

## Bloom's Taxonomy of Learning Outcomes (applied to Teaching NWP to Forecasters)

What and how we teach should be directly related to our intended learning outcomes, or what learners should be able to do after the learning experience. The intended learning outcomes should also drive how we assess learners. Learning outcomes, as discussed here, are often referred to as “learning objectives,” although some consider “outcomes” as broader. For our purposes, you can consider them synonymous.

Most often when we are teaching professionals such as weather forecasters, we are teaching thinking skills, or cognitive skills, so we intend cognitive learning outcomes. However, learning outcomes also can be primarily physical (often called psychomotor skills), such as those related to playing sports or performing music. Learning outcomes also can relate primarily to attitudes or beliefs (often called affective learning outcomes), like learning to be a more dedicated student or more conscientious employee. Note that many things to be learned require all three types of outcomes. Being a weather forecaster requires cognitive skills, but also dedication and mental stamina, and even, to some extent, physical agility to rapidly manipulate data systems and generate products (and to work in rotating shifts).

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 systems to help us think about which kind of thinking skills are required for performing tasks, and how people best learn to perform them. Of course, it follows that these systems 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 significant decisions that require the analysis of many forms of data. In establishing the intended learning outcomes 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 common.

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 skill at that level	Assessment items designed to measure learning at that level
<p><b>Recall (sometimes called Knowledge)</b></p> <p>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.</p>	<p><b>Learners will be able to:</b></p> <p>Define what is meant by the spatial resolution of an NWP model.</p> <p>List the variety of ways of determining the horizontal and vertical resolution of an NWP model.</p>	<p><b>NWP spatial resolution refers to...</b> <i>(choose the best answer)</i></p> <ol style="list-style-type: none"> <li>The number of observations that contribute to a model forecast</li> <li>How frequently products are issued for a domain</li> <li>The spacing between model grid points</li> <li>The number of nested grids in a model run</li> </ol>
<p><b>Comprehension or Understanding</b></p> <p>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.</p>	<p><b>Learners will be able to:</b></p> <p>State which forecast parameters and weather phenomena will have significantly improved accuracy with an increased spatial resolution of an NWP model.</p> <p>Explain the ways in which a precipitation forecast may be improved when spatial resolution of an NWP model is higher.</p>	<p><b>NWP spatial resolution will affect...</b> <i>(choose all that apply)</i></p> <ol style="list-style-type: none"> <li>How well terrain is considered in the model forecast</li> <li>How well precipitation type is forecast</li> <li>How well precipitation quantity is forecast</li> <li>How much data can be assimilated into the model</li> </ol>
<p><b>Application</b></p> <p>Using knowledge to make a small-scale judgment or decision, or in following a procedure.</p>	<p><b>Learners will be able to:</b></p> <p>Determine whether a given situation is likely to be forecast well by a particular NWP model.</p> <p>Use an NWP product to describe the state of the atmosphere.</p>	<p><b>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?</b> <i>(choose the best answer)</i></p> <ol style="list-style-type: none"> <li>Not well at all</li> <li>Moderately well</li> </ol>

	<p>Determine which model fields to use to help forecast severe convection in the _____ region.</p>	<p>c. Very well</p>
<p><b>Analysis</b></p> <p>Determining which information is most relevant, or how it can be classified or organized</p>	<p><b>Learners will be able to:</b></p> <p>Analyze NWP products to determine areas of potential severe convection, poor low-level visibility, high winds, and wind shear.</p>	<p><b>Which atmospheric conditions</b> shown over the _____ region in these 3 NWP model products would make you concerned about severe convection? <i>(list and describe the conditions, and how the model depicts them)</i></p>
<p><b>Synthesis and Evaluation</b></p> <p><i>(These are usually listed as two separate levels, but their skill levels overlap)</i> Using knowledge to create something new—like a new application, hypothesis, or interpretation, or to evaluate the quality of something</p>	<p><b>Learners will be able to:</b></p> <p>Determine potential sources of error present in an specific NWP forecast product.</p> <p>Integrate NWP products into the forecast process.</p> <p>Recommend guidelines for choosing NWP products and fields for specific weather situations.</p>	<p><b>Use these NWP model forecasts</b> and the accompanying satellite imagery, surface and upper-air observations to make a 24-hour precipitation forecast for the _____ region.</p> <p><b>Examine the NWP model forecast</b> 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. What do you think will occur instead?</p> <p><b>Develop a set of guidelines for forecasters</b> in your office for choosing products and fields from the ECMWF model products for making precipitation forecasts in your region.</p>

## Conclusions and Questions

Notice that for all the higher level learning outcomes, there will be lower level outcomes that might also be implied. 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 performance.

However, if you know that learners often have difficulty learning 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 will want to include these “enabling objectives” in your plans and develop formative assessments during training to diagnose and correct this.

- 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?
- Would you recommend another classification system for learning outcomes?
- 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. Remember dates of historic events is much easier than remembering a mathematical formula. So for example, we might say that recall is rated from 1-3. How then would you rate the others?