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ABSTRACT

Noting that children and adults often hold misconceptions about topics in content area texts, particularly those in the area of science where counter-intuitive notions about how the real world works abound, a study examined the effect of activating students' background knowledge about motion theory prior to asking them to read a physics text. Subjects included a group of 38 students who demonstrated incorrect prior knowledge of motion theory in two pretests. Students were provided with two types of texts. The refutation text consisted of information regarding certain principles of motion, but it discussed those ideas as being in contrast with students' intuitive ideas. The nonrefutation version described Newtonian mechanics but did not discuss any of the ideas as being in contrast with commonly held misconceptions about motion theory. Posttest results revealed that the refutation text was more effective at getting students to change their prior misconceptions about the principles of motion. It did not make any difference if students were asked to activate their prior knowledge or not. In lieu of refutation text, it was recommended that teachers use an anticipation-reaction guide or George Posner's and others' four-step model of conceptual change instruction to dispel students' counter-intuitive notions. (HOD)

College Reading and Learning Assistance
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The Role of Refutation Text in Overcoming Difficulty With Science Concepts

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This article examines the role of refutation text (or text which contrasts correct ideas with incorrect ones) in bringing about conceptual change learning. Suggestions are also offered on how teachers can compensate instructionally for science textbooks that contain counter-intuitive notions which are not refuted in print.

The Role of Refutation Text in Overcoming Difficulty With Science Concepts

Children and adults often hold misconceptions about topics in content area texts, particularly those in the area of science where counter-intuitive notions about how the real world works abound. Physics texts are known to be especially rich in information that runs counter to many individuals' sensory experiences and/or previous school learning. McCloskey (1983), for instance, postulated that physics students have difficulty in understanding the principles of motion because of intuitive misconceptions. These misconceptions, he said, may occur because of "optical illusions" experienced when an object's motion is viewed from certain vantage points. For instance, to someome who is viewing from the ground, an object which is dropped from an airplane may seem to fall straight down because the plane is moving at such a rapid rate that the plane is ahead of the object when it hits the ground.

McCloskey found in his study that roughly a third to a half of his physics students had misconceptions about physics that resembled the impetus theory that was held by philosophers several centuries before Newton's time. Early philosophers believed that an object maintained its projectile because of an inner force which was acquired when the object was set in motion. According to impetus theory, a ball which is whirled in a circle at the end of a string would continue to travel in a circle if the string were broken because of circular impetus.

Not only do sudents have misconceptions about physics and other areas of science, but these misconceptions seem to persist. Champagne, Klopfer, and

Anderson (1980) found that misconceptions about classical mechanics sometimes persist in spite of adequate instruction.

With few exceptions (most notably Maria and MacGinitie, 1982, 1983; Roth, 1985), reading researchers have not examined the role of refutation text--text which contrasts correct ideas with incorrect ones--in bringing about conceptual change learning (Posner, et al., 1982) in science. In the present study, we extended the previous work with refutation text in two ways. One, we chose a more complex text that refuted the notion of impetus theory in favor of Newtonian mechanics. The complexity of the task necessitated using an older student population than had previously been studied. Two, we considered the possibility that more than refutation text structure would be needed to get students to relinquish their misconceptions about projectile motion. To test this hypothesis, we looked at the effect of activating students' background knowledge about motion theory prior to asking them to read the physics text.

Finding Students with Misconceptions

A group of 40 students from a developmental studies program in a small southeastern college were chosen for this study. These students were enrolled in a course designed to increase reading ability as part of an overall program for students who entered college with low high school grades, low SAT scores, or a combination of both. It was postulated that this population of students might be at a higher risk than regular college students for holding misconceptions about difficult science principles. As part of the study, they were given a vocabulary and a true-false pretest. The vocabulary test consisted of 15 true-false statements pertaining to vocabulary from the two texts used in the study. The other pretest consisted of 19 true-false statements concerning physics principles. The items were constructed so that false items supported common misconceptions about motion theory, while true items supported Newton's theory of motion. Half of the students had their prior knowledge activated. These students were required to choose the correct path of a projectile after studying a picture that depicted four hypothesized paths of an object which is pushed off a cliff (see figure 1). They then explained in writing why they chose the path.

