Science and Decision Making: How do you decide what to believe?

Critical teaching ideas - Science Continuum F to 10
Level: Working towards level 10

Student everyday experiences

There is a disconnection between 'real' science and the science presented in schools. Many students' everyday experiences highlight this difference. In addition, there are differences in what younger primary and older higher school students believe about the role of science in society and the work of scientists. The views below largely represent those of older students.

Students often believe that science is a set of facts that represent 'truth'. Most science textbooks reinforce this notion in the ways they present science. The decontextualised and generalised ways of representing science in schools lead many students to conclude that school science and consequently science in general has little relevance to their everyday life. While students often see problems with aspects of science in society, most students believe that overall, science is beneficial to society as it can help to improve the quality of their life. In general, students do accept the authority of science.

Students also tend to recognise that scientists are people with different motivations, who often ask different questions about the same phenomenon, and will therefore collect and interpret data in different ways. However, being a scientist requires specialised training and this often undermines students' perceptions of scientists as members of the general public. Students recognise that scientists try to be objective and unbiased. They also recognise that they are not free of biases but believe that doing scientific work forces scientists to be honest and objective.

Students believe scientists can provide important expertise when society and individuals make decisions. They also believe that the science involved in this decision-making needs to be used wisely. While students believe that scientists are and should be concerned with the results (both beneficial and harmful) of their work and should communicate such results to the public, they also believe that the public should seek out such communication from scientists.

Research: Aikenhead (1987), Ryan (1987), Fleming (1987)

Scientific view

Scientific knowledge is the knowledge currently accepted by the scientific community and is a theoretical explanation of the real world. In deciding what is acceptable science, the scientific community undertake a process of public peer review where science experts reach a

consensus about what is the acceptable science. This public process is often referred to as public science as it has undergone a validation process and contributes to the accepted scientific knowledge. The work of professional scientists includes this process of consensus-making peer review. It is this public science that is reported widely.

In constructing public science, scientists engage in a process involving their private science (sometimes called private understanding). This is the work that scientists engage in every day. Personal interest, intuition, curiosity, creativity and interpreting the work of other scientists may all be involved in the daily work of scientists, as are their values and beliefs as scientists and people more generally. Private science remains relatively unreported (e.g. it is often difficult to access scientists' actual log book recordings).

Scientific knowledge is important in the decision making process for society, but there is a mutual responsibility for scientists to convey their knowledge to the public and for the public to seek appropriate expert knowledge and to consider the implications of this knowledge. The interplay between science and ethics is an important consideration in this decision-making process. Science can be seen as the process of rational enquiry which seeks to propose explanations for observation of natural phenomena. Ethics on the other hand can be seen as the process of rational enquiry by which we (people generally) decide on issues of right (good) and wrong (bad) as applied to people and their actions.

It is important to remember that all scientific knowledge is constructed by humans.

Research: Fullick & Ratcliffe (1996)

Critical teaching ideas

- Scientific knowledge is constructed by humans.
- Each scientist knows both private (personal understandings of science) and public science (the science they present to the scientific community for review and subsequent acceptance).
- Experimentation can only lead to private understanding; the community of scientists decide what currently accepted public science is.
- Authentic stories of science can challenge many textbook notions of science and emphasize science as a human endeavour.

Research: Aikenhead (2006)

Explore the relationships between ideas about the nature of science in the Concept Development Maps – Scientific World View, The Scientific Community, Science and Society, Evidence and Reasoning in Enquiry, Scientific Investigations, Scientific Theories and Avoiding Bias in Science.

Students need to be aware that while scientists do have specific training (as many other professions) in order to do their work, they are still members of society, like all other people. This influences the way they construct their interpretations of the work that they do on a day to day basis. This is what forms their private science ideas.

Much of the data generated from this work is from direct (or indirect) observation, and in schools this is often via conducting experiments, although in the work setting, scientists

gather data via observation in multiple ways. For example, from investigation, a scientist could make the decision that 'white things float' if all their results involved white things floating. This is the scientist's private science. This inference can change if you try other objects, such as a green object like a leaf and see if it floats. From the repetition of the investigation the scientist looks to identify the patterns and decides what to believe.

In science investigations intuition can play a major role. 'Intuition' has a different meaning in science to common language; in common language intuition is far more linked to an immediate feeling or response without reasoning or sensing (a random, creative thing). In science intuition has an experience-base that is embedded in a person's private science. While intuition plays a role in the day-to-day work of a scientist (private science), it is less likely to play a role in the science that is reported (public science). To use the floating example above: it would be quite common to hear a scientist say they had a 'gut' feeling that other coloured things will float and that white is not necessary for something to float. Further investigation would then take place and more observations taken so that an inference could then be drawn about what sort of things float.

