Will this be on the test?
Characterizing the cognitive levels of undergraduate biology

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Student expectations of biology

1. What is the nature of the knowledge I am learning?
2. What should I do to learn in biology?

Hall et al 2011

Course expectations of students

1. Learning goals and outcomes
   Students will…
   define, describe, explain, identify, label, etc

2. Nature of assessments
   Students will…
   memorize terms, processes, examples
   bring a number 2 pencil

3. Classroom activity
   Students will…
   take copious, accurate notes (and maybe complete the crossword)
Characterizing assessments

- Concept and content knowledge
  - Vision and Change Core Concepts
  - Map to a textbook

- Skills
  - Cognitive skills using Bloom’s taxonomy, Webb’s depth of knowledge
  - Vision and Change Core disciplinary practices

Bloom’s taxonomy, cognitive domain

- Identifies 6* levels of cognitive skills
- Nested or hierarchical
- Higher levels require more complex cognitive processes

*Note: Synthesis and Evaluation are collapsed into one level as they are not truly hierarchical.
Applying Bloom’s taxonomy

Independent raters

assign a Bloom’s level to

Assessment items

weight by

discuss to

Point value

Reach consensus on each item

Does the MCAT stress rote memorization?

<table>
<thead>
<tr>
<th>N</th>
<th>Weighted ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP Biology</td>
<td>157</td>
</tr>
<tr>
<td>Undergraduate</td>
<td>111</td>
</tr>
<tr>
<td>GRE</td>
<td>108</td>
</tr>
<tr>
<td>MCAT</td>
<td>109</td>
</tr>
<tr>
<td>Medical School</td>
<td>101</td>
</tr>
</tbody>
</table>

Zheng et al 2008
Study objectives

- Characterize and compare the cognitive skills routinely assessed in
  - Introductory biology courses (Study 1, 2)
  - Upper division biology courses (Study 2)

- Characterize the relationship between cognitive skill level and difficulty in biology (Study 2)

Introductory biology, nationally

- 56 faculty (from FIRST II or SI)
  - taught
  - 77 introductory biology courses

- 2 Independent Raters
  - assigned a Bloom’s level to
  - Exam/quiz questions (n=9,317)
  - IRR = 0.65
  - Ratings averaged
Course demographics

Table 2. Course demographics

<table>
<thead>
<tr>
<th>Course type</th>
<th>Proportion of courses</th>
<th>Mean class size (±SEM)</th>
<th>No. courses reporting class size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell and molecular biology</td>
<td>11.7%</td>
<td>144 ± 37</td>
<td>9</td>
</tr>
<tr>
<td>Environmental science</td>
<td>10.4%</td>
<td>70 ± 15</td>
<td>6</td>
</tr>
<tr>
<td>Ecology</td>
<td>5.2%</td>
<td>n.d.</td>
<td>0</td>
</tr>
<tr>
<td>General biology</td>
<td>55.8%</td>
<td>253 ± 20</td>
<td>34</td>
</tr>
<tr>
<td>Genetics</td>
<td>3.9%</td>
<td>70 ± 10</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>13%</td>
<td>81 ± 37</td>
<td>5</td>
</tr>
</tbody>
</table>

*a Courses were categorized based on course title.

*b Courses categorized as “Other” included plant biology, microbiology, and zoology.

Introductory biology, nationally

Syllabus Goals
Assessment Items

Knowledge
Bloom's Level
Synthesis

Momsen et al 2010
Characterizing the biology major

Large, public university, very high research activity
  - Single department of biological sciences
    - 17 research-active faculty
    - ~500 undergraduate majors
    - Courses serve science and engineering majors
  - Focus on a single academic year (2010-11)
  - Collected all exams, term papers, portfolios, high stake homework from courses within major

<table>
<thead>
<tr>
<th>No. Courses</th>
<th>No. Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intro biology</td>
<td>5</td>
</tr>
<tr>
<td>Upper division</td>
<td>21</td>
</tr>
</tbody>
</table>

Applying Bloom’s taxonomy

3 independent raters

Assessment items (n=3151)

Reach consensus on each item

assigned a Bloom’s level to

discussed to

Agreement of 83%
Study 2

Just the facts?!