Insert figure 1 about here

We found very few students who were free of misconceptions about the path a projectile would take (see figure 1, from McCloskey, 1983). Twenty-one percent of our sample incorrectly chose path A, 63 percent, path B, and 0 percent, Path D. Only 16 percent chose C, the correct answer, and of those 16 percent, only two students included an explanation which did not resemble impetus theory. Asking students to explain in writing why they chose a particular path revealed the nature of their misconceptions about motion theory. For example, those who chose path B explained that the projectile fell after it traveled in a straight line for awhile because the force within it gradually lessened, causing the projectile to begin to curve downward before falling straight down (impetus theory). Those students demonstrating incorrect prior knowledge were retained for the study, while those demonstrating correct knowledge were eliminated, leaving 38 subjects.

Two Versions of the Physics Text

We provided students with two types of texts concerning the same principle of motion theory. The refutation text was adapted from a text used by Garner (in press), which in turn was a synthesis of an article in Scientific American (McCloskey, 1983). This refutation text consisted of information regarding certain principles of motion, but it discussed those ideas as being in contrast with students' intuitive ideas (i.e., impetus theory). A portion of the refutation text follows:

"Newtonian Mechanics vs. Impetus Theory"

> A central point to be made is that the medieval impetus theory is incompatible with Newtonian mechanics in several fundamental ways.... To get a sense of some of the motion studies mentioned, imagine the following situation. A person is holding a stone at shoulder height while walking forward at a brisk pace. What will happen when the person drops the stone? What kind of a path will the stone follow as it falls? Many people to whom this problem is presented answer that the stone will fall straight down, striking the ground directly under the point where it was dropped. A few people are even convinced that the falling stone will travel backward and land behind the point of its release. In reality, the stone will move forward as it falls, landing a few feet ahead of the release point. Newtonian mechanics explain that when the stone is dropped, it continues to move forward at the same speed as the walking person, because (ignoring air resistance) no force is acting to change its horizontal velocity.

The non-refutation version of the physics text described Newtonian mechanics but did not discuss any of the ideas as being in contrast with commonly held misconceptions about motion theory. Following is a portion of the non-refutation text that parallels the refutation version above.

"Newtonian Mechanics"

> We certainly learn from our experiences. From repeated exposures to particular events, we learn to induce principles which guide our expectations for future events.... Newtonian mechanics can also be used to predict what path a stone will follow when it is dropped from shoulder height by a person walking forward at a brisk pace. Assuming no air resistance, the stone will move forward as it falls to the ground, coming to rest a few feet ahead of the point at which it was released. That is, the stone continues to move forward at the same speed as the person who is walking. Why? Because no force is acting upon it to change its horizontal velocity. Of course, as the stone falls forward it also moves downward at a steadily increasing speed. The forward and downward motions result in a path that closely approximates a parabola.

We used the Fry readability formula to estimate the difficulty level of the text. Both versions fell at approximately the 10th grade level, within the range of the students' reading ability. The lengths of the two passages were also similar: the refutation text contained 639 words, the non-refutation text 627 words.

Conducting the Study

Students were randomly assigned to one of four groups: a refutation/activation group (R/A), a refutation/non-activation group (R/NA), a non-refutation/activation group (NR/A), and a non-refutation/non-activation group (NR/NA). As noted earlier, students in the activation group studied Figure 1, selected one of four hypothesized paths, and then explained the reasoning behind their choice. The non-activators studied an illustration that depicted a situation involving the relativity of time, not motion, and then wrote their explanations for the situation. We measured changes in students' misconceptions about motion theory by comparing their performance on the pretest measures with their performance on posttest measures after a two-day interim. One posttest measure consisted of a free recall protocol in which students wrote down as much information as they could remember about the version of the physics text they had read. The other posttest consisted of 28 true-false items that supported either impetus theory or Newtonian mechanics. An example of a false item was "A projectile will fall straight down after the original impetus is finally spent." An example of a true item was "Moving objects come to a stop or begin to fall because external forces act to change the speed or direction of their motion."

