Avengers Assemble! Using pop-culture icons to communicate science

E. Paul Zehr

Rehabilitation Neuroscience Laboratory, University of Victoria, Victoria, British Columbia, Canada; School of Exercise Science, Physical, and Health Education, University of Victoria, Victoria, British Columbia, Canada; International Collaboration on Repair Discoveries, Vancouver, British Columbia, Canada; Centre for Biomedical Research, University of Victoria, Victoria, British Columbia, Canada; and Division of Medical Sciences, University of Victoria, Victoria, British Columbia, Canada

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Zehr EP. Avengers Assemble! Using pop-culture icons to communicate science. Adv Physiol Educ 38: 118–123, 2014; doi:10.1152/advan.00146.2013.—Engaging communication of complex scientific concepts with the general public requires more than simplification. Compelling, relevant, and timely points of linkage between scientific concepts and the experiences and interests of the general public are needed. Pop-culture icons such as superheroes can represent excellent opportunities for exploring scientific concepts in a mental “landscape” that is comfortable and familiar. Using an established icon as a familiar frame of reference, complex scientific concepts can then be discussed in a more accessible manner. In this framework, scientists and the general public use the cultural icon to occupy a commonly known performance characteristic. For example, Batman represents a globally recognized icon who represents the ultimate response to exercise and training. The physiology that underlies Batman’s abilities can then be discussed and explored using real scientific examples that highlight truths and fallacies contained in the presentation of pop-culture icons. Critically, it is not important whether the popular representation of the icon shows correct science because the real science can be revealed in discussing the character through this lens. Scientists and educators can then use these icons as foils for exploring complex ideas in a context that is less threatening and more comfortable for the target audience. A “middle-ground hypothesis” for science communication is proposed in which pop-culture icons are used to exploring scientific concepts in a bridging mental landscape that is comfortable and familiar. This approach is encouraged for communication with all nonscientists regardless of age.

communication; education; public health; science; superheroes; popular culture; metaphor; K–12

Years of rigorous athletic training have enabled the Batman not only to resist but to recover from the brutal beating that would have mortally injured most men!

Comment in “Professor Strange’s fear dust” from Detective Comics no. 46, December 1940

Wayne swaps the brace to his bad knee. Puts his weight on it—the knee bends, kicks. He sits again. Cautious... Wayne gingerly pushes a button—the brace starts to shrink tight to his leg, digging in. Wayne grits his teeth.

From the screenplay for the 2012 film “The Dark Knight Rises” (11)

In 1989, editor and writer Dennis O’Neil (17) wrote that Batman “...is the most ‘realistic’ of the great superheroes... He wasn’t bequeathed those abilities; he sweated for them.” The veneer of reality placed around DC Comics’ Dark Knight continues to captivate, largely because it suggests some kind of process that could produce a real superhero. Similar sentiments can be found for other superheroes, such as Marvel Comics’ Iron Man. David Michelinie (8) wrote that Iron Man is “…a super hero with no superpowers... He could be you or me, if we had the money and inventiveness. And the courage. And the willpower."

The characters Batman and Iron Man belong in a fairly small grouping of comic book superheroes who have a relative feeling of “possibility” about them. In this way, Marvel’s Captain America and DC’s Green Arrow, along with a few others, fit here as well. Even those superhero icons who seem to have little obvious basis in reality about them, such as Superman (an alien from another planet) or Thor (the god of thunder), can still be useful metaphors for exploring the concepts of being human.

Examining this concept of possibilities formed the central themes of my first two pop-science books, Becoming Batman: the Possibility of a Superhero (21) and Inventing Iron Man: the Possibility of a Human Machine (25), as well as The Superhero Project, a book aimed at early teenagers (27). Superheroes can make great foils for exploring the limits of human biology and the impact of technology on training and performance. Batman represents the pinnacle of human performance and is a useful superhero for exploring the range of responses to exercise and conditioning. Similarly, Iron Man can be used as an example for amplifying human abilities and performance with assistive technology.

Communicating science to the general public and popularizing science are necessary and rewarding activities. Providing compelling, relevant, and timely points of linkage between scientific concepts and the interests of the general public, however, can be challenging. An emerging avenue for popularizing science is to link scientific concepts to images, personalities, and icons already well known in popular culture.

