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Engaging Teenagers with Science Through Comics

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Introduction

Despite many years of efforts to communicate new scientific knowledge to the public, surveys continue to suggest that many people remain uninformed about current scientific research (Miller 2001, 2004) and fail to recognize how it can be relevant to their lives. There is continued need for investigation on improving methods for engaging people with scientific knowledge. Our goal is to contribute to efforts to disseminate emerging science knowledge by focusing on a particularly relevant science topic, viruses, and a critical age group, teenagers. Prior research suggests that many teenagers have low science achievement and/or low interest in science (Gonzales et al. 2008) and thus can be characterized as having low science identity. How can educators engage all teenagers, even those with low science identity? Guided by identity theory and a model of interest development, we assess one possible, unconventional approach—using comic books to convey science information.

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This study focuses on viruses as scientific content. First, we review why knowledge of viruses is important content to disseminate, and provide evidence that the general public's knowledge of viruses is limited. After discussing the relationship between interest and achievement in science, we describe the rationale for using comics as an educational format. We next summarize key concepts in identity theory and a model of interest development that justify comparing comic and essay formats for disseminating scientific information. We describe the study, results, and implications of our findings for efforts to engage a broad spectrum of youth with science.

Importance of Public Understanding of Viruses

Understanding how viruses and infectious diseases influence our health, communities and environments is vital for all people, not just scientists. Among viruses that infect humans, human papillomavirus (HPV) is so common that half of sexually active men and women become infected at some point in their lives, and approximately 20 million Americans are currently infected with HPV [Centers for Disease Control and Prevention (CDC) 2011]. In the USA, influenza-associated deaths range from 3,000 to 50,000 people per year (Thompson et al. 2010). Over 33 million people worldwide currently live with human immunodeficiency virus (HIV), the virus that causes AIDS; there were 2.6 million new HIV infections in 2009, and one fifth of the people living with HIV in the USA do not know they are infected (CDC 2012; UNAIDS 2010). Nonhuman viruses, such as foot and mouth disease virus, can also have major economic impacts. The 2001 FMD outbreak in the UK affected 7 million animals and resulted in an economic loss of more than $12 billion (Food and Agriculture Organization of the United Nations 2010). In addition to their negative impact on human health and agriculture, viruses also have positive, crucial roles in ecosystems around the world. For example, *Emiliania huxleyi* virus (EhV) regulates algal blooms of its host and, to a larger degree, the balance of global biogeochemical cycles (Mackinder et al. 2009).

Limited Public Understanding of Viruses

Despite the critical roles that viruses play in our lives, many people have limited knowledge of viruses. Results of national and international surveys suggest that misinformation and lack of information can have negative implications for personal health and health environmental policies across diverse socioeconomic and cultural groups (Bogart, et al. 2011; Devroey et al. 2013; Manjunath and Pareek 2003; Poland and Jacobson 2001; Swenson et al. 2010). This is compounded by sensational news stories about outbreaks that rarely provide a larger context that can help promote a basic understanding of how viruses affect people and the environment. The alarming patterns in misinformation, particularly among antivaccine advocates (Jacobson et al. 2007), suggest the need for more robust educational programs. Indeed, the need to educate youth about viruses and infectious disease in a meaningful and relevant way is a high national priority (Joint Committee on National Health Education Standards 2007).

Achievement, Interest, and Engagement in Science

Student achievement in science suggests that much work remains to attain national goals for education. Over 40 % of US middle and high school students, for example, perform below basic achievement levels in science, including fundamental concepts about human biology and viruses (NCES 2011). Moreover, girls and students from low socioeconomic (SES) backgrounds continue to perform significantly below their peers in science assessments (National Center for Education Statistics 2009).

Science achievement is associated with level of interest and attitudes toward science (Singh et al. 2002; Gonzales et al. 2008). Research indicates that the proportion of high school-aged youth who identify with or have interest in pursuing science is declining (Bennett and Hogarth 2009). By eighth grade, 43 % of students express no desire to take further science courses (Gonzales, et al. 2008), and both in the USA and around the world, fewer students—especially girls—express interest in science as a career (Sjøberg and Schreiner 2012). These trends indicate a need to investigate factors that positively impact teenagers' engagement with science (Osborne and Dillon 2008; Osborne et al. 2003).

Comics in Science Education

Comics, also known as graphic novels or graphic stories, refer collectively to a medium that communicates narrative through the combination of imagery and text (Fisher and Frey 2011; see Brenner 2011 and Cohn 2005 on use of the terms). Although comics can vary widely in format, they commonly feature a sequence of images in which characters' dialogue and thoughts are conveyed in bubbles. Comics first gained prominence in American mass media in the early part of the twentieth century, and their appeal to youth has long been noted (Hughes-Hassell 2007; Norton 2003; Sones 1944). Recently, the medium has so risen in status as to merit recognition in the bestseller lists of The New York Times and TIME Magazine (Gustines 2009; Kelly et al. 2005).

As graphic stories moved into the mainstream (Fisher and Frey 2011; Griffith 2010), they diversified beyond the traditional adventure and superhero genres of the past. To keep pace with teenagers' increasing interest, librarians are expanding their collections of graphic novels (Brehm-heeger et al. 2007; Griffith 2010; Gorman 2002; Rutherford 2007; Volin 2011), which now feature content as varied as science, history, biography, philosophy, mathematics, and various forms of fiction (Hosler et al. 2011; Hosler 2000).

Accompanying these trends is growing and widespread interest in comics as means for science learning. According to Harbaugh (2008) in Wired Magazine, comics may be a key to educating a reluctant public about science. Educators have explored the use of comics to increase reading literacy as well as to teach diverse topics (Fisher and Frey 2011; Griffith 2010; Hughes 2005; McTaggart 2005; Thompson 2007), including anatomy, biotechnology, and evolution (Park et al. 2011; Rota and Izquierdo 2003; Uleby 2005). Within health sciences, graphic stories are used in patient outreach and education to help explain diagnoses, illustrate prevention and treatment of injury and disease, and to change attitudes about disease (Green and Myers 2010; Sinha et al. 2011).

