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Distinguishing Between Understanding and Belief

SANDRA, A FIFTH-GRADE TEACHER, has just completed a science unit on molecules, and her class has done well on the unit test that she just handed back. After going over the test, the class heads to recess. Sandra overhears one student who received a high test score asking another, "Do you really believe that stuff about molecules?" The other replies, "No way!" The teacher has never heard such an exchange in 10 years of teaching. She wonders if it is rare for students to disbelieve ideas they have encountered in class or if this occurs regularly and she has just never noticed. In this article, we will show that students frequently do *not* believe what they are learning in school, in science, and in other classes. Because of this, teachers must seriously consider the role of persuasive teaching in their classes.

A key distinction that underpins this article is the distinction between understanding an idea and believing that idea. We think that educational theory and practice have been hampered by a neglect of this distinction. Most theoretical and practical work has conceptualized learning as knowledge change. However, the conceptualization of learning as changes in *knowledge* confuses changes in *understanding* with changes in *belief*. This confusion can lead to mistaken conclusions about how to plan instruction.

This article is divided into three parts. First, we discuss the distinction between understanding and belief. We provide an illustration showing that teachers' interpretations of what students have learned can be seriously in error when they do not consider both understanding and belief. Second, we present some examples to show that students' understandings and beliefs often diverge, which makes it necessary to take both into account when thinking about what students are learning. Many of our examples are drawn from science, because most of our own research is in this area. But we think divergences between understanding and belief occur in other school subjects, as well. Third, we discuss implications for teachers. These implications center on a metaphor of teaching as persuasion.

Understanding and Belief

It is easy to think of instances in which students understand—or at least partly understand—an idea learned in school while believing a completely different idea. Creationists studying evolution may arrive at a good understanding of evolutionary theory but still believe creationism. Psychology students may develop a good understanding of B.F. Skinner's behaviorist principles while believing a more cognitive theory themselves. Teachers generally recognize that their students may understand ideas without believing them when they are covering controversial issues (e.g., creationism; the causes of

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global warming; religious doctrines) or historically important ideas that are no longer widely believed (e.g., Greek mythology; the ancient scientific theory that matter is made of earth, water, fire, and air).

In contrast, researchers and teachers typically fail to distinguish between belief and knowledge when students learn uncontroversial topics that are widely accepted as correct or factual (e.g., the structure of the cell, the main events in the American Civil War). And yet the distinction is equally important in such situations. Although experts may both understand and believe these ideas, students often do not, and this has important consequences for learning, instruction, and assessment.

For these uncontroversial topics (which dominate the curriculum), learning is typically conceptualized as "knowledge acquisition" or "knowledge building" (e.g., Bereiter & Scardamalia, 1993; Carey, 1991). Students are often viewed as constructing a single knowledge structure; they are either tacitly assumed to believe this knowledge structure, or belief is ignored altogether. By contrast, when we distinguish between understanding and belief, we assume that students learning a new topic in school may construct at least two separate conceptual structures. One structure is their understanding of the ideas they are being taught; the other structure is the set of ideas that they themselves believe. In making this assumption, we are drawing on ideas of 20th-century philosophy and applying them to education (Alcoff, 1998).

To illustrate the importance of making the distinction between understanding and belief, we present a hypothetical example (but one based on our research programs) of a middle-school teacher who has just given her students a formative assessment of their basic understanding of molecules. The teacher implicitly conceptualizes the learning process as students constructing single knowledge structures; she is not thinking in terms of understanding and belief. The teacher, however, has a good grasp of the kinds of questions that are needed to uncover students' conceptions of matter. We will consider just a few of her questions.

She first asks the students to draw a picture of what water molecules look like and asks several questions about their pictures. She then asks other questions to find out whether students can apply their knowledge to explain a variety of physical phenomena, such as why water can be poured and why water expands when it freezes.

We consider the answers of five students to these questions. Two students (Juanita and Aaron) give correct answers to all of the teacher's questions. Asked to draw water molecules, they both draw appropriate pictures. Both write that water molecules can be divided, that the parts make up gases rather than water, and that there are empty spaces between the molecules. Both students give excellent answers to the wide range of transfer questions. The teacher concludes that both students have successfully constructed basic *knowledge* of the molecular structure of water and that both are ready to move on to other topics.

