CBE—Life Sciences Education
Vol. 10, 8–10, Spring 2011

Feature
Current Insights

Recent Research in Science Teaching and Learning

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

This themed issue focuses on recent studies about the use of external representations (ERs; visualization formats such as three-dimensional models, graphs, diagrams, pictures, and simulations) in science education and the role they play in the formation of internal representations (mental models and visual imagery). The authors discuss the implications of their findings with respect to understanding students' difficulties with learning science and for the improved design of science curricula.

1. Catley KM, Novick LR, Shade CK (2010). Interpreting evolutionary diagrams: when topology and process conflict. J Res Sci Teach *47*, 861–882.

[Abstract available: http://onlinelibrary.wiley.com/doi/10.1002/tea.20384/abstract]

Modern college-level biology textbooks include diagrams that depict both cladogenic (branching events) and noncladogenic or anagenic (ordered linear progressions) perspectives on evolutionary history. (Speciation via cladogenesis occurs when a population is split into two or more populations that are subjected to different selection pressures; anagenesis is an accumulation of changes over time that leads to transformation of one species or taxon into another.) Although numerous studies have addressed how cladogenic representations are interpreted by students, this study explores the relatively uncharted terrain of the conceptualizations about evolutionary relationships evoked by noncladogenic diagrams. In a first substudy, 50 university students with a wide range of biology backgrounds viewed a pair of noncladogenic diagrams (one of which depicted "hominid" taxa) and then wrote responses to a set of questions about the evolutionary relationships depicted in them. For analysis, three researchers (working independently) assigned codes to the response data; the codes were used to represent variables within major categories such as the nature of evolutionary relationships, time, characters possessed by the taxa, and evolutionary mechanisms. In a follow-up study with 62 students, interpretations of specific evolutionary terms that appeared in the first set of analyzed responses were probed using questions about an unfamiliar context (a scenario about evolutionary relationships between relatively obscure taxa), with the assumption that prior knowledge would thus be less likely to influence the responses. The article discusses in detail the specific interpretations elicited by the diagrams and scenarios used in the two studies and how well these interpretations aligned with scientifically accepted views on the process of speciation (e.g., cladogenesis as the predominant process). The authors conclude that noncladogenic diagrams, although commonly included in college-level textbooks, can lead to misinterpretation of important aspects of macroevolutionary processes and therefore are educationally inappropriate (for this reason as well as others).

2. Schönborn KJ, Anderson TR (2009). A model of factors determining students' ability to interpret external representations in biochemistry. Int J Sci Educ *31*, 193–232.

[Abstract available: www.informaworld.com/smpp/content~db=all~content=a788637377~frm=abslink]

Although the literature contains numerous reports on the facets of student learning that ERs can mediate, and on how students interpret them (in intended as well as unintended ways), the authors contend that there is little empirical research on students' processing of the many types of ERs

DOI: 10.1187/cbe.10-12-0148
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used in the study of biochemistry. They address this deficit in part by the work reported in this article, which recounts the process of development and validation of a model of the factors that influence students' ability to conceptualize and reason about the types of diagrams commonly used in biochemistry textbooks. The article describes the five-stage iterative process by which the authors used a "model of modeling" framework adapted from Justi and Gilbert (2002) to develop the model and define its component factors. The authors describe operational definitions for the resulting seven-factor model (three major factors termed "conceptual," "reasoning," and "representation model," and the four possible interactions between these major factors) that emerged from the process and represent the model as a Venn diagram. They validated the model by analysis of data obtained from three 60–90-min audio- and videotaped interviews with nine third-year university students who had just completed a biochemistry module on immunology. Each interview was focused on the subject's interpretations of one of three different diagrams representing antigen–antibody interactions. The semistructured interview process used a series of questions to probe the subjects' conceptual knowledge prior to viewing the diagram (Phase 1), their reasoning processes and conceptual understandings during interpretation of the diagram presented to them (Phase 2), and their evaluation and critique of the ER and its utility for their learning (Phase 3). The questions were spontaneously modified and supplemented in the course of the interview to effectively probe each subject's unique responses to the original, scripted line of questioning. Analyses of the empirical data from the interviews were used to test the robustness of the operational definitions of the model. The article describes selected examples of the data and how they were used in the process of verifying that each factor of the model made an important contribution to students' ability to interpret the diagrams. The authors conclude by discussing the implications of the model for future research on and educators' understanding of how students use and learn from biochemistry-related ERs. The authors also emphasize the need for future studies to shed light on the transferability of their model to other areas of science and elaborate on the particular ways in which the model could inform instructional choices.

