**Excerpts from Chapter 2:**
**Evaluating the Cognitive Levels of Instructional Materials Using an Educational Taxonomy**

**Table 2.1 Bloom's Taxonomy Simplified as Two Cognitive Levels**

| Cognitive Level | Bloom Level<br>A Simple Phrase to Guide Categorization<br>Verbs Typically Associated with the Category |
|---|---|
| HOC | **Evaluate**<br>**"Defend or judge a concept or idea"**<br>appraise, argue, assess, conclude, criticize, critique, decide, defend, evaluate, judge, justify, prioritize, prove, rank, rate, select, support, validate |
| HOC | **Synthesize**<br>**"Create something new"**<br>adapt, assemble, compose, construct, create, design, develop, devise, formulate, generate, integrate, invent, make, model, plan, pose, produce, pretend, propose, reconstruct, reframe, revise, rewrite, set up, structure, substitute |
| HOC | **Analyze**<br>**"Distinguish parts and make inferences"**<br>analyze, break down, categorize, characterize, classify, compare, contrast, correlate, debate, deduce, diagram, differentiate, discriminate, distinguish, examine, infer, outline, question, rearrange, relate, separate, subdivide, test |
| LOC/HOC | **Apply**<br>**"Use information or concepts in new ways"**<br>act, administer, apply, calculate, change, chart, compute, demonstrate, determine, draw, dramatize, employ, extend, illustrate, implement, inform, instruct, operate, practice, predict, prepare, produce, provide, role-play, show, sketch, solve, transfer, use, utilize |
| LOC | **Comprehend**<br>**"Explain information or concepts"**<br>convert, define, describe, demonstrate, discuss, explain, express, generalize, give examples, indicate, imitate, interpret, paraphrase, restate, summarize, translate |
| LOC | **Know**<br>**"Recall information"**<br>choose, count, duplicate, enumerate, find, identify, label, list, locate, match, memorize, name, order, quote, recall, recite, recognize, repeat, report, reproduce, select, sequence, state, tell |

