How students develop scientific reasoning

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Whether or not former students can apply scientific reasoning to formulate hypotheses and solve problems effectively at work depends in part on what subjects they have studied, says LMU educational psychologist Frank Fischer.

What exactly is meant by the term scientific reasoning, or does its meaning vary depending on the field involved?

Frank Fischer: Generating hypotheses, collecting and evaluating evidence. These are skills that are relevant in all areas of study, even though their relative importance may vary from one subject to another. Scientific reasoning is a multidimensional concept. On the one hand, there is the pure theoretician, who simply constructs theories that can in principle explain some empirical phenomenon or other. The Danish physicist Nils Bohr is a famous example. He is reputed to have had no interest at all in the practical utility of his knowledge and his models. Thomas A. Edison represents the other extreme. He professed no interest whatsoever in formulating scientific theories. His only goal was to supply America with electricity. And then there are those who are interested developing theories that help to solve practical problems. Louis Pasteur is one instance of this type of thinker. Pasteur took an everyday problem and conducted laboratory experiments with a view to finding a solution to it. And the insights he gained did indeed change things for the better. For some researchers, that is the whole point of research work: One looks for ways to tackle a practical problem, carries out experiments to probe the nature of the problem, and applies what one has learned to effectively resolve the issue at hand.

Is scientific reasoning simply a matter of specialized knowledge?

The more one knows about one's subject, the more confidently one can argue and the more trustworthy and compelling those arguments will be. But that also requires intelligence: Indeed, problem-solving calls on a number of general cognitive capabilities. In addition to well-founded knowledge of the issues, and the intelligence required to grasp how they are related to each other, one needs the strategic ability to recognize how concepts and data drawn from a particular field of study can be utilized to solve problems or to further develop theories. One of the questions we are now studying is how this set of skills, which we refer to as scientific reasoning, can be empirically and reliably measured.

Only a minority of students go on to work in research. What use is this ability in other fields of endeavor?

In every subject students have the opportunity to learn how to think and to argue within the terms and limits of the particular field concerned. But that does not necessarily mean that every graduate is in a position to apply this knowledge in everyday practice and to extend this knowledge base over the course of his or her working life. And the relative importance of these skills does of course vary depending on the cultural specificities associated with particular disciplines. In medicine, for example, a great deal of emphasis is placed on the scientific approach. Medical doctors apply their specialized knowledge in light of, and in combination with, their professional experience to diagnose their patients' illnesses, and they make use of scientific evidence and scientific arguments in their communications and discussions with colleagues. In other subjects, this type of direct knowledge transfer into the practical sphere is less well developed. In this respect, they have a lot of catching up to do.

What subjects do you have in mind?

Teachers who have to prepare lessons or lectures, for example, would be well advised to make greater use of insights from educational research, in areas such as the implementation of collaborative learning or assessing the strengths and weaknesses of individual pupils or students. Unfortunately, many in the teaching profession take the view that there is not much in educational research that is of any relevance to their everyday practice. But that is simply not true. Researchers have uncovered a trove of things that could be profitably applied in schools. Research projects have led to the development of innovative learning materials and learning environments, and evaluated their effectiveness. But very little of this has penetrated the walls of the classroom, although teachers could quite easily make use of these advances in their classes.

So whether or not graduates can subsequently make use of insights from science depends on which subjects they studied. Why is that?

Our working hypothesis is these skills are not sufficiently internalized by the students of certain subjects. In contrast to the case in Medicine, where students – at least in the later stages of their studies – are schooled in the rational consideration of clinical evidence, this approach plays a very minor role in many other subjects. As a result, many students leave university without having learned the relevance of the knowledge base they have acquired to their professions, or the ability to recognize situations in which it can be beneficially applied. They therefore fail to keep up with and make use of new advances in their own fields.

What can be done to change that?

One approach would be to restructure these courses. In the context of my current research project at the CAS, we are looking at whether or not one can design interventions which would help students to pick up the habit of thinking in scientific terms and, if so, whether this could be done in a fashion that is applicable to a wide range of disciplines. Another possibility we are investigating is changing the form in which scientific results and insights are presented, so that they can be more easily found – and applied – by the majority of university graduates in their everyday work.

So scientific insights should be presented in a form that is intelligible to the general public?

That is certainly important too. But here we are not talking of communication with the public at large, but with graduates who have at least learned a particular technical vocabulary, although they might not be able to follow the arguments of experts at scientific conferences. We need to do both – ensure that students are better qualified to recognize problems that can be effectively solved with the help of scientific concepts and methods, and make it easier for students to understand the results of academic research. One further possibility is to simplify the mode of presentation of this sort of information. In the course of one experimental investigation, we discovered that when our subjects were asked to read specially prepared summaries of scientific studies that included specialized terminology, they retained more of the content than they did when the whole article was given to them.

But even short summaries must first be noticed and then carefully read.

What we lack is the appropriate interface between research data and their practical application. New forms of further education in academic and scientific subjects could play and important role in this respect. On the one hand, teachers could commit themselves to continuing education in the subjects that they studied at university, and universities could systematically set up networks which would make it possible to bring educators back for regular evening classes or provide courses for them in their schools. There has been some movement in this direction, but these efforts must be supported and strengthened.

What effects is digitalization having on the concept of scientific thinking?

In terms of the practical application of scientifically validated evidence, the advent of search engines has been a great help. They make it easier to find information. However, that does not mean that one can easily find materials that are properly prepared and presented, and readily intelligible. In the medical field, the phenomenon of the well-informed patient who appears in the doctor's surgery with her own diagnosis has become the subject of much investigation. Researchers want to know what impact such patients have on the diagnostic process as such, and some even talk of "shared clinical reasoning" in this context. This is a development that could spread to other areas. New technologies, such as various sorts of visualization tools, also make it possible to create new learning environments that make it easier to assimilate the art of rational argumentation.

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