3. Yarden H, Yarden A (2010). Learning using dynamic and static visualizations: students' comprehension, prior knowledge, and conceptual status of a biotechnological method. Res Sci Educ *40*, 375–402.

[Full text available: www.springerlink.com/content/55682t6748672316/fulltext.pdf]

This study examines the contribution of dynamic versus static visualizations to students' understanding of molecular processes whose complexity and intangibility present barriers to learning of biotechnology-related laboratory methods. The study participants, 173 12th-grade biology students, were divided into an experimental group that used an animation to learn the polymerase chain reaction (PCR) method and a comparison group that used a series of static images reproduced from the animation. Both forms of visualization were accompanied by the same written texts that described what was being shown. A pretest documented students' knowledge of DNA replication and related topics prior to viewing the animation or images, and a posttest (designed to assess a range of thinking skills, including higher-order skills) probed their resulting understanding of PCR. Students worked in pairs and talked to one another about their learning but took the tests individually. Their conversations were videotaped, transcribed, and analyzed using a conceptual status framework that provided an inventory of students' understandings, beliefs about the consistency of what was presented in the animations or images and diagrams with prior knowledge, and sense of the utility of any new conceptions. Although the two study groups had comparable pretest scores, scores on the posttest were significantly higher in the group that learned through the animation. For the group that learned through the static images, regression analysis showed a high correlation between students' prior knowledge about DNA (pretest scores) and their resulting understanding of PCR (posttest): low pretest scorers tended to have low posttest scores. Pretest scores had no notable effect on posttest scores in the group that learned with the animation. The qualitative analysis of students' discourse led the authors to conclude that use of the animations was in particular more successful in addressing various mechanistic aspects of PCR than was use of the static visualizations.

4. Gray K, Steer D, McConnell D, Owens K (2010). Research and teaching: using a student-manipulated model to enhance student learning in a large lecture class. J Coll Sci Teach *40*, 86–95.

[Abstract available: www.nsta.org/publications/browse_journals.aspx?action=issue&thetype=all&id=10.2505/3/jcst10_040_01]

This study addresses the utility of using student-manipulated physical models and modeling activities in large-enrollment, college-level courses. The study context was seven sections of an earth science course for nonmajors (average section size about 150 students). The study was conducted during coverage of the Sun–Earth relationship and the causes of the seasons, topics that many college-level students find difficult to explain. All sections incorporated use of peer instruction and personal response systems ("clickers"). In five sections, students working in groups manipulated and discussed tennis ball/flashlight models of the Earth and Sun in a series of three activities. The activities were bookended by a premodel concept test and a lecture (about the tilt of Earth's axis and the nature of its incoming solar radiation) on one end and a postmodel concept test at the other. Students were encouraged to discuss postmodel concept test questions within their groups if the initial responses for the entire section showed an inaccuracy rate of 25% or greater, and then to tackle the question again. In the two comparison sections, students listened to a lecture on the causes of the seasons, completed the concept tests, and engaged in peer instruction related to problematic questions, but did not use the physical models. Incorporation of the models in five of the sections thus augmented use of an interactive pedagogy (informative testing with peer instruction) previously shown to be effective in numerous other studies. Classroom observations and interview data about students' perspectives on model use supplemented the quantitative data (concept test responses) collected via the response systems. The authors found that the sections using the models showed significantly greater improvement in concept test scores and that the students used and valued the use of the models as an aid to understanding the underlying concepts and as a visual reference for recalling them, evidence in favor of overcoming the logistical barriers for "hands-on" model use in large-enrollment classrooms.