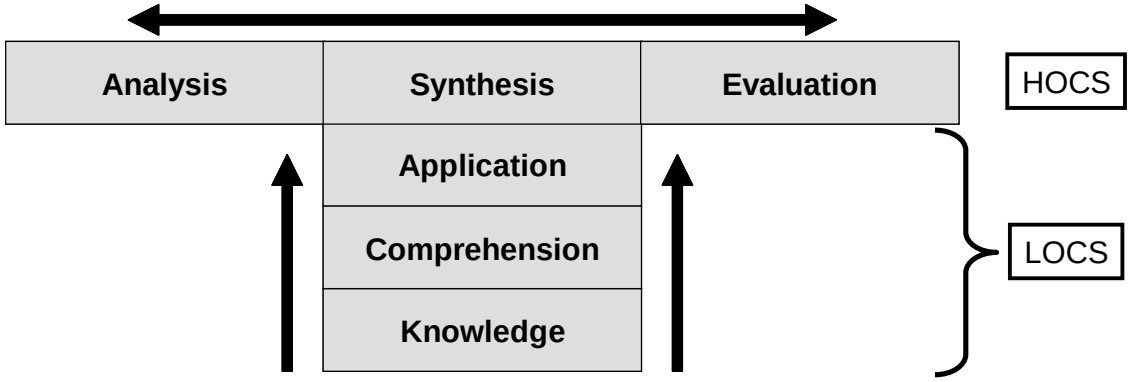



**Figure 2.1. A Diagram Showing the Partial Hierarchy of Bloom's Taxonomy**

**Box 2.1. A Protocol for Categorizing Questions**

1. Review the question and classify based on matching Bloom verbs. If Bloom verbs are not found in the question, determine which verbs are implied.
2. Review course material to discern if the question was answered directly in class or in the text. If so, the question tests recall and is considered a LOC level.
3. Ask the following:
    a. Does the student have to problem solve (HOC) or merely recall information (LOC)? The more conceptual steps required, the more likely the question is at a HOC level.
    b. If the student has to problem solve, is the necessary information present so the student must merely apply content knowledge (LOC), or is some information missing so the student must make inferences to arrive at the correct answer (analysis - HOC)?
    c. Are you judging the Bloom level based on difficulty of the question, i.e. giving a difficult question a HOC ranking even if the task is knowledge-based?
4. Use the Bloom T (Fig. 2.1) to check off all Bloom levels required to successfully answer the question. Classify the question at the highest Bloom level required.
5. Determine if science process skills are required to answer the question. Refer to the Blooming Biology Tool (Appendices B and C) to help guide your categorization.
6. Identify the question type. If it is a multiple-choice question, are there strong or weak distractors? The more plausible the distractor, the more likely the question is a HOC.
7. Determine if the question has multiple parts.
    a. Determine the Bloom level of each part.
    b. Determine if the multipart question has connected or independent components. If components are connected, categorize the question at the highest Bloom level. If not, the independent components should be treated as separate questions.
8. Ask a colleague or teaching assistant (TA) to categorize the question using this protocol. Compare your results and come to consensus.

**Excerpts from Chapter 4:**
**Assessing Higher-Order Cognitive Skills with Multiple-Choice Questions**

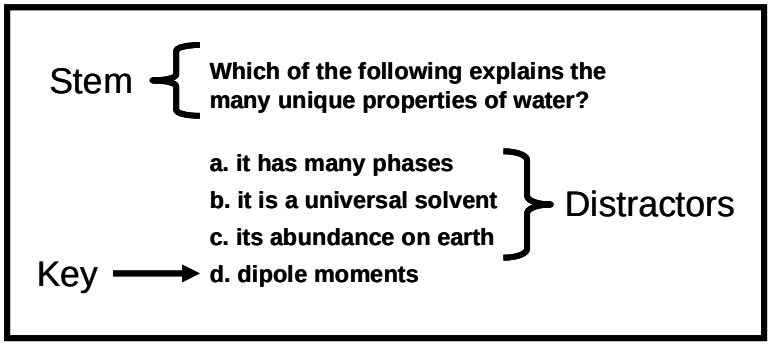



**Figure 4.1. Components of a standard multiple-choice question at the LOC level.**

**Appendix A: Examples of the Different Structures of MCQs Described in Table 4.2**

**Example 1: Context-Dependent**

| | |
|---|---|
| **Description** | Context-dependent MCQs are prefaced with a scenario, data table, graph, or similar introduction, followed by an item or series of items having two or more options. Answers to subsequent questions do not depend on the answer to previous questions, but all are related to the information found in the opening description of the scenario. |
| **Cognitive Level** | HOC and LOC |
| **Discipline** | Astronomy (Green 2002) |
| **Question (answer in bold)** | *A star with a continuous spectrum shines through a cool interstellar cloud composed primarily of hydrogen. The cloud is falling inward toward the star (and away from Earth). An Earthbound observer views the twinkling star.*<br><br>*Which best describes the spectrum seen by an Earthbound observer?*<br>*a) blueshifted hydrogen emission lines*<br>*b) blueshifted hydrogen absorption lines*<br>*c) redshifted hydrogen emission lines*<br>***d) redshifted hydrogen absorption lines***<br>*e) a redshifted hydrogen continuum*<br><br>*The reason the observer views the star as twinkling is because of motion _____.*<br>*a) on the star's surface.*<br>*b) of the Earth.*<br>*c) of the Solar System.*<br>***d) of gas in Earth's atmosphere.*** |
| **Advantages/ Disadvantages** | Context-dependent questions have been found to be very useful for measuring HOC skills because they usually require the student to analyze and problem solve. These kinds of questions are very effective in science because students often have to make inferences from experimental data or diagrams, or evaluate a scenario before arriving at an answer. Multiple questions based on one graph or data set also provide an opportunity to measure several aspects of a student's understanding about a given topic. The disadvantages to these kinds of questions is that the question usually takes longer to answer and sometimes the answer to one item can influence how the student answers the next item. |

