Combining different inoculation types to increase student engagement and build resilience against science misinformation

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Abstract

Inoculation theory, which applies the biological concept of vaccination to misinformation, provides a range of ways to effectively build resilience against misinformation. In this article, we define and organize the various types of inoculation, which includes three delivery mechanisms that can be useful in the classroom—passive, active, and experiential. In passive inoculations, students passively receive inoculating messages while in active inoculations, students actively generate misinformation using misleading techniques. We introduce a new category of inoculation—experiential—which involves misleading students then debriefing them on how they were misled. We then describe how these three techniques were implemented in a general-education science class designed to teach critical thinking and science literacy. Through these activities, we illustrate how the different types of inoculation can be creatively combined to maximize student engagement and learning.

Introduction

Misinformation plagues society in a multitude of ways but two features make it particularly problematic: it spreads faster than accurate information (Vosoughi, 2018) and is

notoriously difficult to dislodge once people believe it (Chan et al., 2017). For these reasons, there has been increasing attention paid to pre-emptive strategies, attempting to build resilience against misinformation before encountering it. An ounce of prevention, after all, is worth a pound of cure. Inoculation theory, coming from the field of psychology, offers a useful framework by applying the concept of vaccination to knowledge (McGuire & Papageorgis, 1961). Just as exposing people to a weakened form of a disease conveys immunity against the actual disease, exposing people to a weakened form of misinformation builds a person's cognitive immunity so they are less likely to be misled by misinformation.

An inoculation requires two key elements—a warning or threat letting the person know of the threat of being misled, and refutations explaining how the misinformation is false. This general structure is quite versatile and can take a variety of methods, such as technique-based inoculation which explains the techniques or logical fallacies used to mislead, and fact-based inoculation which shows how misinformation is false through factual explanations (Banas & Miller, 2013; Schmid & Betsch, 2019).

Inoculations can also be delivered through several different mechanisms. The most common approach is passive, where recipients passively receive an inoculating message. In contrast, active inoculation involves having people generate misinformation themselves, as a form of active learning. In this article, we introduce a third mechanism—experiential inoculation. This involves employing misinformation techniques to mislead recipients, with the intent that their experience of being misled strengthens their engagement with and understanding of the content.

Typically, inoculations are pre-emptive, or prophylactic, hence the words prebunking and inoculation are often used interchangeably. However, there has been some research into

debunking, or therapeutic inoculation, which occurs after encountering misinformation—both

correcting the misinformation and protecting the recipient against future encounters with

misinformation (Compton, 2020). The style of an inoculation message can also vary, such as

whether the content is humorous or serious. Both approaches can be beneficial but for different

reasons, as humorous corrections hold people's attention longer while serious corrections are

seen as more credible (Kim et al., 2020).

Because inoculation is so versatile, it has been used in a variety of contexts, from public

awareness campaigns to social media advertising. Inoculation as a classroom activity is also a

useful pedagogical tool, as the inoculation types can be combined in a multitude of ways. Table 1

summarizes the different types of inoculation.

Table 1: Types of inoculation

	Fact-based	Technique-based	Source-based
Method of inoculation	Explains how specific examples of misinformation are false with factual explanations. Closely related is issue- or topic-based, which focuses on misinformation around a topic.	Explains the techniques used to mislead. Logic-based inoculation is a subset of technique-based that focuses on logical fallacies.	Reveals that a misleading source is not a credible source of information.
	Passive	Active	Experiential
Delivery mechanism	Students passively receive the inoculating message which is communicated in a one-way fashion by the educator.	Students generate the misinformation themselves, as a form of active learning.	Students learn the techniques of misinformation by experiencing being misled.
Order	Prebunking (prophylactic)	Debunking (therapeutic)	

	Inoculation occurs before exposure to misinformation.	Inoculation occurs after exposure to misinformation.	
Style	Non-humorous	Humorous	

In the next three sections, we will outline real-world examples of three inoculation methods, implemented in a general-education science course taught by this article's first author (Melanie) at Massasoit Community College in Brockton, Massachusetts. The course, Science for Life, focuses on teaching students critical thinking, information literacy, and science literacy skills (Trecek-King, 2022).