<table>
<thead>
<tr>
<th>Bloom’s Level</th>
<th>Introductory</th>
<th>Upper Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>1100</td>
<td>2051</td>
</tr>
<tr>
<td>Bloom’s Level</td>
<td>1.55 ± 0.67</td>
<td>1.42 ± 0.87</td>
</tr>
</tbody>
</table>

*For introductory biology only

Study 2

Bloom’s level versus performance*

Knowledge   Bloom’s Level   Synthesis

Percent Correct

1 course, n = 3 exams

*For introductory biology only

Momsen et al 2013
Good news?

Questions with figures ask students to label, interpret, reason with, create, evaluate, etc.

9. Which of the following is a TRUE statement about the polysaccharides shown below?

10. Which of the following represents a monophyletic group?

9. Table 1. Climate data recorded from an unnamed town

<table>
<thead>
<tr>
<th>Month</th>
<th>Minimum Temperature (°C)</th>
<th>Daily Minimum Temperature (°C)</th>
<th>Daily Mean Temperature (°C)</th>
<th>Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>21.3</td>
<td>7.6</td>
<td>18.1</td>
<td>0.45</td>
</tr>
<tr>
<td>February</td>
<td>28.9</td>
<td>7.8</td>
<td>18.1</td>
<td>0.51</td>
</tr>
<tr>
<td>March</td>
<td>40.2</td>
<td>19.1</td>
<td>29.7</td>
<td>0.65</td>
</tr>
<tr>
<td>April</td>
<td>55.9</td>
<td>30.0</td>
<td>43.8</td>
<td>1.46</td>
</tr>
<tr>
<td>May</td>
<td>69.1</td>
<td>45.8</td>
<td>56.0</td>
<td>2.22</td>
</tr>
<tr>
<td>June</td>
<td>77.8</td>
<td>51.0</td>
<td>64.7</td>
<td>2.58</td>
</tr>
<tr>
<td>July</td>
<td>84.5</td>
<td>56.4</td>
<td>70.4</td>
<td>2.58</td>
</tr>
<tr>
<td>August</td>
<td>83.4</td>
<td>54.7</td>
<td>68.0</td>
<td>2.15</td>
</tr>
<tr>
<td>September</td>
<td>71.6</td>
<td>49.2</td>
<td>57.7</td>
<td>1.61</td>
</tr>
<tr>
<td>October</td>
<td>59.2</td>
<td>32.3</td>
<td>46.5</td>
<td>1.28</td>
</tr>
<tr>
<td>November</td>
<td>38.2</td>
<td>17.8</td>
<td>26.0</td>
<td>0.70</td>
</tr>
<tr>
<td>December</td>
<td>25.7</td>
<td>4.8</td>
<td>15.2</td>
<td>0.44</td>
</tr>
</tbody>
</table>

1. (5 pts) Use your knowledge of climate graphs and the data in Table 1 to create a climate graph for this town.
Assessment drives learning

New information

Perceived

Working memory

Processed

Organize
Elaborate
Visualize

Long-term memory

Retrieval

Based on Kolb 1984

Provides practice with
• Disciplinary skills
• Concept understanding
• Metacognitive skills

Will this be on the test?

Moving beyond the facts

Higher-level cognitive skills

Create, integrate, assess, convince
Separate, classify, order, interpret
Show, solve, modify, relate, calculate

Lower-level cognitive skills

Knowledge
Comprehension
Application
Analysis
Synthesis & Evaluation
Ready to **LEVEL UP?**

**Coding assistance**
- Erika Offerdahl
- Lisa Montplaisir
- Elizabeth Anderson
- Amy Williams

**Method development**
- Tammy Long
- Sara Wyse
- Elena Bray Speth
- Diane Ebert-May
- Scott Freeman

*Thanks to over 100 faculty who’ve graciously shared exams, quizzes, and homework assignments.*