STEM Topic: Misconceptions

Richardson, J. 2012. Concept inventories: Tools for uncovering STEM students' misconceptions. Invention and Impact: Building Excellence in Undergraduate Science, Technology, Engineering and Mathematics (STEM) Education. American Association for the Advancement of Science.

> Concept inventories are receiving increased interest from STEM faculty. What are concept inventories, why the interest, and what do I need to know about concept inventories? This chapter answers these questions in the following order. In the first section, you will read a brief history of STEM concept inventory development, which should answer the question, "Why the interest in concept inventories?" In the next two sections, you will read first a short discussion on the theory of assessment as it applies to concept inventories and then a description of how to construct a concept inventory. Together, these two sections should answer the question, "What is a concept inventory?" And finally, you will read how others have used concept inventories and related tools to improve their teaching effectiveness.

Martin-Hansen, L.M. 2008. First-year college students' conflict with religion and science. Science and Education. Vol. 17, 317-357.

> This study took place during a First Year Seminar course where 20 incoming college freshmen studied the central topic of the nature of science within the context of biological evolution. The instructor researched students' understandings in the nature of science as they progressed through the course by examining a variety of qualitative and quantitative data including class writings, pre- and post-test selected items from the VOSTS (Views on Science- Technology-Society), and interviews. The intended outcomes of the course were to reduce the number of student misconceptions in the nature of science and to ease student apprehension when learning about evolution. Data were analyzed to determine whether students were moving toward a more generally accepted idea of the nature of science or toward another type of misconception.

Garin-Doxas, K., Klymkowsky, M., Elrod, S. 2007. Building, using, and maximizing the impact of concept inventories in the biological sciences: Report on a National Science Foundation-sponsored conference on the construction of concept inventories in the biological sciences. Life Science Education. Vol. 6, 277-282.

> The meeting "Conceptual Assessment in the Biological Sciences" was held March 3-4, 2007, in Boulder, Colorado. Sponsored by the National Science Foundation was hosted by University of Colorado, Boulder's Biology Concept Inventory Team, the meeting drew together 21 participants from 13 institutions, all of whom had received National Science Foundation funding for biology education. Topics of interest included Introductory Biology, Genetics, Evolution, Ecology and the Nature of Science. The goal of the meeting was to organize and leverage current efforts to develop concept inventories for each of these topics. These diagnostic tools are inspired by the success of the Force Concept Inventory, developed by the community of physics educators to identify student misconceptions about Newtonian mechanics. By working together, participants hope to lessen the risk that groups might develop competing rather than complementary inventories.

Nehm, R. H., Schonfeld, I.S. 2007. Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools? J Sci Teacher Ed. Vol 18, 699-723.

This study investigated whether or not an increase in secondary science teacher knowledge about evolution and the nature of science gained from completing a graduate-level evolution course was associated with greater preference for the teaching of evolution in schools. Forty-four precertified secondary biology teachers participated in a 14-week intervention designed to address documented misconceptions identified by a precourse instrument. The course produced statistically significant gains in teacher knowledge of evolution and the nature of science and a significant decrease in misconceptions about evolution and natural selection. Nevertheless, teachers' postcourse preference positions remained unchanged; the majority of science teachers still preferred that antievolutionary ideas be taught in school.

Nelson, C.E. 2007. Teaching evolution effectively: A central dilemma and alternative strategies. McGill Journal of Education. Vol. 42, 265-285.

We will continue to have a public that is scientifically illiterate until we find ways to get faculty in post-secondary science classes to use effective pedagogical approaches. In this article, I present three scientifically and pedagogically valid strategies for helping students evaluate their initial understandings of evolution and to compare those understandings with more scientifically valid formulations. Adoption of such strategies in post-secondary teaching is central to more adequate preparation of future scientists, opinion leaders, and secondary school teachers.

Rath, K.A., Peterfreund, A.R., Xenos, S.P., Bayliss, F., Carnal, N. 2007. Supplemental instruction in introductory biology I: Enhancing the performance and retention of underrepresented minority students. Life Sciences Education. Vol. 6, 203-216.

Supplemental instruction classes have been shown in many studies to enhance performance in the supported courses and even to improve graduation rates. Generally, there has been little evidence of a differential impact on students from different ethnic/racial backgrounds. At San Francisco State University, however, supplemental instruction in the Introductory Biology I class is associated with even more dramatic gains among students from underrepresented minority populations than the gains found among their peers. These gains do not seem to be the product of better students availing themselves of supplemental instruction or other outside factors. The Introductory Biology I class consists of a team-taught lecture component, taught in a large lecture classroom, and a laboratory component where students participate in smaller lab sections. Students are expected to master an understanding of basic concepts, content, and vocabulary in biology as well as gain laboratory investigation skills and experience applying scientific methodology. In this context, supplemental instruction classes are cooperative learning environments where students participate in learning activities that complement the course material, focusing on student misconceptions and difficulties, construction of a scaffolded knowledge base, applications involving problem solving, and articulation of constructs with peers.

Bunce, D.M., VandenPlas, J.R., Havanki, K.L. 2006.Comparing the effectiveness on student achievement of a student reponse system versus online WebCT quizzes. Journal of Chemical Education. Vol. 83, 488-494.