Prior studies suggest that graphic stories, with their illustrated narrative, may have positive impacts on readers' engagement, memory, and conceptual learning (Matuk et al. 2009) and that these benefits are most evident among novice learners (Mallia 2007; Tatalovic 2009). Carney and Levin (2002) found that illustrations accompanying text reinforce information in the text, provide coherence, and help establish settings in the narrative (see also Fang 1996). Mayer and Gallini (1990) determined that illustrated expository text on the mechanisms of scientific devices improved conceptual recall and creative problem solving among students who had low prior knowledge of the subject. Similarly, medical outreach materials that used cartoons received more attention and resulted in more correct answers than materials that did not use cartoons, particularly among patients with less than high school education (Delp and Jones 1996; Houts et al. 2006). In another study, low-literate participants not only showed preference for instructions with pictograms but also demonstrated greater understanding of complex information when it was accompanied by pictograms (Mansoor and Dowse 2003). People who read illustrated vs. nonillustrated instructions for using different asthma inhalers showed greater recall and performance, especially with the more complicated inhaler (Kools et al. 2006).

There is substantial evidence for the cognitive benefits of graphic presentations (Carney and Levin 2002). Not only do children generally prefer information conveyed in images over information presented as text (Kikuchi et al. 2002; Mantzicopoulos and Patrick 2011), but images can make science content more accessible, engaging, and memorable to youth (Avraamidou and Osborne 2009; Nagata 1999; Negrete and Lartigue 2004). Levie and Lentz (1982) suggest that by providing external representations, pictures support deeper understanding of the text by helping readers organize information and manage models of these situations in their working memory. By guiding readers to notice relations that are otherwise implicit in the text, pictures help readers build mental models that are more elaborate than they would normally have been able to construct from the text alone (Glenberg and Langston 1992). This notion is supported by Pike et al. (2010) who demonstrated that children made more accurate bridging inferences when the stories they read contained illustrations that supported relevant mental models.

There is preliminary evidence that comics are effective at capturing the attention of youth who are less engaged with science content and that they prepare them for deeper understanding. Hosler and Boomer (2011) found the greatest improvement in attitudes toward biology and comics among students with the lowest prior content knowledge, and the authors concluded that “comic book stories lose nothing to traditional textbooks while having the added potential benefit of improving attitudes about biology” (Hosler and Boomer 2011, p. 316). Attracting youth who do not usually engage with science, who do not identify with characteristics of scientists, or who have low achievement in science is a particularly important goal. Although all youth are not expected to pursue science careers, a spark produced through situational interest can be the first step in becoming a lifelong science learner.

Educators express a tension between the potential benefits of comics for engaging youth with science and the risk of providing “low level” entertainment without commensurate learning (Locke 2005; Thompson 2007). Yet, the research reviewed above suggests that the comics may have advantages over conventional science texts, particularly for youth who do not identify with science. We next describe identity theory and a model of interest development that provide rationales for exploring comics as a format for engaging teenagers with science information without sacrificing knowledge.

Identity Theory

Social psychologists have studied identity as a key concept for understanding human behavior for many decades (for a review, see Stryker and Burke 2000). The central idea of identity theory is that individuals define themselves and the situation and shape their behavior and interactions in a way that verifies their identity (Burke and Stets 2009). A consistent self-identity is important for a sense of worth and well-being (Burke and Stets 2009). Individuals often have several identities based on roles, relationships, and interests that are ordered in a salient hierarchy. Prior numerous studies grounded in identity theory have focused on topics such as parenthood identity, conflicts between parent, spouse and worker demands, the development of professional identities, and managing an identity “spoiled” by stigma (e.g., Goffman 1963). We conceptualized science identity as an indicator of how much youth think of themselves as interested in and good at science. Teenagers who consider science as relevant to their self-concept and something that they are good at should have higher science identities than teenagers who do not consider science as relevant to their self-concept and who are not good at science.

Identity theory suggests that identities will guide behavior toward self-verification. People seek to match their behavior to be consistent and relevant to their identity and their situation (Stets 2006). Thus, the degree to which youth consider themselves a "science kind of person" should be relevant for interpreting and acting on different types of educational materials. Youth may discriminate between science materials depending on whether the materials reinforce a science identity. Thus, teenagers with low science identity should be less receptive to and less engaged with material that they perceive as science (e.g., essays) than material that they may not perceive as science (e.g., comics). We define "engagement" with these reading materials as stated interest in the materials, measured by rating how much they would like to read more of them.

This synopsis of the key elements of identity theory provides a framework for the current study. Although identities can change over time through new roles, social interactions, social networks, and experiences, for this brief intervention, we considered identities as fixed predictors that shape responses to the study stimuli—comic books or essays. We next turn to an interest development model to further frame predictions about the potential benefits of unconventional science materials such as comic books compared to conventional science essays.

Situational Interest

Hidi and Renninger's (2006) research-based model of interest development suggests that environmental stimuli can spark new interest in a topic, or situational interest. This initial trigger that motivates engagement can be the first phase of developing interest in a topic over time. Situational interest occurs through environmental stimuli such as an interesting article in a waiting-room magazine, an interactive museum exhibit, or television program that focuses attention on a specific topic. In the Hidi and Renninger (2006) model, situational interest is always motivating and includes a positive affective component. If supported and maintained through continued meaningful engagement, this situational interest may develop over time into individual interest, a mostly stable orientation toward a topic that is associated with greater knowledge and enjoyment in the topic (Hidi and Harackiewicz 2000). Many recent informal science projects focus on increasing situational interest to engage more youth with science, and in particular, youth with low science interest. The hope and expectation is that for at least some youth, the efforts to make informal science engaging through comic books will eventually lead to more individual interest in science, even for those with initially low science identity.

The Current Study

This study addresses both the need for materials that engage student interest in science, specifically in virology, as well as the need for systematic research into the impacts of different formats of materials on student engagement and interest in science. Our overarching research question was: Can high quality comics about viruses increase the desire to engage more with science, particularly among teenagers who do not perceive themselves as interested in science? To investigate this question, we created two formats—comics and essays—for presenting the same virology-related content and compared their impacts on the attitudes, engagement, and knowledge of teenage readers. We particularly focused on the impacts of these materials on teenagers with self-reported low self-identification with science.

Comics that feature emotionally charged stories and high quality artwork should trigger situational interest in many teenagers and may thus also be viable means for science learning. To test these hypotheses, we measure both the engagement with the materials (i.e., teenagers' self-reported desire to engage further in the materials) and the educational value (i.e., teenagers' knowledge of viruses) of comics, as well as attitudes toward viruses, and use these measures to assess differences between those who read the comic and those who read the essay. Rather than expect this brief intervention to have direct impacts on teenagers' science identities, we seek to spark situational interest in science through non-conventional materials. Thus, consistent with other studies on the development of interest (e.g., Hidi 1990; Hidi and Renninger 2006), our analysis focuses on readers' engagement and content knowledge.