For scientists, the highest authority to judge the work of scientists is the scientific community. This community of experts subject each other's work to scrutiny. When submitting their work for this expert scrutiny, scientists present it in ways that are more acceptable to a community of experts and this is known as a scientists' public science. This public process of consensus-making is called 'peer review'. Many theories are initially rejected because they confront the ideas valued by society as a whole or because they challenge scientifically accepted views held by other scientists.

Many more controversies in science can be accessed in Halman's (1998) book 'Great Feuds in Science – Ten of the liveliest disputes ever'. Some of Halman's examples are powerful demonstrations of how very difficult it can be to replace an accepted theory that has been socially and scientifically accepted with a new theory in the light of new evidence. Similarly, it is important that students should experience a consensus-making process and be able to describe such a process that they use in order to decide what to believe.

Teaching activities

The science represented in school often does not represent an authentic view of contemporary science. The 'humanness' of science is often removed, providing a decontextualized view of science not connected to society or individuals' everyday world. While science in schools can be viewed as at best only telling a story about science, it is important that this science education (story) is as authentic as possible in representing science. Some of the activities below are designed to reintroduce the context and the 'humanness' of science and try to represent a more authentic story of science by paying attention to the context. The science when telling this sort of story can often make the science 'messy' as it does not fit into neat categories.

Provide an open problem to be explored via play or through problem solving.
Some extended activities can be undertaken with students to help them experience the difference between private science and public science and the moral and ethical decisions that accompany particularly public science.

For example, there are many illustrations in television drama of ethical dilemmas that can be used in science classrooms. One example that has been used by some science teachers is an episode of 'Grey's Anatomy'. The episode called 'Runaway Train' was about the doctors deciding how to proceed with two patients who had been impaled on a piece of railway track. Only one of the two could possibly be saved. In groups students can explore the medical/science view, the ethical view, the view of the family, the legal view etc. in reaching a decision. A more comprehensive discussion of this activity is available:

- Who decides?

This use of popular media is very useful for creating scenarios that capture students' imaginations.

Research: Corrigan, Dillon & Gunstone (2007)

Focus students' attention on overlooked detail.
Tracking the life of a number of significant people in science can highlight the tentative nature of what are the acceptable views of science at a particular time in history. For example the history of Galileo's life and ideas provides some wonderful insights. Some of the ideas to be followed up are indicated below.

Galileo spent a great deal of his life exploring motion and falling objects, particularly through exploring the use of an inclined plane to roll balls. For many of his investigations he used combinations of thought experiments and practical experimentation. The idea of him dropping balls off the Leaning Tower of Pisa is highly improbable, even though this has widely become the story of what he is famous for. For example the first story of Galileo dropping something off the Leaning Tower appeared some 40 years after he was dead. The article at Physics World provides further discussion of this:

- Physics World: The legend of the Leaning Tower

Meanwhile, the central role of Galileo's thought experiments in the development of his ideas is usually completely ignored.

Galileo also paid attention to the technologists of his time, such as cannon makers. When they bored their cannons the cannon makers estimated where cannon balls would land. They also graphed results of shooting a body in a horizontal direction. Evidence of such work existed in 12th century but had no impact at that time; Galileo, however, interpreted these results differently and was largely credited with this work.

Galileo was also committed for trial to recant his support of the ideas of Copernicus that the Earth rotated around the Sun, which he did before his death. However, it was later found that the Copernican ideas were more likely and therefore more acceptable to the scientific community. This relationship between researchers and society (and the Church in this instance) is an important idea to explore. An effective way of communicating these ideas is through an activity called Retrying Galileo.

- Retrying Galileo – this website is part of the Resource Center for science teachers using Sociology, History and Philosophy of Science.

The aim of this role play is to demonstrate how difficult it is to understand a new theory or to overturn an old theory which has become part of society's way of thinking. The purpose is not to take sides either for Galileo or against him.

Further resources

Websites

- NobelPrize.org - the Nobel Prize Organisation provides a biography on all Nobel Prize winning scientists.
- The Resource Centre for science teachers using Sociology, History and Philosophy of Science – this site is an online library that provides curriculum modules, essays, historical updates, book and video reviews, case studies and discussion relating to issues around the nature of science.