

Assessing - How do we get beyond the final exam and effectively assess what our students are learning?

David Steer

Associate Professor, Geology and Environmental
Science

University of Akron

steer@uakron.edu (330) 972-2099

Teaching Introductory Geoscience in the 21st
Century

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Introductory Exercise

Examine the six questions below. Assume you are a student in classes where these questions would be appropriate. Rank the questions from easy to most challenging based on the character of the question.

- A. Which one of the following values approximates best to the volume of a sphere with radius 5m?
a) 2000m^3 b) 1000m^3 c) 500m^3 d) 250m^3 e) 125m^3
 - B. Design a method for mitigating the effects of acid mine drainage.
 - C. What is the capital of Maine?
 - D. How would you restructure the school day to reflect children's developmental needs?
 - E. Contrast the floor of the Atlantic Ocean with the shape of a bathtub.
 - F. Which statements in the President's State of the Union address were based on facts and which were based on assumptions?
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Were some questions easier to rank than others? If so, which?

Were there some questions that were more difficult to separate? If so, which?

Comprehension Surveys for Bloom's Taxonomy

Teaching Goal 1: To understand the features of Bloom's Taxonomy

(Level 0: I have never heard of Bloom's Taxonomy.)

Level 1: I can identify how many levels there are in BT.

Level 2: I can place several levels of BT in correct order.

Level 3: I can describe and name the six categories of BT.

Level 4: I can explain how I might use BT in planning a lesson.

Teaching Goal 2: To create exercises representing all categories of Bloom's Taxonomy

Level 1: I understand where multiple choice questions and essay questions might place in BT.

Level 2: I can classify a series of simple questions in BT.

Level 3: I can analyze how to classify a series of exercises based on the categories of BT.

Level 4: I can make up questions representative of the six categories of BT.

Bloom's Taxonomy: A Framework for Learning

Over forty years ago, Benjamin Bloom and several co-workers created a taxonomy of educational objectives that continues to provide a useful structure for organizing learning exercises and assessment experiences at all levels of education (Bloom and others, 1956; Anderson and Sosniak, 1994; Anderson and Krathwohl, 2001). Bloom's taxonomy divided cognitive learning into six levels, from lower-level thinking skills such as memorization to higher order thinking that involves the evaluation of information. The taxonomy has been used by instructors in geology courses to guide the development of questions that address a full range of cognitive skills. Each taxonomy level is described briefly below and examples of specific questions linked to each of level are discussed. The revised framework of Pohl (2000) is displayed (original levels in parentheses).

Bloom's Taxonomy (original)	Learning Skill	Question stems*
Remembering (Knowledge)	Recognizing and Recalling	What is . . . ? Who, what, when, where, how ...? Describe . . .
Understanding (Comprehension)	Interpreting, Exemplifying, Classifying, Summarizing, Inferring, Comparing, Explaining	What would happen if . . . ?; What does . . . illustrate about . . . ?; What is analogous to . . . ? How would you explain . . . ?; Illustrate the . . . ?; What was the main idea . . . ?
Applying (Application)	Executing and Implementing,	How could . . . be used to . . . ? What is another example of . . . ? Use these steps to solve ... Clarify why ...
Analyzing (Analysis)	Differentiating, Organizing, Attributing	How does . . . affect . . . ? What are the differences (similarities) between . . . ? What causes . . . ? How does . . . compare/contrast with . . . ?
Evaluating (Synthesis)	Checking, Critiquing, Reorganizing, Assessing, Making judgments	What is a possible solution for the problem of . . . ? How does . . . relate to what we learned before about . . . ? Why is . . . important? What is the best . . . , and why? Do you agree/disagree that . . . ?
Creating (Evaluation)	Generating, Planning, Producing	Can you design a ...? What would happen if ...? Can you create new uses for ...? How many ways can you ...?

* revised from King, A., 1995, Teaching of Psychology, v.22, p. 13-17.

Summary of Bloom's Taxonomy

Remembering (Knowledge)

Answers to remembering questions indicate if a student knows and can recall specific information. Examples of questions that assess knowledge are some types of multiple choice questions, true/false questions, definitions, matching questions, or lists. Questions that ask students to define, identify, list, or name are often "knowledge" questions.

Understanding (Comprehension)

Responses to understanding questions report information or observations. Students must possess some basic knowledge of the subject to correctly answer these questions. Understanding questions can fall into several categories and may require that students convert, summarize, classify, infer, compare, or explain information.