We expect that science essays will trigger "science" or "not science" self-identities among youth, but that comic books will not. That is, because youth who do not identify with science will label conventional essays as not relevant to them, they may also fail to find them engaging. In contrast, science comic books, with their vivid drawings and dynamic plot lines, should be less likely to trigger associations with science, and thus, low science identity youth may be more open to exploring them. Thus, we expected differences in youths' engagement with the two formats. We did not expect to see measurable differences in reported attitudes toward viruses with this single, brief exposure to the materials.

Because conventional essay formats are familiar to youth as a standard method for science learning and assessment, we might expect the essay group to show higher content knowledge of viruses. At the same time, research on comics suggests that their affective impacts might be beneficial to learning. We therefore compare scores on the virus knowledge quiz for the two groups (comic/essay) to determine whether readers assigned to the comics or the essays had higher knowledge after reading the comic or essay, but do not predict or hypothesize differences between the groups.

Our hypotheses, based upon prior research and theories reviewed above and directly related to our focal question, were the following:

1. Among teenagers with lower identification with science, those assigned to read the comic would want to continue to engage with the science learning materials more than those assigned to the essay.
2. This brief intervention would produce no differences between the comic and essay groups in perceptions about the importance of and interest in studying viruses.

In addition to the hypotheses above, we report findings for teenagers across all science identity categories, to understand how impacts of these materials may differ for youth with different levels of science identity.

Methods

Participants

Participants in the survey study were 873 students enrolled in a required ninth or tenth grade level biology class. Fifteen classes from six public high schools in a mid-size Midwestern US city participated. Minority enrollment in these schools ranged from 13 to 49 % and participation in the free/reduced lunch program at the different schools ranged from 13 to 61 %. More detailed descriptive information of the participants (by condition) is shown in Table 1.

Table 1 Descriptive statistics by condition (comic/essay)

	Overall (N=873) % or M (sd)	Comic (N=434) % or M (sd)	Essay (N=439) % or M (sd)	χ^2 (df) or t	Significance
Female (percentage)	49 %	51 %	47 %	1.04 (1)	ns
Age (in years)	15.3 (.9)	15.3 (.9)	15.4 (.9)	1.59	ns
Race/ethnicity (proportion)				0.80 (3)	ns
White and Asian	75 %	76 %	74 %		
Hispanic	10 %	10 %	11 %		
Black	5 %	5 %	6 %		
Mixed/other	10 %	10 %	10 %		
Race/ethnicity by gender					
Female				2.7 (3)	ns
White and Asian	76 %	79 %	72 %		
Hispanic	10 %	9 %	11 %		
Black	6 %	5 %	7 %		
Mixed/other	8 %	7 %	10 %		
Male				1.2 (3)	ns
White and Asian	74 %	72 %	75 %		
Hispanic	10 %	11 %	10 %		
Black	5 %	5 %	5 %		
Mixed/other	11 %	12 %	9 %		
Read comic books, manga or other graphic novel in past year	42 %	47 %	53 %	2.9 (1)	ns
Socioeconomic status proxy (scale alpha=0.76)	−0.02 (0.6)	0.02 (0.6)	−0.04 (0.6)	−1.37	ns
Items for the latent class analysis of "Science Kind of Person"					
How interesting is science to you? (1–4, 4=very interesting)	2.7 (1.0)	2.7 (1.0)	2.7 (1.0)	0.33	ns
Grades (1–7, 1=mostly below C's, 7=mostly A's)	5.0 (1.8)	5.0 (1.8)	5.0 (1.9)	−0.04	ns
Science identity items (1=SD, 5=SA)					
"People in my life think of me as a science person"	2.5 (1.1)	2.5 (1.2)	2.5 (1.1)	−0.15	ns
"I have always liked science"	3.3 (1.2)	3.3 (1.2)	3.3 (1.3)	0.03	ns
"I'm just not a science person" (reverse coded)	3.0 (1.3)	3.0 (1.3)	3.0 (1.3)	0.05	ns

"manga" is a form of graphic story telling; "SES proxy" was comprised of seven variables including mother's education, father's education, and participation in free and reduced lunch program

ns nonsignificant at the p=0.05 level, *SD* strongly disagree, *SA* strongly agree

Materials and Instrument

The intervention materials used in the survey study were two different comics and two corresponding essays, each focused on a unique virus (influenza or foot and mouth disease). The materials were developed by the World of Viruses project funded by the National

Institutes of Health (NIH) through a Science Educational Partnership Award (SEPA). World of Viruses is an integrated educational media initiative that creates radio documentaries, books (Diamond et al. 2012; Zimmer 2012), interactive iPad apps, and activities aimed at educating youth and the public about virology (see http://www.worldofviruses.unl.edu). The World of Viruses comics were developed by experienced, professional graphic novel writers and artists to be characteristic of the medium, with "edgy" plot lines and illustrations (see Fig. 1), and virologists vetted all scientific content. The resulting 10- to 20-page graphic stories each focus on a specific virus in the context of a plot-driven narrative. In addition to the story elements, the comics feature images of people that are underrepresented in science fields (racial/ethnic minority and/or women) and illustrations of viruses.

To equalize the two formats for comparison, the essays were written by an award-winning professional science writer, who used the scripts from the comics as a basis for the content. Thus, both the comics and essays conveyed the same factual information about viruses, but the comic format included fictional story elements and graphics.

Fig 1 Excerpts from World of Viruses comics used in this study

Attached to both the comic and the essay was a survey instrument comprised of items adapted from existing measures (Boyce et al. 2006; Currie et al. 1997; Fraser 1978; Wardle 2002) and new items pertaining to the constructs of interest. Items included close-ended measures of attitude and knowledge regarding viruses and people who work with viruses (see the Appendix for the subscales used in the analyses); measures of interest in science and in reading more similar materials; measures of the frequency of comic/graphic story/manga reading; and measures of demographic variables, including socioeconomic status and school grades. Through short, exploratory interviews with youth in the target population and a pilot study conducted prior to the data collection, we were able to identify potential sources of response error in the questionnaire and to refine the instrument items.

Procedures

The study was designed to identify the impact of the comics in comparison to a traditional presentation of science content. Using a table of random numbers to select a "starting" seat, teenagers were systematically assigned within classes to receive packets that included either the comic or the essay and the survey. This method of assignment to the essay or comic condition ensured that differences in responses to the comic or essay were from the exposure to the material and not from selection effects. The teenagers typically took about 15–20 min to read the materials.

