



Engineers Assemble: The Use of Popular Culture in Engineering Education

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The idea of other universes appeals to most of us. Whether it's a universe where lonely kids are swept away to learn magic in a haunted castle, or where vampires and werewolves run the world, or where superheroes take on the bad guys and win, most of us have a favorite escape. Our students sometimes seem to spend most of their time in their favorite alternate universes to the consternation of their parents and teachers. We spend a lot of time trying to pull them back into this universe to teach them engineering. But sometimes, we can actually use those other universes to explore the concepts we want our students to understand. I discovered this method basically by accident in a recent class. Since it worked, I have spent some time researching why it worked so I can use the techniques in other classes. This is the story of what I did, how it worked, why I think it worked, and the principles that I am going to apply in future classes.

The Class

The experiment started mostly as a joke based on a bet. I teach an Environmental Engineering class, and I teased my daughter by saying that, since everything is dependent on or affects the environment or both, everything I did was preparation for the class. We had a bet that she couldn't name anything I couldn't connect to environmental issues. This turned into a good exercise for me in looking for connections. When class started I discovered that all the students shared my interest in the Marvel Cinematic Universe as portrayed in movies such as The Avengers, Iron Man, Captain America, and others in this genre. It seemed a natural extension to have an "Avengers theme" for the class and find ways to connect the Avengers to the concepts I was teaching in Environmental Engineering.

The Marvel Universe from the comics has long been popular with scientists and engineers. The movies have brought even more students into the fandom. However, it is not our universe. As Ryan Haupt says, "We know there are enough other differences about their universe, such as the fact that radiation gives people super powers, mutants are attractive and being smart is considered a virtue."¹ Since the movies were so recent and well-known, it was an easy universe for us to 'visit'. When I introduced new concepts, we often explored them in terms of the Marvel Universe before we talked about them in terms of our universe. We also used Avengers as memory aids.

This Environmental Engineering class is a junior-level class which meets for 50 minutes, 4 times per week, for a 10-week quarter. I primarily lecture but I try to incorporate active learning as much as possible. Civil engineering students are required to take the class and it is a technical elective for mechanical engineering students, so there is typically a mix of students. This particular class consisted of seven male students; five civil engineering and two mechanical engineering. My background is civil and environmental engineering. I am the only female engineering teacher in the department.

During this class, I essentially substituted the pop culture references for the daily life examples I would normally use. They were used as introductions to a topic or as ways for students to test how well they understood the concepts. Occasionally, I used an Avenger problem for a homework question. We had to be careful that everyone had the same background material, which we usually accomplished by a short discussion. The engineering clubs also were sponsoring movie nights with the Avengers movies, so anyone who wanted to could easily see them. In class, we typically used still photos from the movies or frames from the comic books to focus the discussion. Rarely, we watched clips. Here are some of our favorite specific examples.

Thermodynamics:

In looking at how energy and matter interact in the world, we reviewed the laws of thermodynamics and how much energy is contained in matter. Iron Man's suit was a great test case. After reviewing the laws of thermodynamics, we looked at all the elements of Iron Man's suit to determine whether they violated the laws that govern our universe. Iron Man's arc reactor puts out 3 gigajoules/second of electricity. Part of their homework was to calculate how much mass he could produce if all of that output was converted to mass with no losses. Several students were shocked at their answers. Although they were junior engineering students who had already completed chemistry and physics, it was the first time they started to get an intuitive feel for the amount of energy contained in matter.

Water cycle/scarcity vs. abundance:

When we needed to review the water cycle, first we looked at the lovely footage of the world of Asgard in the movie Thor. It's a beautifully imagined flat world with a mountainous core and water pouring ceaselessly off the edge. I asked the class, "Where does the water come from in Asgard?" They concluded that it is continually replenished – apparently by magic. This led to a great discussion on a worldview of abundance versus a world view of scarcity and how our world view affects our use of resources.

Technology in Society:

In the comics and movie, the Black Widow's bracelets fired an electric pulse to take down bad guys. Our discussion of the Black Widow led us to a discussion of engineering students in India who are developing anti-rape undergarments which give attackers a 3,800 kv electric shock^{2,3}. We talked about how society affects the need for technology and how technology affects society.

Mnemonic devices:

When we studied EPA's hazardous waste laws, the students learn the four characteristic wastes: corrosive, toxic, ignitable and reactive. Traditionally, I have shown pictures of four drums with corrosion, skull and crossbones, flames, and explosions. This year, in addition, I showed pictures of Rust (a little-known Marvel hero whose super power is the ability to instantly oxidize any metal), Red Skull (who was injected with a serum to try to turn him into a super soldier but it turned him into a monster), Johnny Storm (who controls fire and can turn into a man of fire), and The Hulk (who is the definition of reactive). This was surprisingly effective in helping students remember the characteristics. As one student said after the test, "It was easy. I just shut my eyes and remembered the dudes."

The Results:

This class is always a small class (10 or less in the four years I've taught it), so this was primarily a qualitative study. The students completed an anonymous course evaluation survey in 2011 and 2013. The survey uses a Likert scale with 5 as excellent and 0 as very poor. Table 1 compares the results.