Applying (Application)

Application often involves applying rules or principles to new situations, using known procedures to solve problems or demonstrating how to do something. Questions that ask students to solve a problem using a known equation or to select a procedure to complete a new task would be considered application questions.

Analyzing (Analysis)

Answers to analysis questions may give directions, make commentaries, scrutinize data, explain how something works, or distinguish fact from opinion. Analysis requires that students break information into component parts to identify its organization. Students are expected to find links between data and interpretations and to discover which material is relevant to a task and which is extraneous. Questions that ask students to diagram, illustrate, outline or subdivide would be considered analysis questions.

Evaluating (Synthesis)

Responses to evaluation questions make judgments about facts, data, opinions or research results using evidence and scientific reasoning. Good answers require students to analyze and synthesize information and clarify ideas. Evaluation questions might ask a student to appraise, criticize, justify, or support an idea or concept. Synthesis combines a series of parts into a greater whole. Good answers to synthesis questions may predict the outcome for a particular event and may involve making generalizations and developing a "big picture" view of a phenomenon or feature. Questions that ask students to combine, compile, create, devise, plan, or organize are often considered synthesis questions.

Creating

Create-level exercises require students to generate new products, ideas or ways of solving problems.

Bloom's Taxonomy Exercise

Review the examples of exercises used in a general education Earth Science course at UA and rank them according to Bloom's Taxonomy.

Place each exercise into one of the six classes (remember, understand, apply, analyze, evaluate/synthesis, create). Some exercises may display multiple questions that can be ranked at different levels in the Taxonomy. Choose the highest level.

Complete the table below by circling the abbreviation of the appropriate taxonomy level.

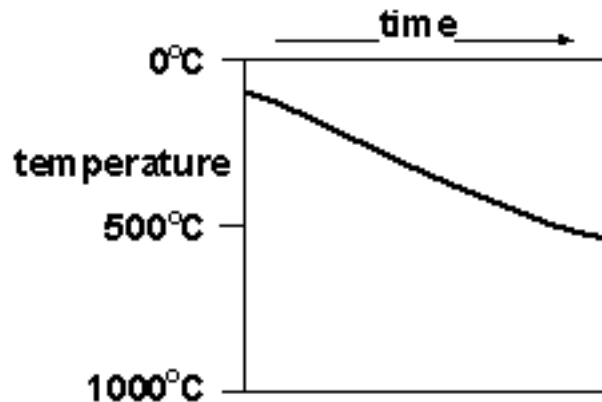
Exercise	Taxonomy Level					
The Rock Cycle	R	U	Ap	An	E	Cr
Atmospheric Pressure and Condensation	R	U	Ap	An	E	Cr
Earthquake Warning System	R	U	Ap	An	E	Cr
Venn Diagram (Hurricanes vs. Tornadoes)	R	U	Ap	An	E	Cr
Reading Quiz: Coasts	R	U	Ap	An	E	Cr
NEO Concept Map Interpretation	R	U	Ap	An	E	Cr
Groundwater Rubric	R	U	Ap	An	E	Cr
Earth's Layers Concept Map	R	U	Ap	An	E	Cr
Relative Time Diagram	R	U	Ap	An	E	Cr

This Bloom's Taxonomy Exercise	R	U	Ap	An	E	Cr
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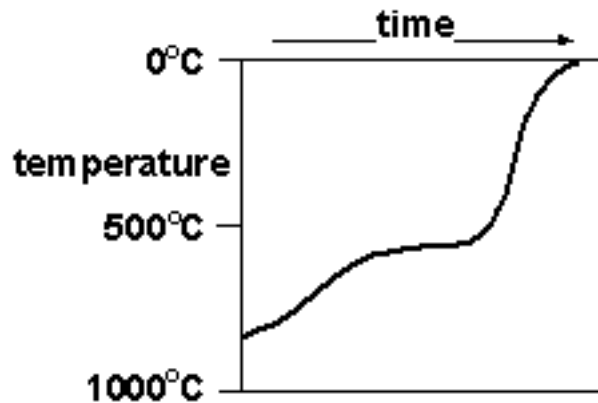
Context: Students complete these exercises following discussions of the rock cycle.

