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Feature
Current Insights

Recent Research in Science Teaching and Learning

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This feature is designed to point *CBE—Life Sciences Education* (*CBE-LSE*) readers to current articles of interest in life sciences education as well as more general noteworthy publications in education research. URLs are provided for the abstracts or full text of articles. For articles listed as "Abstract available," full text may be accessible at the indicated URL for readers whose institutions subscribe to the corresponding journal.

1. Hartley LM, Wilke BJ, Schramm JW, D'Avanzo C, Anderson CW (2011). College students' understanding of the carbon cycle: contrasting principle-based and informal reasoning. Bioscience *61,* 65–75.

[Abstract available: www.jstor.org/pss/10.1525/bio.2011.61.1.12]

The authors describe a study that used diagnostic question clusters (DQCs) to examine undergraduate students' reasoning patterns about carbon-transforming processes. (DQCs are "diagnostic" because they aim to provide information about specific reasoning tendencies, and "clusters" because they are sets of questions designed to identify patterns in thinking about interrelated, core concepts). As stated by the authors, this work moves beyond studies that look at single (and perhaps unrelated) misconceptions about the carbon cycle to identify patterns in students' thinking that connect to fundamental principles—ones that extend across and constrain biological systems and processes at multiple scales. The DQCs were taken from published sources or developed by the authors, and delivered in several formats: multiple-choice, multiple true–false, or mixed (e.g., choice of response, followed by explanation of choice). A pair of DQCs was used; one cluster focused on conservation of matter, and the other on conservation of energy. The DQCs were administered to 525 students enrolled in biology courses (at all levels, introductory to advanced) at 13 universities representing diverse institutional types. In each course, one of the DQCs was administered at the beginning of the semester, and again as a "posttest" for half of the students; the remaining half of the class received the other (new) DQC as the posttest (to compare the levels of difficulty of the two clusters). One of three active learning lessons about tracing matter and energy through the carbon cycle intervened between the two DQC tests. The course instructors scored the tests, using a rubric that categorized responses to indicate whether they exhibited use of "[scientific] principle-based," "informal," or "mixed" (principle-based and informal) reasoning. (The article includes numerous examples of sample questions and corresponding student responses for these categories.) Among several qualitative trends in the data, the authors describe two that predominated: 1) students often avoid the necessity of separately tracing matter and energy by using energy as a "fudge factor;" and 2) lack of fundamental understandings about atoms and molecules can explain inability to use principle-based reasoning. Quantitative analysis of trends revealed that a majority of students applied a combination of principle-based and informal reasoning across all topical categories (matter, energy, photosynthesis, transformation, and oxidation) in both the pre- and posttests. Additionally, although the percentage of students whose responses evidenced principle-based reasoning doubled after instruction (from an average of 12–27% across all categories), 16% of the students persisted in using informal reasoning (22% exhibited this reasoning pattern prior to instruction). The authors conclude by discussing the relationship of their findings to existing research on the deep-seated nature of informal reasoning, and the implication of their findings for use of standard biology textbooks and for college biology teaching.

2. Potvin P, Mercier J, Charland P, Riopel M (2011). Does classroom explicitation of initial conceptions favor conceptual

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change or is it counter-productive? Res Sci Educ *25,* Online First (in press).

[Full text available: www.springerlink.com/content/y584456707031832/fulltext.pdf]