At the core of this article is the idea that pop-culture icons like superheroes can be used as foils to communicate real science. A key aspect is that the scientific validity of the icon is irrelevant because the true science can be revealed in examining the icon directly. As such, the two quotes above represent excellent points-counterpoints where the false 1940 depiction of exercise training and injury is contrasted with the more accurate 2012 depiction showing the debilitating effects of a life fighting crime.

Over the last decade, I have been involved in many public communication activities trying to get science in the hands of those who need it most—our friends, neighbors, and family in
the general public who may have little to no science background.

The amazing science communicator, astronomer, astrophysicist, author, cosmologist (and one of my personal science superheroes) Carl Sagan (1934–1996) wrote that “...almost no one understands science and technology. This is a prescription for disaster... sooner or later this combustible mixture of ignorance and power is going to blow up in our faces” (15). His quote is a timely reminder that it is a real obligation for we scientists to work toward communicating more effectively with the citizens of the societies within which we live and work.

In my own activities (comprising book writing, editorials, magazine articles, talks, blogs, and peer-reviewed papers), I use superheroes for science promotion to the general public. I have been equally keen to talk to colleagues about “how and why” to do similar activities.

This brief article draws heavily on my own experiences using superheroes to explore themes of training and detraining in physiological systems in Becoming Batman and Inventing Iron Man. Here, I articulate the “middle-ground hypothesis” conceptual approach that I have emphasized in science communication. This represents a subtle twist of focus that I suggest is necessity for science communication nowadays (12). Implementing this strategy means changing the way in which we scientists present our science. Part of that change is reflected in the very structure of this article, which is deliberately written in the first person voice to be more accessible.

**Popular Culture Contains Ready-Made Elements for Science Communication**

Superhero movies and television shows are extremely popular and have been so for some time. These represent excellent opportunities for exploring scientific concepts in a mental “landscape” that is comfortable and familiar. Using this common ground, the scientific principles used (or violated) in pop culture can then be explored in nonthreatening settings. Superheroes have already been very effectively used to convey psychological principles to the general public (6, 14).

In the vanguard of popularizing science—physics in this example—is James Kakalios. Kakalios is a physics professor at the University of Minnesota who for years taught an introductory freshman seminar about physics initially entitled “Everything I Know About Physics I Learned from Reading Comic Books.” This seminar became the basis for his influential book, *The Physics of Superheroes* (4). In this book, Kakalios describes that the issue of whether comic book science is correct or not misses the point. He always includes the correct physics in the discussion so that the student or reader always arrives at the real science regardless of the starting point.

As scientists, we are trained to always pursue relentless rigor for truth and accuracy. When this approach is applied to science communication, our efforts can often be stilted and miss the mark (12). Related to this idea of accuracy, in the preface to *The Physics of Superheroes*, Arizona State University Prof. Lawrence Krauss, author of many pop-science books including *The Physics of Star Trek* (5), wrote that “...few things are more memorable than confronting one’s own misconceptions... if you want to reach out to understand popular misconceptions, then exploiting where we get our cultural perspectives from is a good place to start. And if that means borrowing from Superman, or Star Trek, I am all for it!”

These strategies can be used to create a bridge between academics and their knowledge of science and the target audience. To effectively convey our messages, we should use vehicles that already exist to transport our message. If we choose something that is well understood—and well liked—as our vehicle, it will be much more readily accepted by the target audience.

This is, in fact, an approach opposite to that used very commonly in education, science communication, and public health. In typical approaches, we scientists try to communicate our science as if we were the actual audience. For example, Maziak et al. (9) wrote that the “clinical approach to obesity is also confusing the public health agenda, by placing the healthcare system as the first line of response to the obesity epidemic...” This is also highlighted by Teutsch and Fielding (16), when they wrote that effective core public health activities (including exercise, physical activity, and nutrition) “requires expanding public health skills in areas such as quantitative policy analysis, communication, and community engagement.”

Referring back to the previous point of Lawrence Krauss about placing our science in cultural context of our society, perhaps there is a need to apply more creative solutions on all levels. Of course, applying this means breaking away from communication methods we scientists may find safe and comforting (1). By way of a personal anecdote, I remember vividly an exercise physiology course I took as an undergraduate. My professor stood in front of us and said, basically, exercise is really good for you and will allow you to have a healthier life. This, though and very critically because of the impression it made, was followed by my professor immediately saying that the real reason we should care about exercise is that being really active means you can eat another piece of pie or have an additional snack or beverage and remain healthy.