When we take belief as well as understanding into account, however, we find that the picture is more complex. It is true that both students *understand* the molecular model of water, but when we examine their beliefs, we find that neither *believes* it.

- Juanita thinks to herself, "If molecules are too small to see, how do scientists know they really exist? Maybe they just made all of this up." Although Juanita does not have a model of her own, she does not believe it is reasonable to think that molecules really exist.
- Aaron understands the model he was taught well enough but does not believe it. "It's crazy to think that something wet could be made of hard particles," he thinks. He knows that on the exam he is supposed to write what the teacher has taught, so that is what he does. But if the teacher were to ask Aaron what he really believes, she would find that he has his own separate model: he thinks that water is simply water through and through and is not made up of particles of any kind.

Three other students (Brooks, Susan, and Emily) all provide answers that suggest that they have constructed their own alternative theory that water molecules consist of round, thin shells with water inside. When asked to draw pictures of molecules, they all draw round circles. They write that molecules can be divided, and that water escapes from inside the shells when they are divided. All three students answer the transfer questions according to this water-in-shells conception.

The teacher concludes that these students have constructed a water-in-shells model, and that the next instructional steps for these students is to provide better explanations of the molecular model of matter so as to help them construct the accepted scientific knowledge. But once again, the picture becomes much muddier when we view learning as changes in both understanding and belief:

- Brooks actually *does* understand the scientific model (which we would find out if we asked him what scientists believe about all of the questions), but when answering the questions, he decides to write what *he* believes, which is the water-in-shells model. The assessment thus fails to show that although he has an understanding of the molecular model, he does not believe it.
- Unlike Brooks, Susan has a *mis*understanding of the scientific model (she thinks that scientists believe that there is water rather than empty space between the water molecules). However, like Brooks, she decides to write down what *she* believes, which is the water-in-shells model.
- Emily has a misunderstanding of the scientists' model that differs from Susan's; she thinks scientists believe the water-in-shells model. She herself believes, as Aaron does, that water is simply water through and through, without any constituent particles. She writes down what she thinks the scientists believe because she knows this is expected on school exams.

The teacher's interpretation of all three students' conceptions is off the mark. Because she has not assessed both understanding and belief, the teacher does not find out that each of the three students has a different understanding of what scientists believe, that Aaron and Emily share a believed model that differs from Susan's beliefs, or that all three students have understandings that differ from their beliefs. As a result, her planned instruction for these students does not address their actual instructional needs.

Our point in presenting this extended example is to show that when one conceptualizes learning merely as knowledge change, one gets only a partial view of the true learning process, which can involve changes in both understood models and believed models. By not distinguishing what is understood from what is believed, the teacher mistakenly concludes that Juanita and Aaron have made the desired knowledge changes, and that Brooks, Susan, and Emily have all adopted the water-in-shells model. In reality, the situation is much more complex.

We would argue that researchers have consistently made the same conceptual mistake that this hypothetical teacher has. The research literature shows almost no attempts to separately assess what students understand and what they believe (e.g., see the studies reviewed in Guzzetti et al., 1993). As a consequence, when students answer questions in existing studies, we do not know if they are reporting what they believe, what they understand (but do not believe), or some mixture of the two.

Divergence of Understanding and Belief

Our argument has assumed that when students are learning, they at least sometimes construct two separate conceptions: one conception that they believe and another that corresponds to their understanding of the ideas presented. This is obviously true when a student learns about another religion or when a creationist student learns about evolutionary theory. But is it true of more mundane subject matter? Do students learning more conventional topics in science, history, math, and other school subjects construct understandings that are separate from their own belief structures? In this section, we present several examples from our own research on science learning that show that they do, and we briefly note some additional examples in other subject areas.