Passive Inoculation

Passive inoculation involves the educator explaining how misinformation is misleading to students in a one-way fashion. Including misinformation in the science classroom, such as pseudoscience and science denial, can help students better understand the characteristics of good science. Like the general public, many students hold a variety of science misconceptions, and addressing these false beliefs directly increases student engagement and teaches them how to recognize and not fall for them in the "real world" (Mason et al., 2008). This approach, misconception-based learning, involves teaching scientific concepts by exploring how the science might be misunderstood (McCuin et al., 2014).

Science for Life covers a range of pseudoscience and science denial issues, such as ghosts, psychics, fad diets, energy medicine, fake news, astrology, the MMR vaccine and autism "controversy", conspiracy theories, and climate change denial. Including diverse forms of misinformation helps students understand that we can all be fooled, increasing empathy for others who hold different beliefs, and reducing defensiveness when their own beliefs are

evaluated. After the misinformation is explained to the students, they evaluate the claims using tools provided in class, such as the characteristics of pseudoscience (Trecek-King, 2021) and the techniques of science denial (Cook, 2021). Additionally, the FLOATER framework (Falsifiability, Logic, Objectivity, Alternative explanations, Tentative conclusions, Evidence, and Replicability) was introduced as a guide for evaluating claims (Trecek-King, 2022).

For example, after a brief explanation of what homeopathy is and how it's supposed to work, students quickly recognize the implausibility of the claims and discover for themselves that homeopathy is pseudoscience. As students often assume homeopathy is medicine that is "natural" and "safe", they are shocked to learn what it actually is (and that it's allowed to be sold alongside evidence-based medicine). Students who have previously purchased homeopathic "treatments" often report feeling deceived and vow to not "waste their money" in the future.

Active Inoculation

The modern conception of active inoculation involves students learning the techniques used to mislead by creating misinformation themselves (Roozenbeek & van der Linden, 2018), in contrast to McGuire's original conception of recipients actively generating refutations of misinformation (McGuire & Papageorgis, 1961). Imagine a child seeing a magic trick for the first time. Without any prior knowledge, the trick could look like magic! We might explain the trick to the child (i.e., passive inoculation) or we could teach the child how to do the trick (i.e., active inoculation).
Science for Life includes several active inoculation exercises and students enjoy pretending to be a charlatan.

In the "Please don't fail me" assignment, students pretend it is the end of the semester and they are failing the class because they did not do the work (Cook et al., 2022). Students are

told to compose an email to their instructor explaining why they should receive a passing grade, using at least four logical fallacies learned in class, such as appeal to emotion, ad hominem, red herring, slippery slope, appeal to authority, or false choice (see Table 2 for definitions). Students then read their classmates' emails, identifying any fallacies and explaining why they are fallacious. Students are encouraged to have fun with the assignment, and their submissions are often humorous.

Table 2: A sample of logical fallacies

Logical fallacies	Definition
Ad hominem	Attempts to discredit an argument by attacking the source.
Appeal to authority	Argues that a claim is true because of the (supposed) authority of the person asserting it.
Appeal to emotion	Manipulates a person's emotions to win an argument, in place of evidence.
False choice	Oversimplifies a complex issue into two options.
Red herring	Attempts to distract from the main issue by bringing in irrelevant information.
Slippery slope	Suggests that taking a minor action will inevitably lead to major consequences.

In the "Selling Pseudoscience" assignment, students put on their grifter hats and create advertisements for a health pseudoscience product, such as the example in Figure 1 (Trecek-King, 2022). After learning about the characteristics of pseudoscience and the techniques used to sell it, students are told they have been hired by the Beautifaux Company to create an advertisement for social media, such as Instagram or Facebook, for one of their latest products—either a weight loss pill or a muscle-building supplement. Students are instructed to give their

product a catchy name and use misleading techniques to "sell" it online, and are encouraged to use humor and be creative.