Now, I am not endorsing this as a public health strategy, but I can tell you that in two sentences that professor outlined the problem, found a hook, and had all of the students fully engaged for the rest of the term. This was all achieved simply because he knew how to communicate with us in a way that had context and resonance. This same concept underlies effective science communication.

**Pop-Culture Icons as Contextual Connects That Can “Bridge the Gap” and Occupy the Middle Ground**

Another way to conceive of the arguments I make above is to say that we need to meet nonscientists (regardless of age) “half way,” at the very minimum, if we are going to truly communicate with them. We need to meet the general public on the middle ground that exists between us. This process involves translating what we want to communicate not just into simpler concepts for nonspecialists but into a context that the target audience is ready to receive.

This middle ground is the understanding of the pop-culture icon and serves to connect our science with our audience. This middle ground hypothesis is shown in Fig. 1 and is meant to include communication and teaching efforts for all groups and ages. Figure 1 literally shows two people talking with a gap of
space between them. This middle ground can either facilitate the movement of ideas (building a bridge) or stop things cold (put up a wall). I use pop-culture icons that evoke vivid imagery of the communication activities occupying the middle ground between my audience and the science I write about. This is the reason for showing the Batman and Avengers symbols in the speech bubbles over the head of each person.

James Kakalios (4) also described a related approach in the preface to The Physics of Superheroes. Kakalios wrote (and made use of a great food metaphor) that “I hope you will be so busy enjoying this superhero ice cream sundae that you won’t realize that I am sneakily getting you to eat your spinach at the same time.” Others have also used this concept to great effect when considering metaphors for stem cell research (2), making healthy food choices (18, 19), body image in young men (20), and positive social helping behaviors (13).

**Some Examples of Applying the Middle-Ground Hypothesis**

Underneath the common middle-ground bridge are shown examples of the principles of exercise science that could be explored, drawn from the themes I have actually used in my examples of the principles of exercise science that could be

Fig. 1. The “middle-ground hypothesis” for using pop-culture icons as connectors for communicating science concepts to the general public. The Avengers symbol is trademark of and copyright Marvel Comics. The Batman logo is a trademark of and copyright DC Comics. All rights reserved.

Accordingly, Kakalios wrote (and made use of a great food metaphor) that “I hope you will be so busy enjoying this superhero ice cream sundae that you won’t realize that I am sneakily getting you to eat your spinach at the same time.” Others have also used this concept to great effect when considering metaphors for stem cell research (2), making healthy food choices (18, 19), body image in young men (20), and positive social helping behaviors (13).

**Holy Homeostasis, Batman! Balance in Batman’s body is challenged by fighting and getting bashed around. What will be the fate of the Dark Knight?**

![Image](http://advan.physiology.org/)

**Fig. 2. Mechanical injury curve for Batman showing the relationship between the size of impacts on the body and the number of repetitions required to produce musculoskeletal injury.** [From Ref. 22 with permission.]

This is a simple musculoskeletal injury curve inspired by the text of Roger Enoka (3) but placed in the context of Batman’s fighting career. The reference point for low number of repetitions and large impact on the body is the scene in the Warner Brothers film “The Dark Knight Rises” from 2012, where Batman is literally crushed by the archvillain Bane. The reference point for high repetitions with low impact is the broken down state of Bruce Wayne’s body shown at the beginning of “The Dark Knight Rises.” Evaluating these injuries in this context provides a good link to sport injuries of many kinds experienced by both professional and lay athletes. This is useful to reveal the lack of validity in terms of injury and recovery that is often shown in comic books, movies, and

**Fig. 3. Illustration of homeostasis and homeostatic regulation in health and disease as viewed through the responses of Batman’s body to injury.** [From Ref. 22 with permission.]