> The use of computers to gather student responses is not new to science education. Use of electronic response systems, especially in large lectures, dates back to the 1960s *(3).* Research on the effectiveness of this approach has been limited to its influence on increased rates of passing the course *(4).* More work is needed to test the effectiveness of computers and ConcepTests on student achievement. It is this question that led to the incorporation of the Student Response System (SRS) into a second-semester nursing course. SRS is a Web based questioning system *(5)* designed to assist instructors in receiving and analyzing student responses to questions posed in lecture or recitation. In this study, the electronic student response system, SRS, was used primarily as a means of delivering electronic ConcepTests for students working in pairs.

Tanner, K., Allen, D. 2005. Approaches to biology teaching and learning: Understanding the wrong answers – teaching toward conceptual change. Cell Biology Education. Vol. 4, 112-117.

> Underpinning science education reform movements in the last 20 years—at all levels and within all disciplines—is an explicit shift in the goals of science teaching from students simply creating a knowledge base of scientific facts to students developing deeper understandings of major concepts within a scientific discipline. For example, what use is a detailed working knowledge of the chemical reactions of the Krebs cycle without a deeper understanding of the relationship between these chemical reactions of cellular respiration and an organism's need to harvest energy from food? This emphasis on conceptual understanding in science education reform has guided the development of standards and permeates all major science education reform policy documents (American Association for the Advancement of Science, 1989, 1993, 2001; National Research Council, 1996). However, this transition to teaching toward deep conceptual understanding often sounds deceptively simple, when in reality it presents a host of significant challenges both in theory and in practice. Most importantly, few if any students come to the subject of biology in college, high school, or even middle-school classrooms without significant prior knowledge of the subject. It is no surprise, then, that students can never be considered blank slates, beginning with zero knowledge, awaiting the receipt of current scientific understanding. Yet, there is often little time invested by instructors in finding out in depth what students already know and, more specifically, what they do not know, what they are confused about, and how their preconceptions about the world do or do not fit with new information they are attempting to learn. In this feature, we explore key ideas associated with teaching for understanding, including the notion of conceptual change, the pivotal role of alternative conceptions, and practical implications these ideas have for teachers of science at all levels in designing learning experiences for students.

Sundberg, M. 2003. Strategies to help students change naïve alternative conceptions about evolution and natural selection. NCSE Reports. Vol. 23, No 2.

> The purpose of my ongoing research in biological education is to identify and describe teaching strategies that are effective against such entrenched beliefs and that will promote a more sophisticated understanding of basic concepts. In this paper, I summarize the results of my most

successful interventions to address (1) major concepts related to evolutionary theory and (2) concepts related to the nature of science.

Dove, J.E. 1998. Students' alternative conceptions in Earth science: A review of research and implications for teaching and learning. Research Papers in Education. Vol. 13, 183-201.

A considerable amount of information is now available about alternative conceptions in the physical and biological sciences and their implications for teaching and learning. However, a growing number of publications have also appeared which have investigated alternative conceptions about Earth science. Some of these studies have addressed topics taught in geology, geography and science such as conceptions about rocks, earthquakes, volcanoes, the Earth's structure, landforms, weathering and erosion and soil. This paper reviews the literature on these topics, hereto reported across a broad spectrum of papers in science, geological and geographical journals, and presents some new findings. While there are many possible origins for the alternative conceptions identified, it is argued that some of these ideas re founded on various pedagogical practices, such as the imprecise use of language, oversimplification of concepts, use of rote learning, and stereotyping of landforms, as well as on the inadequate use of prerequisite knowledge of students, and the abstract nature of some of the subject matter in Earth science. Moreover, it is suggested that an awareness of, and attention to, these matters would improve teaching and student learning significantly.

McComas, W.F. 1998. The principle elements of the Nature of Science: dispelling the myths. *Adapted from the chapter in W. F. McComas (ed.) The Nature of Science in Science Education*, 53-70. © 1998 Kluwer Academic Publishers, Netherlands

The "myths of science" discussed here are commonly included in science textbooks, in classroom discourse and in the minds of adult Americans. These fifteen issues, described here as "myths of science," do not represent all of the important issues that teachers should consider when designing instruction relative to the nature of science, but may serve as starting points for evaluating current instructional foci while enhancing future curriculum design. Misconceptions about science are most likely due to the lack of philosophy of science content in teacher education programs and the failure of such programs to provide real science research experiences for preservice teachers while another source of the problem may be the generally shallow treatment of the nature of science in the textbooks to which teachers might turn for guidance. Some of these myths, such as the idea that there is a scientific method, are most likely caused by the explicit inclusion of faulty ideas in textbooks while others, such as lack of knowledge of the social construction of scientific knowledge, are the result of omissions in texts.

House, J.D. 1994. Student motivation and achievement in college chemistry. Int'l J. of Instructional Media. Vol. 21, 1-6.

The initial assessment of learner characteristics is an important component of instructional design models; however, limited attention has been given to the importance of students' initial motivation. The purpose of this study was to investigate the relationship between students' achievement expectancies and academic self-concept and their subsequent achievement in college chemistry. There were three main findings from this study. First, several specific learner characteristics were significant predictors of achievement. Second, students' achievement expectancies and academic self-concept were more significant predictors of performance than were students' prior achievement and their prior instructional experience. Finally, prior achievement was the only variable to significantly enter the regression equation for predicting students' earning the highest grade possible vs. earning lower grades. These findings suggest that students' academic self-concept and achievement expectancies are significant predictors of overall grade performance in chemistry while prior achievement was the only significant predictor of high grade performance.