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ENGINEERING AND TECHNOLOGY
Published: 08 December 2023
doi: 10.3389/frym.2023.1303154

NEW SCIENTIFIC TECHNOLOGIES: NAVIGATING THE PATH OF RIGHT AND WRONG

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YOUNG REVIEWERS:

ALESSANDRO
AGE: 12

ÇAĞAN
AGE: 11

ÇAĞLA
AGE: 9

To guide our decisions and actions in our daily lives, we often rely on our internal sense of right and wrong, called ethics. Our ethics help us to be kind, truthful, and fair. Scientists also have ethical "rules" to follow to ensure that their research—and the powerful technologies that spring from it—are used to help people, not harm them. Ethical guidelines for scientists include respecting human rights, limiting harm to animals, keeping the public safe, and being honest and truthful about their work. In this article, we will explain what scientific ethics are and why strong ethics are particularly important as powerful new technologies develop more quickly. We will give examples of what can happen if scientists do not follow ethical rules and explain how these situations are not always simple. Finally, we will describe how new technologies may change which behaviors societies consider ethical. Join us in an exploration of the "conscience" of science!

WHAT IS ETHICS?

How do you know right from wrong? Is it simply because of the rules you must follow at home or at school and the laws of the town or country you live in, or is there more to it? Is it because of what you learn in church, or from watching how people you respect act and treat others? Maybe you make your choices based on your conscience—the little inner voice that guides you and helps you to feel good when you do the right things and guilty when you go against your values. Generally, all these factors and more combine to form a person's sense of right and wrong.

ETHICS

The guidelines in a person's mind and heart that help them make good choices and avoid harming others. Ethics help people do the right thing.

Ethics are like an invisible guidebook in our minds and hearts that helps us decide what is the right and kind thing to do. Ethics help us think about our actions and how they might make others feel. In some situations, the choice between right and wrong can seem obvious, such as in clear cases of harm like stealing or hitting for no reason. For example, you know how it is sometimes hard to tell the truth, especially if you think you might get in trouble? But deep down, if a little voice tells you it is better to be honest, that voice is your ethics talking! Also, if you see someone feeling left out and you invite them to play, your ethical voice is urging you to be caring and considerate. But there are also times when the line between right and wrong is difficult to draw. In these less certain situations, ethical "rules" can help guide our choices.

TECHNOLOGIES

Tools, equipment, and methods that scientists develop to solve problems and improve lives. Many technologies can help or harm people, so they must be used carefully and ethically.

Ethics are important in all aspects of our lives, including work. And ethics are especially critical in jobs that involve new **technologies** that can directly impact people, society, or the environment—like science.

POWERFUL TECHNOLOGIES NEED POWERFUL ETHICS

Science has incredible power to make discoveries and inventions that can improve human health, solve environmental problems, and generally make our lives easier and more enjoyable. But just as a hammer can be used to do the "right" thing (drive in a nail) or the "wrong" thing (break a neighbor's window), many scientific tools developed with only the best purposes in mind could be misused for evil purposes if they get into the wrong hands. This is especially worrying because as science advances, technologies are becoming easier to access, more powerful, and potentially dangerous. Scientists must have a strong code of ethics in place, guiding their work and ensuring that new technologies are used to help, not harm people.

SYNTHETIC VIRUSES

Lab-made viruses designed to help treat diseases by targeting and destroying bad cells without harming the good ones.

Synthetic viruses are an example of a developing technology that could be used to help or to harm. You can think of a virus as a USB stick that needs a computer—a cell—to run its programs, except that viruses can only "plug into" specific types of cells. If viruses can be

designed to specifically plug into cancer cells and load a "program" (a **gene**) that says, "cancer cell, you must die," then these viruses could be injected directly into the tumor, or maybe even into the bloodstream, to help cure the patient. This would be a great tool for doctors and could help many people. But just as a USB stick could deliver either a useful program or damaging malware to a computer, in the wrong hands dangerous synthetic viruses could be created that spread easily between humans (through the air or through human contact, for example). These viruses could cause diseases or contain genes that would harm or even kill people.

GENE

Instructions inside cells that determine how an organism looks and all of its functions.

Scientific ethics are the set of moral principles and values that serve as the conscience of science, guiding the work of scientists and helping to make sure powerful scientific and medical technologies are not used for the wrong purposes (Figure 1). These ethical principles are often made into laws and regulations that help keep the use of new technologies safe, accurate, and fair, and ensure that scientific discoveries are used in responsible ways that protect the rights and wellbeing of humans, animals, and the environment.

SCIENTIFIC ETHICS

The guidelines and values that help scientists make sure their work is honest, safe, and used to help, not harm, people, animals, and the planet.

