Why and How to Develop a Concept Inventory

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Goals of this Presentation

*After this presentation, you should be able to:*

- Explain why a concept inventory is a useful educational tool
- List the steps involved in the process of developing a concept inventory
What is a concept inventory?

A. A list of the concepts you want your students to learn

B. Statements reflecting concepts your students already know

C. A means to assess student understanding of key concepts

D. All of the above
Background

- Cognitive science has informed educational practices
- Recognition of need for developing learning/critical thinking skills in students
- Focus on core concepts and skills/competencies
Step 1: Identify what is most critical for your students to learn

- Evolution
- Structure & function
- Information flow
- Pathways & transformations
- Systems
- Impact of Microbes
Backward Design of Curriculum

1) LEARNING OUTCOMES: Identify desired results

2) ASSESSMENT: Decide acceptable evidence

3) INSTRUCTION: Plan learning experiences

A concept inventory is an assessment tool!

Understanding by Design by Jay McTighe & Grant Wiggins
Step 2: Write Learning Outcomes

Anatomy of a learning outcome:
STUDENT CENTERED ❤️
1) State the condition
2) Describe a performance (ACTION VERB)
3) Give the criteria

After this presentation, students will be able to explain the steps used to design a concept inventory.
Creation of the ASM Concept Inventory Task Force(s)

**Microbiology Concept Inventory**
Leader: Tim Paustian, University of Wisconsin, Madison

**Microbiology for Health Sciences Concept Inventory**
Leader: Heather Seitz, Johnson County Community College
Andrea Rediske, Jeffrey Pommerville, Lucy Kluckhohn-Jones, Maureen Whitehurst, Megan Howard, Rachel Horak

**Review team**
Leader: Nancy Boury, Iowa State University
Chris Parker, Julia Massimelli, Theodore Muth

**Psychometrician**
Shannon Harris, University of Wisconsin, Madison

**ASM Education Department**
Amy Chang, Kelly Gull, Michelle Sloan

**NSF Funding:**
Division of Undergraduate Education (DUE)
Conference Proposal 1625772
Step 3: Write T/F question and ask students to explain their thinking

Concept: METABOLIC PATHWAYS
(Curriculum Guidelines Fundamental Statement #12)

Learning outcome: Explain the metabolic process whereby one microbial cell may produce a product that is beneficial or harmful to a neighboring cell

T/F question: Oxygen produced by photoautotrophic cyanobacteria through photosynthesis is consumed by chemoheterotrophic microbes in the ocean during aerobic respiration.

TRUE
FALSE

Please explain your reasoning for your answer.
Step 4: Analyze the student data to identify misconceptions

- Read student open ended explanations and categorize (~100 per each team of 3 faculty)
- Agree on the most common categories (develop a team code)
- Score all of the explanations (~300)
- Identify the top three most common “misconceptions” and using the students words write distractors
Example of coding data:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Stevens</td>
<td>Buchner</td>
<td>Smith</td>
<td>Consensus</td>
<td>Oxygen produced by photautotrophs</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>Question 13</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2: Oxygen is not present in the cell</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>DK</td>
<td>dk</td>
<td>dk</td>
<td>dk</td>
<td>3: I could not make an educated guess</td>
</tr>
<tr>
<td>5</td>
<td>61</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>4: Heterotrophs need oxygen</td>
</tr>
<tr>
<td>6</td>
<td>62</td>
<td>G</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td>5: It seems logical</td>
</tr>
<tr>
<td>7</td>
<td>76</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>6: Aerobic respiration requires</td>
</tr>
<tr>
<td>8</td>
<td>81</td>
<td>G</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td>7: I guessed on this one.</td>
</tr>
<tr>
<td>9</td>
<td>188</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>8: I don't know a lot of these terms</td>
</tr>
<tr>
<td>10</td>
<td>193</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>9: Wouldn't it be anaerobic respiration?</td>
</tr>
<tr>
<td>11</td>
<td>204</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>10: If it consumes oxygen, I would...</td>
</tr>
<tr>
<td>12</td>
<td>205</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>11: Photoautotrophs produce oxygen</td>
</tr>
<tr>
<td>13</td>
<td>222</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>12: That process can actually happen</td>
</tr>
<tr>
<td>14</td>
<td>226</td>
<td>G</td>
<td>dk</td>
<td>g</td>
<td>g</td>
<td>13: I am not completely sure of this</td>
</tr>
<tr>
<td>15</td>
<td>239</td>
<td>G</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td>14: That makes sense using my criteria</td>
</tr>
<tr>
<td>16</td>
<td>252</td>
<td>3</td>
<td>c</td>
<td>3</td>
<td>3</td>
<td>15: Yes because photoautotrophic...</td>
</tr>
<tr>
<td>17</td>
<td>278</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>16: This is considered anaerobic</td>
</tr>
<tr>
<td>18</td>
<td>280</td>
<td>5</td>
<td>c</td>
<td>5</td>
<td>5</td>
<td>17: Chemoheterotrophs do not need...</td>
</tr>
<tr>
<td>19</td>
<td>292</td>
<td>4</td>
<td>ns</td>
<td>4</td>
<td>4</td>
<td>18: It's produced during the anaerobic</td>
</tr>
<tr>
<td>20</td>
<td>297</td>
<td>G</td>
<td>g</td>
<td>g</td>
<td>g</td>
<td>19: Just makes sense</td>
</tr>
<tr>
<td>21</td>
<td>304</td>
<td>C</td>
<td>c</td>
<td>c</td>
<td>c</td>
<td>20: During aerobic respiration cells</td>
</tr>
<tr>
<td>22</td>
<td>316</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>21: The chemoheterotrophic microbe...</td>
</tr>
<tr>
<td>23</td>
<td>333</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>22: They absorb all chemicals because</td>
</tr>
<tr>
<td>24</td>
<td>342</td>
<td>NS</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>23: Phytoplankton and zooplankton</td>
</tr>
</tbody>
</table>
## Example of student misconceptions

<table>
<thead>
<tr>
<th>Question number</th>
<th>Code</th>
<th>Number of comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>4 = confusion aerobic/anaerobic respiration; chemohetrotophs anaerobic</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>5 = chemohetrotophs don’t need/metabolize oxygen; use/absorb chemicals not oxygen; use organic molecules; use CO2 not O2</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>2 = heterotrophs need oxygen; absorb oxygen (and carbon)</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>3 = heterotrophs eat products of autotrophs; consume other organisms; nutrients from chemical in plants; carbon from other organisms</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>8 = confusion with chemoautotroph</td>
<td>5</td>
</tr>
</tbody>
</table>
Step 5: Write a multiple choice question (with response explanation!)

Question?
A. Distractor (using students’ own words!)
B. Distractor
C. Correct Answer!
D. Distractor

Please explain your reasoning for your answer.
Step 6: Revise and Review Questions

Step 7: Reliability and Validity Testing

Step 8: Assess Student Learning

- Pre-post course assessment of student learning
- Pre-post curriculum assessment of student learning (retention of information)
- Impact of curricular innovations
- Impact of background variable (i.e. gender, ethnicity, GPA, age, prior education etc.)
- Analyze student pre-conceptions
- Further analyze student misconceptions (LEE HUGHES)
- Use as a focal point for faculty development (JOHN BUCHNER)
Completed Concept Inventories in Microbiology:

• One published Host-Pathogen Interactions Concept Inventory (University of Maryland)

• Two new concept inventories Microbiology Concept Inventory (MCI) for general microbiology and Health Sciences Concept Inventory (MHSCI) for allied health under review with *Journal of Microbiology and Biology Education*