The Rock Cycle

1. The graph below illustrates how the temperature changed with time for part of the rock cycle. Which of the following processes is best represented by the graph?
- a) Sediment is lithified to form sedimentary rock.
 - b) Sedimentary rocks are converted to metamorphic rocks.
 - c) Metamorphic rocks are uplifted to Earth's surface.
 - d) Magma cools to form plutonic igneous rock.
 - e) Sedimentary rock is converted to magma.



2. The graph below illustrates how the temperature changed with time for part of the rock cycle. Which of the following is best represented by the graph?
- a) magma forms a plutonic igneous rock that is then uplifted to the surface
 - b) sediment is lithified and then metamorphosed
 - c) volcanic igneous rock is melted to form new magma
 - d) plutonic igneous rocks are uplifted and weathered to form sediment
 - e) sediment is lithified to sedimentary rock that is then weathered to form new sediment



Context: Students complete this exercise following a lecture or reading on air pressure and adiabatic lapse rates.

Atmospheric Pressure and Condensation

An instructor asked her class to summarize some information from the section of the chapter you just read. Four students submitted the four statements below as part of their answers. She returned the statements and told the students that they could correct them for full credit. Identify what is wrong with each statement and describe how you would fix these answers to earn full credit.

- A. The temperature of a rising parcel of air decreases by the normal lapse rate.
- B. The percentage of oxygen in the atmosphere decreases with altitude.
- C. When it rains you have to use the wet adiabatic lapse rate to figure out temperatures at higher elevations.
- D. The dry adiabatic lapse rate is higher than the wet adiabatic lapse rate so air temperatures should be higher in dry air (before condensation occurs) than in wet air (after condensation occurs).

Context: Students complete this exercise following discussion of seismic waves and earthquake hazards.

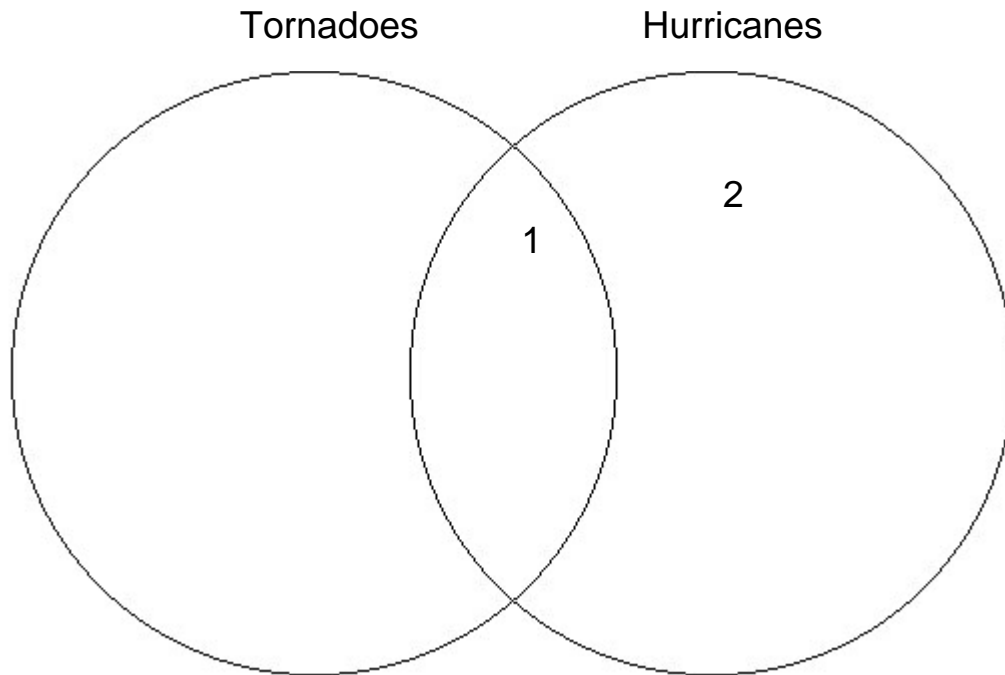
Earthquake Warning System

Warning times associated with other natural hazards can be measured in months (volcanoes), days (hurricanes), or minutes (tornadoes). Recently some scientists have suggested that it would be possible to create an earthquake warning system in regions like southern California where there is an extensive network of seismograph stations. Their suggestion was that the arrival of P waves could trigger an alarm that would give people time to react before the arrival of the more damaging S waves, and later surface waves. Suppose the system is designed and implemented. Develop a community action plan to help citizens best respond to the alarm.