According to the classical view of conceptual change, making students aware of their initial conceptions (and of possible discordances between their conceptions and the conceptions of others) is an essential step in learning (Posner *et al.*, 1982). The authors contend that, although this idea is widespread, there is little research demonstrating that "explicitation" of initial conceptions actually does have a positive impact on students' subsequent learning. They contend there is an essential flaw in much existing research in the area, in that specific operation of "classroom explicitation of initial conceptions (CEIC)" has been studied in the context of teaching sequences and the effect of CEIC alone has not been isolated from the effects of the sequences themselves. Conversely, the authors contend that there are sound reasons to think that having students state their conceptions aloud in class (and listen to other students do the same) could be counterproductive, citing, for example, the sometimes riveting influence that hearing erroneous words or statements can have on one's own ideas (the so-called "contamination effect" or "suggestion effect"). This study was thus designed to elucidate whether CEIC alone can have a favorable or unproductive effect on learning in a classroom context in which the instructor is intentionally using teaching methods designed to promote conceptual change. For this study, that context was use of a 75-min, problem-based activity about electricity (the "electronics challenge"), conducted with 875 13-yr-old volunteers from 21 schools. The activity consisted of 20 sequential circuit-building tasks performed by students (using materials such as wires, bulbs, switches, and resistors) in the absence of verbal teaching or clues from the teacher. The activity was designed to provoke conflict between students' commonly held initial conceptions and the actual behavior of the circuits they constructed. Prior to the activity, all students viewed a video that provided a basic introduction. This was done to reduce variations due to differences in teachers' instructions. Students took multiple-choice pre- and posttests that addressed basic concepts and misconceptions about electricity. Test results were compared between two conditions with (treatment) and without (control) CEIC. Randomly selected CEIC students (n = 199) participated in a small-group, question-and-answer session about electricity concepts conducted after the pretest, but prior to the "electronics challenge" activity. In the session, a moderator asked students to justify (in front of the group) the two most popular answers to each question. Statistical analysis of the test data were used to evaluate the effect of CEIC on relative success with each of the posttest questions. The data supported the conclusion that, under conditions in which no explicit teaching was performed, CEIC had a beneficial effect on learning and led to no apparent "contamination effect." However, the boys in the group benefited less from this learning activity and form of CEIC than did the girls, suggesting a promising avenue for future research on the way boys and girls learn in this context.

3. Wenk L, Tronsky L (2011). First-year students benefit from reading primary research articles. J Coll Sci Teach *40,* 60–67.

[Abstract available: www.nsta.org/publications/browse_journals.aspx?action=issue&id=10.2505/3/jcst11_040_04]

This article describes a study that explored the impact of reading and critical examination of the primary research literature on first-year college students' understanding of scientific inquiry processes. The study was conducted in a course that contributes to Hampshire College's first-year science program. Hampshire College has a 30-yr history of using primary literature in introductory science courses; their initial approach was based on Herman Epstein's model (1972). At Hampshire, members of the natural sciences faculty have worked with cognitive science researchers to document student learning outcomes from these courses, and a result of this collaboration was the development of the research instrument used in this study to assess the skills that accrue from first-year students' reading of the primary literature. As reported by the authors, the instrument's value is that it allows for addition of an "outcomes-oriented dimension" to the informal or less direct indicators of student development (such as faculty impressions or student attitudes and levels of satisfaction) often used to document the impact of course-embedded experiences of a similar nature. The authors describe the instrument and findings from its use in an exemplar introductory course (Drugs in the Nervous System) taken by both majors and nonmajors. They interpret their results (n = 41 students) as providing evidence that first-year students in a carefully orchestrated one-semester course can make substantive gains in understanding the primary literature—particularly in their ability to explain various facets of how scientific investigations can be organized and the investigative findings analyzed and interpreted. The study also identified aspects of students' processing of primary literature that appeared to require more extensive experiences for gains to be evident—for example, students' ability to pose alternative explanations and future research directions. The authors are careful to describe the course settings in which this and similar studies have been conducted, in particular highlighting the pedagogical strategies used to support the students' learning as they make these early excursions into the primary literature.

4. Feldon DF, Timmerman BC, Stowe KA, Showman R (2010). Translating expertise into effective instruction: the impacts of cognitive task analysis (CTA) on lab report quality and student retention in the biological sciences. J Res Sci Teach *47,* 1165–1185.