Refutation Text Dispels Misconceptions

We analyzed the data using an analysis of covariance on the true-false posttest scores, with vocabulary and the true-false pretest scores as covariates. This analysis revealed that the refutation text was by far more effective at getting students to change their prior misconceptions about the principles of motion ($F \langle 1,28 \rangle = 5.59$, $p < .05$). It did not make any statistical difference, however, if students were asked to activate their prior knowledge or not ($F \langle 1,28 \rangle = 2.26$, $p > .10$). We also looked for changes in ideas about projectile motion from the pretest explanation of figure 1 to the free recall part of the posttest. Again we found a statistically significant effect for the refutation text ($F \langle 1,28 \rangle = 4.42$, $p < .05$), and it made little difference whether or not students' prior knowledge was activated ($F \langle 1,28 \rangle = .78$, $p > .10$). Table 1 shows the proportion correct for both the free recall and the true-false posttest.

Insert table 1 about here

What Does it Mean?

Professional journals and methods textbooks used in teacher education courses are filled with activities designed to help students relate their background experiences to material to be read. Although empirical support for some or many of these activities is slim, most of us have one or two favorite prereading strategies that we find intuitively appealing and that appear beneficial to student learning. Nonetheless, recent research suggests that activating students' knowledge, when it is in contradiction to what the textbook presents, can be detrimental to learning. For example, Alvermann, Smith, and Readence (1985) found that students who held strong counter-intuitive notions about one or more science concepts related to the sun's light and heat actually let their incorrect prior knowledge override the correct textual information.

Based on the results of the present study, refutation text structure was clearly more effective than non-refutation text structure in helping students relinquish their misconceptions about motion theory, whether or not students activated prior knowledge. Practically speaking, however, we cannot rely on textbook adoption committees to choose texts on the basis of the type of structure. Even if they were to include text structure among their criteria, information that might be counterintuitive for some students might not pose a problem for others. How, then, does a teacher account for these individual differences among students and thus ensure that opportuntities for conceptual change will not be left up to chance?

We suggest two ways that teachers can help students change their minds about incorrectly held concepts, especially when those misconceptions are not refuted in the text. The first way entails the use of an anticipation-reaction guide (Readence, Bean, and Baldwin, 1981). The teacher could construct several statements that can be answered using either impetus or Newtonian theory and ask students to anticipate whether or not these statements are true or false based upon their intuitive concepts or prior learning. Items such as the following might be presented and discussed:

Anticipation	Reaction	
__________	__________	Objects are kept in motion by an internal force that gradually dissipates.
__________	__________	A projectile travels along a straight line for some time after it is launched.
__________	__________	Carried objects fall straight down when they are dropped.

After this assessment of prior knowledge, teachers should alert students to the fact that some of the ideas presented in the text they are about to read may be in contrast to the ideas they held before reading it. They should be asked to note these ideas, and told that they will be asked to react again to the statements when they are finished reading the text. After they have read the text, they should then reread each statement and react to it based upon what the text had to say. If, even after noting the inconsistencies, students are still unwilling to relinquish their prior misconceptions, the teacher would at least see the need for more teaching, and may wish to engage students in experiments which illustrate Newtonian principles.

The second way a teacher might help students change their minds about incorrectly held concepts is based on Posner et al.'s (1982) four-step model of conceptual change instruction.

1. Develop student dissatisfaction with misconception. In prereading discussion of "Newtonian Mechanics" (the non-refutation text used here for illustration purposes), elicit from students their predictions about the path a stone will take if dropped from shoulder height by a person walking forward a a brisk pace. Invite students to sketch their predictions on a piece of paper. Next, assuming the majority of students have drawn paths similar to A,B, or D in Figure 1, have them read the first two paragraphs of the text to see if Isaac Newton would agree with their predictions.

2. Determine if the new conception is understandable. After reading the frst two paragraphs of the text, students should demonstrate that they understood what the text description meant by reconstructing their sketch from step 1. (Note: A dictionary definition or illustration of a parabola may

help.) Keep in mind that the students may not be willing to relinquish their belief in impetus theory quite yet. It is only important at this point that they can represent correctly the path the stone would take according to Newtonian mechanics.