Context: Students complete this exercise at the beginning of class as a review of a reading assignment or as a follow up a lecture segment on the characteristics of extreme weather systems.

Venn Diagram: Tornadoes vs. Hurricanes

List the features that are unique to either group or that they share on the back of this page. Provide a brief but clear description of each feature (see examples). Two features are included as examples. Write the appropriate number in the corresponding locations on the Venn diagram below. (One example has been included.)



Features

- | | |
|-------------------------|-----|
| 1. Low pressure systems | 11. |
| 2. Form over oceans | 12. |
| 3. | 13. |
| 4. | 14. |
| 5. | 15. |
| 6. | 16. |
| 7. | 17. |
| 8. | 18. |
| 9. | 19. |
| 10. | 20. |

Context: Students complete this exercise at the beginning of class as a review of a reading assignment or at the end of a lecture segment on coastal processes.

Reading Quiz: Coasts

Circle the correct answer to the questions below.

1. The most expensive natural disaster in U.S. history was
 - a) Mississippi Flood, 1993
 - b) Hurricane Andrew, 1992
 - c) Northridge Earthquake, 1994

2. Coastal processes are influenced by
 - a) human activity
 - b) tectonic cycles
 - c) climate cycles
 - d) all of these.

3. Sea level was _____ during the last ice age.
 - a) lower
 - b) higher

4. Waves are deflected (refracted) toward
 - a) headlands
 - b) bays.

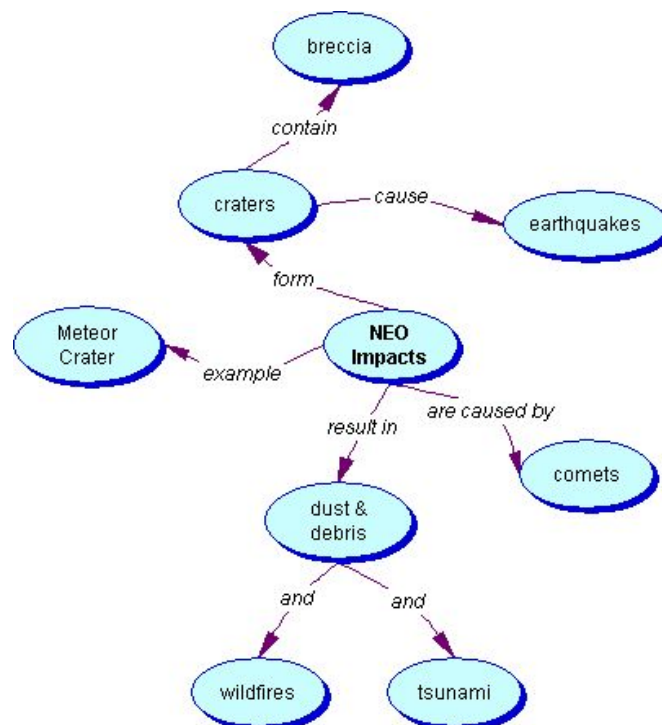
Context: Students complete this exercise as a homework assignment or as a formative assessment exercise at the end of a lecture on NEO impacts.

NEO Concept Map Interpretation

Review the concept map presented below that describes the characteristics of NEO impacts. Score the concept map using the grading rubric and redraw the diagram making whatever changes you believe are appropriate to earn a “4” on the grading scale.

Grading Rubric

- 0 The concept map does not contain any information about NEO impact events.
- 1 The concept map contains some relevant terms but several key terms are omitted and many linking phrases are either absent or inaccurate.
- 2 The concept map contains most relevant terms but they are poorly organized and some linking phrases are absent or incorrect.
- 3 The concept map contains most relevant terms but one or two key term(s) may be absent. The diagram is reasonably well organized, and almost all linking phrases are appropriate.
- 4 The concept map contains all relevant terms in a well organized display that has appropriate linking phrases for each pair of terms.



Context: Students complete this exercise following a review of the characteristics of groundwater systems, including the properties of aquifers.

Groundwater Rubric

You are part of a team that is given an assignment to help locate a new well field that will supply your town with water. In examining the potential site locations you recognize that there are several different factors that will influence groundwater availability and no site is perfect.

You are asked to create a **scoring rubric** to evaluate at least five factors that will influence the availability of groundwater. The location that scores the highest using the scoring rubric will be selected for the well field. One factor is included as an example in the table below; identify four more.

You are given the opportunity to identify which is the most important factor and double its score. Which factor would you choose?