[Abstract available: http://onlinelibrary.wiley.com/doi/10.1002/tea.20382/abstract]

Poor instruction is commonly cited as being one of the more important influences on the high rates of student attrition in the sciences (Seymour, 2001). In this study, the authors hypothesize that, in particular, the way in which research methods and scientific inquiry skills such as problem solving are taught, typically through instructor lectures and assigned readings, makes an important contribution to low retention and academic underperformance in the biological sciences. In light of what is known about the development of expert cognition, the authors contend that although instructors may insert accounts of their own research programs and experiences into these instructional approaches, the messages about inquiry and problem solving conveyed are often incomplete or inaccurate, or left mostly or entirely implicit. In this study, they test the hypothesis that incorporation of cognitive task analysis (CTA), a set of techniques designed to help experts better articulate their problem-solving strategies, could address these challenges of high attrition rate and underperformance in scientific problem solving. They make the case that CTA-based instructional interventions could be particularly beneficial in the ill-structured domain of biological inquiry, in which there are multiple paths to multiple solutions, less readily manipulable variables, and uncertainty about how the seemingly relevant principles, concepts, and rules can be organized and directed toward the best solution. The authors tested the hypothesis in sections of an introductory biology course that included a laboratory experience. Students in the course received supplemental instruction (SI) that incorporated CTA derived from interviews conducted with expert biologists (treatment group), or SI that was developed and implemented by a biology professor who had received multiple awards for teaching (control group). The students were randomly assigned to groups, and were not aware of their participation in the study or of the conditions of the study. Additionally, the instructors and the researchers did not know which students were assigned to the treatment or control groups while the study was ongoing. Comparison of the treatment and control groups' scores on instruments designed to assess general scientific reasoning (Lawson's Classroom Test of Scientific Reasoning) and motivation (Motivated Strategies for Learning Questionnaire) revealed no significant initial differences between the groups with respect to these factors. The instructional content related to scientific inquiry was presented to both experimental groups in the form of a series of 5- to 10-min Internet-delivered streaming videos that students viewed outside of class prior to each week's laboratory class meeting (that is, as SI). The videos viewed by both the treatment and control groups featured explanations provided by the award-winning biology instructor; the control videos were scripted by that instructor, while the treatment (CTA-based) videos were based on protocols developed as the result of extensive, iterative interviews with three expert biologists on the faculty at the same institution. These interviews probed the ways in which the biologists approached the scientific process, including aspects such as how they formulated research questions and selected decision points and cueing events used in selecting specific problem-solving strategies. While both sets of videos viewed by the students focused on the same topics related to major aspects of scientific inquiry, the level of detail and specificity of the statements made about each aspect was greater for the CTA videos; the CTA videos also tended to be organized as a set of step-by-step actions and decisions to be made. By contrast, the control videos tended to be more abstract, and incorporated statements of principles accompanied by examples. In the laboratory class, which was led by a teaching assistant, students in both groups engaged in these aspects of inquiry throughout the semester. The laboratory class culminated with a multiple-week, inquiry-based investigation of fruit fly genetics, about which the students wrote formal, scientifically formatted reports. The reports were scored by three raters who used a Universal Lab Report Rubric. Rubric scores on the discussion sections of the reports were significantly higher in the CTA group than in the control, particularly for items connected to analyzing and using data to support valid conclusions, considering alternative explanations, and understanding the limitations and implications of the investigation. (The researchers did not anticipate finding differences in the introduction, methods, and data analysis and presentation sections of the results due to the common methodology established by the instructor and required for both groups). Results of the study, which used a quasi-experimental, double-blind design, thus support the hypothesis that use of CTA favors student performance on tasks that require use of inquiry skills. Additionally, the CTA treatment group had a significantly lower rate of attrition from the course than did the control group of students (although the rates of attrition in both groups were relatively low). The authors conclude by discussing the various reasons why they think that the explicit, precise, procedurally based CTA approach had value in this instructional context (learning about processes of scientific inquiry), and provide outlines of the protocols used in the CTA videos that could be informative to instructors considering adoption of the approach.

I invite readers to suggest current themes or articles of interest in life sciences education, as well as influential papers published in the more distant past or in the broader field of education research, to be featured in *Current Insights*. Please send any suggestions to Deborah Allen (deallen@udel.edu).

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