Chi-square tests for categorical variables and a *t* test for the difference in means between the comic and essay groups for interval/ratio variables were conducted and because there were no significant differences between the groups on the independent variables or demographic characteristics, we determined that the random assignment worked (see Table 1).

Analyses

We used latent class analysis (LCA, see McLachlan and Peel 2000; Collins and Lanza 2010) to classify teenagers according to their identification with science. LCA is similar to factor analysis in that it assumes the existence of latent constructs that are measured via indicator variables. In LCA, however, the constructs and the indicators are categorical rather than continuous. If the model fits the data, then the latent construct explains the patterns in the observed data. The result of LCA is the classification of individuals into the latent categories, which should lead to a parsimonious and insightful description of their shared characteristics. In the present case, we employed five indicators of science identity (general interest in science, science grades, and three items that assess strength of identification with science, see Table 1) and fitted the model using Mplus (Muthén and Muthén 2011).

The LCA yielded a four-class solution using the Bayesian information criterion (see Lubke and Neale 2008) with the latent classes ordered along a single continuum from high to low science identity. The Bayesian fit statistics indicated that adding another category or collapsing two categories would have had a worse fit than the four category solution. Teenagers in the high identity group strongly self-identified as "science people" and reported high scholastic performance in science. Teenagers in the low identity category strongly identified as "nonscience people" and reported poor scholastic achievement in science. The other two categories, labeled high-middle and low-middle, are between these extremes.

The conclusion that the latent classes represent an underlying dimension was corroborated using discrete factor analysis (DFA, e.g., Wirth and Edwards 2007). The DFA showed that a single factor provided acceptable fit to the science identity indicators (RMSEA=0.057; CFI=0.997; TLI=0.994). We chose the LCA over the DFA because the former leads directly to a classification of youth into groups and therefore allowed us to consider the interaction between science identity and the type of reading materials. In the present study, the classification probabilities were highly accurate (average classification accuracy=92.41 %) with most of the classification error occurring between the two middle groups. As shown in Table 2, the proportion of teenagers assigned to read either comics or essays did not differ over the science identity groups.

Table 2 shows the distribution of participants in the latent classes across the relevant demographic characteristics. It is interesting to consider these data with regard to the use of demographic variables as proxy measures for science identification. The proportion of non-white/Asian teenagers was significantly lower in the higher science identity groups. In addition, means on our measure of socioeconomic status (SES) increased with each increase in science identity. In other words, teenagers with low science identity were more likely to be economically less well off and non-white/Asian. Nonetheless, there remained a relatively large proportion of non-white/Asians in the higher identity groups, and visual inspection of the within-group SES distributions showed that lower SES teenagers were also present in these groups. Using either race/ethnicity or SES as proxies for science identity would consequently misclassify these teenagers. The proportion of girls also differed over the groups, and mean difference in age was marginally significant, but these effects are not ordered by science identity. Thus, our science identity variable is a more appropriate measure of the construct of interest than the social status measures that are often used as surrogates.

The main results of this study were obtained by means of linear regression. The outcome variables of interest were teenagers' (a) desire to read more about viruses, (b) perceived importance of viruses, (c) interest in studying and working with viruses, and (d) knowledge of viruses. The first construct was measured specific to the condition that teenagers' were assigned to (e.g., teenagers in the comic condition were asked to respond to the statement, "I would like to read more comics about viruses"). The desire to read more was measured as a single 5-point Likert scale, and we used ordered logistic regression for this outcome (Harrell 2010). We conceptualize this "read more" variable as a desire to continue to engage with the materials. Survey items measuring the last three constructs (importance of viruses, interest in viruses, and knowledge of viruses) are listed in the Appendix.

The focal predictor variables were type of reading material (comic vs. essay) and science identity group (low to high). Our main reason for considering the science identity factor was to measure the interaction with type of reading materials. We expected the comics to have a greater effect for teenagers who have lower than higher identification with science. Therefore, we tested three specific contrasts: each of the lower interest groups to the highest interest group to examine the interaction. To isolate the effects of the comics compared to essays by science identity, we also included age, gender, race/ethnicity, and SES as covariates. We used fixed

Table 2 Characteristics of the science identity categories

	Class 1 Low *N*=139	Class 2 Middle low *N*=306	Class 3 Middle high *N*=280	Class 4 High *N*=135	*p* value
Gender (% girls)	37 %	47 %	60 %	46 %	< 0.001
Race (% not white or Asian)	35 %	30 %	23 %	19 %	< 0.01
Age [mean (sd)]	15.32 (0.70)	15.41 (0.90)	15.26 (0.91)	15.20 (0.97)	0.051
Socioeconomic status (SES proxy)	−0.16 (0.64)	−0.10 (0.66)	0.04 (0.62)	0.20 (0.55)	< 0.001
Assigned condition (% comic)	45 %	54 %	49 %	52 %	0.291

For the variables gender, race, and type of reading material, the *p* value is from a chi-square test of association; for age and SES, from a one-way ANOVA *F* test effects to control for the possibility that students from the same class were more similar than to each other expected by random sampling (i.e., we controlled for teacher-level clustering).

Results

In this section, we report the results for each of the four regression analyses. In addition to results for the main hypotheses, we mention effects of demographic covariates where they arise.

Desire to engage more Teenagers in the comic group were almost five times more likely to want to read more of the learning materials than teenagers in the essay condition [OR=4.82; 95 % confidence interval (CI), 3.16–7.35]. In addition, this desire to engage more with the materials had a significant interaction between science identity and comic vs. essay condition. As hypothesized, the comics had an even greater effect in contrast to the essays for the bottom two science identity categories than for the top two categories, and this difference was substantial. As shown in Table 3, we treated the interaction in terms of three contrasts. In each contrast, we compared the difference between the comic and the essay for the high science identity category versus a lower identity category. The contrast tests show that the difference between the comic and essay conditions is largest for those with low science identity (OR=7.69, 95 % CI, 4.76–12.5), not as large for those in the middle-low science identity group (OR=2.85, 95 % CI, 1.92–4.35), and only slightly larger for the middle-high group (OR=1.61, 95 % CI, 1.09–2.38) compared to the high science identity group. The difference in desire to continue engaging with the virus materials between the comic and essay conditions is significant at all levels of science identity, but is substantially larger (over seven times) in the lowest compared to the highest science identity groups.

