WAYNE STATE School of Medicine | Department of Biochemistry, Microbiology and Immunology

BMI Teaching Trends Newsletter – May 2023

Teaching Matters
By Dr. Matthew Jackson

May 2023 Teaching Trends Newsletter

This is the third installment of the *Teaching Trends* newsletter describing the new *Critical Thinking in Science Course* that Kevin Theis and I developed and delivered last fall. These paragraphs describe the roles of inductive and deductive reasoning in hypothesis development and the prediction making that advances scientific discovery.

The basic assumptions of science are that nature is orderly and therefore lends itself to some level of predictability. Every truth must be subject to empirical observation which must be based on logical processes (5). Logic is a system that permits scientists to draw inferences and make predictions from observation. The most commonly used cognitive processes used by scientists are inductive and deductive reasoning with abductive reasoning (inference to the best explanation) sometimes used when it is not possible to accurately sample some populations (1,6). Inductive reasoning is the foundation for scientific discovery used to generate a hypothesis which may or may not lead to a theory (4). A scientific theory should be able to: i) identify a pattern of empirical observation; ii) support predictions of the pattern into the future; and iii) contribute to an explanation of causation for the pattern. Some theories must wait for methods to catch up. For example, Darwin's theory of evolution by natural selection had to await Mendelian genetics to explain how gene inheritance affects phenotype. There is always the potential that a theory can be falsified by observations that do not support the predictions, although the scientist must always retain the capacity for alternative explanations. Little scientific progress would be made if existing theories were abandoned at the first sign of contradictory results. An example is the discovery of Neptune in 1846 by John Couch Adams and Urbain Le Verrier (2) who independently observed a perturbation in the orbit of Uranus. Rather than discarding the laws of Kepler and Newton that predicted perfectly elliptical orbits for all planets they hypothesized the existence of a previously undiscovered celestial body which impacted Uranus' orbit. Scientific knowledge provides a method for organizing things and leads to the development of hypotheses to explain past events while maintaining a level of abstractness (and concomitant falsifiability) so that they can predict future events (3). Acceptance of a hypothesis depends on a level of confidence which is a product of reproducibility through empirical observation resulting in acceptance of a hypothesis as a theory (7).

The problem of induction is how do we know that our observations of specific events can enable us to make predictions? Our innate heuristic practices and cognitive biases can interfere with the development of testable hypotheses that must follow the rules of deductive reasoning for investigation. Education of a student of the sciences should include a discussion of the problem of induction and an awareness of the pitfalls of inductive reasoning and to consider the possibility of black swan events. Human nature is not programmed for the black swan because we tend to focus on patterns that confirm our preconceived beliefs (8). Unfortunately, textbooks and journal articles are written to support the narrative fallacy that science progresses infallibly thereby obviating the impact of the outlier as well as the reasoning process that was used to disregard or include these findings in a scientific report (9). Therefore, students are not provided the opportunity to fully appreciate the epistemological foundations that are available to us.

Students enrolled in our Critical Thinking in Science course were introduced to the teachings of several philosophers who studied science. We discussed that critical thinking in science has its roots in philosophical teachings which are disregarded in the education of future scientists. Traditionally, when these students reach the graduate level, they are compelled to focus on gaining the core knowledge in their field of study while developing the necessary technical skills to make contributions to a specific project. The aim of our new course was to broaden the scope of our students' graduate education by helping them understand how hypotheses should be developed through inductive and deductive reasoning and by introducing them to the biases in the decision-making processes that lead to scientific error.

References

1. 7 Scientific Thinking. Dunbar K, Klahr D. 2012. In book: Oxford Handbook of Thinking and Reasoning Edition: 1, Chapter: 35; Publisher: Oxford University Press.
2. 13Philosophy of Science: A Very Short Introduction. Okasha S. 2016. Oxford University Press
3. 14Primer in Theory Construction. Reynolds PD. 2007. Routledge
4. 20 The Scientific Attitude, Defending Science from Denial, Fraud, and Pseudoscience. McIntyre L. 2019. MIT Press, Cambridge, Massachusetts
5. 33Research Methods in the Social Sciences. Frankfort-Nachmias, C, Nachmias, D, DeWaard, J. 2015. MacMillan Press
6. 34Inference to the Best Explanation. Lipton P. 2000. In: W.H. Newton-Smith (ed) A Companion to the Philosophy of Science (Blackwell,) 184-193.
7. 35Health Behavior: Theory, Research, and Practice. Glanz K, Rimer BK, Viswanath K. 2015. Jossey-Bass – Wiley
8. 36The Black Swan: The Impact of the Highly Improbable. Taleb N. 2010. New York Random House
9. 37Scientific Thinking without Scientific Method: Two Views of Popper. Boland LA. 1994
   New Directions in Economic Methodology, R. Backhouse, ed. (Routledge)