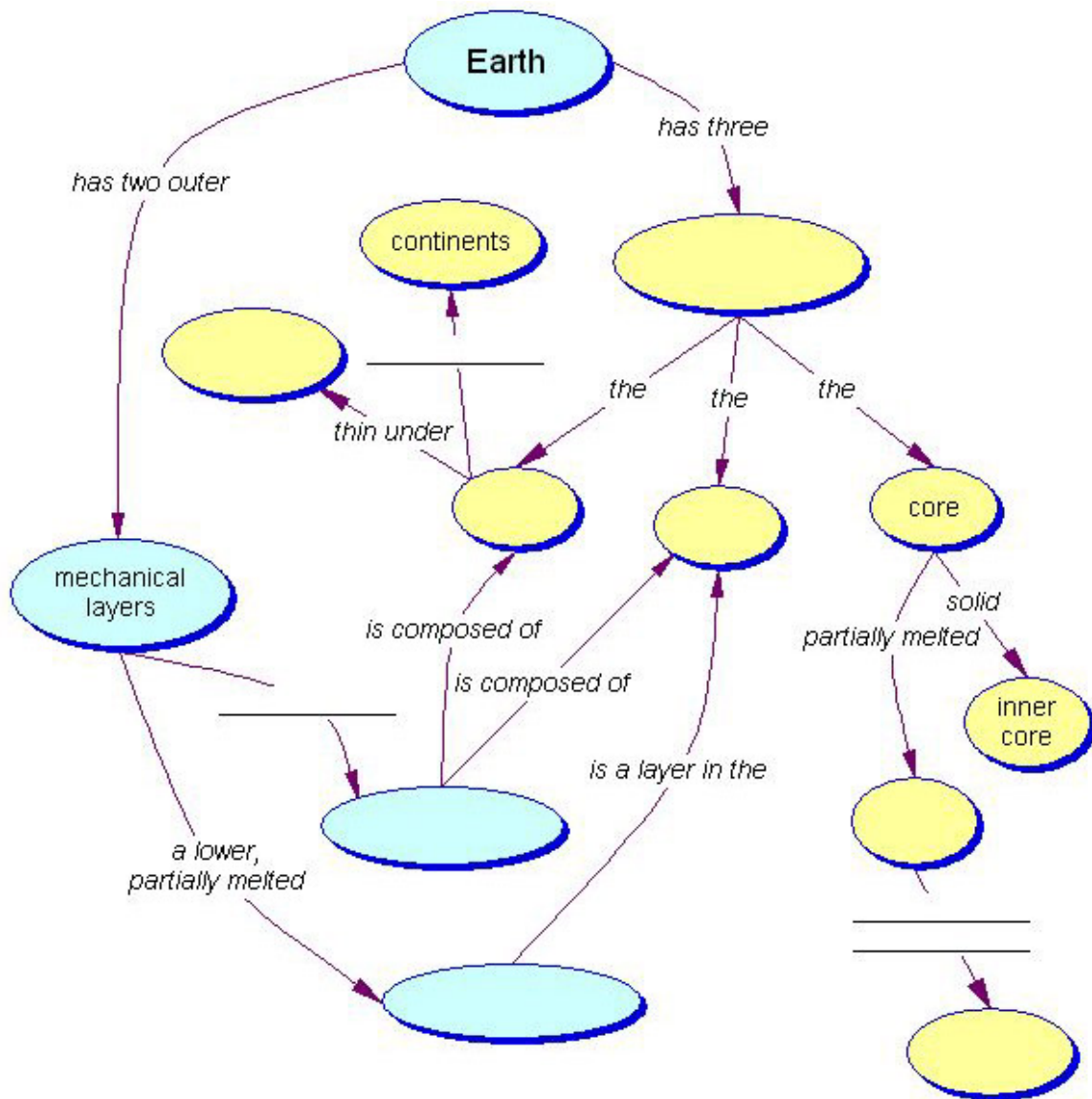
Factors	Good (3)	Moderate (2)	Poor (1)
Depth to water table	Shallow	Intermediate	Deep

Context: Students complete this exercise as a homework assignment or at the start of class following a reading assignment on the structure of Earth.

Earth's Layers Concept Map

Complete the concept map below by correctly adding some of the terms provided to the appropriate blank locations as key terms or connecting phrases/terms. Some necessary terms are not included in the list; others may not be applicable to this diagram.

