

Appendix B: Bloom's Taxonomy of Educational Objectives

In 1956, educational psychologist Benjamin Bloom chaired a committee of College and University Examiners who were charged with the development of a classification system that would capture the intellectual behavior important in learning. This classification system was to delineate the "intended behavior" of students - the ways in which individuals are to act, think or feel as a result of participating in a unit of instruction expressed in measurable observable formats (learning objectives). This became known as Bloom's Taxonomy. The committee identified three overlapping domains: the cognitive, affective, and psychomotor.

In the discussion below, these three domains will be discussed, and the levels of learning in each enumerated. Verbs that are typically used to describe learning objective in these domains will be presented, along with examples from the Syllabus. Unlike a generic discussion of Bloom's Taxonomy, this one has been specialized and expanded to include the kinds of verbs used to describe learning objectives typically encountered in an engineering education. These verbs are listed in Table B1.

In the process of converting the topical Syllabus of Appendix A to a set of learning objectives, it is convenient to identify patterns of Bloom verbs that naturally accompany technical topics. Table 7 shows such patterns of verbs that correspond to the five levels in the MIT activity based proficiency scale (Table 6).

B.1 The Cognitive Domain

The cognitive domain encompasses a complex, hierarchical series of intellectual skills involving the acquisition and use of knowledge that ranges from simple recall to the ability to judge and evaluate learned material. Bloom (1956) identified six levels within the cognitive domain.

1. **Knowledge** refers to those behaviors and situations that emphasize remembering, either by recognition or recall, of specifics and ideas, of terms and materials, and of abstraction and phenomena. Students have the ability to store in their mind certain information and later to remember and recall it, often with slight alteration.

Verb examples that represent intellectual activity on this level include: *describe, list, match, and recognize.*

Examples from the Syllabus:

Describe data and symptoms

List assumptions and sources of bias

Recognize conceptual and qualitative models

2. **Comprehension** refers to those objectives, behaviors, or responses that represent an understanding of the literal message contained in a communication, without necessarily relating it to other material. In coming to this understanding, the student may change the communication in his/her mind, or in overt responses, to reflect a parallel form more meaningful to him/her.

Verb examples that represent intellectual activity on this level include: *classify, explain, extrapolate, interpolate, locate, translate.*

Examples from the Syllabus:

Locate and classify essential results of solutions and test data

Interpret bounds and trends

Explain discrepancies in results

Table B1: Bloom Cognitive Verbs Appropriate for Technical Topics

Level	Group	Verbs	Verbs not used
Knowledge			
	Recognize	label, name, recognize , recall , underline	outline
	List	list , record, repeat, reproduce, state	knows, recite
	Describe	define , describe	identify, select
	Match	arrange, match, order, relate	
Comprehension			
	Locate and classify	arrange, classify , identify , indicate, locate , sort	predict, describe
	Explain	discuss , explain , express, give examples, report, summarize	defend
	Translate	convert, interpret , paraphrase, restate, translate	distinguish, rewrite
	Interpolate	interpolate, infer	comprehend, estimate
	Extrapolate	extend, extrapolate, generalize	
Application			
	Prepare	choose , prepare , schedule , select , sketch	produce, relate
	Use	apply , change, employ , manipulate, modify, operate, use , utilize	discover
	Practice	demonstrate , execute , illustrate, practice , show	predict
	Resolve	compute, measure, solve	construct
Analysis			
	Analyze and test	analyze , appraise , calculate, elicit , examine , experiment , question , test	identify, point out
	Categorize	breakdown, categorize, diagram, inventory, outline, separate, subdivide	infer, relate, select
	Discriminate	compare , differentiate, distinguish, discriminate , reconcile	illustrate, deconstruct
Synthesis			
	Plan	collect, plan , propose	categorize, prepare
	Create	compose, create , design, devise, formulate , generate, set up, tell, write	explain, conduct
	Construct	arrange, assemble, construct , combines, compiles, manage, organize, synthesize , set up	relate
	Rearrange	modify, rearrange, reconstruct, reorganize, revise, rewrite	summarize
Evaluation			
	Assess	assess, conclude, estimate , predict, rate, score	appraise, explain, summarize
	Evaluate	attack, criticize, critique, evaluate , value	compare, interpret, appraise
	Defend	argue, defend, justify, support	contrast, relates, select, describe, discriminate

