know•ing (nō ing) *adj* : **1** suggesting that one has knowledge. **2** showing an ability to recite facts. *n* : **1** a state of awareness following the inundation of trivial bits of information. **2** temporary knowledge typically lost shortly after a quiz or test.

knowing versus understanding

un•der•stand•ing (ŭn'dər stăn'dĭng) *adj* : **1** characterized by or having comprehension, good sense, or discernment. **2** endowed with reasoning. *n* : **1** individual or specified judgment. **2** comprehension well beyond factual recall.

TEACHING THAT GOES BEYOND TRIVIALITIES

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ABSTRACT: In this century of science and technology, it is essential that students learn to critically assess science issues in historical perspectives. The traditional method of teaching students to memorize information bits cannot accomplish the goal of creating a science- and technology-literate public. However, if teachers transform their learning environment into one that encourages and supports student conceptual understanding, not only will graduates be able to make informed decisions regarding science, but numerous studies show that student achievement also increases, often dramatically. *This article promotes National Science Education Content Standard A and Iowa Teaching Standards 1, 3, 4, 5, and 8.*

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? To what extent will knowing this make a difference in their lives? How and to what extent is it important? How well 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 these 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 do not understand the significance of that information and are unable to apply that information to significant problems.

Requiring students to memorize large amounts of information makes no sense in today's world where it can be so easily retrieved. Importantly, the ability to remember particular information is largely a matter of having repeatedly used that information for other tasks.

Consider how chemistry teachers easily recall the symbols and atomic weights for elements they often use in solving problems. The same is true in any discipline where a practitioner repeatedly uses information and through that repeated use comes to easily recall it. Unfortunately, teachers often wrongly believe the ability to recall esoteric information comes from memorization rather than repeated use. Rather than emphasizing memorization, teachers should have students access, retrieve and use information in meaningful higher level learning experiences that require critical thinking and creativity.

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, what Vygotsky referred to as the zone of proximal development, where a student cannot alone comprehend an idea, but with appropriate assistance from a teacher or peer, the concept may be understood (Vygotsky, 1978, 1986). All students should 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 for Meaningful Learning and Assessment

Helping students understand concepts and how those concepts make sense of facts is best accomplished by creating experiences where students investigate such relationships. For example, rather than merely having students list food groups and the foods in them, a teacher could first conduct a group brainstorming session in which students list the foods they have eaten during the past few days. Afterward, ask students to individually consider what categories they could create for the different kinds of foods that have been listed. Then have students pair and discuss their individual ideas for a minute or so. Finally, share the ideas generated in larger groups or with the entire class. Paramount in the larger setting is concentrating on the rationale students have for the proposed categories and seeking consensus on how best to categorize the foods. These exploratory experiences create a foundation for students to more fully engage in and understand the more formal concepts that follow.

These food groups developed by students should now be compared to those established by nutritionists, and similarities and differences discussed. Through library research, reading from texts, input and/or a visit by a nutritionist, students learn in great detail ***why*** the groups are so divided. My experience has been that the students' lists will often show remarkable similarity to those of the professionals, but some differences. The importance of the exploratory experiences becomes clearly evident here. Students ***want*** to know how their groupings compare to those of the experts, and they are genuinely interested in the rationale for the groupings. Exploratory experiences, when effectively conducted, establish a concrete foundation for abstract ideas that follow and create motivation for learning.

To further promote learning and to assess the extent to which students understand desired concepts, have students work to apply concepts in meaningful ways. For instance, have students work to classify those foods from their lists of everyday meals and devise their own menus. The key point in an application activity is to ensure that whatever you have students do requires them to use the targeted concepts in a different manner.

This progression follows the "learning cycle" suggested by Robert Karplus of the University of California at Berkeley in collaboration with the Science Curriculum Improvement Study (SCIS), and reflects what is known about how people learn (Inhelder and Piaget, 1964; Karplus, 1972; Eakin and Karplus, 1976; Rubba, 1984). The learning cycle model has been extensively studied and shown to promote the learning of science concepts and many equally important science education goals (Abraham, 1982; Ward and Herron, 1980; Purser and Renner, 1983). The progression in the learning cycle is divided into three phases that are often referred to as (1) Exploration, (2) Concept introduction and development and (3) Concept application.

