Interpretation, invention, and interaction: How students (mis)understand cladograms

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This series of projects investigates three different facets of undergraduate students' understanding of cladograms, from graphic interpretation, to representational invention, to interactive design. The driving goal across them is to inform and develop an effective instructional application that will support learners making sense of this difficult scientific representation.

Method & Results—Animated cladograms: The errors students make when reasoning with cladograms are well-documented in prior research (Gregory, 2008; Halverson, Pires, & Abell, 2008; Meir, Perry, Herron, & Kingsolver, 2007). In this project, we seek to understand why and how these misreadings occur. The process of interpretation, we posit, involves an interaction between semiotic, perceptual, and prior knowledge assumptions on the part of the viewer. In 152 individual interviews, undergraduate students viewed one of four different presentations of the same cladogram, of which they were asked to interpret various structural elements, and to reason about the relationships depicted. All students were at least aware of the misconceived folk theory of evolution, in which a simple, primitive ancestor gradually transforms into a more sophisticated and complex mammal. We observed that the visual structure of the cladogram cued interpretations based in a folk theory of evolution, in which thematic elements of the narrative mapped onto structural elements of the cladogram. When we used animation to alter the external narrative depicted in the diagram, we observed that viewers' internal narrative understandings of it changed. Our manipulation showed that certain assumptions made when interpreting cladograms, such as spatial metaphors, are more flexible than others, such as Gestalt perceptual processes (Novick & Catley, 2007), and prior knowledge of a folk theory of evolution. A better understanding of why students make these errors may guide designers and educators preparing suitable interventions.

Method & Results—Invented cladograms: Given that the representational system of cladograms is so difficult for novices to comprehend, we sought to find whether there are more intuitive ways for graphically depicting phylogenetic relationships. In 22 individual interviews, we asked undergraduate students to invent representations to depict the relationships between a group of children with shared toys, or between a group of animals with shared morphological traits. They were asked to explain their invented representations, and then to make sense of a standard cladogram of the same data. In our ongoing analysis, we expect to find that inventing systems of representation that are personally meaningful will prepare students to better understand the standard cladogram's system of representation; but that the kind of representation invented will frame the meaning students later make—whether in an advantageous or detrimental manner—of the standard cladogram. Ultimately, we hope our observations will suggest a representation of phylogenetic relationships that might bridge the gap between novice and expert understanding (Roschelle, 1996); and inform an effective sequence of instruction for improving representational competence with cladograms.

Ongoing Research—Interactive cladograms: As our research thus far indicates, a major hurdle to grasping the representational system of the cladogram is its confinement within a flat, two-dimensional space. Frozen on the page, novice viewers can only assume the conventions for reading other kinds of static diagrams, and consequently, they overlook that the cladogram is in fact a three-dimensional structure. In response, we are designing and building a Flash-based computer application that will allow the user to compare, build, and manipulate phylogenetic representations. It is intended for use by teachers conducting interactive demonstrations, for students learning independently, and as an interactive museum display in an evolution-themed exhibit. Our underlying theoretical motivations for the design are that removing viewers from the perceptual conventions of 2D representations, overriding diagrammatic cues to a folk theory-based interpretation, facilitating understanding through multiple representations (Ainsworth, 2006), and encouraging the construction of personally meaningful representations (Edens & Potter, 2001; Gobert & Clement, 1999;

Kiili, 2003; Papert & Harel, 1991), will all facilitate learners' sense-making of cladograms. We will conduct observations and interviews with students using this interactive application in an undergraduate biology course.

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