Taxonomies of Learning Outcomes
(with an application to teaching NWP interpretation)

What and how we teach should be directly related to learning outcomes--what we want learners to be able to do following the learning experience. The intended learning outcomes should also determine how we assess learners.

When we are teaching professionals like weather forecasters, we are teaching thinking skills, or cognitive skills, so we intend cognitive learning outcomes. Learning outcomes also can be related to physical skills or attitudes, but these are not addressed here. However, note that almost all professions require all three types of learning, including cognitive skills, conscientiousness and mental stamina, and some degree of physical agility. Each of these may require practice during training.

There are a variety of cognitive skills, and they are not learned in the same ways. Researchers of learning and cognition have found it useful to create classification schemes to help us think about which kind of thinking skills are required for performing tasks, and how people best learn to perform them. It follows that these schemes also tell us how to assess learning.

Cognitive skills can be relatively simple—if we want people simply to memorize facts or steps in a process. Or they can be more complex—if we want people to be able to make difficult decisions that require the analysis and evaluation of many forms of data. In establishing the intended learning outcomes, designing training, and assessing learning, it is critical to see the difference.

The most famous classification system of learning outcomes is Bloom's Taxonomy, which has been used for over 50 years. It helps to distinguish learning outcomes based on the cognitive skills required and their level of complexity. It has evolved over the years, so you may see other versions of it, but the one presented here is one of the most recent. It has been criticized over the years for not making clear distinctions in the higher levels, but it remains a popular system. (See the Conclusions and Questions section)

To understand the taxonomy, it is useful to see examples of it in action. The table below describes the taxonomy and provides examples of learning outcomes and assessment items intended to assess learning at each level in the taxonomy.

Outcome level and cognitive tasks associated with that level	Learning outcomes describing a cognitive skills at that level	Assessment items designed to measure learning at that level
Remembering Remember definitions or details of a concept, principle, or concrete thing. Includes everything from recalling dates of events, to what data is provided in a satellite channel, to the features of a conceptual model of a weather system.	**Learners will be able to**: Define what is meant by the spatial resolution of an NWP model. List the variety of ways of determining the horizontal and vertical resolution of an NWP model.	**NWP spatial resolution refers to…** *(choose the best answer)* a. The number of observations that contribute to a model forecast b. How frequently products are issued for a domain c. The spacing between model grid points d. The number of nested grids in a model run
Understanding Explain something, or infer something from what is known. Includes being able to discuss the implications of something and describe it in one's own words.	**Learners will be able to:** State which forecast parameters and weather phenomena will have significantly improved accuracy with an increased spatial resolution of an NWP model. Explain how a precipitation forecast may be improved with higher spatial resolution in an NWP model.	**NWP spatial resolution will affect**… *(choose all that apply)* a. How well terrain is depicted in the model forecast b. How well precipitation type is forecast c. How well precipitation quantity is forecast d. How much data can be assimilated into the model
Application Make simple judgments or decisions, or follow a procedure.	**Learners will be able to:** Determine whether a given situation is likely to be forecast well by a particular NWP model. Use an NWP product to describe the state of	**Using the winds and vertical motion fields from an NWP model with a resolution of 5-km,** how well do you think a sea breeze on the coast of _____ will be forecast? *(choose the best answer)* a. Not well at all

	the atmosphere. Determine which model fields to use to help forecast severe convection in the _____ region.	b. Moderately well c. Very well
Analysis Determining which information is most relevant, or how it can be classified or organized	**Learners will be able to:** Analyze NWP products to determine areas of potential severe convection, poor low-level visibility, high winds, and wind shear.	**Which atmospheric conditions** shown over the _____ region in these 3 NWP model products would make you concerned about severe convection? *(list and describe the conditions, and how they are captured in the model)*
Synthesis (or Create) and Evaluation *(These are usually listed as two separate levels, but their skill levels overlap)* Creating something new—like a new application, hypothesis, or interpretation, or to evaluate the quality of something	**Learners will be able to:** Determine potential sources of error present in an specific NWP forecast product. Integrate NWP products into the forecast process. Recommend guidelines for choosing NWP products and fields for specific weather situations. Conduct research on the effectiveness of NWP models to depict local effects of terrain.	**Use these NWP model forecasts** and the accompanying satellite imagery, surface and upper-air observations to make a 24-hour precipitation forecast for the _____ region. **Examine the NWP model forecast** for the _____ region. Comparing it to the accompanying satellite products and surface and upper-air charts, and describe where it is most likely to be incorrect in its forecast, and what you think will occur instead. **Develop a set of guidelines for forecasters** in your office for choosing products and fields from ECMWF model products for making precipitation forecasts in your region.

Conclusions and Questions

Notice that for all the higher level learning outcomes, lower level outcomes will also be implied. (You need to "Understand" before you can "Evaluate.") For the summative, or final assessment, it is better to assess at a higher level and assume that these "enabling outcomes" are being demonstrated at the same time within the more complex cognitive skill being assessed.

However, if you know that learners often have difficulty learning at the lower level outcomes, for example, they carry misconceptions into their higher level tasks or lack more basic knowledge and skills that decreases their effectiveness, you may want to include these "enabling objectives" in your plans and develop formative assessments during training to diagnose and correct these.

Reflection Questions

- After reviewing the table, what can you say about the level of realism and complexity of the outcomes and assessment items as we move into higher levels of complexity in the learning outcomes?
- At what levels are job competencies typically written? Why do you think this is true?
- Do you have a difficult time distinguishing the Application level from the Analysis and Synthesis levels? If so, you are not alone. Many have complained that Bloom's taxonomy is not a true taxonomy because it is not systematic, the items are not sufficiently distinct, and instead, highly connected and integrated. Do you agree? Does this diminish its utility?
- If you had to rate the level of complexity of each level in Bloom's taxonomy from 1 to 10, how would you rate them? You might want to use a range of numbers since not all Recall are equally complex. Remembering dates of historic events can be much easier than remembering a mathematical formula (at least in the short term). So for example, we might say that recall is rated from 1-3. How then would you rate the others?