**Example 2: Two-Tiered**

<table>
<tr><td>Description</td><td>Two-tiered MCQs are similar to the context-dependent MCQs in that they have more than one question. However, the two-tiered MCQs differ because the first MCQ requires a selection and the second MCQ probes why the respondent selected the answer to the first question.</td></tr>
<tr><td>Cognitive Level</td><td>HOC</td></tr>
<tr><td>Discipline</td><td>Biology</td></tr>
<tr><td>Question (answer in bold)</td><td>You have tried different combinations of fertilizers to find the ideal mix with which to grow your favorite heirloom tomatoes. You set up an experiment to test your old and new fertilizer mixture. For each trial, you plant 30 of the same variety of heirloom tomato plants in the same soil under following conditions:<br><br>
<table>
<tr><th>Variable</th><th>trial 1</th><th>trial 2</th><th>trial 3</th><th>trial 4</th></tr>
<tr><td>fertilizer mix</td><td>old</td><td>new</td><td>old</td><td>new</td></tr>
<tr><td>sunlight (hours/day)</td><td>8</td><td>12</td><td>8</td><td>8</td></tr>
<tr><td>water ( ml/day)</td><td>500</td><td>300</td><td>300</td><td>300</td></tr>
<tr><td># tomatoes produced</td><td>80</td><td>140</td><td>100</td><td>100</td></tr>
</table>
<br>1. Consider the following statement: "The new fertilizer mixture affects the number of tomatoes a plant can produce." If the fertilizer experiment can be used to test the statement, which trials should be compared?<br><br>
a. trials 1 and 2<br>
b. trials 2 and 3<br>
c. trials 3 and 4<br>
d. all trials<br>
e. none of the trials<br><br>
2. Your selection is most closely associated with which of the following explanations?<br>
a. one should compare trials that show the new fertilizer yields many more tomatoes than the old fertilizer<br>
b. one should compare trials that show a difference in the number of tomatoes yielded<br>
c. one should compare all trials because conclusions can only be drawn from experiments that have been repeated numerous times<br>
d. one should only compare trials that isolate the variable tested<br>
e. one should only compare trials that support the hypothesis tested</td></tr>
<tr><td>Advantages/ Disadvantages</td><td>The advantage to using two-tiered questions is that students who use test taking strategies to correctly answer the first tier question still have to justify their answer in the second tier. Also, the second tier options are usually based on common misconceptions – faculty can use this strategy to determine which misconceptions their students have. However, the disadvantage of having the second tier MCQ is that it may cue a student to the correct answer in the first tier (Palmer and Devitt, 2007). For this reason, many two tier questions use a MCQ for the first tier and a free response for the second tier.</td></tr>
</table>

**Example 3: Complex (K-Type)**

| | |
|---|---|
| **Description** | Complex MCQs, also commonly referred to as K-Type questions, have several grouped options from which one must choose the correct answer or a group of answers from several options. |
| **Cognitive** | HOC |

| | |
|---|---|
| **Level** | |
| **Discipline** | Physics/Chemistry (ETS) |
| **Question (answer in bold)** | *Which of the following functions could represent the radial wave function for an electron in an atom? (r is the distance of the electron from the nucleus; A and b are constants.)*<br>*I. A* $e^{-br}$<br>*II. A sin(br)*<br>*III. A/r*<br><br>***a) I only***<br>*b) II only*<br>*c) I and II only*<br>*d) I and III only*<br>*e) I, II, and III* |
| **Advantages/ Disadvantages** | Most agree that these kinds of questions are very confusing and often mislead students (Albanese 1993 ; Haladyna, Downing et al. 2002). These questions also take up more space and require more time. Instructors should avoid using them if at all possible. An alternative to this kind of question is the multiple true/false question (see below). |

**Example 4: Matching**

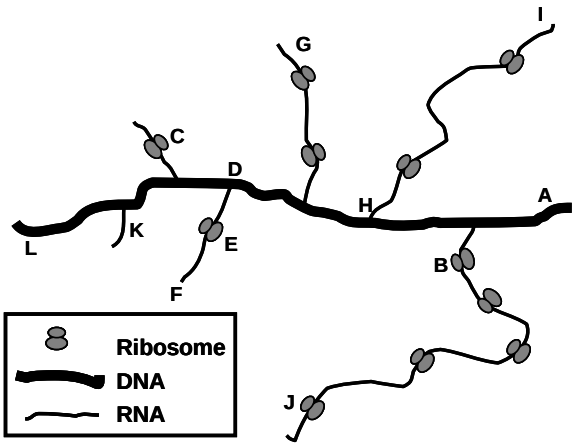
| | |
|---|---|
| **Description** | Matching questions provide several stems and options that must be paired. |
| **Cognitive Level** | LOC |
| **Discipline** | Immunology |
| **Question (answer in bold)** | *a. neutrophil* ____***D***___ *acts as a chemical gradient*<br>*b. cytokines* ____***C***___ *assists in clotting*<br>*c. platelet* ____***E***____ *may contain many epitopes*<br>*d. chemokines* ____***A***___ *engulfs cells by phagocytosis*<br>*e. antigen* ____***B***___ *increases body temperature* |
| **Advantages/ Disadvantages** | Although little research has been done to determine how effective matching questions are at measuring students' understanding of content, these kinds of questions are most likely to probe students' LOC skills because most matching requires identification based on memorization. The difficulty, but not necessarily the cognitive level, of the question can be increased by adding more items to match (ref). |