During the exploration phase of the learning cycle the focus is on creating experiences that have students inquire into a phenomenon or problem and explore it through group or individual activities. During this exploration, the teacher's role is to observe and listen to students, ask questions that will keep students engaged, but provide minimal formal instruction. The focus of the exploratory phase is to provide meaningful experiences for students that will (a) set a stage for introducing more formal science concepts, (b) raise questions in students' minds that will increase mental engagement, and (c) provide a window into students' thinking and misconceptions.

During the concept development phase, students are introduced more explicitly to the science concepts in question. Having the experiences that occurred in the exploratory phase precede the more formal instruction in the concept introduction phase is crucial for helping students link abstract science concepts to those prior experiences. This means that the exploratory activity should be used extensively in concept development and, if warranted, students should be encouraged to return to the exploration activity to address issues that arise in concept development. Introduction of definitions and new vocabulary should, for the most part, be introduced after students have developed a beginning understanding of the science concept. This encourages students to see vocabulary as a label for an idea that they now already understand to some extent. Students are now in a position to compare their prior and lingering ideas with those of other sources, usually in scientific terms. Students are then in a better position to truly modify previously held misconceptions and add to their understanding of the concept.

Finally, having students consider how those ideas may be applied further develops their understanding of the science concepts. This can be accomplished in a number of ways that include, but are not limited to, related laboratory investigations, connection to societal issues, and a deeper and/or novel look at the original exploratory activity. In applying their emerging understanding of a science idea students will develop new links, thus strengthening their understanding. Teachers will better understand their students' thinking and struggles, thus informing their decisions on how to proceed.

When assessing for students' understanding, teachers should develop questions that have students apply targeted science concepts. Whereas multiple choice, fill-in-the blank, and true-false test items are easily scored, they too often assess only recall of information. Essay, short answer, and problem-solving questions that require students to use science concepts help teachers more accurately assess students' understanding and determine persistent misconceptions. The following example shows the difference between questions that assess knowledge and those that assess understanding:

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

Oftentimes the most accurate assessment of students' understanding comes in authentic problem based application experiences. Even students who do well on written application assessments will revert to misconceptions in such activities. This is often surprising and frustrating to teachers, but such outcomes have a silver lining. Teachers now understand and can create further learning experiences to develop a deep understanding of science content.

Classroom Implementation

Science textbooks, for the most part, ignore research on how people learn and introduce vocabulary and concepts prior to meaningful experiences and discussion of those experiences. Colburn and Clough (1997, p. 31) write:

> Unfortunately, because textbooks often determine most pedagogical decisions, science is often taught by a different three step process. Content is typically introduced verbally, followed by a step-by-step cookbook activity to illustrate and "verify" what was just presented, and ended with a highly structured activity designed to have students practice using the new content. While at times being hands-on, students are rarely mentally engaged in a meaningful manner.

Applications are generally found only in the “extension problems” at the end of the chapter, and are often reserved for those bright students who “finish early.” This time honored textbook model is so ubiquitous that teachers often follow it without considering whether it is the best way to promote learning.

All science teachers want to better promote student learning, and effectively implementing the learning cycle is one avenue for doing so. However, the already overwhelming demands placed on teachers make difficult the learning and introduction of new teaching models and strategies. So that teachers may become accustomed to new roles with less stress, Colburn and Clough (1997) provide guidance for teachers to gradually make the transition to the learning cycle.

The learning cycle approach may be used in all science subjects and at all levels of science teaching. When used by teachers who ask effective questions, encourage student involvement, and effectively play off students' ideas, the learning cycle helps students to be mentally engaged, connect experiences to science ideas, and more effectively transfer skills to new problems (Zoller, 1991). This enhances understanding rather than mere recall of facts. Teachers recognize the learning cycle's potential and its ability to enhance intellectual and conceptual development (Marek and Methven, 1991).

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, science learning and teaching becomes more enjoyable and meaningful for both students and teachers.

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