3. Application is the ability to use previously learned material in situations which are either new, or contain new elements, as compared to the situation in which the abstraction was learned. This means that the problem should be drawn from material the student is not likely to have yet had contact with,

or be a problem known to the student, but having a different slant that he/she is unlikely to have thought of.

Verb examples that represent intellectual activity on this level include: *practice, prepare, resolve, use.*

Examples from the Syllabus:

Prepare margins and reserves

Practice engineering cost-benefit and risk analysis

Use assumptions to simplify complex systems and environments

4. Analysis is the breakdown of material into its constituent parts and detection of the relationship of the parts and of the way they are organized. While clear lines can be drawn between analysis and comprehension or analysis and evaluation, it is useful to think of it as an aid to more complete comprehension and as a prelude to evaluation.

Verb examples that represent intellectual activity on this level include: *analyze, categorize, discriminate, test.*

Examples from the Syllabus:

Analyze possible improvements in the problem solving process

Discriminate hypotheses to be tested

Test hypotheses and conclusions

5. Synthesis is defined as the putting together of elements and parts so as to form a whole. This is the category in the cognitive domain that Bloom tells us most clearly provides for creative behavior on the part of the learner, but within the limits set by the framework.

Verb examples that represent intellectual activity on this level include: *construct, create, plan, rearrange.*

Examples from the Syllabus:

Plan evolutionary adaptation over time

Create one's professional portfolio

Construct the abstractions necessary to model the system

6. Evaluation is the making of judgments about the value, for some purpose, of ideas, works, solutions, methods, material, etc. It involves the use of criteria and standards for appraising the extent to which particulars are accurate, effective, or satisfying. It may be quantitative or qualitative.

Verb examples that represent intellectual activity on this level include: *assess, defend, evaluate.*

Examples from the Syllabus:

Assess one's skills, interests, strengths and weaknesses

Evaluate supporting evidence

A way in which to view the structure of the Bloom verbs is shown in Table B1, which gives the six levels, and identifies three to five key verbs within each level. Some common synonyms for those key verbs are also listed. Verbs in *Italics* of Table B1 are commonly used Bloom verbs, and those in regular font were added to better fit with technically oriented topics of the Syllabus. The verbs in the column to the far right of Table B1 are commonly used Bloom verbs that we recommend *not* be used with the Syllabus. This is because the verbs either appear at two levels, and therefore are ambiguous, or because they have a technical connotation apart from their common meaning, which causes them to be misplaced in terms of level. Entries in bold will be used in the Bloom verb patterns discussed below.

B.2 The Affective Domain

The affective domain relates to the emotional component of learning. It emphasizes a feeling, tone, an emotion, or a degree of acceptance or rejection. Affect encompasses a range from simple attention to organization and characterization of complex, but internally consistent, qualities of character and conscience. Krathwohl, Bloom and Masia (1964) developed five levels in the affective domain.

1. Receiving (*attending*): Receiving speaks to an awareness that a learner is conscious of something, that he/she take into account a situation, phenomenon or state of affairs. It also addresses the learner's willingness to receive information. In other words the climate must be set so that students attention is grabbed and directed in a particular manner.

Verb examples which represent intellectual activity on this level include: *ask, accept, hold*.

Examples from the Syllabus:

Accepts the need for a commitment to service

Accepts the goals and roles of the engineering profession

2. Responding: At the responding level, students are sufficiently motivated that they are not just willing to attend, but are actively attending. It involves a continuum from acquiescence in responding, to willingness to respond, to satisfaction in response. In other words, it is active participation by the students in their own learning.

Verb examples that represent intellectual activity on this level include: *answer, assist, discuss*.

