Moving Students From Information Recitation to Information Understanding: Exploiting Bloom's Taxonomy in Creating Science Questions

By Thomas Lord and Sandhya Baviskar

Recent studies have indicated that college undergraduates have retained little understanding of the information in the science courses they have taken when they graduate. Science is taught as detailed, factual content and most students are evaluated by their ability to recall and summarize the information provided. As such, students concentrate their studies on terms and definitions, spending little time on application and analysis. To correct the problem, instructors are encouraged to formulate more questions around the mid and upper levels of Bloom's taxonomy in the examinations they prepare.

A little over a decade ago, a *New York Times* article appeared, alerting readers to the fact that more and more graduates from the nation's colleges and universities are leaving their academies without the ability to use information they have learned. The article reported a sharp gap emerging between the ability of students to learn basic principles and their ability to apply knowledge or explain what they learned (Bloom 1989). Unfortunately, few people in academia took note of this finding, and today the situation has reached a critical level. It doesn't seem to matter from what institution students have received their diplomas; graduates from our most elite universities share the same difficulty as those from open-enrollment colleges. Today's baccalaureate-degree recipients do not develop enduring understandings of the subject matter they've learned in college.

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One of the most revealing studies supporting this issue comes from Harvard University. In their study on the university's graduates, Matthew Schneps and Philip Sadler found that Harvard's best and brightest students had enormous misunderstandings regarding basic concepts in physics, chemistry, and biology. When students randomly selected were asked questions on such topics as the phases of the moon, simple electrical circuits, and mirror reflection, they repeatedly could give no explanation or they provided plausible but erroneous answers to the questions (1988). In another study, a science professor at a midsized, state-supported university, noted that a month after completing a general biology course, few undergraduates were able to adequately answer questions concerning information they had previously learned in class (e.g., "beside divide, describe what a body cell does during its lifetime"). Even more discouraging is that many life-science majors revealed huge misconceptions on such basic biology topics as how the human body makes water, how a plant cell makes enzymes, or what happens during an inflammatory reaction (Lord 2005).

While the fault for the misunderstandings is generally leveled against students themselves, the institution's professors should also shoulder the blame. In a traditional college classroom, instructors tend to present large amounts of factual information by telling students what they need to know through lecture. To evaluate learning, instructors formulate questions based on the recall and summarization of the information they provided earlier in the class. In essence, college students today are expected to simply regurgitate the information they have been told to learn. This traditional approach to teaching neither challenges students to understand what is being taught, nor provides them with an opportunity to reflect on the information they have studied. It is not surprising, therefore, that students are graduating from the nation's universities without an appreciable understanding of information for which they have earned college credits. Recognizing this, highly esteemed academic societies are encouraging a modification in the way instructors evaluate students, a change from evaluating factual content knowledge to evaluating understanding.

Interestingly, many of the recommendations from these organizations center around the way instructors ask questions in their classes and on their exams (Brualdi 1998). For example, at a recent National Association of Biology Teachers conference, a presentation by Lord, Baviskar, and Palazzi (2005) centered around converting questions presently based on nomenclature to a higher level (i.e., application). The researchers presented findings that suggested such a shift would not only bring about a change in the thinking of students but also a change in the way professors approached instruction. Instead of describing detailed content during class through lecture, professors would challenge students to holistically use the information being presented with things they know. According to studies, the majority of college professors base their ideas about what students know from answers on written examinations presented at various times during a semester. While professors with small enrollment classes may assess student learning through subjective means such as essay exams or face-to-face discussions, the majority of college and university professors administer lengthy objective examinations based on the content they presented during lectures. Black and Williams (1998) point out that this is not only an efficient way to evaluate a large amount of information in a short period of time, but teaching and testing the factual content is an extremely convenient and less time-consuming way to evaluate. Wiggens and McTighe (1998) also found that the majority of professors construct their exams with the types of questions that are the easiest to test and grade. Rarely is knowledge involving understanding, application, and attitudes measured. Even in higher-level courses, the researchers found that questions requiring analysis, assessment, and fusion were rarely asked. Bruner and Shore (1996) suggest that the tendency toward ease and expediency of assessing students is why most college students, when they graduate, possess only a marginal understanding of what they have learned.

About Bloom's taxonomy

If one accepts the idea that teaching for understanding rather than knowledge will bring students to a higher level of learning, the question of a hierarchical plan for conceptualization arises. This would be a monumental task for an educator to undertake; fortunately, such a sequential scheme already exists. In 1956, a team of theorists led by Benjamin Bloom developed a series of six learning levels for categorizing degrees of abstraction of questions (Bloom et al. 1956). The series is based on degrees of difficulty and includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills.