3. Determine if the new conception is plausible. Help students reconcile the text information with their previous conceptions of motion theory by reading aloud to them a portion of an encyclopedia article on the myths surrounding the medieval impetus theory. Be careful, however, that students do not think they are alone in their misconceptions. Explain that many people today still find it difficult to gived up the impetus motion. As proof of this have students take home copies of Figure 1 to try out on relatives and friends.

4. Invent a situation for making use of the new conception. The objective here is to help students convince themselves of the usefulness of Newtonian mechanics in explaining something of real-world importance to them. Athletes, freefallers, pool players, pilots, etc. all would find Newtonian principles of motion of importance in understanding their activities. Students could be asked to predict, for instance, where a freefaller would be in relation to the airplane and the ground at the time when he opens his chute. Or they might be asked to predict where rescue equipment or vital supplies would fall if they were dropped from an airplane or pushed off a cliff to people waiting for relief below. Students asked to think about these situations might be convinced of the need for learning Newtonian principles.

In conclusion, teachers who have access to text which refutes common misconceptions about difficult concepts may have an easier time convincing students to relinquish those misconceptions in favor of more sophisticated principles than teachers who do not have such access. However, in lieu of refutation text, teachers still have several techniques at their disposal which seem to be successful in dispelling counter-intuitive notions.

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Figure 1. Four Hypothesized Paths for an Object Pushed Off a Cliff.

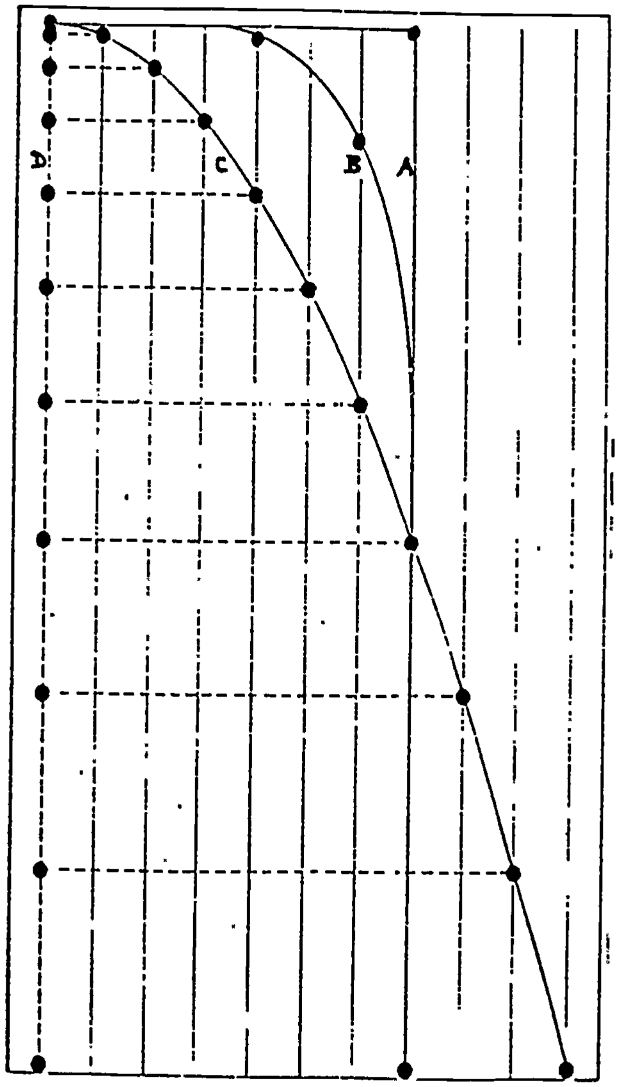

Table 1. Proportion Correct for Free Recall and True-False Posttest

Test	Activation		Non-Activation	
	Free Recall	True-False	Free Recall	True-False
Refutation				
M	.50	.47	.67	.63
Non-Refutation				
M	.14	.41	.25	.44

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