5. Chang J-Y, Quintana C, Krajcik JS (2010). The impact of designing and evaluating molecular animations on how well middle school students understand the particulate nature of matter. Sci Educ *94*, 73–94.

[Abstract available: http://onlinelibrary.wiley.com/doi/10.1002/sce.20352/abstract]

This study investigated the effect of participation in a sequence of modeling activities on middle school students' understanding of the particulate nature of matter. Previous studies have shown that although various types of physical models can help ameliorate the difficulties that the abstract nature of atoms and molecules can present for learning fundamental chemistry concepts, the use of animations alone might not be an effective aid for overcoming these difficulties. This study was therefore designed to tease out the comparative benefits of middle school students' use of animations in three contexts: as part of a combination of activities in which students constructed, interpreted, and evaluated (critiqued one another's) animations (Treatment 1); as part of construction and interpretation activities only (Treatment 2); or as part of viewing and interpreting teacher-generated animations. Three seventh-grade teachers from different schools, along with 271 of their students (from eight classes), participated in the study. Students in a given class were randomly assigned to one of the three treatment groups for participation in three chemistry lessons that incorporated use of Chemation as a tool to support their learning. Chemation is a program for visualization, construction, interpretation, and exchange of models and animations of atoms and molecules that runs on handheld computers; all participating teachers and students were experienced users of Chemation. The three treatment groups completed the same pre- and postinstructional chemistry achievement tests, which assessed lesson-related content knowledge and content knowledge in combination with animation constructing, interpreting, and evaluating ability. Students also wrote down their interpretations of the animations they viewed or constructed and their connections to the macroscopic phenomena relevant to the lessons. The researchers used two-factor analysis of covariance to analyze the effects of different treatments on the test scores, and they developed and used two separate coding schemes to assess the quality of the student-generated animations and of the students' interpretation of animations. They found that the quality of the student-generated animations was higher with Treatment 1 (construction, interpretation, and peer evaluation activities) versus Treatment 2 (no peer evaluation activities). Students' interpretations of the animations were also significantly better in Treatment 1 than in either Treatment 2 or 3 (interpretation of teacher-generated animations); the lack of significant difference between Treatments 2 and 3 indicated that interpreting ability was as good in students who only viewed animations as it was in students who constructed them. The analysis of the test scores revealed that in this context, student design of animations coupled with peer evaluation (Treatment 1) had a significantly positive impact on student achievement in chemistry (as compared with viewing teacher-generated animations, Treatment 3). However, the authors caution that the results did not favor the use of a "design-only" approach (Treatment 2); in the absence of student engagement in peer evaluation of the animations, the value to students' learning of chemistry appeared to be on a par with that of viewing teacher-generated animations.

The following are recent *CBE-LSE* articles on use of ERs:

6. Dahmani H-R, Schneeberger P, Kramer IM (2009). Analysis of students' aptitude to provide meaning to images that represent cellular components at the molecular level. CBE Life Sci Educ *8*, 226–238.

7. Harris MA, Peck RF, Colton S, Morris J, Neto EC, Kallio J (2009). A combination of hand-held models and computer imaging programs helps students answer oral questions about molecular structure and function: a controlled investigation of student learning. CBE Life Sci Educ *8*, 29–43.

8. O'Day DH (2007). The value of animations in biology teaching: a study of long-term memory retention. CBE Life Sci Educ *6*, 217–223.

I invite readers to suggest current themes or articles of interest in life science 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).

REFERENCE

Justi RS, Gilbert JK (2002). Modeling teachers' views on the nature of modeling, and implications for the education of modelers. Int J Sci Educ *24*, 369–387.