In a study of Indian children's knowledge of astronomy (Samarapungavan, Vosniadou, & Brewer, 1996), one 7-year-old was interviewed and gave answers that consistently indicated a belief in the heliocentric model of the universe. The next day at lunchtime, Neeta approached the interviewer and asked whether the earth really moved or whether the sun and moon moved around the earth. The interviewer asked Neeta what she really thought. Neeta responded that according to her teacher, the earth spins on its axis to cause the day/night cycle, but that she thought that the sun and moon went up and down, from ocean to sky and back, to cause the day/night cycle.

If Neeta had not approached the interviewer, we would have had no idea that her own beliefs diverged from what she had originally said. This example shows that researchers, including ourselves, have typically failed to recognize the need to investigate students' beliefs as well as their understandings. We simply do not know from this study how many other students were like Neeta, or whether there were other students who mixed beliefs and understandings in more complex ways when they responded to the interviewer's questions.

Several studies recently completed by Chinn and colleagues have tracked changes in both understanding and belief as students of various ages have studied scientific concepts. These studies have used the simple procedure of asking students first to explain what scientists believe and then to explain their own beliefs. The studies have consistently shown that many learners of all ages are ready to assert that what they believe is different from what scientists believe.

For example, in one study in which undergraduates read eight short scientific passages presenting counterintuitive scientific ideas that are universally accepted by scientists, 87 percent of the undergraduates professed disagreement with the scientists on at least one of the eight topics, and 64 percent disagreed with the scientists on at least two of the topics (Chinn, 2001). Nakhleh (1994) similarly found that undergraduates often understood but did not believe the proposition that molecules are constantly moving in some solids such as wood.

In a study with sixth graders, Chinn and Malhotra (2001) found that 76 percent disagreed with scientists' ideas at least once as they observed and responded to several science experiments. In these studies, students show that they do not blindly accept what they learn based on authority. But we do not yet understand why they decide to agree with the scientists on some occasions and to disagree on other occasions.

In another study, Chinn and Nelson (2001) investigated what middle-school students learned as they read carefully designed explanations of molecular theory. The explanations were effective at promoting improved understanding of molecules, but most students indicated they did not believe some important aspects of the molecular theory. The students were asked to draw pictures of what water, gasoline, steel, and plastic would look like through a microscope powerful enough to show what these substances are made of. First they drew the pictures and answered related questions according to what they had learned from the text. Then they drew and responded according to their own beliefs. Most students explicitly acknowledged holding beliefs that differed from scientists' beliefs on one or more substances.

To illustrate some of the ways in which understanding and belief can differ, Figure 1 displays three pairs of drawings made by children who exhibited differences between understanding and belief. Figure 1(a) shows pictures drawn by a student who seems to have generally understood the scientific model but has a different belief of her own: there is water between the molecules, and the molecules look different from the molecules in the scientific model. Figure 1(b) shows a common situation in which students develop a misunderstanding of the scientific ideas and have a still different conception that they themselves believe. Figure 1(c) shows an interesting case of a child who had previously learned a different representation of molecular bonds (the ball-and-stick model) and believed that this is the way water *really* looks. He correctly understood the model described in the text but thought that this model was wrong and the ball-and-stick model was correct. This example shows that students may treat conceptually equivalent diagrammatic representations as substantively different theories.

So far we have provided examples from our own research, all of which suggest that researchers and educators alike will not understand the learning process without considering both understandings and beliefs. Although the needed research has not yet

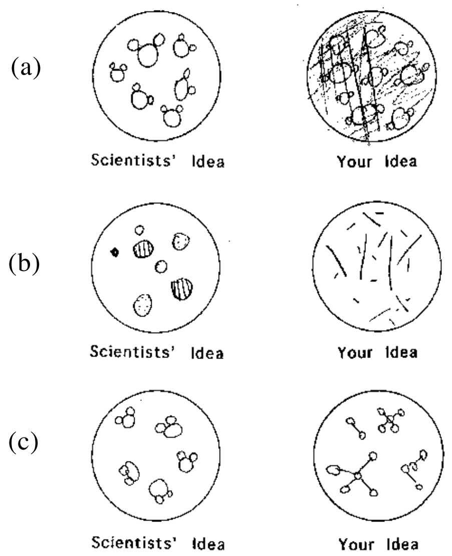

Figure 1. Middle-school children's drawings of what scientists think water is made of and what they think water is made of.