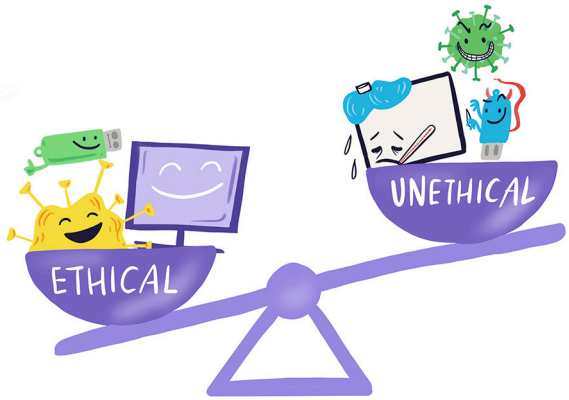

Figure 1

Figure 1

Scientific ethics act as the "conscience" of science, to make sure that scientific discoveries are used to help people, not harm them. For example, just as a USB stick could carry a helpful program or dangerous malware, synthetic viruses could contain beneficial genes to fight cancer, for example, or, in the wrong hands, they could be used to harm or even kill humans. Strong scientific ethics can help tip the scale toward responsible, ethical use of powerful new technologies (Figure created by carlottacat.com).

GUIDING PRINCIPLES FOR SCIENTISTS

While the exact ethical guidelines that scientists should follow can differ based on many factors, including the type of science (medical science vs. plant science, for example), the university or institute where the research is happening, or the local culture, there are some commonly accepted guidelines that all scientists should follow (Figure 2). Here are a few:

- **Respect human rights**: Scientists should protect the wellbeing, dignity, and independence of anyone involved in their research studies. They must clearly explain a study's risks and benefits and make sure that all participants agree to be in the study. This is

INFORMED CONSENT

When people freely choose to take part in a scientific study and fully understand its purpose, risks, and benefits. Scientists have the ethical responsibility to explain everything clearly.

called **informed consent**, and it ensures that people are joining a study by their own choice and not being pressured to take part.

- **Use animals ethically**. If animals must be used in research, they should be treated humanely, by minimizing their pain and suffering.
- **Report dangers promptly**. If researchers discover any health risks or safety concerns of a new treatment or technology, they should report them immediately. Safety should be a primary concern, especially if studies involve vulnerable groups like children, prisoners, pregnant women, or other at-risk populations.
- **Consider the broad impacts**. Scientists should think about how their work might affect society and the environment, not just immediately but in the longer term. Scientists have a responsibility to minimize any negative outcomes their research might have.
- **Be honest**. Scientists should be truthful and open about all aspects of their work. This includes making sure their results are accurate and never falsifying (making up) data. They should clearly give others credit for their work, and never **plagiarize** the work of other scientists**.** Finally, they should be open about any factors that might bias their research, such as personal relationships or sources of funding.

PLAGIARIZE

To copy someone else's work and pretend it is your own. Plagiarism is wrong because it is stealing another person's ideas.

Figure 2

Ethical principles that guide the work of scientists include treating animals kindly, respecting human rights, being honest, considering the broader impacts of the work, and reporting any dangers promptly (Figure created by carlottacat.com).

Figure 2

BREAKING THE RULES

You might be wondering whether there are any real-life examples of situations in which scientists have ignored the principles of scientific ethics, leading to negative consequences. Examples of unethical

scientific conduct certainly *do* exist because scientists are humans who can sometimes make bad choices, just like the rest of us.

One famous example is the Tuskegee Syphilis Study, which took place from 1932 to 1972. In this experiment, hundreds of African American men who had a sexually transmitted disease called syphilis were deliberately left untreated by researchers. The researchers wanted to study the way syphilis affected the body. A look back at our list clearly shows that this study was unethical on many levels. The men were generally poor and could not read and did not provide informed consent. They were also lied to about their condition—they were not told that they had syphilis or that it was sexually transmitted—and they were given fake treatments, even after penicillin became available and could have cured them. Many of the men died or suffered from serious complications, like blindness, because of the experiment.

A more recent example of unethical scientific conduct occurred in 2018, when a scientist announced that he had edited the genes of twin girls before they were born, using a powerful new technology called CRISPR-Cas9 [1]. The scientist claimed he wanted to make the babies resistant to HIV infection by disabling the gene that allows HIV to enter cells. While this might sound like a good idea, many other researchers and the public were shocked and worried about the twins' futures. The scientist faked some important approval paperwork and did this experiment without the support or agreement of local authorities or the scientific community. Many researchers felt that he did not consider the potential long-term effects his experiment could have on the girls and their future children. Finally, some felt this experiment was unnecessary because there are other, less risky ways to prevent HIV infection without altering human DNA.

RIGHT OR WRONG? IT IS COMPLICATED!

It is important to remember that, in some cases, scientific ethics are different from the rules of a game or a school's dress code. What is considered right or wrong can differ across cultures, and can also change over time, as a society's knowledge and values develop. As an extreme example, when the Tuskegee Syphilis Study started, there were no official guidelines governing ethical research on humans. This in no way makes those actions right, but there were no formal rules to protect people from such unethical experimentation.