Figure 1: Example of a social media advertisement employing the techniques used to sell pseudoscience, created by this article's first author (Trecek-King, 2022).

Simply put: an excellent way to learn the techniques used to mislead is to apply the techniques to "mislead" others. No one likes to be manipulated, and students report feeling empowered by their increased ability to spot misinformation. Students often express that, once they can see the misinformation techniques, they're hard to "unsee."

There are numerous ways to use active inoculation in the classroom. The key difference is that in active inoculation, in contrast to passive, students create the misinformation rather than have it explained to them.

Experiential Inoculation

Experiential inoculation involves students experiencing (and falling for) misinformation, followed by a debrief. In previous literature, the terms active and experiential inoculation have been used interchangeably (Green et al., 2022; Roozenbeek & van der Linden, 2018); however, we distinguish between the two. With active inoculation, the explanation of misleading techniques occurs before the inoculation, while with experiential inoculation, the technique explanation comes after. Importantly, students should go into an experiential inoculation unaware of the misinformation techniques, or the exercise is less effective—part of its strength depends on the feelings associated with being fooled. The other difference is that with experiential inoculation, the recipient does not actively create misinformation (i.e., active inoculation), but is instead misled by misinformation techniques.

Science for Life begins every semester with a personality reading. The exercise, borrowed from Bertram Forer's classic experiment (Forer, 1949), which he first conducted in an introductory psychology class and has been used since in psychology classes for over fifty years. Students are told the instructor has a friend who is a well-known psychic, and she has agreed to provide students with free personality assessments. They fill out a brief questionnaire that asks for their name, birth date, and brief answers to a few questions about their interests. In the following class, students are given their readings, which include vague Barnum statements such as "You have a tendency to be critical of yourself," and "At times you're extroverted and sociable, while at other times you're introverted and reserved." Students are then asked to rate the accuracy of their reading on a scale of 1 to 5, with 5 being the most accurate. On average, students rate the accuracy between 4 and 5, which is consistent with Forer's original findings

(Forer, 1949). Students then discuss their psychic readings in small groups and (eventually) discover they all received the same reading.

Following this, the students receive a debrief explaining how and why they were misled (as well as an apology). The how is straightforward: it is easy to fake psychic powers, especially when recipients want to believe. The students learn about a few tricks commonly used by "psychics" as well as some of the thinking errors that can contribute to being misled, such as the Barnum effect, the rainbow ruse, and confirmation bias (see Table 3 for definitions). The goal is to teach students the importance of skepticism and critical thinking so they can protect themselves against being manipulated.

Table 3: A sample of techniques used by and psychological biases exploited by psychics

Manipulative techniques	Definition
Barnum statements	Assertions that are vague and general but seem to be specific to an individual.
Barnum effect	The tendency to assign high accuracy to personality descriptions that are presented as tailored specifically to them but are in reality vague and general.
Confirmation bias	The tendency to search for, interpret, and remember information that confirms existing beliefs.
Rainbow ruse	A statement which simultaneously awards a person opposite personality traits; by covering both possibilities, they can't be wrong.

Explaining to the students why they were fooled is essential. Misleading students can be tricky, especially at the beginning of the semester when relationships have not yet formed. Yet over the years, this exercise has proven to be foundational to the course. No one likes to think they can be fooled, but the truth is we are all vulnerable. Simply telling them this is insufficient;

it is more effective to show them. It is important to clarify to the students that while the exercise did not (and cannot) disprove psychic powers, just because something appears paranormal does not mean it is. This highlights the importance of considering natural explanations and demanding extraordinary evidence for extraordinary claims.