Figure 2 illustrates the condition by science identity interaction compared to the high science identity group. To simplify the presentation we focus on the top two response

Table 3 Multiple ordered logistic regression for desire for continued engagement

Effect	Adjusted odds ratio	95 % CI
Main effects		
Condition [essay (0) vs. comic (1)]	4.82	(3.16–7.35)
Identity		
High (1) vs. middle-high (0)	1.16	(0.68–2.00)
High (1) vs. middle-low (0)	2.78	(1.59–4.76)
High (1) vs. low (0)	11.11	(5.88–25.0)
Interaction		
High ID (1) vs middle-high (0)/comic(1)	1.61	(1.09–2.38)
High ID (1) vs middle-low (0)/comic(1)	2.85	(1.92–4.35)
High ID (1) vs low (0)/comic(1)	7.69	(4.76–12.5)
Extra contrast: high identity/essay (0) vs. low identity comic (1)	1.1	(0.54–2.06)
Demographic variables		
Gender [male (0) vs. female (1)]	1.20	(0.94–1.55)
Age	1.00	(0.91–1.12)
Race [white/Asian (0) vs. other (1)]	0.97	(0.71–1.32)
Socioeconomic status (SES proxy)	0.86	(0.68–1.08)

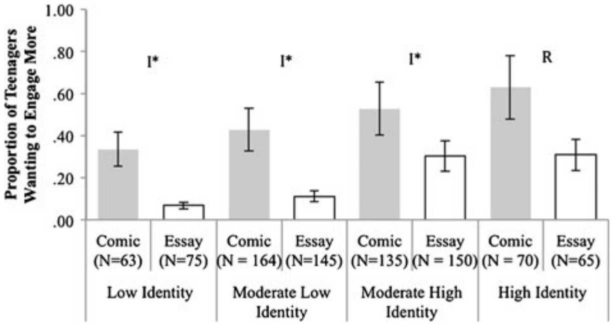

Fig 2 Proportion of teenagers agreeing or strongly agreeing that they wanted to engage more with science materials by science identity and comic/essay condition. *I** indicates $p<0.05$, significant interaction for the difference between comic and essay compared to the reference (*R*) category, high identity. Error bars illustrate that the difference between comic and essay within each identity group is statistically significant, $p<0.05$

categories; we provide the percentage who strongly agree or agree that they want to read more comics/essays about viruses in the comic and essay groups separately. The figure clearly illustrates that more youth in the comic than in the essay condition want to read more and that the difference between the comic and essay conditions is larger in the lower than higher science identity groups.

Figure 2 also provides an insight regarding the potential impact of comics for an important group—youth with low science identity. The figure shows that a similar proportion of low science identity youth in the comic group agrees that they wanted to read more about viruses as high science identity youth in the essay group. We tested whether the difference between these two groups was significant and found it was not (OR=1.1; 95 % CI, 0.54–2.06), (see the extra contrast in Table 3). That the difference is not statistically significant is noteworthy because it highlights the possibility that comics can engage the same proportion of low science identity youth as conventional essays can engage youth who already have a high science identity.

Perceived Importance and Interest As hypothesized, there was no difference between the comic and essay groups on the scale measuring the perceived importance of viruses, and there was no interaction between science identity and condition. Teenagers with higher SES scores rated the importance of viruses higher than teenagers with lower SES scores ($t=1.984$, $df=834$, $p=.0476$; Cohen's $d=0.09$[1]). In addition, there was no difference between the comic and essay groups on teenagers' interest in viruses or studying viruses and no interaction between science identity and condition. Girls rated their interest in studying viruses higher than did boys ($t=2.277$, $df=834$, $p=0.023$; Cohen's $d=0.11$).

Knowledge Assessment There was no difference between the teenagers in the comic and essay groups on knowledge of viruses. Therefore, the concerns of educators that comics may not be educational (Dorrell et al. 1995) were not confirmed and the argument that comics are better at conveying information was also not confirmed. There was also no interaction between science identity and reading materials. Girls scored lower on the knowledge items than boys ($t=-2.062$, $df=834$, $p=.040$; Cohen's $d=0.10$), and non-Asian minorities scored lower than whites and Asians ($t=-2.098$, $df=834$, $p=.036$; Cohen's $d=0.16$).

[1] Cohen's *d* is estimated in these analyses by Hedges' *g*.

Summary

There was a substantial difference between the two conditions on teenagers' desire to engage more with the materials, across all levels of science self-identity. Teenagers in the comic condition were almost five times more likely to want to continue reading materials about viruses than teenagers in the essay condition. In addition, with respect to the desire to engage more with the materials, there was a significant interaction between science identity and material assigned, with teenagers in the lowest science identity group being over seven times more likely to want to read more comics than essays than those in the high identity group. These patterns of findings provides support for our prediction that the comics are more effective with teenagers who have low science identity and are therefore less inclined to read about science in the conventional essay format.

In both the comic and essay groups, there were no differences in how teenagers rated the importance of viruses or in their interest in studying or working with viruses. Furthermore, there was no interaction between science identity groups and condition (comic/essay) on the importance of and interest in viruses. Given the brief intervention and the conceptualization of the nonconventional materials as a way to generate situational interest, this result is consistent with the prediction that attitudinal constructs such as the importance of viruses or interest in studying viruses would remain relatively stable and not differ by type of intervention.

Confirming neither concerns from educators nor promises of comic book advocates, there were no differences on youths' scores on the test of their knowledge of viruses whether they had just read the comic or the essay; therefore, comics and essays were equally effective at conveying content about viruses and infectious disease. The main difference between comics and essays, therefore, was the desire to read more similar materials, particularly among youth who have lower science identities. We next discuss the potential implications of nonconventional materials for informal science education.

Conclusions/Discussion

Comics are an intriguing genre for informal science education. Although originally designed for entertainment, there is now tantalizing evidence that they may have educational potential. Even more importantly, science comic books may particularly engage and educate youth who think of themselves as not being a "science kind of person" and therefore unlikely to be interested in science content. Is Wired Magazine correct to focus on comics as a way to keep a broader audience engaged with science? Our results support this notion.

