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

BMI Teaching Trends Newsletter – January 2023

Teaching Matters
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Kevin Theis and I completed the first year of the new Critical Thinking in Science Course, IM7140. We were very encouraged by our students' participation in small group discussion and their presentations. Please feel free to share your thoughts or questions about the new course with Kevin or me.
I will share a portion of the background material that was used to develop the course in the upcoming Teaching Trends newsletters.

Teaching the Four Cs

Reports from the American Association for the Advancement of Science (1) and the National Commission on Excellence in Education (2) acknowledged that there was a need for school curricula to include more than just content mastery and that critical thinking skills were needed to promote intellectualism in the philosophical sense (3). Beginning in the 1980s, collaborative learning with experiences designed to inculcate the scientific method were emphasized in K-12 education. However, the transition to this style of education was not universally adapted by undergraduate institutions. This may explain why recent employer surveys revealed that the majority of new hires with 16 years of formal education lack the critical thinking and problem-solving skills necessary for employment (4). Perhaps emphasis on the "four Cs" – critical thinking, communication, collaboration, and creativity may reverse the trend observed by employers (5).

Critical thinking has been defined by the American Philosophical Association (APA) in the context of six skills, 16 subskills, and 19 dispositions (6). Skills defined by the APA include interpretation, analysis, and inference while the dispositions include inquisitiveness and open-mindedness. The objective of the APA was to provide educators with the tools to provide their students with the type of instruction that will allow them to enter the workforce with fundamental problem-solving skills. There is equivalence between the six critical thinking skills and Bloom's hierarchical taxonomy used for classification of educational learning objectives (knowledge, comprehension, application, analysis, synthesis, evaluation) although evaluation aligns more closely with a strict

definition of critical thinking while synthesis aligns with creative thinking (7). A fully developed scientific attitude requires both. A curriculum that includes discussion of the cognitive biases and logical fallacies associated with a current topic such as global warming is an example which can provide students with a foundation in scientific thinking while instilling an awareness of their responsibility addressing science denialism (8). Students pursuing a graduate degree have an opportunity to practice critical thinking skills through critical appraisal of pertinent journal articles in a specific domain as well as review articles that frame the historical progression of a particular field which is essential for a philosophical approach to science (9). Ultimately, graduate students armed with the proper introduction during their coursework would apply their critical thinking skills to their independent research project. Graduate students embarking on a career in science are often given a research project that is a continuation of past work with the intent of continuing the lab's progress with the goal of maintaining a publication record and funding. A student's scientific attitude would benefit from the writings of philosophers who described the application of logic to scientific discovery. For example, comparison of the Francis Bacon research-then-theory approach to Karl Popper's theory-then-research approach (10) will help them become the stewards of their research project early in their academic careers.

Critical thinking education is a structured process that teaches the principles of deductive reasoning (and the rules of logical argument) and its distinction from inductive reasoning (11). Inductive reasoning begins with a premise that supports a conclusion making the conclusion part of the reasoning process that inductive reasoning is trying to prove. Inductive reasoning is also referred to as "cause and effect reasoning" or "bottom-up reasoning" because it seeks to prove a conclusion first. Inductive reasoning has a role in the scientific process but students must be taught to recognize and avoid its inherent errors in logic that can result from various forms of cognitive bias. In contrast, deductive reasoning is founded on a premise and the argument provides a true and valid conclusion. With deductive reasoning, the conclusion must be true if the premises are also true. Deductive reasoning (top-down reasoning) uses general principles to create a specific conclusion. For graduate students to develop as critical thinkers, they should be aware of the distinction between the two different reasoning processes when reading research literature or designing their own experiments. Critical thinking skill development requires deliberate practice (12) in a curriculum that uses the method of infusion with explicit expectations: required reading, classroom discussion, written assignments, and oral presentations (13,14). While content knowledge is required for critical thinking the actual development of the ability requires practice because it is not a natural, intuitive process but a higher-order skill (15).

Next I will describe the sources of scientific error that can be the root of bad science.

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