Science Media Project teachers continued to work across schools and disciplines to exchange ideas and experiences for creating lessons, instituting class blogs and media projects, and elementary and high school teachers worked together to create projects where their respective students collaborate on science. Omaha Science Media Project teachers have also shared their work with peers throughout the district and presented their work at statewide and national conferences.

## Summary

Through our outreach efforts and learning research studies, we gained an understanding of how people reason about unseen phenomena, the kinds of materials that might engage youth who show little interest in science, and how to begin to combat the misinformation pervasive in this field. Clinical interviews comparing experts', teachers', and teens' beliefs about infectious disease revealed distinct mental models of infection, vaccination, and immune response. Of particular interest was the finding that 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. Our focus groups revealed that adult radio listeners do learn new ideas from science education radio programs, and our use of media helped Omaha teachers develop new ways of motivating their students to learn about virology. Our studies also confirmed the power of comics about viruses to motivate teenagers to want to read more about science. Across all levels of science identity, youth were more engaged with the comics than comparable text-based materials. These findings illustrate the need for continued educational efforts on these topics, particularly those that leverage the strengths of complementary forms of outreach programs and media initiatives to have maximum audience impact. Most importantly, targeted research from the cognitive and social sciences can inform future strategies for educating people about the scientific concepts that underlie health and disease.

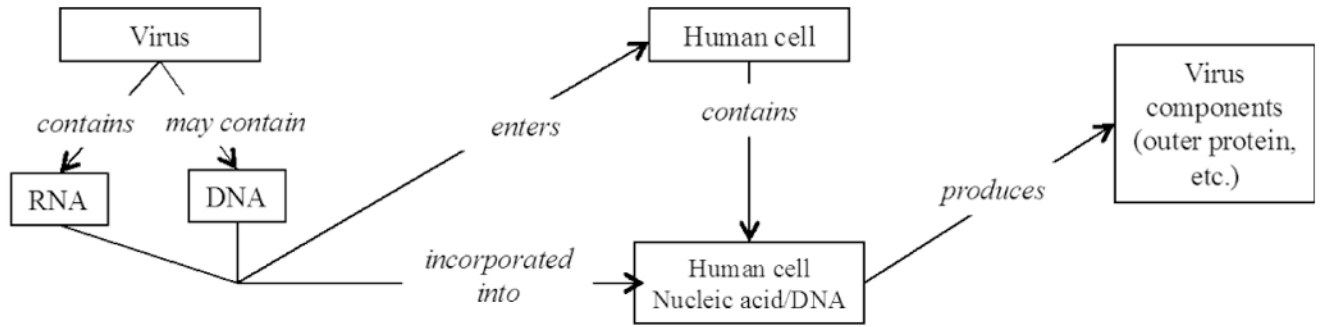
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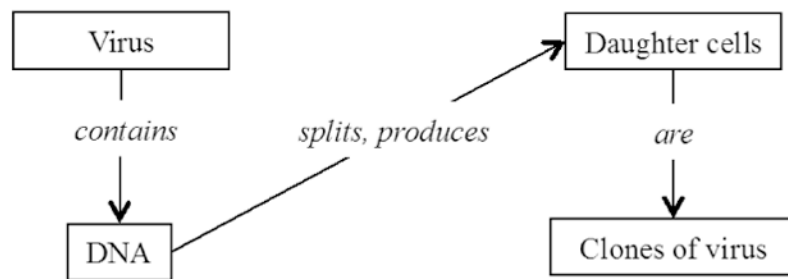
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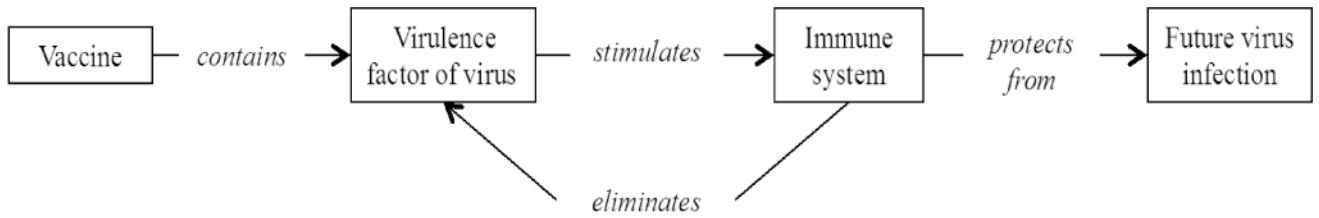


**a. Virus uses host nucleic acid model**

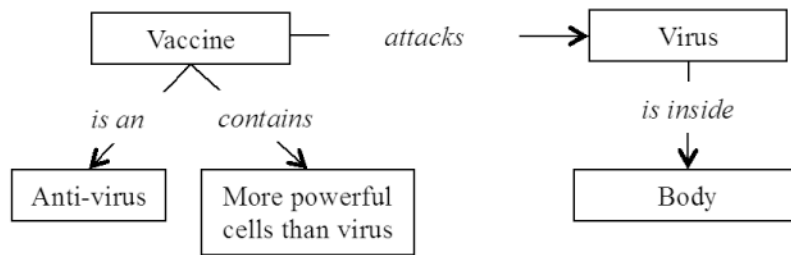


**b. Virus cell division model**

**Figure 1.** Mental models of virus replication: Part a shows a mental model more commonly held by virologists. Part b shows a mental model held by some students and teachers (Jee et al. 2013)



**a. Vaccine stimulates immune system model**



**b. Antivirus model**

**Figure 2.** Mental models of vaccines: Part a shows a mental model more commonly held by virologists. Part b shows a model held by most students (Jee et al. 2013).



**Figure 3.** The project teamed with the science writer, Carl Zimmer, to develop a book of essays on viruses for the general public. The book, *A Planet of Viruses*, was published by the University of Chicago Press in 2012 and is now available in five languages.





**Figure 4.** The World of Viruses comics included stories about HIV, influenza virus, foot and mouth disease, human papillomavirus (HPV) and the regulator of ocean algal blooms, *Emiliania huxleyi* virus (Diamond et al. 2012).





**Figure 5.**

Each comic developed for the World of Viruses project was released as a free iPad app on the Apple Store. These apps included enhanced features with audio narration, images of the viruses that can be opened and internal structures identified, radio documentaries on the viruses, video of the real scientists depicted in the comics, and activities to explore additional features of the biology of the viruses.



**Figure 6.**  
As part of the World of Viruses project, teachers and students were mentored by journalists to create audio and video stories about virology research.