The levels of Bloom's taxonomy can be thought of as a hierarchical triangle (Figure 1). Elements of the first level *(Knowledge)* may assist with the understanding of the next one *(Comprehension)*. The learning actions at a certain level in the taxonomy help the instructor develop a level of mastery for each student (in a particular topic) and question cues/verbs help in developing appropriate questions for that level (Figure 2). Thus, Bloom's taxonomy is a tool to design, assess, and evaluate student learning.

The taxonomy is useful in another way: It allows the instructor to gauge the level of questions asked on the exams. For example, if a question on the test asks students to identify a structure defined in a sentence or shown on a graphic, the instructor knows the query fits in level one, *Knowledge*. If, on the other hand, students are asked to interpret a graph or predict what would happen if a certain event was to continue, the instructor would realize the question would require more thinking of students and reside in level two, *Comprehension*. Similarly, a question requiring students to clarify or illustrate a statement would be even more difficult to answer and push the level of difficulty to level three, *Application*. Questions in the three highest levels are the most difficult to answer. Level four, *Analysis*, urges students to break down what is asked and examine the meaning of the various sections, while *Syntheses* (level five) encourages students to combine question elements to solidify understanding. *Evaluation,* the sixth and most difficult level, requires that students assess the understandings and make recommendations for its utilization.

Couching questions with Bloom's hierarchy

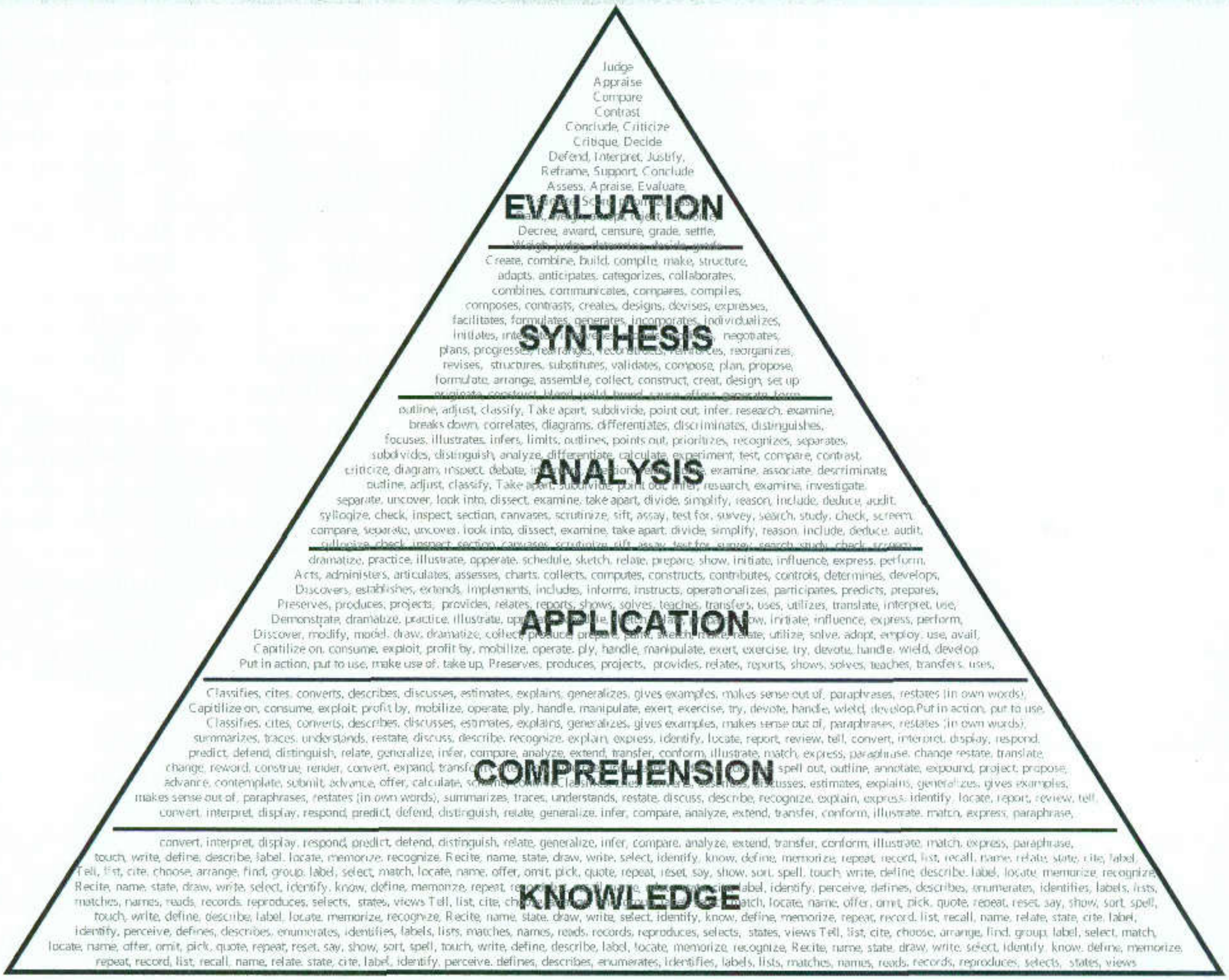
The best way to explore couching questions with Bloom's taxonomy is to create a series of queries in the taxonomy based on a single science theme. In that way, students can see the relationship between the question and the taxonomic level. For example, let's suppose an instructor is interested in learning the depth of student understanding on the five tastes sensations in one's mouth. The instructor might start with the statement, "Humans eat a huge variety of things yet they have only five distinguishable taste regions on their tongue (sweet, sour, salty, bitter, and umami [taste sensation that verifies important amino acids])." With taste reception understanding in mind, the instructor can then construct test questions concerning taste that fit each category of Bloom's scheme.