been conducted, we think that the same will prove to be true of many other subjects besides science. For example, preliminary results from an interview study by Samarapungavan suggest that some first graders develop a conception of mathematics as a gamelike, arbitrary manipulation of symbols that does not, they believe, correspond to anything in the real world. A foreign language teacher recently told Chinn that her high school students have sometimes questioned the accuracy of what she teaches them, despite the fact that she is a native speaker of the language. Furthermore, in the important area of strategies for studying and learning, Dole, Brown, and Trathen (1996) provided a case study of a sixth grader who understood how to use a story-mapping strategy but resisted using it because she did not believe it was useful.

Examples such as these suggest that the distinction between understanding and belief is likely to be important in many areas of the curriculum. To understand how students learn, it is important to understand the course of both belief and understanding and the interplay between the two. If educators do not consider both, they will make mistakes in their judgments about what students know and what they have yet to learn.

Implications for Teachers: Teaching as Rational Persuasion

The research showing that belief and understanding often diverge has important implications for teachers. This research suggests the value of adopting the metaphor of teaching as persuasion, with persuasion viewed as a rational process based on reasoned argumentation. This rational persuasive process should be founded on respect for students' conceptions rather than on any pressure to adopt new conceptions. We discuss several specific implications for teachers below.

1. Decide when you are willing to try to persuade students to change their beliefs. Our finding that students frequently do not believe widely accepted theories suggests that teachers should sometimes view their teaching as persuasion. Because persuasion seems somewhat coercive, teachers are often uncomfortable with viewing themselves as persuaders (Dole & Sinatra, 1999). Yet almost everyone would prefer that civil engineers actually believe the well-established principles of building safe bridges that they learn in their engineering classes. And most would hope that their students will believe that active study methods such as elaboration and explanation will improve their performance in school. We think teachers will need to develop their own ethical criteria for deciding which situations merit persuasion and which merit only the promotion of understanding.

2. When conducting formative assessments, consider assessing both understanding and belief. The examples we have shown emphasize the importance of gathering information about what students understand *and* what they believe. Teachers may draw incorrect conclusions about what students need to learn if they do not gather both types of information. Moreover, teachers cannot decide whether persuasion should be a goal of instruction without information about students' actual beliefs.

3. When conducting assessments for grades, consider assessing only understandings. We think teachers should consider avoiding the use of generic questions on exams, such as "What is the shape of the earth?" and replacing them with questions directed clearly at understanding, such as "According to scientists, what is the shape of the earth?" The first kind of question may be ethically objectionable in many situations.

To illustrate, consider what happens when Neeta, the Indian girl we discussed earlier, is asked the generic question, "What is the shape of the earth?" This question implicitly assumes that there is a correct answer and that Neeta should believe this answer. Such a question places a child like Neeta in a dilemma. Should Neeta write what she really believes (the earth is flat), or should she write what the teacher will count as a correct answer (the earth is round)? Given that the physical evidence available to a 7-year-old seems to support Neeta's theory quite well (the earth does appear to be flat!), we would argue that students should be allowed to describe the earth's shape according to what scientists believe without being compelled to pretend to believe the scientists' ideas.

When students are introduced to more of the evidentiary basis for these ideas, assessments should also ask students to show their understanding of this evidentiary base, but even then, we would suggest that it is unfair to grade students according to whether they believe this evidence. If students are graded on whether they say they believe the evidence, they will often only pretend to believe, and no real persuasion will take place.

4. Present much more evidence in support of topics covered in class. As soon as teachers realize that students often choose not to believe ideas that they understand, it becomes clear that much more instructional time should be devoted to giving students access to a broader base of evidence in support of important conceptions. Students will be rationally persuaded only if they are given good reasons to support new conceptions.