Technology is a particularly powerful factor that can change a society's notion of right and wrong. New technologies can give us options that we did not have before, making our old choices look wrong or unethical. For example, gasoline-powered cars have been the norm for over a century, despite their damaging effects on the environment—we simply did not have any other good options for transportation. But as electric vehicles continue to improve, more

people may begin to feel that it is unethical to drive polluting, gas-powered vehicles. The same may be true for eating meat. As synthetic meats become less expensive and tastier, there may come a day when even meat eaters feel it is ethically unacceptable to eat animals. As norms evolve, many future generations will judge the past through their standards, criticizing and judging people for past behaviors that, looking back, were clearly wrong. Today, the number and power of technologies that are available to us is increasing more rapidly than ever, which means that our ethics may begin to change exponentially, too. Maybe there will even be a future in which it will seem unethical *not* to alter the genes of our unborn children, to protect them against cancer or other diseases that people commonly suffer from today!

WRAPPING UP: THE POWER OF CHOICES

Science can be a powerful force, with the potential to bring incredible advances that benefit humanity. Scientific ethics is the guiding light that helps scientists navigate the complexities of their work, making sure new technologies serve society without causing harm or violating human rights. While laws and regulations can provide scientists with ethical guidance, technology is advancing so rapidly that official laws and codes of conduct often lag way behind. This means it is critical for individual scientists to have strong ethics and to take personal responsibility for their behavior. Adding ethics training as a regular part of a scientific education could help scientists understand the guidelines they are expected to follow in their work.

The future of science depends on maintaining the public's trust (to learn more about trust in science, see this Frontiers for Young Minds article). If people see that scientists have strong ethics and conduct their research in a responsible, honest, and respectful way, it will be easier for the public to trust and support science and to follow scientific advice that could keep them healthy.

As science and society continue to evolve, new technologies will continue to change our options, and our ideas about what is acceptable and what is not will change, too. Science gives us amazing tools, but it is up to us how we use them. With ethical minds guiding research, the wonders of science can bloom while protecting human lives and the health of the planet.

ACKNOWLEDGMENTS

Articled inspired by the Sparks! Serendipity Forum at CERN. For more info on this particular topic, see talks by Juan Enriquez and Andrew Hessel, and Enriquez's book [2].

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SUBMITTED: 27 September 2023; **ACCEPTED:** 21 November 2023;
PUBLISHED ONLINE: 08 December 2023.

EDITOR: Claudia Marcelloni, European Organization for Nuclear Research (CERN), Switzerland

SCIENCE MENTORS: Sezgin Ersoy and Marco Montemurro

CITATION: Debad SJ and Enriquez J (2023) New Scientific Technologies: Navigating the Path of Right and Wrong. Front. Young Minds 11:1303154. doi: 10.3389/frym.2023.1303154

CONFLICT OF INTEREST: SD was employed by SJD Consulting LLC. JE was employed by Excel Venture Management.

YOUNG REVIEWERS

ALESSANDRO, AGE: 12
I am Alessandro, a 12-year-old student from Italy. I started to get interested in science when I was a kid. I wanted to become a scientific researcher, so my parents bought me the "kit of the little scientist." With that, I made my first experiment. I was proud of myself. My passion has still continued and I started studying to follow my dream.

ÇAĞAN, AGE: 11
My name is Çağan. I am in fifth grade. Some of the things I enjoy doing are reading, playing football and basketball, science, ancient languages, and computer science. I love reading adventure novels, especially the Harry Potter book series. I played the piano for 4 years, now I am interested in other instruments. I love nature, plants, and animals.

ÇAĞLA, AGE: 9

My name is Çağla, I am in the 3rd grade. Things I like to do are gymnastics, reading, painting, and listening to music. I enjoy science fiction and fantasy books. I did ballet for 3 years. I am playing piano. I really enjoy playing games. I love nature, animals, and plants.

AUTHORS

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Susan has been the main editor for FYM since 2015, making all our science clear and interesting—so that nobody feels it is "boring" or "too hard." She has a Ph.D. in viral immunology (how the immune system protects us against viruses). Susan lives outside Washington, DC, and has a teenage son, two birds, and four dogs. She fosters beagles and helps them to get adopted, which means that sometimes she has *more* than four dogs! In her spare time she enjoys reading, crossword puzzles, and being outdoors. *susan@sjdconsultingllc.com

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Juan is interested in how life sciences and brain research can change businesses and society. He earned a B.A. and an M.B.A. from Harvard University. Juan was the founding director of the Harvard Business School's Life Sciences Project and is a research affiliate at MIT's synthetic neurobiology lab. He now works for Excel Venture Management, which helps to build companies that use life-sciences technologies to solve big problems in healthcare and beyond. Juan has given 9 TED talks on a variety of topics, and he is the author of several books, including *Right/Wrong: How Technology Transforms Our Ethics*. *jenriquez@excelvm.com