Appendix: Bloom's Taxonomy of Educational Objectives

This Appendix is an abbreviated version of that in Crawley, E. F., *CDIO Syllabus Report*, January 2001.

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. It is the first of these domains which is of interest here.

In the discussion below, the levels of learning in the cognitive domain will be enumerated according to this taxonomy. Verbs typically used to describe learning objectives in these domains will be presented, along with examples from the department's Conceive-Design-Implement-Operate (CDIO) Syllabus. The discussion of Bloom's Taxonomy has thus 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 1.

I. The Cognitive Domain

The cognitive domain encompasses a 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 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

 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 1, 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 1 are commonly used Bloom verbs, and those in regular font were added to better fit with technically oriented topics of the Syllabus. Entries in bold will be used in the Bloom verb patterns discussed below.

II. 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.

To simplify this process, a *menu* of Bloom verbs for each of the over 300 entries has been created. In this way, a faculty specializing the Syllabus could simple 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 of the CDIO Syllabus, Problem Identification and Framing (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 Framing
> *Recall/Recognize/Identify/Analyze/Evaluate* data and symptoms
> *Recall/Describe/Explain/Analyze/Evaluate* assumptions and sources of bias
> *Recall/Define/Discuss/Practice/Evaluate* issue prioritization …
> *Recall/Describe/Interpret/Choose/Formulate* a plan of attack …

where the five verbs indicate, respectively, the first through fifth activity based proficiency level. 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".

Table 1. Bloom Cognitive Verbs Appropriate for Technical Topics

Level	Group	Verbs
Knowledge		
	Recognize	*label, name, **recognize**, **recall**, underline*
	List	***list,** record, repeat, reproduce, **state***
	Describe	***define, describe***
	Match	*arrange, match, order, relate*
Comprehension		
	Locate and classify	*arrange, **classify, identify**, indicate, **locate**, sort*
	Explain	***discuss, explain**, express, give examples, report, summarize*
	Translate	*convert, **interpret**, paraphrase, restate, **translate***
	Interpolate	*interpolate, infer*
	Extrapolate	*extend, extrapolate, generalize*
Application		
	Prepare	***choose, prepare, schedule, select,** sketch*
	Use	***apply,** change, **employ**, manipulate, modify, operate, **use**, **utilize***
	Practice	***demonstrate,** execute, illustrate, **practice,** show*
	Resolve	*compute, measure, solve*
Analysis		
	Analyze and test	***analyze, appraise**, calculate, **elicit, examine, experiment, question, test***
	Categorize	*breakdown, categorize, diagram, inventory, outline, separate, subdivide*
	Discriminate	***compare**, differentiate, distinguish, **discriminate**, **reconcile***
Synthesis		
	Plan	*collect, **plan**, propose*
	Create	*compose, **create,** design, devise, **formulate**, generate, set up, tell, write*
	Construct	*arrange, assemble, **construct,** combines, compiles, manage, organize, **synthesize**, set up*
	Rearrange	*modify, rearrange, reconstruct, reorganize, revise, rewrite*
Evaluation		
	Assess	*assess, conclude, **estimate**, predict, rate, score*
	Evaluate	*attack, criticize, critique, **evaluate**, value*
	Defend	*argue, defend, justify, support*