Examples from the Syllabus:

Discuss the motivation for continued self-education

Discuss the importance of both a depth and breadth of knowledge

3. Valuing: Simply put, something has value or worth. At this level, behavior is sufficiently consistent and stable as to be characterized as a belief or attitude. The student is perceived as holding a value. This level ranges from acceptance of a value, to preference, to commitment to a value.

Verb examples that represent intellectual activity on this level include: *demonstrate a belief in, embrace, follow, join, share, value*.

Examples from the Syllabus:

Embrace one's responsibility for self improvement

Value a willingness to work independently

4. Organization refers to the process learners go through after they internalize values and are faced with situations for which more than one value is relevant. This necessitates the organization of values into a system, determining the relationship among them, and establishing dominant and pervasive values. The emphasis is on comparing, relating, and synthesizing values.

Verb examples that represent intellectual activity on this level include: *alter, combine, complete, integrate, order, organize, relate, synthesize* .

Example from the Syllabus:

Integrate the potential benefits and risks of an action

5. Characterization by a value or value complex: At this level the individual acts consistently in accordance with the values he/she has internalized. A behavior is pervasive, consistent, predictable, and characteristic of the student. Student beliefs, ideas, and attitudes are integrated into a total philosophy or view of the world.

Verb examples that represent intellectual activity on this level include: *discriminate, display, influence, presuppose, qualify, resolve, solve, verify.*

Example from the Syllabus:

Resolves conflicting issues in the balance between personal and professional life

B.3 The Psychomotor Domain

The psychomotor domain emphasizes physical skills. It involves muscular or motor skill, some manipulation of materials and objects, or some act which requires a neuromuscular coordination. It captures the complexity of grace, strength, and speed that is often involved in physical activity or skill acquisition.

While there are a few examples in the CDIO Syllabus that touch on the psychomotor domain, these topics all have an important cognitive component as well. Therefore the cognitive verbs are consistently used for these topics, and the psychomotor categories are not used in the Syllabus.

For completeness, it is worth outlining the breakdown of this domain by Simpson (1972) into seven levels.

- 1. Perception** is defined as the ability to use sensory cues to guide motor activity.
- 2. Set** refers to the readiness to take a particular course of action. This includes physical and emotional set as well as mental.
- 3. Guided Response:** refers to imitation and trial and error in which the adequacy of the performance is judged by the instructor or by a defined set of criteria.
- 4. Mechanism:** describe learned responses that have become habitual, movements can be performed with some confidence and proficiency.
- 5. Complex Overt Responses:** is the skillful performance of motor acts that involve complex movement patterns. Proficiency is indicated by a quick, accurate, and highly coordinated performance, requiring a minimum of energy. In this category, responses are automatic.
- 6. Adaptation:** is the level at which skills are so well developed that the individual can modify movement patterns to fit special requirements or to meet a problem situation.
- 7. Origination** is the creation of new movement patterns to fit a particular situation or specific problem. Outcomes at this level emphasize creativity based upon highly developed skills.

B.4 Bloom Verb Patterns for the CDIO Syllabus

In specializing the CDIO Syllabus to any particular program and thereby creating a framework of learning objectives, one Bloom verb must be selected for each of the over 300 lowest level topics in the

Syllabus. The Bloom verb chosen should correspond to the expected proficiency level of a graduating engineer, developed through the survey and consensus process. The activity based proficiency rating can be translated to a Bloom verb domain and level using the rough equivalence listed in Table 8.

In order to simplify this process, we tried to create a *menu* of Bloom verbs for each of the over 300 entries. In this way, a faculty specializing the Syllabus could simply choose the Bloom verb for each topic that corresponded to the designated level of proficiency.

