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CASE STUDY

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, whereas in active inoculations, students actively generate misinformation using misleading techniques. We introduce a new category of inoculation—experiential—which involves misleading students and 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.

Misinformation plagues society in a multitude of ways, but two features make it particularly problematic: It spreads faster than accurate information (Vosoughi et al., 2018) and is notoriously difficult to dislodge once people believe it (Chan et al., 2017). For these reasons, more research attention has been paid to preemptive strategies in an attempt to build people's 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, as it applies the concept of vaccination to knowledge (McGuire & Papageorgis, 1961). Just as exposing people to a weakened form of a disease helps them develop 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.

An inoculation requires two key elements: (i) a warning or threat letting the person know of the threat of being misled, and (ii) refutations explaining how the misinformation is false. This general structure is quite versatile and can use 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, in which 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—which 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 preemptive, or prophylactic, so the words "prebunking" and "inoculation" are often used interchangeably. However, there has been some research into debunking, or therapeutic inoculation, which occurs after a person encounters misinformation and involves 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 using content that is either humorous or serious. Both approaches can be beneficial for different reasons, as humorous corrections hold people's

Table 1. Types of inoculation.

	Fact-based	Technique-based	Source-based
Method of inoculation	Explains how specific examples of misinformation are false, using factual explanations. This method is closely related to the issue- or topic-based method, which focuses on misinformation around a topic.	Explains the techniques used to mislead. Logic-based inoculation is a subset of the technique-based method that focuses on logical fallacies.	Reveals that a misleading source is not a credible source of information.
Delivery mechanism	Passive Students passively receive the inoculating message, which is communicated in one-way fashion by the educator.	Active Students generate the misinformation themselves as a form of active learning.	Experiential Students learn the techniques of misinformation when they experience being misled.
Order	Prebunking (prophylactic) Inoculation occurs before exposure to misinformation.	Debunking (therapeutic) Inoculation occurs after exposure to misinformation.	N/A
Style	Nonhumorous	Humorous	N/A

attention longer, whereas serious corrections are seen as more credible (Kim et al., 2021).

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 inoculation types can be combined in a multitude of ways. Table 1 summarizes the different types of inoculation.

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 (Trecek-King) 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, 2022c).

Passive Inoculation

Passive inoculation involves an educator explaining to students in a one-way fashion how misinformation is misleading. 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 students' engagement and teaches them how to recognize and not fall for these beliefs 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 (measles, mumps, and rubella) vaccine and autism

"controversy," conspiracy theories, and climate change denial. Including diverse forms of misinformation helps students understand that we can all be fooled, which increases students' empathy for others who hold different beliefs and reduces their defensiveness when their own beliefs are evaluated. After the teacher explains the misinformation to the students, they evaluate the claims using tools provided in class, such as the characteristics of pseudoscience (Thinking Is Power, n.d.) and the techniques of science denial (Cook, 2021). Additionally, the FLOATER framework (Falsifiability, Logic, Objectivity, Alternative explanations, Tentative conclusions, Evidence, and Replicability) is introduced as a guide for evaluating claims (Trecek-King, 2022b).

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

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

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., 2023). 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 of the logical fallacies). Students then read their classmates' emails, identify any fallacies, and explain why they are fallacious. Students are encouraged to have fun with the assignment, and their submissions are often humorous.

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, 2022a). 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 a social media platform (e.g., 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 they are encouraged to use humor and be creative.

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, it is hard for them to "unsee" when the techniques are used.

There are numerous ways to use active inoculation in the classroom. In active inoculation, in contrast with passive inoculation, students create the misinformation rather than having it explained to them.

Experiential Inoculation

Experiential inoculation involves students experiencing (and falling for) misinformation, followed by a debrief about their experience. In previous literature, the terms "active inoculation" and "experiential inoculation" have been used interchangeably (Green et al., 2022; Roozenbeek & van der Linden, 2018); however, we note that the two terms have key differences. With active inoculation, the explanation of misleading techniques occurs before the inoculation, whereas with experiential inoculation, the technique explanation comes after. Students should go into an experiential inoculation unaware of the misinformation techniques, or the exercise will not be as 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, as they do in active inoculation, but is instead misled by misinformation techniques.

Science for Life begins every semester with a personality reading. The exercise is borrowed from Bertram Forer's classic experiment (Forer, 1949), which he first conducted in an introductory psychology class and which has been used since in psychology classes for more than 50 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 statements such as "You have a tendency to be critical of yourself" and "At times, you're extroverted and sociable, and at other times you're introverted and reserved." These generic statements can induce the Barnum effect, in which individuals interpret statements as applying to them specifically. 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

Figure 1. Example of social media advertisement employing the techniques used to sell pseudoscience. *Source.* Trecek-King (2022a).

Table 3. A sample of techniques used (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 a person 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 that simultaneously awards a person opposite personality traits; by covering both possibilities, the statement cannot be considered wrong

(eventually) discover they all received the same reading.

Following this, the teacher debriefs the students, explaining how and why they were misled (as well as offering an apology). The "how" is straightforward: It is easy to fake psychic powers, especially when recipients want to believe something. 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 of manipulative techniques). The goal is to teach students the importance of skepticism and critical thinking so they can protect themselves against being manipulated.

The teacher must explain to the students why they were fooled. Misleading students can be tricky, especially at the beginning of the semester, when relationships between the teacher and students have not yet formed. Over the years, however, this exercise has proven to be foundational to the Science for Life course. No one likes to think they can be fooled, but the truth is that we are all vulnerable. Simply telling students this is insufficient, though; it is more effective to show them. The teacher should clarify for the students that although the exercise did not (and cannot) disprove psychic powers, just because something appears paranormal does not mean it is. This fact highlights the importance of considering natural explanations and demanding extraordinary evidence for extraordinary claims.

Students' reactions to this exercise are overwhelmingly positive. Apologizing to them helps lighten the mood, as does joking with them (e.g., "At least I fooled you for free, and for educational purposes!"). Many students laugh like it was a fun game, and the few who are initially upset come 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 as they explore a range of pseudoscientific claims. Fooling students also helps them build empathy for others who have been fooled,
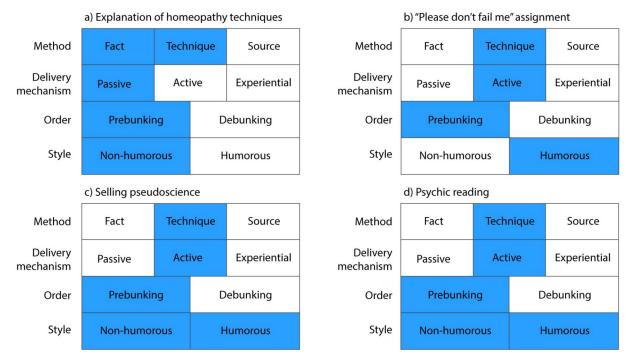
Figure 2. Classification of inoculation types as implemented in four classroom activities.

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., 2023), all of which combine logic-based inoculation with the active delivery mechanism.

In this article, we defined and organized various types of inoculation based on their 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 earlier. 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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