

Exploring Cognitive Demand in Instruction and Assessment

Karin K. Hess

Over the past decades, educators and psychologists have attempted to develop models for understanding cognitive complexity as it relates to designing instruction and assessments. In 1956, Benjamin Bloom headed a group of educational psychologists who developed a classification of levels of intellectual behavior important in learning. Bloom created this taxonomy for categorizing the levels of abstraction of questions that commonly occur in educational settings. Using these levels for analysis, Bloom found that over 95 % of the test questions students encounter at the college level require them to think only at the lowest possible level...the recall of information.

Bloom's committee identified three domains of educational activities: **Cognitive** - mental skills (*Knowledge*); **Affective** - growth in feelings or emotional areas (*Attitude*); and **Psychomotor** - manual or physical skills (*Skills*). The cognitive domain involves knowledge and the development of intellectual skills. Within the cognitive domain, Bloom identified six levels - from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order, classified as evaluation. Different sources list somewhat different verb examples to represent intellectual activity on each of Bloom's levels. Some of these verb examples are listed here. It is important to note that *sometimes the same verbs appear as examples in more than one cognitive level* (e.g., write, summarize, test, explain, etc.). While educators have found these cues useful in lesson planning, this overlap of verbs indicates that focusing only on verbs to determine level of cognitive demand is not fully adequate.

Bloom's Taxonomy Levels with "verb cues" for questioning

1. **Knowledge**: arrange, collect, define, describe, duplicate, examine, identify, label, list, memorize, name, order, quote, recognize, relate, recall, repeat, reproduce, show, state, tabulate, tell, who, when, where...
2. **Comprehension**: associate, classify, contrast, describe, discuss, distinguish, differentiate, estimate, **explain**, express, extend, identify, indicate, interpret, locate, predict, recognize, report, restate, review, select, **summarize**, translate...
3. **Application**: apply, calculate, choose, change, classify, complete, demonstrate, discover, dramatize, employ, examine, experiment, illustrate, interpret, modify, operate, practice, relate, schedule, show, sketch, solve, use, **write**...
4. **Analysis**: analyze, appraise, arrange, calculate, categorize, classify, compare, connect, contrast, criticize, differentiate, discriminate, distinguish, divide, examine, experiment, **explain**, infer, question, order, select, separate, **test** ...
5. **Synthesis**: arrange, assemble, collect, combine, compose, construct, create, design, develop, formulate, generalize, integrate, invent, manage, modify, organize, plan, prepare, propose, rearrange, rewrite, set up, substitute, what if?, **write**...

6. **Evaluation**: appraise, argue, assess, attach, choose, compare, conclude, convince, decide, defend, estimate, judge, predict, rate, core, select, support, value, evaluate, rank, **test**, measure, recommend, **explain**, discriminate, support, **summarize...**

Since Bloom's early work, many others have used various schemas to describe cognitive demand in different learning and assessment contexts. A few are included here:

National Assessment of Educational Progress (NAEP)	
Aspects of Reading (1990-2005)	Mathematical Abilities (1990-2005)
Forming a general understanding Consider the text as a whole and provide a global understanding of it.	Conceptual understanding Recognize, label, and generate examples of concepts; use & interrelate models, diagrams, manipulatives, & varied representations of concepts; etc.
Developing interpretation Extend initial impressions to develop a more complete understanding of what was read.	Procedural knowledge Select and apply appropriate procedures correctly; verify or justify the correctness of a procedure using concrete models or symbolic methods; or extend or modify procedures to deal with factors inherent in problem settings.
Making reader/text connections Connect information in the text with knowledge & experience.	Problem solving Recognize and formulate problems; determine the consistency of data; use strategies, data, models; generate, extend, & modify procedures; use reasoning in new settings; & judge the reasonableness & correctness of solutions.
Examining content and structure Critically evaluating, comparing and contrasting, and understanding the effect of such features as irony, humor, & organization.	