As an example of creating such a menu, consider subsection 2.1.1, Problem Identification and Formulation (under section 2.1 Engineering Reasoning and Problem Solving). The following Bloom verb menu options can be created for each entry:

2.1.1 Problem Identification and Formulation

Recall/Recognize/Identify/Analyze/Evaluate data and symptoms
Recall/Describe/Explain/Analyze/Evaluate assumptions and sources of bias
Recall/Define/Discuss/Demonstrate/Evaluate issue prioritization ...{CP}
Recall/Describe/Interpret/Choose/Formulate a plan of attack ...

where the five verbs indicate, respectively, the first through fifth activity based proficiency levels (Table 6). The verb *recall*, among the weakest of the Bloom verbs for knowledge, is used to connote the result of an exposure, the lowest activity based proficiency. *Recognize*, *describe* and *define* are representative of “being able to participate”, the second activity based proficiency level. At the third activity based level, *identify*, *explain*, *discuss* and *interpret* connote “being able to understand and explain”. *Analyze*, *practice* and *choose* denote skills of a person who is “skilled in the practice of”, the fourth activity based level. Finally, at the fifth level, *evaluate* and *formulate* are verbs which connote the ability to “lead or innovate”.

In attempting to create the equivalent five verb menu for each of the low level entries in the Syllabus, it became obvious that there were a relatively small number of underlying patterns, rather than 300 odd unique menus. Those patterns as summarized in Table 7. The patterns were determined by simple reverse engineering. First the specific verbs were assigned for the customized MIT version of the Syllabus listed in Appendix C. Then all the verbs actually used, listed in bold in Table B1, were examined for patterns.

First a pattern was chosen for the relatively small set of affective topics, which carry the annotation {A}. It was found that all affective entries can be linked to the pattern of Bloom verb:

Has been exposed to/Accepts the need for/Engages in discussion of/Embraces/Resolves
conflicting issues in

Where the entries map to activity based proficiency levels 1-5.

Likewise all cognitive processes, which are annotated {CP}, fit with the pattern:

Recall/Describe/Discuss/Demonstrate/Evaluate

These two patterns are listed, along with some common synonyms, in Table 7.

The vast majority of the low level entries in the Syllabus are cognitive objects. These require a richer set of Bloom verb patterns. Through several iterations, it was found that all entries map to about 27 patterns. These patterns are made up of 3 patterns for verbs in activity based proficiency levels 1-3, combined with 9 options at levels 4 and 5, as shown in Table 7. There are a relatively small number of verbs at the lower levels which make sense when combined with engineering topics and learning objectives. At the fourth activity based level, “to be skilled in the practice or implementation of”, a major split occurs. Some topics are primarily outside of the control of engineers. For these topics, the appropriate verbs are some form of *analyze*. The fifth level which corresponds to an analysis task tends to be *evaluate*. In contrast, for topics which tend to be under the control of engineers, the

appropriate fourth level verb tends to be *apply*. The corresponding fifth level verb is some form of *synthesize*.

The structure of the menu implied in Table 7 reflects these trends. For any lowest level Syllabus topic, there is one of the three verb sets from levels 1-3, denoted with a letter a,b or c, plus one of the nine patterns from levels 4 and 5, which tend to be either a Synthesis or Evaluation pattern. Synthesis patterns are designate S1 through S5, while Evaluation patterns are designated E1 through E4. The annotation in brackets is just the notation for one of a-c, followed by the notation for one of the nine higher level patterns

Again, referring to the example in the text, we can consider the patterns for the subsection:

2.1.1 Problem Identification and Formulation

Data and symptoms {c-E1}

Assumptions and sources of bias {a-E1}

Issue prioritization {CP}

A plan of attack {b-S2}

The topic “data and symptoms” is ultimately evaluated by engineers (at least as a part of Problem Identification and Formulation), and so carries the pattern {c} at the 1-3 levels, and the pattern {E1} at the 4-5 level. Issue prioritization is a cognitive process, and maps to that pattern in Table 7. “A plan of attack” is ultimately synthesized by an engineer, and therefore is a pattern {S2} at the 4-5 level.

Using Table 7 and the annotation in Appendix C, a five-verb Bloom pattern is therefore suggested for each low level topical entry in the Syllabus.