The comics appealed to more youth who do not identify themselves as "science people." The comics did not seem to act on self-identity in the same way as science essays. When presented in the comic format, the learning materials triggered situational interest, a first step in motivating learning. As mentioned earlier, prior research indicates that situational interest, if supported and sustained through repeated engagement, can gradually develop into a more lasting individual interest in that topic (Hidi 1990; Hidi and Harackiewicz 2000). Furthermore, interest and personal engagement in a topic are stronger predictors of behavior than academic achievement (Hidi and Renninger 2006). That many teenagers wanted to read more comics, particularly teenagers with low science identity, is an important finding. It suggests that comics could be an influential step in developing interest in science in the youth most resistant to conventional educational materials. The finding that teenagers have similar knowledge of viruses after reading either the comic or the essay suggests that comics can be both engaging and effective at conveying science knowledge and may be a useful tool for attracting hard-to-reach teenagers to science.

Because rapid advances in science require lifelong learning, it is important to discover ways to continually engage the public with advances in science, especially for those who do not have an interest in or an aptitude for science. This suggests that comics may enable a wider audience of nonspecialists, individuals who do not typically seek out science information, to engage with science-related topics, thus fostering scientific literacy. Even though they are not perceived as science, but rather as interesting stories, comics can provide an avenue to science learning.

We were concerned that, similar to findings by Durik and Harackiewicz (2007) with math, comics might dampen interest in those who already identified with science. Their studies found that adding colors and pictures to a mathematics task negatively affected motivation in learners who already had high individual interest in the domain, and concluded that these extra features may have been distracting or perceived as juvenile. The comics in the current study, however, were found to be effective in engaging teenagers who already identify with science. In contrast to the essays, the comics were engaging to more teenagers at all levels of identification with science. Thus, this type of information presentation does not appear to negatively impact situational interest for those already knowledgeable and interested in the topic. Consequently, the use of comics as a way to generate interest in science topics may be appropriate across a wide spectrum of learners.

Leveraging the potential of comics requires an understanding of the specific features that are effective, for whom these materials are most useful, and the amount of exposure needed to effect results. Future studies will also need to assess impacts in situations that better resemble how teenagers typically engage with comics, and if continued comic reading will lead to long-term knowledge gains, particularly for those less likely to read other science materials. If innovative comics can attract and engage youth who might otherwise avoid science, then they may provide motivation to pursue further science learning.

Generating and sustaining interest in science learning is a growing challenge for our times. Just over half of the teenagers in this study had low to moderate science identity. Most people do not think of themselves as science-oriented, and yet they regularly make decisions about health care and science policy. The results from this study suggest possible avenues for addressing these important knowledge deficiencies. Similar to many others working on creative approaches to informal science education, we emphasize thinking broadly about how information is delivered. This study provides evidence that creating innovative materials about science, such as the comic books used here, may be an effective means to reach youth with low science identities.

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Appendix

Items Used in Subscales

1. Importance of viruses and studying viruses
   a. The world is better because people study viruses.
   b. Knowing about viruses helps prevent disease.
   c. People should understand viruses because it helps their lives.
   d. It is important that people study viruses.
   e. People who study viruses can improve the world.
   f. People are healthier because of science.

2. Interest in viruses and studying viruses.
   a. I don't want to know more about viruses (reversed).
   b. Life would be boring without viruses.
   c. Viruses are boring (reversed).
   d. It can be fun to learn about viruses.
   e. It would be interesting to have a job that works with viruses.
   f. Viruses can be interesting.

3. Knowledge of viruses.
   a. Viruses need a host to reproduce.
   b. There are more humans than viruses (reversed).
   c. The body's immune system fights viruses.
   d. Viruses take over cells to make more viruses.
   e. Cells and viruses are about the same size (reversed).
   f. T cells fight viruses.
   g. Viruses have their own DNA or RNA.
   h. Vaccines prevent disease.

References

Avraamidou, L., & Osborne, J. (2009). The role of narrative in communicating science. *International Journal of Science Education, 31*(12), 1683–1707. doi:10.1080/09500690802380695.

Bennett, J., & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students' attitudes to school science and to science. *International Journal of Science Education, 31*(14), 1975–1998. doi:10.1080/09500690802425581.

Bogart, L. M., Skinner, D., Weinhardt, L. S., Glasman, L., Sitzler, C., Toefy, Y., et al. (2011). HIV misconceptions associated with condom use among black South Africans: An exploratory study. *African Journal of AIDS Research AJAR, 10*(2), 181–187. doi:10.2989/16085906.2011.593384. http://www.tandfonline.com.

Boyce, W., Torsheim, T., Currie, C., & Zambon, A. (2006). The family affluence scale as a measure of national wealth: Validation of an adolescent self-report measure. *Social Indicators Research, 78*(3), 473–487. doi:10.1007/s11205-005-1607-6.

Brehm-heeger, B. P., Conway, A., & Vale, C. (2007). The amazing and unexpected places an anime club can lead unsuspecting librarians. *Young Adult Library Services, 5*(2), 14–17.

Brenner, R. (2011). Comics and graphic novels. In S. A. Wolf, K. Coats, P. Enciso, & C. Jenkins (Eds.), *Handbook of research on children's and young adult literature* (pp. 255–267). New York: Taylor & Francis.