Mathematical Complexity of Items - NAEP 2005 Framework

The demand *on thinking* the items requires:

Low Complexity

Relies heavily on the recall and recognition of previously learned concepts and principles.

Moderate Complexity

Involves more flexibility of thinking and choice among alternatives than do those in the low-complexity category.

High Complexity

Places heavy demands on students, who must engage in more abstract reasoning, planning, analysis, judgment, and creative thought.

Andrew Porter's Survey of Enacted Curriculum	
English Language Arts Cognitive Levels	Mathematics Cognitive Levels
Recall Provide facts, terms, definitions, conventions; describe; etc.	Memorize Recall basic mathematics facts; etc.
Demonstrate/Explain Follow instructions; give examples; etc.	Perform procedures Do computational procedures or algorithms; etc.
Analyze/investigate Categorize, schematize; distinguish fact from opinion; make inferences, draw conclusions; etc.	Demonstrate understanding Communicate mathematical ideas; use representations to model mathematical ideas; etc.
Evaluate Determine relevance, coherence, logical, internal consistency; test conclusions; etc.	Conjecture, generalize, prove Determine the truth of a mathematical pattern or proposition; write formal or informal proof; etc.
Generate/create Integrate, dramatize; predict probable consequences; etc.	Solve non-routine problems, make connections Apply and adapt a variety of appropriate strategies to solve problems; etc.

Norman Webb's Depth of Knowledge Levels (1997)

1. **Recall** - Recall or recognition of a fact, information, concept, or procedure
2. **Basic Application of Skill/Concept** - Use of information, conceptual knowledge, follow or select appropriate procedures, two or more steps with decision points along the way, routine problems, organize/display data
3. **Strategic Thinking** - Requires reasoning, developing a plan or sequence of steps to approach problem; requires some decision making and justification; abstract and complex; often more than one possible answer
4. **Extended Thinking** - An investigation or application to real world; requires time to research, think, and process multiple conditions of the problem or task; non-routine manipulations, across disciplines/content areas/multiple sources

Webb's work has been applied to different content areas and used in test item development, as well as in alignment studies to determine the degree of alignment (match) between states' standards and the tests used by states for accountability purposes. Webb's Depth of Knowledge (DOK) Levels are also being used more and more by local schools and districts to develop curriculum materials and performance assessments to demonstrate learning.

Webb describes his DOK levels as “nominative” rather than as a taxonomy; DOK levels name 4 different ways students interact with content. Each level is dependent upon how *deeply* students understand the content in order to respond, not simply the “verb” used. *The Webb levels do not necessarily indicate degree of “difficulty” in that Level 1 can ask students to recall or restate a simple or a much more complex concept, the latter being much more difficult. Conversely, depth of understanding a concept is required to be able to explain how/why a concept works (Level 2), apply it to real-world phenomena with justification/supporting evidence (level 3), or to integrate one concept with other concepts or other perspectives (level 4).*

Applying Webb's DOK Levels to Bloom's Taxonomy of Educational Objectives (Karin Hess)