- | | |
|--------------------------------|---|
| 1. <i>compositional layers</i> | 5. <i>is the source of Earth's</i> |
| 2. <i>crust</i> | 6. <i>an upper rigid</i> |
| 3. <i>one of three</i> | 7. <i>characteristic of terrestrial planets</i> |
| 4. <i>oceans</i> | |

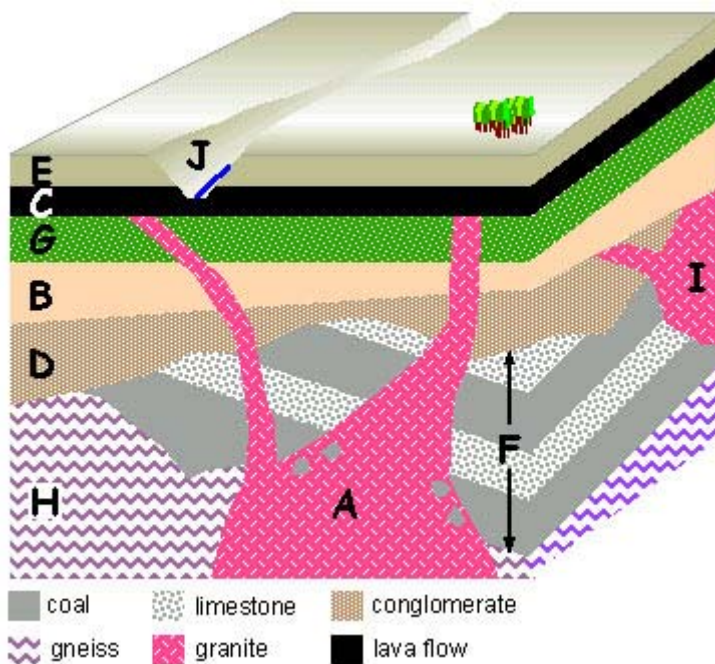


Context: Students complete this exercise following a lecture segment that describes the three principles (superposition, original horizontality, cross cutting relationships) used to unravel the sequence of geological events.

Relative Time

Complete the exercise by using the principles of superposition, original horizontality, and cross-cutting relationships to determine the order of events for the idealized location shown in the figure.

Place the rock units in their order of formation, oldest to youngest.



Oldest

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Youngest

One Question Style, Many Uses

Different assessment methods can be used to target multiple levels of Bloom's Taxonomy.

Formative Assessment Methods and Bloom's Taxonomy						
<i>Bloom's Taxonomy</i>	<i>Learning Skill</i>	Learning Tool (Assessment Method)				
		Venn Diagram	Image Analysis	Concept Map	Open-ended Question	Evaluation Rubric
<i>Remembering</i>	<i>memorization and recall</i>	•	•	•	•	•
<i>Understanding</i>	<i>comprehend</i>	•	•	•	•	•
<i>Applying</i>	<i>using knowledge</i>				•	•
<i>Analyzing</i>	<i>taking apart information</i>	•	•	•	•	•
<i>Evaluating</i>	<i>reorganizing making judgments</i>			•	•	•
<i>Creating</i>	<i>Planning or generating new ideas</i>			•	•	•

Venn diagrams and concept maps are examples of assessment methods can be used in different ways to match with multiple levels of the taxonomy.

Venn Diagrams

Remembering – Provide a list of terms to be distributed in a labeled Venn diagram.

Analyzing – Provide a labeled Venn diagram and have students identify and place relevant terms.

Evaluate – Take some sample Venn diagrams created by another class and have students rank them and justify their rankings.

Evaluation Rubrics

Remembering – Provide a partially a list of suitable terms and risk levels for students to use for assigning risk.

Analyzing – Create an incorrect evaluation rebric that may feature unsuitable terms, leave off some necessary terms, or use inappropriate values. Ask students how rubric could be improved.

Evaluate – Provide a scenario and have students evaluate risk from scratch.

Create – Have students evaluate a scenario and come up with an emergency response plan or resource allocation plan.

References:

- Anderson, L.W., and Krathwohl, D.R., 2001, A Taxonomy for Learning, Teaching, and Assessing: A revision of Bloom's Taxonomy of educational objectives. Longman.
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- Pohl, M., 2000. Learning to think: Thinking to Learn, Models and strategies to develop a classroom culture of thinking, Cheltenham, Victoria, Australia: Hawker Brownlow Education, pp. 7-8.