Burke, P. J., & Stets, J. (2009). *Identity theory.* New York: Oxford University Press.
Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*(1), 5–26.
Centers for Disease Control and Prevention. (2011). *Genital HPV infection—CDC fact sheet*. Washington: Department of Health and Human Services.
Centers for Disease Control and Prevention. (2012). *HIV in the United States: At a glance*. Washington: Department of Health and Human Services.
Cohn, N. (2005). Un-defining "comics". *International Journal of Comic Art, 7*(2), 236–248.
Collins, L., & Lanza, S. (2010). *Latent class and latent transition analysis: With applications in the social, behavior, and health sciences*. Hoboken: Wiley.
Currie, C. E., Elton, R. A., Todd, J., & Platt, S. (1997). Indicators of socioeconomic status for adolescents: The WHO health behaviour in school-aged children survey. *Health Education Research, 12*(3), 385–397.
Delp, C., & Jones, J. (1996). Communicating information to patients: The use of cartoon illustrations to improve comprehension of instructions. *Academic Emergency Medicine, 3*(3), 264–270. doi:10.1111/j.1553-2712.1996.tb03431.x.
Devroey, D., Riffi, A., Balemans, R., Van De Vijver, E., Chovanova, H., & Vandevoorde, J. (2013). Comparison of knowledge and attitudes about vaccination between Belgian and immigrant adolescents. *Journal of Infection and Public Health, 1*(6), 1–9.
Diamond, J., Powell, M., Fox, A., Downer-Hazell, A., & Wood, C. (2012). *World of viruses*. Lincoln: University of Nebraska Press.
Dorrell, L. D., Curtis, D. B., & Rampal, K. R. (1995). Book-worms without books? Students reading comic books in the school house. *The Journal of Popular Culture, 29*(2), 223–234.
Durik, A. M., & Harackiewicz, J. M. (2007). Different strokes for different folks: How individual interest moderates the effects of situational factors on task interest. *Journal of Education and Psychology, 99*(3), 597–610. doi:10.1037/0022-0663.99.3.597.
Fang, Z. (1996). Illustrations, text, and the child reader. *Reading Horizons, 37*, 130–142.
Fisher, D., & Frey, N. (2011). *Engaging the adolescent learner: Making the most of graphic novels in the classroom*. Newark: International Reading Association.
Food and Agriculture Organization of the United Nations. (2010). *FAO warns of increased foot-and-mouth threats*. Rome: FAO Media Centre. http://www.fao.org/news/story/en/item/41702/icode/.
Fraser, B. J. (1978). Development of a test of science-related attitudes. *Science Education, 62*(4), 509–515.
Glenberg, A. M., & Langston, W. E. (1992). Comprehension of illustrated text: Pictures help to build mental models. *Journal of Memory and Language, 31*(2), 129–151. doi:10.1016/0749-596X(92)90008-L.
Goffman, E.(1963).Stigma: Notes on the management of spoiled identity. Prentice-Hall. ISBN 0-671-62244-7.
Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., & Brenwald, S. (2008). *Highlights From TIMSS 2007: Mathematics and science achievement of U.S. fourth- and eighth-grade students in an international context (NCES 2009–001 Revised)*. Washington: National Center for Education Statistics, Institute of Education Sciences, US Department of Education.
Gorman, M. (2002). What teens want. *School Library Journal, 48*(8), 42.
Green, M. J., & Myers, K. R. (2010). Graphic medicine: Use of comics in medical education and patient care. *British Medical Journal, 340*, 574–577.
Griffith, P. E. (2010). Graphic novels in the secondary classroom and school libraries. *Journal of Adolescent & Adult Literacy, 54*(3), 181–189. doi:10.1598/JAAL.54.3.3.
Gustines, G. G. (2009). Introducing the New York Times graphic books best seller lists—NYTimes.com. *New York Times*. http://artsbeat.blogs.nytimes.com/2009/03/05/introducing-the-new-york-times-graphic-books-best-seller-lists/?scp=5&sq=introducingthenewyorktimesgraphic&st=cse
Harbaugh, B. (2008). How comics can save us from scientific ignorance. *Wired Magazine*, *16* (12). http://www.wired.com/culture/education/magazine/16-12/pl_print
Harrell, F. E. (2010). *Regression modeling strategies: With applications to linear models, logistic regression, and survival analysis*. New York: Springer.
Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549–571. doi:10.3102/00346543060004549.
Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for the 21st century. *Review of Educational Research, 70*(2), 151–179. doi:10.3102/00346543070002151.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychology, 41*(2), 111–127.
Hosler, J. (2000). *Clan Apis* (2nd ed.). Columbus: Active Synapse.
Hosler, J., & Boomer, K. B. (2011). Are comic books an effective way to engage nonmajors in learning and appreciating science? *CBE Life Sciences Education, 10*(3), 309–317. doi:10.1187/cbe.10-07-0090.
Hosler, J., Cannon, K., & Cannon, Z. (2011). *Evolution: The story of life on earth*. New York: Hill and Wang.

Houts, P. S., Doak, C. C., Doak, L. G., & Loscalzo, M. J. (2006). The role of pictures in improving health communication: A review of research on attention, comprehension, recall, and adherence. *Patient Education and Counseling, 61*(2), 173–190.

Hughes, S. (2005, April 8). Comic book science in the classroom [Audio podcast]. On National Public Radio. http://www.npr.org/templates/story/story.php?storyId=4581832

Hughes-Hassell, S. (2007). The leisure reading habits of urban adolescents. *Journal of Adolescent & Adult Literacy, 51*(1), 22–33. doi:10.1598/JAAL.51.1.3.

Jacobson, R. M., Targonski, P. V., & Poland, G. A. (2007). A taxonomy of reasoning flaws in the anti-vaccine movement. *Vaccine, 25*(16), 3146–3152. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/17292515.

Joint Committee on National Health Education Standards. (2007). *National health education standards: Achieving excellence* (2nd ed.). Atlanta: American Cancer Society.

Kelly, J., Grossman, L., & Lacayo, R. (2005). Time's list of the 100 Best Novels. *Time Magazine*. Retrieved from http://entertainment.time.com/2005/10/16/all-time-100-novels/#all

Kikuchi, H., Kato, H., & Akahori, K. (2002). Analysis of children's web browsing process: ICT education in elementary school. In *International Conference on Computers in Education Proceedings* (pp. 253–254). Los Alamitos: IEEE Computer Society. doi:10.1109/CIE.2002.1185917.

Kools, M., Van De Wiel, M. W. J., Ruiter, R. A. C., & Kok, G. (2006). Pictures and text in instructions for medical devices: Effects on recall and actual performance. *Patient Education and Counseling, 64*(1–3), 104–111.

Levie, W., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Technology Research and Development, 30*(4), 195–232.

Locke, S. (2005). Fantastically reasonable: Ambivalence in the representation of science and technology in super-hero comics. *Public Understanding of Science, 14*(1), 25–46. doi:10.1177/0963662505048197.

Lubke, G., & Neale, M. (2008). Distinguishing between latent classes and continuous factors with categorical outcomes: Class invariance of parameters of factor mixture models. *Multivariate Behavioral Research, 43*(4), 592–620. doi:10.1080/00273170802490673.

Mackinder, L. C. M., Worthy, C. A., Biggi, G., Hall, M., Ryan, K. P., Varsani, A., et al. (2009). A unicellular algal virus, *Emiliania huxleyi* virus 86, exploits an animal-like infection strategy. *Journal of General Virology, 90*(9), 2306–2316. doi:10.1099/vir.0.011635-0.

Mallia, G. (2007). Learning from the sequence: The use of comics in instruction. *Interdisciplinary Comics Studies*, *3*(3). http://www.english.ufl.edu/imagetext/archives/v3_3/mallia/index.shtml?print#

Manjunath, U., & Pareek, R. P. (2003). Maternal knowledge and perceptions about the routine immunization programme—a study in a semiurban area in Rajasthan. *Journal of Medical Sciences, 57*(4), 158–163. Retrieved from http://www.indianjmedsci.org/article.asp?issn=0019-5359;year=2003;volume=57;issue=4;spage=158;epage=163;aulast=Manjunath.