**Example 5: Simple True/false**

| | |
|---|---|
| **Description** | Standard true/false provide one statement that one must determine is true or false. These questions are also presented in other ways such as, yes or no, requiring a student to make a choice between to basic options. |
| **Cognitive Level** | LOC |
| **Discipline** | Geology (Coughenour, C., personal communication) |
| **Question (answer in bold)** | *A Richter magnitude 6 earthquake has 10 times more ground motion than a magnitude 5.*<br>*True (t) or false (f)?* ____***t***____ |

| | |
|---|---|
| **Advantages/ Disadvantages** | There is conflicting information about the effectiveness of this format in measuring student understanding (Grosse 1985). True/false questions with less than five true/false items may have increased associated error due to guessing (Grosse 1985). Therefore, multiple true/false items are more robust. The cognitive level at which these kinds of formats probe depends on how the question is written. The question below measures recall but true/false questions can be written at higher cognitive levels. |

**Example 6: Multiple True/False**

| | |
|---|---|
| **Description** | Multiple true/false questions provide only one stem followed by several statements about the stem that one must identify as true or false. |
| **Cognitive Level** | HOC |
| **Discipline** | Biology |
| **Question (answer in bold)** | *A cartoon of an electron micrograph is shown below. A piece of chromosomal DNA containing a single gene is illustrated as a thick line. Thin lines radiating from the DNA are mRNA molecules in the process of being transcribed. Ribosomes are attached to the mRNA. <u>Newly synthesized peptides are not shown.</u>*<br>  <br><br>*Refer to the drawing when answering the true (t)/false (f) questions below.*<br>__**f**__ *The sequence of bases in the mRNA labeled K is complementary to the sequences of bases in the mRNA labeled F.*<br>__**t**__ *The promoter for this gene is closer to L than to A.*<br>__**t**__ *Ribosome J has made fewer peptide bonds than ribosome B.*<br>__**f**__ *In the RNA transcript labeled H-I, the 5' end of the RNA is at H.*<br>__**t**__ *The RNA polymerase located at position D (directly above E) is moving toward the right.*<br>__**f**__ *The cell from which this chromosomal DNA was isolated is eukaryotic.*<br>__**t**__ *The distance between ribosome E and end F is increasing.*<br>__**f**__ *Ribosome C has just synthesized the carboxy terminus of the protein.* |
| **Advantages/ Disadvantages** | The example above shows how a true/false question can be written to measure HOC skills. The student must analyze a diagram and apply their knowledge of RNA transcription and protein translation to answer the questions. Standard true/false questions can be structured similarly to test HOC skills. |

**Example 7: Alternate-Option**

| | |
|---|---|
| **Description** | This is similar to a standard MCQ, but because it only has two options it is called an alternate-option question; one of the options is a distractor. |
| **Cognitive Level** | HOC |
| **Discipline** | Chemistry |
| **Question (answer in bold)** | *Based on the information provided below, how would you describe this reaction?*<br>$C_2H_4(g) + H_2O(l) \rightarrow C_2H_5OH(l)$<br><br>$\Delta G°_f(C_2H_5OH(l)) = -175$ kJ/mol<br>$\Delta G°_f(C_2H_4(g)) = 68$ kJ/mol<br>$\Delta G°_f(H_2O(l)) = -237$ kJ/mol<br><br>***a) The reaction is spontaneous.***<br>*b) The reaction is non-spontaneous.* |
| **Advantages/ Disadvantages** | As mentioned before, a two option question can be just as effective as a standard MCQ with 3 or 4 options because many students easily eliminate options and make their choices based on two options anyway. An advantage to MCQs with only 2 options is that the test length can be increased to test the same content, thereby reducing the error associated with guessing. |