ELA/Soc St Examples	Webb's Depth of Knowledge Levels			
Bloom's Taxonomy	Level 1 Recall & Reproduction	Level 2 Skills & Concepts	Level 3 Strategic Thinking/ Reasoning	Level 4 Extended Thinking
Knowledge Define, duplicate, label, list, memorize, name, order, recognize, relate, recall, reproduce, state	<ul style="list-style-type: none"> o List/generate ideas for writing or research o Recall, recognize, or locate basic facts, ideas, principles, concepts o Identify/describe key figures, places, or events in a particular context 			
Comprehension Classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate	<ul style="list-style-type: none"> o Write a simple sentence o Select appropriate word(s) to use in context when meaning is evident o Identify or describe characters, setting, plot, problem, solution o Describe or explain: who, what, where, when 	<ul style="list-style-type: none"> o Determine or recognize main idea/generalizations o Take and organize notes around common ideas/topics o summarize ideas/events o Make basic inferences or logical predictions from text o Explain relationships/cause-effect 	<ul style="list-style-type: none"> o Write full composition using varied sentence types & structures to meet purposes o Explain, generalize, or connect ideas using supporting evidence o Make inferences about theme or author's purpose 	<ul style="list-style-type: none"> o Write full composition demonstrating synthesis & analysis of complex ideas o Compare multiple works by same author, across time periods, genres, etc.
Application Apply, choose, demonstrate, dramatize, employ, illustrate, interpret, practice, schedule, sketch, solve, use, write	<ul style="list-style-type: none"> o Apply spelling, grammar, punctuation, conventions rules in writing o Use structures (pre/suffix) or relationships (synonym) to determine word meaning o Use resources to edit/revise 	<ul style="list-style-type: none"> o Write paragraph using a basic structure or template o Edit final draft for mechanics and conventions o Use context clues to determine meaning o Use text features to find information 	<ul style="list-style-type: none"> o Edit final draft for meaning/progression of ideas o Apply a concept in other/new contexts o Support ideas with examples, citations, details, elaboration, quotations, text references 	<ul style="list-style-type: none"> o Define and illustrate common social, historical, economic, or geographical themes and how they interrelate
Analysis Analyze, appraise, calculate, categorize, compare, criticize, discriminate, distinguish, examine, experiment	<ul style="list-style-type: none"> o Identify specific information contained in maps, charts, tables, graphs, or diagrams 	<ul style="list-style-type: none"> o Analyze a paragraph for simple organizational structure o Determine fiction/ nonfiction; fact/opinion o Describe purpose of text features o Identify use of literary devices 	<ul style="list-style-type: none"> o Analyze an essay o Compare information within or across text passages o Analyze interrelationships among text elements, situations, events, or ideas o Analyze use of literary devices 	<ul style="list-style-type: none"> o Analyze multiple works by the same author, across time periods, genres, o Analyze complex/abstract themes
Synthesis Rearrange, assemble, collect, compose, create, design, develop, formulate, manage, organize, plan, propose, set up, write	<ul style="list-style-type: none"> o Brainstorm ideas, concepts, or perspectives related to a topic 		<ul style="list-style-type: none"> o Synthesize information within one source or text o Develop a model for a complex situation 	<ul style="list-style-type: none"> o Synthesize information across multiple sources or texts o Given a situation/problem, research, define, and describe the situation/problem and provide alternative solutions
Evaluation Appraise, argue, assess, choose, compare, defend, estimate, judge, predict, rate, select, support, value			<ul style="list-style-type: none"> o Cite evidence and develop a logical argument for concepts o Make & support generalizations, using text evidence 	<ul style="list-style-type: none"> o Gather, analyze, & evaluate information to draw conclusions o Evaluate relevancy, accuracy, completeness of information from multiple sources

