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Epistemological Resources

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Abstract: Research on epistemologies has presumed a unitary ontology of "beliefs"; we propose a manifold ontology of "resources" and discuss implications for instruction.

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Epistemological beliefs are beliefs about knowledge and learning (see Hofer & Pintrich, 1997a for review). Some physics students, for example, may believe learning consists of memorizing formulas provided by the teacher, while others may believe it entails applying and modifying their own understandings (Hammer, 1994). Awareness of these beliefs can provide teachers an alternate perspective into students' behavior. E.g. rather than see students as lacking common sense, a teacher could see them as believing common sense is irrelevant.

Research on epistemologies has mostly emulated research on conceptual knowledge in assuming students possess articulate, context-independent "mis-beliefs" (Hammer & Elby, in press). That is, just as research on conceptual understanding has assumed naïve physics to be made up of "misconceptions" (e.g. "motion requires force") that differ from expert conceptions ("acceleration is caused by force"), research on epistemologies has understood students to have "misbeliefs" (e.g. "knowledge is certain") that differ from expert beliefs (e.g. "knowledge is tentative"). On this view, developing a more sophisticated epistemology requires changing beliefs, just as developing more sophisticated domain knowledge requires the replacement of misconceptions with correct conceptions. In neither case could the naïve constructs be understood to contribute to that development.

This unitary ontology presents a number of difficulties. In considering naïve epistemologies to be made up of constructs such as "knowledge is certain," current perspectives offer no account of the raw material from which students could develop new beliefs, as (Smith, diSessa & Roschelle, 1993/1994) argued regarding misconceptions. Second, just as evidence from interview protocols (diSessa, 1993; Tytler, 1998) suggests naïve reasoning in physics is not generally consistent in the manner a misconceptions account implies, there is evidence of inconsistency in student epistemologies, across disciplinary domains (Hofer & Pintrich, 1997b) and across contexts within a given domain (Leach, Millar, Ryder & Séré, 1999). Finally, there is a substantive difficulty with the assumption that epistemologies consist of context-independent beliefs (Elby & Hammer, submitted). This requires unitary assessments of sophistication, e.g., that "knowledge is tentative" is more sophisticated than "knowledge is certain," when in some contexts that clearly does not hold (e.g. regarding knowledge that the earth is round instead of flat).

These considerations suggest that an adequate model should be comprised, at least in part, of fine-grained epistemological resources, analogous to diSessa's (1993) "phenomenological primitives" (or "p-prims") in intuitive physics. On this view, a naïve epistemology draws on these resources, activating them—sometimes appropriately, sometimes not—in a manner that is sensitive to context. Furthermore, students presumably possess epistemological resources that could help them learn physics, but activate them only in other contexts. For example, many students appear to view scientific knowledge as coming from authority. Still, even small children have epistemological resources for understanding knowledge as invented ("How do you know your doll's name is Ann?" "I made it up!") or knowledge as inferred ("How did you know I brought you a present?" "I saw you hide something."). We have begun to try to characterize naïve epistemologies as made up of resources such as these (Hammer & Elby, in press):

Knowledge as propagated stuff: Someone invoking this resource treats knowledge as a kind of stuff that can be passed from a source to a recipient. This stuff is not "conserved": the source does not lose any knowledge. In this sense, knowledge is like fire, or sickness, or a state of contamination. *Knowledge as free creation*: Invention is a common experience for children, and "I made it up" a routine explanation for the origin of many ideas, including stories, imaginary characters, and games. Knowledge by this resource does not have any source other than the child's mind, where it arises spontaneously. *Knowledge as fabricated stuff*: Children may also think of knowledge as inferred or developed from other knowledge. Thus the answer to "How do you know?" is "I figured it out from [the source material]." An adequate framework should include many other resources as well, regarding the nature of knowledge, stances ("trusting," "rejecting," "doubting"), and forms (e.g. "stories," "rules," "rules systems") and activities (e.g. "guessing," "listing," "comparing") (Collins & Ferguson, 1993).

Epistemological Anchors and Instructional Strategies

There is much, however, we may infer simply from the notion that students have such resources. Clement, Brown & Zeitsman (1989) described productive conceptual resources as "anchoring conceptions." E.g, introductory physics students often have difficulty understanding the Newtonian idea of a *passive force*, such as the force exerted upward by a table on a book. Part of that difficulty is in their understanding how a table can "exert" a force. Students easily see a compressed spring as exerting a force, however. This can serve as an anchoring conception, as "bridging analogies" (Clement *et al* 1989) help them regard a table as a very stiff spring (Minstrell, 1982).

Similarly, the notion of context-dependent epistemological resources suggests the strategy of looking for "epistemological anchors." Rather than understand student epistemologies only in terms of counter-productive misbeliefs to be exposed and confronted, a teacher may understand students as having productive epistemological resources they naturally invoke in other contexts. For example, we have used the following story as an analogy to promote metacognitive reflection in physics students:

> "Imagine you have met a new person and he irritates you for some reason you can't put your finger on. So you think about it, trying to figure out what it is about him that bugs you, and eventually you realize that it's because he looks and sounds a bit like a character in a movie you saw recently. Having figured that out, you know that it's not really this new guy who irritates you, but that movie character, and you don't have to worry about it any more. Or, you may realize you've met him before and had an unpleasant interaction, in which case there's good reason for that feeling of irritation."

This may serve as an epistemological anchor to help students understand the phenomenon of having an intuitive sense that a physical object will behave in a certain way, but not being able to explain why. For example, although Newton's First Law says that an object moves at a constant velocity if there are no forces acting on it, most students have the intuitive sense that the motion will die away. The analogy may help students understand the importance of looking into the experiential bases for that sense. Other anchors may include activities of arranging furniture, to activate resources for thinking of ideas as connected ("If the sofa's by the door, the bookcase only fits by the chair"), and of giving directions to a traveler, to activate resources for understanding the importance of precision.

An Agenda for Research

Research on epistemologies has depicted students as holding context-independent, counter-productive epistemological theories, just as research on conceptual knowledge has been dominated by views of alternative frameworks and misconceptions. Recent work in intuitive physics (diSessa, 1993; Clement *et al* 1989; Brown, 1993) has begun to describe students' conceptual resources; the difference has instructional significance (Hammer, 1996). We are beginning a program of research to identify students' productive epistemological resources and epistemological anchors; here we have argued this will have instructional significance as well.

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