![Image](http://advan.physiology.org/)

**Size of impact on the body**

**Repeated fights over many years**

**Number of repetitions**

**Failure! @ (too many injuries, no rest, no healing for the Dark Knight)**

**Wellness… Batman is ready to rumble!**

**Success! @ (Batman has rest and heals)**

**Compensations in Batman’s body try to restore balance**

![Image](http://advan.physiology.org/)
Concussion and the dangers of head trauma also form major themes of Becoming Batman, Inventing Iron Man, and The Superhero Project. The illustration shown in Fig. 4 is taken from Inventing Iron Man and shows a simplified idea around the concept of concussion. Figure 4A shows the basic concept of head impact and implications for brain trauma in concussion, whereas Fig. 4B shows the critical mismatch between neuronal metabolism and energy demand that gives rise to concussion symptoms. This example can also be used to highlight the difference in repeated injury potential when contrasting musculoskeletal and brain injury, for example, the critical consideration of secondary impact syndrome, the need to avoid repeated concussive incidents, and the increased susceptibility to repeated concussions with lower impacts over time.

I have also used related approaches to address muscle strength and genetic regulation via myostatin through the lens of Superman (26) and tissue repair in orthopaedic injury as looked at via Wolverine (23). Although this was not the focus of these two articles, they could also be used to highlight the fallacy of some “superhero powers” and why certain abilities could be problematic if they were actually real. For example, a major part of Wolverine’s mythology is accelerated and unprecedented wound healing ability. Different writers have made ample use of his “mutant healing factor,” with some examples even showing an accelerated healing of grievous bodily injury that occurs in minutes (or sometimes seconds). This raises a really interesting opportunity to explore biological cell growth and development in real organisms. For example, this could lead to discussion of what mechanisms (if any) could regulate such proliferative cell growth to avoid the formation of cancerous tumors and the current state of therapies in oncology.

Superheroes can also be used to highlight not only high performance but also reduced performance. I used the concept and implications of habitual use of the Iron Man exoskeleton to highlight and parallel the deconditioning effects and health implications of physical inactivity (25). An example of this is shown in Fig. 5, where the negative deconditioning effects of habitual use of a full body exoskeleton such as the Iron Man armor (right) is compared with space flight (middle right), bed rest (middle left), and a physically inactive lifestyle (left).

Does This Approach Actually Work?

Since embarking on this increase in public outreach and communication using pop culture, I have often thought about “impact,” that is, how many people am I now reaching with this form of science messaging that I wouldn’t have reached before and what is that reach actually achieving (if anything)? I have not been able to formally assess this using, for example, surveys or feedback forms. Instead, I have relied on anecdotal indicators completely outside of my control, namely, media uptake and messages received from readers.

As for media, I have found that my books and blog posts that use popular culture (and, in my hands, this has been to use superheroes) have resulted in hundreds of interviews in magazines, newspapers, television, radio, magazine, books, and on the web. This has suggested to me that combining a science message with popular culture has allowed me access points to a very large audience.

Messages from readers have taken different forms. Based on almost 6 yr of experiences since the publication of Becoming Batman, the positive feedback absolutely dwarfs any of the negative commentary. Some of this was discussed with particular reference to blog commentaries in my earlier Advances in Physiological Education article from 2011 (24). Taken in a longer view now, the messages range from simple messages congratulating me for my approach to dramatic stories of direct impact on the lives of those who have contacted me.

One reader wrote to say that my books helped him select life sciences as his major in college:

...I read Inventing Iron Man and Becoming Batman in a week and I found them simply extraordinary as a learning tool. I was undecided as to what I wanted to major in (my college forces you to take a hard science along with Computer Science) and while I was on the fence, you definitively inspired me to lean towards biology...

Another reader wrote an email message that had the following subject line: “How Paul Zehr and Batman saved my life.” I opened this message with some trepidation and learned that the writer had long been inspired by the superhuman exploits of superheroes as well as the grandeur of human physiology and television shows, such as highlighted in the two quotes at the beginning of this article.

Fig. 4. Illustration of concussive impact and mechanical trauma in the skull and brain (A) and the metabolic, cardiovascular, and neurological mismatch to energy demand (B) for Iron Man. [From Ref. 25 with permission.]
particularly the brain. This reader had experienced a period of extreme depression and had contemplated suicide. Finally, he realized that he wanted to become a neuroscientist but wondered if there was any avenue to explore science and superheroes. In his words:

... one day, on a whim I Googled the terms “Batman and Neuroscience” and lo and behold I was led straight to your book “Becoming Batman”. I read up about you and soon found in you what I had been looking for since my teen years, a mentor, something to aspire towards, someone to look up to. I figured if you can find a way to combine your hobbies and your professional academic interests then why couldn’t I? I was happy again for the first time in a long time and I have you to thank for it...