Knowledge

In this level, students are required to recall facts pertaining to the topic that has been taught. The instructor would ask students to describe, list, or name the factual information they've learned in class. In our taste-receptor plan the question could be, "List the five taste

FIGURE 1

Bloom's triangle with levels and cue words.



sensations in the mouth." The Bloom team believed that this level of thinking would be the easiest for the instructor to construct and score; as such, he discovered that questions of this type encompass over 50% of exam questions (Huitt 2004).

Comprehension

In the second taxonomic level, students are required to reword and explain in a meaningful manner something they have learned. Descriptors such as translate, construe, interpret, and extrapolate are commonly used at this level. In our taste-receptor example, a question appropriate to this level would be, "Explain where the five taste regions reside on your tongue; include in your description the reception zones where taste overlap is likely to occur." At this level, students reveal an understanding of relationships and are able to alter and advance information above the way it was presented. The Bloom team recognized this as being more difficult than the first level and discovered that about 20% of the questions on typical science examinations fall into this category (Huitt 2004).

Application

In the third level, students are required to think holistically about the concepts learned and apply them to novel situations. In our taste-receptor example, an Application-level question could be, "Locate the various taste receptors on the tongue using the labeled liquids provided." In this category, students are able to exploit information and put to action the knowledge they've learned. Bloom believed about 12% to 15% of the questions asked on college exams are of this type (Huitt 2004).

Analysis

Here, students are expected to break ideas into component parts and uncover the unique characteristics of what they have been taught. Terms like *deduce*, *scrutinize*, and *survey* are frequently encountered in questions in this category. In our taste-receptor example, students may be asked to "Determine the location of the various taste-receptor sites on the tongue for each of the unlabeled solutions provided." This is a far more difficult task than those given in the preceding categories because students must recognize a sensation they aren't told the name of. This requires a neural dissection of a gustatory experience as students encounter interpretation. Thinking such as this requires divisible screening of the thought process, and because of its difficulty, is used infrequently in test construction.

Synthesis

Students who function at this level are able to pattern knowledge in new, original ways and exploit their creativity. Terms like *formulate*, *generate*, and *restructure* are often found at this level of the taxonomy. In our taste-receptor plan, a question at this level could be, "Describe a gustatory sensation experienced from the blend of two different taste receptions." Here students must combine what they experience into what is considered a novel sensation. Such original thought resides high on a learning hierarchy and is seldom seen on course exams.

Evaluation

At this level, course instructors expect students to make judgments about what they have learned based on either external or internal criteria. Students must prioritize their understandings as they form their conclusions. An Evaluation-level question in our taste-receptor plan would be, "According to research by the American Obesity Association, approximately 127 million people in this country are seriously overweight and the problem continues to grow larger every year. Discuss how gustatory reception and obesity are related." Here students are forced to appraise their insights as they relate their understandings to a real-word problem. Such analysis is extremely difficult for students.

Conclusions

Because professors tend to stress the factual content of what is being taught to students, most of the questions on the tests belong to the Knowledge and Comprehension levels of the taxonomy. Anderson and Sosniak (1994) noted that 60% of questions on our college tests are Knowledge level, 20% Comprehension, and 15% are Application level. Analysis-level questions are seldom seen and Synthesis- and evaluation-level questions account for only 3% of exam questions and therefore make up only a small segment of college tests (Figure 3). Actually, some researchers feel that, instead of acting alone, the higher-ordered thinking levels often merge. Lawson (1990) writes that thinking comes together as a continuum in the upper segments of Bloom's levels. According to Lawson, in bright individuals, analysis often serves to order and structure a problem. After this, synthesis is employed to generate solutions, and evaluation assesses the suggested solutions against the objectives identified in the analysis phase.

