Physics Education Research (PER) seminar: learning goals and intended outcomes

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Goals for today's seminar

1. recognize the difference between a learning goal and an outcome,
2. classify learning outcomes on a spectrum of cognitive processes,
3. create outcomes from WSU-based goals.

Goals vs outcomes

1. Learning goal: what students know, understand, or be able to do.
   - Goals are often broadly defined, general in statement, few in number, difficult to test for.
2. Learning outcome: what performance or behaviors will indicate accomplishment of the goals.
   - Outcomes are generally narrowly defined, specific in statement, large in number, easy to test for.
   - The outcome is to the goal what the prediction is to the hypothesis. As experimental result can verify or refute a hypothesis, so does a learning outcome measure a level of attainment of a learning goal.
   - Levels of attainment can be spelled out explicitly, e.g., pass/fail, A/B/C/D/F, comprehensive/intermediate/cursory. The construction of rubrics can stem from this practice.

Goals vs outcomes

Learning goals and outcomes used in concert combine to articulate to students (i) what they need to do, and (ii) how far they have traveled along the road towards achieving the goals you have set.

Learning goals and outcomes remind us that people should be able to demonstrate their expertise in multiple ways.

An example follows.

An example from *Classical mechanics (Phys 320)*

WSU learning goal #3: SCIENTIFIC LITERACY

"Graduates will have a basic understanding of major scientific concepts and processes ..."

An example from *Classical mechanics (Phys 320)*

WSU learning goal #3: SCIENTIFIC LITERACY

"Graduates will have a basic understanding of major scientific concepts and processes ..."

LG3: Phys & astro goal #3: SCIENTIFIC LITERACY

"A student who has completed the undergraduate program in physics will be able to understand the important concepts in ... mechanics ..."

An example from *Classical mechanics (Phys 320)*

LG3: *Classical mechanics* outcomes related to variables in physical problem-solving:

Introduce: Identify relevant elements (quantities, coordinate systems) in a physical problem.

Reinforce: Distinguish between relevant and non-relevant elements in a physical problem.

Master: Choose optimal elements in a physical problem.

An example from *Classical mechanics (Phys 320)*

LG3: *Classical mechanics* outcomes related to laws in physical problem-solving:

Introduce: Recognize and apply relevant physical principles to solve a one-step closed problem.

Reinforce: Recognize and apply relevant physical principles to solve multi-step closed problems.

Master: Recognize and apply relevant physical principles to solve multi-step open-ended problems.

An example from *Classical mechanics (Phys 320)*

LG3: *Classical mechanics* outcomes related to units in physical problem-solving:

Introduce: Identify units and their associated concepts, e.g., force is expressed in newtons.

Reinforce: Check that the units expected for a given quantity follow logically from formal substitution in mathematical expressions, or graphical analysis.

Master: Apply dimensional (unit) analysis in general expressions, limits of general expressions, or graphical analysis.

An example from *Classical mechanics (Phys 320)*

A rubric constructed from these outcomes might look like this:

	Introduce	**Reinforce**	**Master**
Elements (variables)		✓	
Laws (principles)			✓
Units	✓		

The rubric could be used for an individual student in one course,

-or- for an individual student as she progresses through the degree,

-or- for a specific course, where it fits in the course hierarchy; when used in this latter way, it is called a curriculum map. Our BS Physics degree is in desperate need of curriculum mapping (but this discussion will be postponed till the spring).

How to construct goals and outcomes: cognitive taxonomies

There are many of these. I am familiar with three:

1. Bloom's taxonomy (Bloom & Krathwohl 1956)
2. A revision of Bloom's taxonomy (Krathwohl 2002)
3. Six facets of understanding (Wiggins & McTighe 1998; 2006)

Bloom's Taxonomy

One-dimensional, hierarchical, influential.

1. **Knowledge**
2. **Comprehension**
3. **Application**
4. **Analysis**
5. **Synthesis**
6. **Evaluation**

Bloom's Taxonomy

Within the hierarchy, Bloom and others classify representative outcomes, in the form of verbs:

1. **Knowledge:** arrange, duplicate, list, name, recognize, recall, reproduce.
2. **Comprehension:** classify, discuss, express, indicate, recognize, restate, select.
3. **Application:** apply, demonstrate, employ, interpret, practice, sketch, use.
4. **Analysis:** analyze, calculate, compare, criticize, discriminate, examine, question.
5. **Synthesis:** arrange, collect, construct, design, formulate, organize, prepare, set up.
6. **Evaluation:** appraise, assess, choose, defend, evaluate, predict, select, value.

Krathwohl's two-dimensional revision of Bloom's taxonomy

1. The first dimension is the "knowledge" dimension.
2. The second dimension is the "cognitive process" dimension.

Krathwohl's two-dimensional revision of Bloom's taxonomy

The "knowledge" dimension:

A **Factual knowledge** - Discipline-specific elements required for acquaintance or problem-solving.

B **Conceptual knowledge** - Interrelationships among elements; classifications and categories; generalizations; models and structures.

C **Procedural knowledge** - Method of inquiry; skills and algorithms; techniques and methods.

D **Metacognitive knowledge** - Strategic knowledge; contextual and conditional knowledge; one's own cognition and self-knowledge.

Krathwohl's two-dimensional revision of Bloom's taxonomy

The "cognitive process" dimension:

1. **Remember**
2. **Understand**
3. **Apply**
4. **Analyze**
5. **Evaluate**
6. **Create**

Krathwohl's two-dimensional revision of Bloom's taxonomy

The rubric might look like this:

	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual						
B. Conceptual						
C. Procedural						
D. Metacognitive						

Six facets of understanding (Wiggins & McTighe)

Not hierarchical, but rather integrated and overlapping:

1. **Explanation**
2. **Interpretation**
3. **Application**
4. **Perspective**
5. **Empathy**
6. **Self-knowledge**

Discussion of this is postponed till a later seminar.

An exercise

Task: Use action verbs to invent outcomes related to BS Physics goals. They can be course-related or program-related. Submit these at the end of the seminar so I can compile them.

Handouts: Bloom's taxonomy, list of goals.

Upcoming seminars

1. Janet Gail Donald's book, "Learning to think: disciplinary perspectives".
2. Wiggins & McTighe's book, "Understanding by design".
3. Collaborative learning techniques
4. Classroom assessment techniques
5. Curriculum mapping
6. Concept inventory construction and item response theory

Reference list

Bloom & Krathwohl, *Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners. Handbook I: cognitive domain.* New York: Longmans, 1956.

Donald, *Learning to think: disciplinary perspectives*. San Francisco: Jossey-Bass, 2002.

Krathwohl, "A revision of Bloom's taxonomy: an overview", *Theory into practice*, 41(4), 2002.

Handelsman, Miller, & Pfund, *Scientific teaching*. New York: W.H. Freeman & Co., 2007

Undergraduate graduation requirements - Seven learning goals and outcomes. http://ugr.wsu.edu/faculty/7goals.html

Undergraduate students - Physics & astronomy - WSU. https://physics.wsu.edu/undergrads/

Wiggins & McTighe, *Understanding by design*, 2nd ed. Upper Saddle River, NJ: Merrill/Prentice Hall, 2005.