Accomplishing this goal will be difficult, because at no level of education until graduate school is there a focus on the evidentiary basis for believing ideas. In middle schools, high schools, and even colleges, textbooks simply present the accepted canon of knowledge, with little evidence presented that would support belief. Yet students need extensive evidence to understand why anyone would believe that substances are made of molecules, or why historians think economics was an important cause of the American Civil War. Even if students do not believe the evidence is adequate, it is valuable for them to have an understanding of what the evidence is.

5. Show students that new ideas are not inconsistent with current experiences. Students often have experiences that seem inconsistent with new information but, in fact, are not. For instance, students' everyday experiences indicate that solids such as steel look completely solid, and these experiences seem inconsistent with the idea that solids are made of molecules with empty space between them. If teachers show students a picture of an apparently solid green square that proves on closer examination to be made of thousands of dots with spaces between them, students may see how something that looks solid might not be solid in reality. Although this does not constitute actual evidence for the molecular theory of solids, it can help students understand how the molecular theory could possibly be true. Showing students that new ideas are at least plausible can be an important part of persuasion.

6. Help students understand principles of expert reasoning. We do not think there is time in the curriculum to provide an extensive base of evidence for every single topic covered in school. However, it is possible to provide students with better grounds for believing topics by providing them with a better understanding of the methods experts generally use to support their ideas. When we read an article in *Scientific American,* for example, we usually believe what we read because we believe scientists generally employ reliable methods, and we have an understanding of what these methods are and what their limitations are. Students should learn about methods of authentic research (not oversimplified cookbook-style methods) so they have a genuine appreciation for why methods used by scientists, mathematicians, historians, and other scholars can yield trustworthy conclusions (Chinn, 1998). This approach places persuasion on a more rational basis.

7. Encourage students to suspend belief as they try to understand complex new conceptions. Students might often distort difficult ideas they are learning because they try too soon to fit these ideas into their own belief systems. For example, Chinn (1997) found that many middle-school students learning about molecules seemed to distort key ideas about molecules immediately upon encountering them to make the new ideas fit their prior beliefs. These students might have been better off to try to understand the new molecular model on its own terms without worrying right away about whether the model was believable.

When students are learning complex new theories, such as molecular theory or modern economic theory, it is unlikely that these theories will seem believable until students construct a conceptual structure that is sufficiently elaborated for them to begin to see the explanatory power of the theory. Therefore, students should learn to try to understand new theories in their own right, as mature scholars do, without distorting ideas to make them fit their own beliefs.

One way to accomplish this goal is to give students ample practice at constructing and contrasting alternative conceptual structures, some of which are not believed (cf. Cavalli-Sforza, Weiner, & Lesgold, 1994). Teachers can develop tasks in which students (a) contrast expert ideas with their own ideas, (b) contrast opposing ideas held by different classmates, or (c) contrast two rival ideas that were important historically. Such tasks give students practice at constructing elaborated understandings of theories that they do not yet believe. And the tasks can help students appreciate the value of understanding theories on their own terms before leaping to conclusions about what to believe.

One approach to helping students understand complex conceptual structures is to present them with good explanations. Recently, many educators have worried that they should not present explanations to students, because it is not right to expect students to believe explanations on the basis of authority (e.g., Hynd, 2000). Instead, many argue that students should be allowed to develop their own conceptions strictly through exploration or guided discovery (e.g., Tinker & Thornton, 1992). While exploration and guided discovery are worthy instructional methods, we think explanations are also valuable.

It seems to us that the objection to explanations makes sense only if one assumes that students feel compelled to believe the explanations they encounter. The research summarized in this article shows that many students feel no such compulsion, even in science. Moreover, if teachers explicitly encourage students to try to understand theories without necessarily believing those theories, then the explanations can be directed squarely at promoting understanding rather than at promoting belief. Rationally grounded persuasion will be more likely if students have opportunities to develop an accurate understanding of the target theory.

Conclusion

Our central recommendation is that both researchers and teachers should begin to gather information about students' beliefs as well as their understandings in order to develop more accurate theories about the real learning process, which can involve changes in belief as well as changes in understanding of new ideas. By finding out about both, researchers and teachers will develop a much better understanding of the learning process and how to facilitate learning through a process of rational, evidence-based persuasion that respects students' rights to make up their own minds.

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