It is generally believed by the test creator that, while short-answer and multiple-choice questions can be used efficiently to test the lower levels of learning behaviors, they are not sufficient to assess the higher levels. However, objective probes, such as multiple-choice questions, can be written for the Analysis, Synthesis, and Evaluation categories. For example, at the Analysis level, students can be asked to select the least important incidence from a list of occurrences that would influence the outcome of a major storm. Under the Synthesis level of the taxonomy, science students could be asked, "Which of the following elements could be chemically constructed from the combination of all the gases of the earth's atmosphere?" For the Evaluation level a question might be,

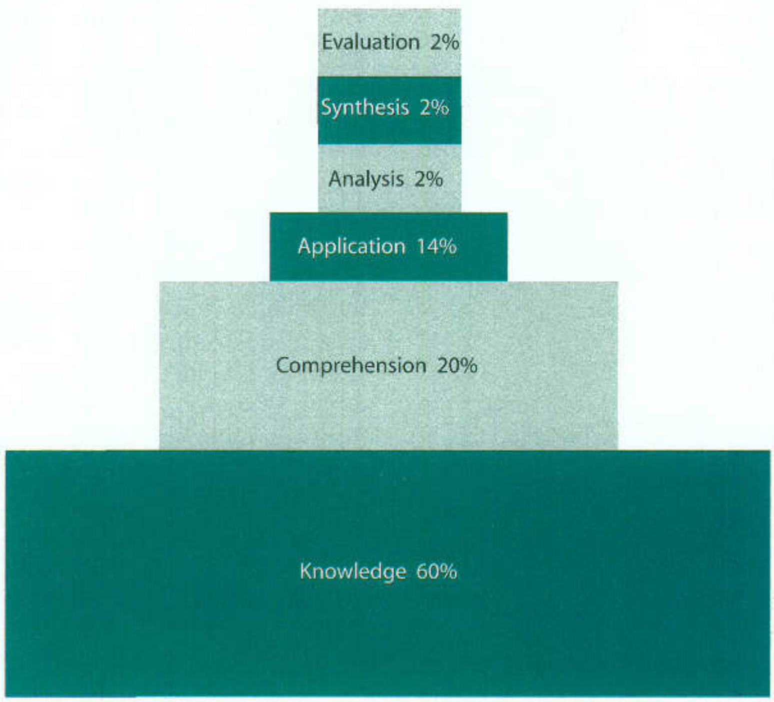
FIGURE 2

The learning level in Bloom's classification with corresponding actions and question cues.

Bloom's level	Potential action(s) of student	Question cues/verbs
Knowledge	Recall the memorized information	List, define, label, identify, name, find, write, state, describe, tell
Comprehension	Summarize in own words, paint a picture, make a flow chart	Describe, categorize, summarize, explain, interpret, outline, compare, distinguish, predict, translate
Application	Apply rules or concepts to a problem	Apply, calculate, solve, show, illustrate, construct, classify
Analysis	Break concepts into parts and analyze how different parts are related to one another	Review, design, analyze, construct, investigate, categorize, separate, compare and contrast
Synthesis	Create something new from different concepts	Create, design, invent, plan, propose, devise, compose, construct
Evaluation	Evaluate, argue in support/against, panel discussion	Assess, decide, grade, recommend, justify, judge, debate, verify, argue, recommend

FIGURE 3

Bloom's hierarchy triangle showing percent usage of levels on exam questions.



"From an assessment of a collision of a meteor the size of a VW bug traveling 150 mph striking the Mojave Desert, which answer below would best describe the size of the dust plume created by the impact?" Questions such as these, while difficult to construct, can be graded as efficiently as test items from the lower categories.

But changing the difficulty levels of questions instructors ask on exams won't alter the situation by itself. Along with creating more challenging test items, instructors should also challenge the way students think during class. Instructors must move from covering course information for students through lecturing to helping students discover course information through inquiry. Contemporary students want to be active, rather than passive, in the assimilation of information. As such, instructors must move from lecture-based to inquiry-based lessons, challenging students to develop the information for themselves in ways they can grapple with and understand it. If they're used to being challenged during the lessons each class period, students will have less problems handling the challenges posed by upper-level questions in Bloom's hierarchy. Instructors need, therefore, to teach the way they test.

Developing questions based on Bloom's hierarchy would be a productive way of reversing the dangerous trend of graduating college students with a large number of misunderstandings in courses they have taken. Shouldn't we expect our college graduates to know more than just the superficial aspects of the world's basic natural processes? How much longer should we graduate students with a marginal understanding of what they've taken in college? The answers may not be as difficult as we might presume; all it will take is the way college instructors teach and question their students. Albert Einstein once said, "I never teach my pupils; I only attempt to provide the conditions in which they can learn." ■

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