I have also used superheroes (and other popular culture icons) in teaching my own classes. For example, in a course on human motor control neurophysiology, I have a section on the brain-machine interface. In this section, I first briefly introduce the concept of using neuronal signals to communicate with and control computers and machines. I then give some extreme examples of science fiction elements of the brain-machine interface. The most compelling is that of Doctor Octopus in the 2004 movie “Spider-Man 2.”

There is a scene early on in Spider-Man 2 where Doc Ock (as played by Alfred Molina) is shown using an integrated neuroprosthetic (his robotic “octopus-like” arms) that connects directly to his brain. The scene in the movie shows the elegant use of the robotic limbs for both pure science and supervillain activities and make an excellent contrast with the state of the art for real-life human applications that lag behind the Spider-Man universe. My students seem to grasp much more effectively the overarching ideas using these kinds of examples.

Of course, none of the above are examples of “hard data” or anything beyond anecdotal analysis. For me, though, these responses and examples of the direct impact using fictional characters can have on the lives of real people have validated for me the power of the approach I have taken. This, in turn, continues to inspire me to keep on this path.

Conclusions

Popular culture is rife with excellent opportunities for exploring scientific concepts in a middle-ground mental landscape that is comfortable and familiar to the general public. Often, the science we want to get across may make the audience uncomfortable. Trying to make things as pleasant—and as fun—as possible maximizes the likelihood of engaging with the science concepts through the middle ground we’ve chosen. This maximizes the likelihood of the audience engaging with the science concepts through the middle ground we’ve chosen because they want to.

An important part of this process involves translating what we want to communicate not just into simpler concepts for nonspecialists but into a context that the target audience is
ready to receive. This usually means going outside your comfort zone to more effectively enter the comfort zone of your audience.

It’s not enough to simply ask yourself what your audience should, need, or ought to know. Instead, the real questions are how will they know it, what is the medium through which they are ready to know it, and how do I translate my message into a comfortable message for them. This highlights a main issue that can readily be appreciated when looking at science communication this way—the power of story. We are drawn to stories, and if we can package our messages within the context of a compelling story, we will have much greater success. Pop culture contains many compelling stories, and it makes sense to use these for our purposes in communicating science.

I have chosen to use superheroes for my science communication efforts because they provide so many ready-made examples for exploring the truth and fiction of their powers. Since superheroes are now so very much mainstream popular culture, they represent excellent material for use in the middle ground. Having said that, though, there are disadvantages to using superheroes for this purpose. Namely, as put to me by one helpful reviewer, “how should the scientist ‘re-educate’ the general public who may not want to be ‘re-educated’?” Some may wish to enjoy the belief that maybe Superman could really fly or that Batman could really sustain all his injuries and always recover (as captured in the quote at the beginning of this article).

This is definitely a crucial issue but not one that can easily be dealt with by any science communicator using any methodology. A closed mind is very difficult to deal with. In fact, I have had some readers of my books take me to task for deconstructing some of the mythologies of the superheroes I’ve put under the scientific lens. My suggestion is, as with all such efforts, to be well prepared about the foundational scientific principle(s) you are trying to communicate with a pop-culture icon and stay true to our science.

In closing, the objective of this article is to share some personal experiences and provide guidance about how to use middle-ground outreach to help bring scientific understanding to the broader public. In this sense, the broader public includes all nonscientists, be they adults or children in the K–12 system. It is my goal that by sharing these experiences and approaches, like-minded academics and teachers at all stages of their career—including undergraduate and graduate trainees—may be encouraged to integrate popular culture touchstones in their own outreach and teaching practices (24) as has been suggested for social marketing theory in health promotion (7). As Marshall McLuhan (1911–1980), Canadian philosopher of communication theory, wrote, “the medium is the message” (10). I strongly suggest that if we truly wish to effectively communicate our science with our audiences, we have to be a bit of both medium and message.

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Author contributions: E.P.Z. conception and design of research; E.P.Z. performed experiments; E.P.Z. analyzed data; E.P.Z. interpreted results of experiments; E.P.Z. prepared figures; E.P.Z. drafted manuscript; E.P.Z. edited and revised manuscript; E.P.Z. approved final version of manuscript.

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