Math/Sci Examples	Webb's Depth of Knowledge Levels			
Bloom's Taxonomy	Level 1 Recall & Reproduction	Level 2 Skills & Concepts	Level 3 Strategic Thinking/ Reasoning	Level 4 Extended Thinking
Knowledge Define, duplicate, label, list, memorize, name, order, recognize, relate, recall, reproduce, state	<ul style="list-style-type: none"> Recall, recognize, or locate basic facts, ideas, principles Recall or identify conversions between and among representations or numbers, or within and between customary and metric measures 			
Comprehension Classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate	<ul style="list-style-type: none"> Make conversions between and among representations or numbers, or within and between customary and metric measures Evaluate an expression Locate points on a grid or number line Solve a one-step problem 	<ul style="list-style-type: none"> Specify and explain relationships (cause-effect; why or how; non-examples/examples) Make and record observations Take notes to organize information/ideas Summarize results or concepts Make basic inferences or logical predictions from data/observations 	<ul style="list-style-type: none"> Use concepts to solve non-routine problems Explain, generalize, or connect ideas using supporting evidence Make or justify conjectures Explain thinking when more than one response is possible Explain phenomena in terms of concepts 	<ul style="list-style-type: none"> Relate mathematical or scientific concepts to other content areas or concepts Develop generalizations of the results obtained and the strategies used and apply them to new problem situations
Application Apply, choose, demonstrate, dramatize, employ, illustrate, interpret, practice, schedule, sketch, solve, use, write	<ul style="list-style-type: none"> Follow simple procedures (recipe-type directions) Calculate, measure, apply a rule Apply an algorithm or formula (area, perimeter, etc.) Represent in words or diagrams a scientific concept or relationship 	<ul style="list-style-type: none"> Select a procedure according to criteria and perform it Solve routine problem applying multiple concepts or decision points Retrieve information from a table, graph, or figure and use it solve a problem requiring multiple steps 	<ul style="list-style-type: none"> Design investigation for a specific purpose or research question Conduct a designed investigation Use concepts to solve non-routine problems Use reasoning, planning, and evidence 	<ul style="list-style-type: none"> Select or devise approach among many alternatives to solve a problem Conduct a project that specifies a problem, identifies solution paths, solves the problem, and reports results
Analysis Analyze, appraise, calculate, categorize, compare, criticize, discriminate, distinguish, examine, experiment	<ul style="list-style-type: none"> Retrieve information from a table or graph 	<ul style="list-style-type: none"> Categorize, classify materials based on characteristics Compare/ contrast figures or data Select appro graph and display data Interpret data from a simple graph Extend a pattern 	<ul style="list-style-type: none"> Compare information within or across data sets or texts Analyze and draw conclusions from data Generalize a pattern Interpret data from complex graph 	<ul style="list-style-type: none"> Analyze multiple sources of evidence analyze complex/abstract themes Gather, analyze, and evaluate information
Synthesis Rearrange, assemble, collect, compose, create, design, develop, formulate, manage, organize, plan, propose, set up, write	<ul style="list-style-type: none"> Brainstorm ideas, concepts, or perspectives related to a topic 	<ul style="list-style-type: none"> Use models to represent mathematical concepts 	<ul style="list-style-type: none"> Synthesize information within one source or text Formulate an original problem, given a situation Develop a scientific/mathematical model for a complex situation 	<ul style="list-style-type: none"> Synthesize information across multiple sources or texts Design a mathematical model to inform and solve a practical or abstract situation
Evaluation Appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate			<ul style="list-style-type: none"> Cite evidence and develop a logical argument for concepts Describe, compare, and contrast solution methods Verify reasonableness of results 	<ul style="list-style-type: none"> Gather, analyze, & evaluate information to draw conclusions Apply understanding in a novel way, provide argument or justification for the application

References

- Anderson, D. and Krathwohl, D. editors (2005). *Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*
- Bloom B. S. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. New York: David McKay Co Inc.
- Hess, K. (2004). "Applying Webb's Depth-of-Knowledge (DOK) Levels in Reading." [online] available: www.nciea.org
- Hess, K. (2005). "Applying Webb's Depth-of-Knowledge (DOK) Levels in Social Studies." [online] available: www.nciea.org
- Hess, K. (2005). "Applying Webb's Depth-of-Knowledge (DOK) Levels in Writing." [online] available: www.nciea.org
- Hess, K. (2006). "Applying Webb's Depth-of-Knowledge (DOK) Levels in Science." [online] available: www.nciea.org
- Krathwohl, D. R., Bloom, B. S., & Bertram, B. M. (1973). *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain*. New York: David McKay Co., Inc.
- Petit, M. & Hess, K. (2006). "Applying Webb's Depth-of-Knowledge (DOK) and NAEP levels of Complexity in Mathematics." [online] available: www.nciea.org
- Webb, N. (March 28, 2002) "Depth-of-Knowledge Levels for Four Content Areas," unpublished paper.
- Webb, N. (August 1999). Research Monograph No. 18: "Alignment of Science and Mathematics Standards and Assessments In Four States." Washington, D.C.: CCSSO.
- Webb, N. (1997). Research Monograph Number 6: "Criteria for Alignment of Expectations and Assessments on Mathematics and Science Education. Washington, D.C.: CCSSO.