Students' reactions to this exercise have been overwhelmingly positive. Apologizing helps to lighten the mood, as does joking with them ("At least I fooled you for free, and for educational purposes!"). Many laugh like it was a fun game, and the few who were initially upset came around within a couple of class meetings. This activity establishes a tone for the course in which students are encouraged to be skeptical, active participants while exploring a range of pseudoscientific claims. Importantly, fooling students helps build empathy for others who have been fooled, which becomes relevant later in the semester when they learn how to mislead people.

Conclusion

Educators play an essential role in protecting students from potentially harmful misinformation. Inoculation theory provides a versatile framework for building student resilience against misinformation and offers creative ways for educators to engage their students. Inoculation researchers are developing exciting, cutting-edge solutions to misinformation, including online games, such as Bad News (Roozenbeek & van der Linden, 2018), Go Viral (Basol et al., 2021), and Cranky Uncle (Cook et al., 2022), all of which combine logic-based inoculation with the active delivery mechanism.
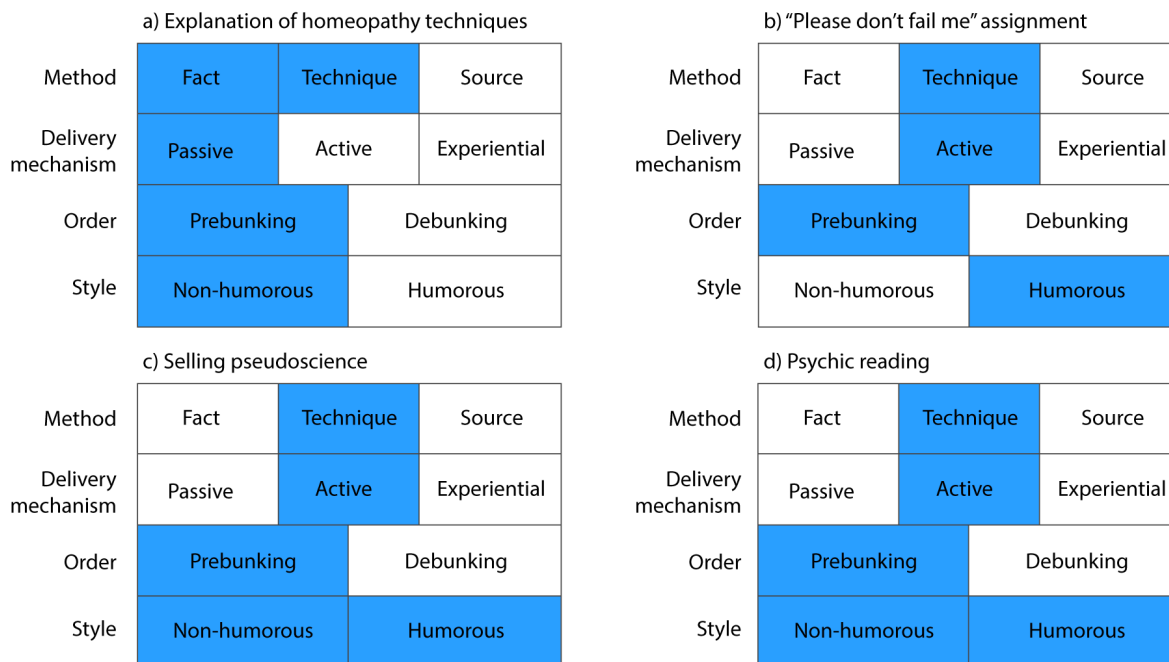
Figure 2: Classification of inoculation types as implemented in four classroom activities.

In this article, we defined and organized various types of inoculation based on the method, delivery mechanism, order, and style. We then provided examples of passive, active, and experiential inoculation lessons. Figure 2 illustrates the inoculation types that appeared in each of the four classroom activities described above. These case studies showed how the various types of inoculation can be creatively combined in unique ways, offering many permutations for educators to meet their own classroom needs. Inoculation activities are engaging and effective, and educators are limited only by their imaginations when it comes to finding new ways to inoculate their students against misinformation.

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