Table 1
Course Evaluation Comparison;
2011 (without Avengers theme) and 2013 (with Avengers theme)

	2011	2013
Number of Responses	8	7
Number of students enrolled	10	7
"The course as a whole was"	4.0	4.0
"The course content was"	3.7	4.0
"The instructor's contribution to the course was"	4.5	4.6
"The instructor's effectiveness in teaching the subject matter was"	4.3	4.6
Combined score	4.1	4.3

The evaluations were equal or higher in all cases in 2013, with the Avengers theme, than in 2011, without the Avengers theme. However, the small sample size makes a statistical comparison problematic. The 2011 and 2013 classes covered the same material with two primary changes: the Avengers theme and a portfolio assignment instead of a final exam.

In addition to the Likert scale questions, students are asked to write responses to "What aspects of the teaching or content of this course do you feel were especially good?" In 2011, all eight students responded. The top aspects mentioned were "the teacher's attitude" by three students, "assignments" by two students, and "PowerPoints" by two students. In 2013, apparently some students responded multiple times because the report shows 13 comments from seven students. The top aspects mentioned were "The Avengers theme" by 11 students and "teacher's attitude" by three students. Two pertinent comments were "The usefulness of the Avengers theme is a great example of the purpose of fiction – to predict how real decisions are made in difficult but relevant circumstances" and "Homework questions on the Avengers made the homework something cool to research of [sic] figure out rather than just get through and done with."

The students also submitted reflections on the class as part of their final. In 2013, the students were unanimously positive about the class. Their comments included statements like "All my friends in other classes are jealous" and "It helped me see that engineering doesn't have to be separate from my real life." Their level of enthusiasm for the class was certainly higher than students in previous years. For the first time since I have taught the class, people who were not in the class have come to me, sometimes months later, to talk about the ideas we discussed in the class. The students have been talking about the class to others and have sparked their interest. I have most of the students in senior classes this year and they seem to have retained the material better than previous classes.

Why did it work?

Since this class was successful, I wanted to understand why. There is little literature on the use of pop culture in teaching engineering. However, some of the literature on teaching methods in higher education is relevant. Ken Bain, in *What the Best College Teachers Do*, points out that

students learn best when we make a safe space and start from what they know.⁴ In this specific instance, many of the students know the Marvel Universe better than I do. They were able to be the experts while I asked questions. Therese Huston points out that relating class concepts to knowledge students already have promotes deep learning rather than superficial learning.⁵ In this class, all the students knew $E=mc^2$. However, their estimates of how much matter corresponds to the amount of energy produced by Iron Man's arc reactor weren't even close. They had memorized an equation but hadn't internalized the concept.

This fits with Bloom's taxonomy as described by James McMillan⁶. In the terms of Bloom's taxonomy, they remembered and comprehended much of their physics knowledge, but had not moved on to application, analysis, and synthesis. By using the Marvel Universe as a laboratory, they were able to apply their knowledge, analyze the results and evaluate their work. Or in terms of Bloom's revised taxonomy, they were able to apply factual, conceptual, and procedural knowledge in more developed cognitive processes – not just remembering and understanding, but applying, analyzing, and evaluating. At times, we also applied metacognitive knowledge by asking ourselves how we got to our conclusions.

In the past, I typically tried to start from what students know by asking questions about daily life. However, I got a much more enthusiastic response when I asked about the Marvel Universe. I theorize that students were more willing to answer questions about a fictional universe because it feels safer to them. Since Iron Man's armor doesn't really exist, there is less danger in stating an opinion. If students answer a question about daily life incorrectly, it seems like a failure, but if they disagree with a question about the Marvel Universe, it's more of a disagreement than a failure. This matches with the experiences of several teachers as reported by Ken Bain.⁷

Cautions:

I have tried using similar techniques in other engineering and general studies classes. There are several factors that I believe are important to using this technique successfully.

First, I make sure only to use pop culture that I appreciate and enjoy. If it's something that I do not enjoy, my lack of personal connection to the material comes through and it ruins the safe space I am trying to create.

Second, I make sure the class also appreciates the pop culture I am planning to reference. One reason the Avengers worked so well in this class was that it was a shared universe. Not everyone in the class has to be a diehard fan of the universe, but most need to feel positive about it and at least be familiar with it. I've found the best way to discover what fandoms are represented in the class is to ask. It's a great icebreaker discussion as students are coming into the class, and also helps demonstrate that I'm interested in them.

Third, I always make sure to provide an introduction to the specific feature I am discussing to make sure no one feels left out. For example, when discussing whether Iron Man's suit violates the laws of thermodynamics, first we reviewed what his suit could and couldn't do. No fan can know everything about a universe, so it's important to establish a common understanding in the instructional setting. This does not take long and is a great way to get students talking. Once

they've started discussing the parts of Iron Man's armor, it's easy to keep talking about how to apply the laws of thermodynamics.

Fourth, I always make sure to keep track of my learning objectives. I could cheerfully discuss the Avengers for the entire class period, but having specific learning objectives for the day keeps me honest in making sure we still get the learning done.

Conclusion

Pop culture, whether it is the Avengers or another fandom, does have a place in teaching engineering. I probably will use the Avengers theme as long as I have students coming to me and saying "I hear we get to talk about the Avengers in Environmental Engineering. I can't wait." It is an effective tool to make students feel safe and to build new knowledge on the foundation of their current knowledge.

Acknowledgments

This paper would not have been possible without the generous permission of the students in this class to use their work for this study. I also would like to thank the Walla Walla University Ethics in Research Committee for their feedback on the study design. The comments of the ASEE peer reviewers significantly improved this paper.

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