Mansoor, L. E., & Dowse, R. (2003). Effect of pictograms on readability of patient information materials. *The Annals of Pharmacotherapy, 37*(7–8), 1003–1009.

Mantzicopoulos, P., & Patrick, H. (2011). Reading picture books and learning science: Engaging young children with informational text. *Theory Into Practice, 50*(4), 269–276. doi:10.1080/00405841.2011.607372.

Matuk, C. F., Diamond, J., & Uttal, D. H. (2009, October). Heroes, villains and viruses: How graphic narratives teach science. Paper presented at the International Visual Literacy Association (IVLA2009), Chicago, IL.

Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words? *Journal of Education and Psychology, 82*(4), 715–726. doi:10.1037/0022-0663.82.4.715.

McLachlan, G., & Peel, D. (2000). *Finite mixture models*. New York: Wiley.

McTaggart, J. (2005). Using comics and graphic novels to encourage reluctant readers. *Reading Today, 23*(2), 46.

Miller, S. (2001). Public understanding of science at the crossroads. *Public Understanding of Science, 10*(1), 115–120. doi:10.1088/0963-6625/10/1/308.

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: What we know and what we need to know. *Public Understanding of Science, 13*(3), 273–294. doi:10.1177/0963662504044908.

Muthén, L. K., & Muthén, B. O. (2011). *Mplus user's guide* (6th ed.). Los Angeles: Muthén & Muthén.

Nagata, R. (1999). Learning biochemistry through manga—helping students learn and remember, and making lectures more exciting. *Biochemical Education, 27*(4), 200–203. doi:10.1016/S0307-4412(99)00052-7.

National Center for Education Statistics. (2009). *National assessment of educational progress (NAEP), 2009 science assessment*. Washington: Institute of Education Sciences, US Department of Education.

National Center for Education Statistics. (2011). *Digest of Education Statistics (NCES 2011–015)*. Washington: Institute of Education Sciences, US Department of Education.

Negrete, A., & Lartigue, C. (2004). Learning from education to communicate science as a good story. *Endeavour, 28*(3), 120–124. doi:10.1016/j.endeavour.2004.07.003.

Norton, B. (2003). The motivating power of comic books: Insights from Archie comic readers. *The Reading Teacher, 57*(2), 140–147.
Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. London: Nuffield Foundation.
Park, J. S., Kim, D. H., & Chung, M. S. (2011). Anatomy comic strips. *Anatomical Sciences Education, 4*(5), 275–279. doi:10.1002/ase.224.
Pike, M. M., Barnes, M. A., & Barron, R. W. (2010). The role of illustrations in children's inferential comprehension. *Journal of Experimental Child Psychology, 105*(3), 243–255. doi:10.1016/j.jecp.2009.10.006.
Poland, G. A., & Jacobson, R. M. (2001). Understanding those who do not understand: A brief review of the anti-vaccine movement. *Vaccine, 19*(17–19), 2440–2445. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11257375.
Rota, G., & Izquierdo, J. (2003). Comics as a tool for teaching biotechnology in primary schools. *Electronic Journal of Biotechnology, 6*(2), 85–89. doi:10.2225/vol6-issue2-fulltext-i02.
Rutherford, D. (2007). Great graphic novels for teens. *Young Adult Library Services, 5*(3), 40–43.
Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*(6), 323–332.
Sinha, I., Patel, A., Kim, F. S., MacCorkle, M. L., & Watkins, J. F. (2011). Comic books can educate children about burn safety in developing countries. *Journal of Burn Care & Research, 32*(4), E112–E117.
Sjøberg, S., & Schreiner, C. (2012). A comparative view on adolescents' attitudes towards science. In M. W. Bauer, R. Shukla, & N. Allum (Eds.), *The culture of science: How the public relates to science across the globe* (pp. 200–213). London: Routledge. 9780415873697.
Sones, W. (1944). The comics and instructional method. *Journal of Educational Sociology, 18*, 239.
Stets, J. E. (2006). Identity Theory. In P. J. Burke (Ed.), *Contemporary social psychological theories* (pp. 88–110). Stanford: Stanford University Press.
Stryker, S., & Burke, P. J. (2000). The past, present, and future of an identity theory. *Social Psychology Quarterly, 63*(4), 284–297.
Swenson, R. R., Rizzo, C. J., Brown, L. K., Vanable, P. A., Carey, M. P., Valois, R. F., et al. (2010). HIV knowledge and its contribution to sexual health behaviors of low-income African American adolescents. *Journal of the National Medical Association, 102*(12), 1173–1182. National Medical Assn. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3095017/.
Tatalovic, M. (2009). Science comics as tools for science education and communication: A brief, exploratory study. *Journal of Science Communication, 8*(4), 1–17.
Thompson, T. (2007). Embracing reluctance when classroom teachers shy away from graphic books. *Library Media Connection, 25*(4), 29–29.
Thompson, M., Shay, D., Zhou, H., Bridges, C., Cheng, P., Burns, E., et al. (2010). Estimates of deaths associated with seasonal influenza—United States, 1976–2007. *JAMA : The Journal of the American Medical Association, 304*(16), 1778–1780.
Uleby, N. (2005, February 14). Holy evolution, Darwin! Comics take on science (Audio podcast). On National Public Radio. http://www.npr.org/templates/story/story.php?storyId=4495248
UNAIDS (2010). Global report: UNAIDS report on the global AIDS epidemic 2010. Geneva: Joint United Nations Programme on HIV/AIDS (UNAIDS).
Volin, E. V. A. (2011). Good comics for kids collecting graphic novels for young readers. *Children & Libraries: The Journal of the Association for Library Service to Children, 9*(1), 3–10.
Wardle, J. (2002). Assessing socioeconomic status in adolescents: The validity of a home affluence scale. *Journal of Epidemiology and Community Health, 56*(8), 595–599. doi:10.1136/jech.56.8.595.
Wirth, R. J., & Edwards, M. C. (2007). Item factor analysis: Current approaches and future directions. *Psychological Methods, 12*(1), 58–79. doi:10.1037/1082-989X.12.1.58.
Zimmer, C. (2012). *A planet of viruses*. Chicago: University Of Chicago Press.