Iowa Science Teachers Journal

Volume 31 | Number 1 Article 2

1994

Understanding vs. Knowing

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How well do students understand concepts in science? Are teachers evaluating what students actually comprehend or merely how well they can recite information? How valuable are tests? What do they actually measure? How appropriate are the lessons to the children's developmental levels?

These and similar questions should be an important part of every teacher's evaluation procedure. We need to stop and ask ourselves such questions as: Why do I want my students to know this? Will knowing this make a difference in their lives? Is it important? Do the students really understand this? How can I be sure? From here, teachers can begin to design significant lessons and learning experiences for their students and develop evaluation procedures that measure understanding instead of merely how well a student has memorized data or how well students can take tests.

Two incidents may help to illustrate what I mean. I once visited an elementary classroom in which the students were studying nutrition. An activity in which they were involved at that time included writing the names of ingredients found on food labels. The students then were to circle all the ingredients that contained sugar. One group had circled the term "corn syrup." I asked the students why they had circled corn syrup.

"Because it's in the sugar group!" they replied.

"How do you know that?" I asked them.

They looked at me as if I were an alien being complete with antennae. "Because it is! We learned it!"

"What I mean is, how do you know that it belongs in the sugar group? What about it makes you want to put it there?" I asked again.

"It was on the list," they insisted. "It just goes there."

It had not occurred to any of the students in the group that corn syrup might *be* a sugar and that sweetness might be a characteristic which would help identify it. Of course, children know that sugar is sweet, but in this context, an ingrained dependence on the teacher to set the agenda for what should be "known" had clouded their ability to think. As a result, they held stubbornly to the idea that corn syrup is a sugar because it was found on a certain list.

Similarly, the entire class knew what the food groups were and what common foods belonged in each of them, yet not one of these nine year olds could make up a simple menu using foods from the representative groups. They were quite adept at reciting memorized data, but they couldn't use that knowledge to solve a very basic problem. In short, they didn't understand the relationships involved, let alone understand how this information applied to their lives. The teacher, obviously embarrassed, thought that the children were "not paying attention." From my perspective, the problem did not appear to lie with the children, who were all enthusiastically involved in the activity, but with the approach used.

This is not unique to elementary or primary children. I once taught a class in chemistry which included many students who were considered "gifted." Although quite intelligent, they could not use math concepts to solve problems. They were all enrolled in trigonometry, but none could set up a simple algebraic ratio problem. They had no trouble computing once I set up the equation, but most could not even justify the method of cross multiplication; they could not explain why it was possible. Like the nine year olds, they had memorized functions, but could not apply them. Again, they did not understand the relationships.

These two examples illustrate quite clearly why it is absolutely essential that teachers test for understanding, rather than for memorization skills. Filling students with data is pointless if they are unable to apply their knowledge.

Students need to be challenged to use information in a constructive way, whether they solve problems, apply principles in everyday situations, or analyze experimental results. The difficulty of the exercises must be adjusted to the appropriate developmental level, but all students need to be given the opportunity to search for understanding and comprehension in their science classes, not just to accumulate otherwise meaningless terms and numbers so that they can regurgitate them onto a test sheet and then forget them.

The Learning Cycle

Memorization of facts involves recall, requiring only a low level of mental activity, and teachers should not make it their ultimate goal. Instead, students must be challenged to use their creative abilities through higher level learning experiences.

In order for students to connect facts and concepts, they must go through logical steps which illustrate these relationships. For example, rather than merely having students list food groups and the foods in them, a teacher could introduce the unit with a group brainstorming session in which students list the foods they have eaten in the past few days. Afterward, students could sub-divide the foods into groups of their choosing, with group or class consensus. These food groups could then be compared to those established by nutritionists. My experience has been that the students' lists will often show remarkable similarity to those of the professionals.

An important step in learning is involved at this stage. Through research in the library, reading from texts, from teacher input and/or visits by a nutritionist, students learn in greater detail *why* the groups are so divided. Finally, students work to classify those foods from their lists of everyday meals and devise their own menus.

This procedure follows the guidelines of the "learning cycle" suggested by Robert Karplus of the University of California at Berkeley in collaboration with the Science Curriculum Improvement Study (SCIS), and based on the developmental psychology of Jean Piaget (Inhelder and Piaget 1964, Karplus 1972, Eakin and Karplus 1976, Rubba 1984). The steps in the learning cycle are (1) Exploration, (2) Concept introduction and development and (3) Concept application.

First, the students focus on a problem and explore it through group or individual activities. During this exploration, the teacher provides minimal guidance while the students raise questions about the phenomenon (Rubba 1984).

Second, interaction between students and teacher or other resources allows development of the concept. Introduction of definitions, new vocabulary or principles relates directly to the exploration and allows students to compare their own explanations with those of other sources, usually in scientific terms. Students then may modify previously held misconceptions and add to their understanding of the concept.

Finally, the results are shown to correspond to an application of the concept in some way. This can be done through a series of related activities, discussion of some issues involved or further research. Students should also be free to return to the exploration phase if the situation warrants it, in order to further expand their understanding. Learning thus allows students to develop understanding through activities which build on previously practiced skills or acquired knowledge in a logical manner so that the application of the knowledge makes sense. Too often we have seen students who have memorized scattered bits of information but who do not understand the concepts behind them.

Classroom Implementation

Textbooks generally compound the problem by beginning with vocabulary and general background facts, then (sometimes) follow up with an exercise which usually has only one pre-determined answer. Applications are generally found in the "extension problems" at the end of the chapter, and are often reserved for those bright students who "finish early." This traditional textbook model is so ingrained in us as a model for teaching that we often follow it without thinking about the consequences for learning. By simply rearranging the order of the text's material, teachers can go a long way toward improving student understanding! From there, teachers can begin to implement open-ended questioning techniques as students explore, thus enhancing learning even more.

The chemistry students mentioned earlier were still able to build meaning in chemistry through the learning cycle, even though they were quite perplexed and often upset by the change in the approach at which they had been so successful. The longer a school district waits to implement this approach, the more difficult it is for students and parents to accept and understand it, especially those "A" students who have been extremely successful at memorizing.

When testing for understanding, teachers should develop questions which will test students' abilities to apply what they have learned. Whereas multiple choice, completion and true-false test items measure mainly memorization of facts; essay, short answer and related problem-solving questions can be devised which will more accurately assess learning. Even better, teachers may informally assess students as they supervise work on activities, and compile a portfolio of student work for assessment. Problems can then be pin-pointed and supplementary or remedial work done to help the student.

The following example shows the difference between questions which assess knowledge and those which assess understanding:

Knowledge (facts)	*Understanding (concepts)*
Name the food groups.	Look at this menu which shows Lisa's meals on Monday. Do you think it is balanced? Explain your answer.

The learning cycle may be utilized at all levels of science. It allows students to play an active role in their own learning, relates topics, provides a smoother transition from information to concepts and helps students more effectively transfer skills to new problems (Zoller 1991). This enhances understanding rather than stressing mere recall of facts. Teachers who use this model recognize its potential and its ability to enhance intellectual and conceptual development (Marek and Methven 1991). It is important to remember, however, that if any phase of the learning cycle is omitted, its effectiveness is reduced (Rubba 1984).

For teachers who are interested in enhancing their science teaching effectiveness, implementation of the learning cycle can improve student understanding of natural phenomena and increase their interest. In short, learning becomes more enjoyable and meaningful for both students and teachers.

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