Cognitive Learning Objectives and New Educators: Techniques for Navigating the Early Years and EC2000

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Abstract

The current engineering education environment presents many challenges to the new engineering educator including simultaneously navigating outcomes-based accreditation, learning how to teach, and conducting technical and/or educational research. Although obscured at times, *learning* is the ultimate desired outcome of each of these. This paper describes techniques for using cognitive learning objectives to both enhance and measure student learning, i.e., student achievement of course and program outcomes. These techniques may not require significant additional time on the part of the instructor. Rather, preparation time may even decrease. These techniques have been learned by the author through participating in various NSF, ASEE, and ASCE sponsored teaching workshops during the past four years. In particular, this paper summarizes Bloom's Taxonomy for cognitive learning objectives, describes how to use these for writing both course and lesson objectives, how to organize and design course work consistent with the stated objectives, and then use these objectives as a guide for measuring student learning.

I. Introduction

Of the many challenges that a new engineering educator faces, learning to teach is but only one. The challenge of learning how to teach while simultaneously learning how to conduct research and then to do so while implementing new accreditation procedures need not be considered an impossible hurdle or obstacle. Rather, this is a time of great opportunity, a time when the landscape of engineering education is facing significant and observable changes.

Effective communication is obviously one hallmark of effective teaching. In the past four years, this author has participated in and assisted with various NSF[1], ASEE[2], and ASCE[3] sponsored teaching workshops. At each of these workshops, cognitive learning objectives and their use was mentioned as a critical element of effective communication in the classroom.

Surrounded by but not directly involved in EC2000 matters, this author learned via these workshops and personal experience in the classroom how cognitive learning objectives could be used to enhance student learning, optimize lesson preparation, and become the basis for the measurement of student performance. Now that this author is directly involved with EC2000 matters, it seems a simple rather than difficult challenge to develop program educational

objectives and outcomes. Indeed, this author believes that, in the end, the straight-forward use of cognitive learning objectives goes a long way towards developing an assessment program.

II. Cognitive Learning Objectives

The essence of a learning objective in the cognitive domain is that it is a statement of what the *learner* (student) should be able to *do* at the end of a specified lesson, exercise, block of material, or course. The cognitive learning objective focuses on knowledge, intellectual abilities, and intellectual skills[4]. In some ways, they are similar to goals that an instructor or department might set for a course. However, cognitive learning objectives are much more specific and are inherently *measurable*. Examples from a basic mechanics course in statics are:

A. *Define what a free-body diagram means*.
B. *Describe the role of the free-body diagram in the calculation of reactions.*
C. *Determine the bar forces in the given truss structure and loading*.
D. *Evaluate the adequacy of the truss structure given its member strengths. Suggest ways in which to correct any deficiencies or to otherwise improve the structure.*

Notice that these examples cover a spectrum of relatively simple to complex tasks. The following (hierarchical) taxonomy, known as Bloom's Taxonmoy[5], is a helpful way in which to understand and think about various levels and complexity of learning objectives. The taxonomy begins at a simple foundational level and proceeds to a "highest" and most complex sixth level.

1. **Knowledge**. *Consists of recollection of facts, basic definitions, lists of information, or methodology or procedures.* (Objective A.)
2. **Comprehension**. *Consists of restating or interpreting concepts or definitions in one's own words but not necessarily solving problems.* (Objective B.)
3. **Application**. *Consists of straightforward solution of (single-solution) problems.*
4. **Analysis**. *Consists of breaking a complex problem into simpler problems that may be approached via the application of engineering principles.* (Objective C.)
5. **Synthesis**. *Consists of taking many parts to produce a new whole. Engineering design is frequently associated with this level.*
6. **Evaluation**. *Consists of producing a value judgement about a problem, solution, proposal, etc.* (Objective D.)

A particular objective may fit within more than one level of Bloom's hierarchy depending on the context in which it is used. For instance, Objective C may reasonably fit within the Application level if the problem to be solved is a direct and simple application of a particular problem solving technique. Or, it could be classified in the Analysis level if the problem requires a more complete or creative analysis. In this particular statics course, one may need to proceed with judgement about when and where to use the "method of sections" in combination with the "method of joints" in order to optimize the solution procedure. This objective could even be classified in the Evaluation level if there were additional value judgements to be made either about the structure itself or the solution process; Objective D is one such example.

Benefits of using learning objectives include:

1. *Learning objectives provide a focus for both the student and teacher*. The students know exactly what it is that they are supposed to learn. It keeps their efforts focused and efficient on the critical task-level "goals" of the lesson, homework, project, exam, or course. Additionally, the teacher keeps his or her effort focused on the specific items that need to be accomplished rather than going off on personally interesting tangents that yield minimal learning benefit for the associated cost.

2. *Learning objectives appeal to various learning styles*. With reference to the names of preferred learning modes in the Felder-Silverman[6] model, sequential learners tend to prefer lists of tasks such as those that cognitive learning objectives represent. The global learner use the learning objectives to help understand where the course material is headed, particularly if connections are drawn between various learning objectives and the course material. The verbal learner sees a nice itemized list whereas the visual learner sees a "schedule" of tasks (if arranged in that format).

3. *Learning objectives improve classroom communication and demonstrate effective classroom leadership*. Teaching is unlike many public presentations. The listener (student) is expected to be able to *do* something by the end of the presentation. The presenter (teacher) is usually expected to both formulate the goal and to help develop the tools necessary to reach that goal. It is in this latter respect that the teacher operates particularly as a leader. Cognitive learning objectives are one efficient and effective way of communicating the desired outcome also and at times the method by which to achieve that outcome.

4. *Learning objectives inform the teacher about student learning and also aid greatly in writing appropriate exams*. The task-level nature of cognitive learning objectives means that they are inherently measurable. Instructors should take advantage of this by writing both assessment questions and exam questions in a similar manner as the objectives themselves. This means that both the *techniques* used to create the learning objective should be used to write the exam question *and* the objectives themselves should be used as a model for the exam question. This has advantages such as it insures a match between covered material and the associated exam as well as it makes exam writing easier. This idea can be easily extended to assessment of the entire course and the final exam, in particular.

At times, critics level the charge that cognitive learning objectives "spoon-feed" the material to students. Or, that they remove spontaneity from the course or otherwise restrict the freedom of intellectual exploration. There are a number of ways to circumvent these potential pitfalls. For example, write the learning objectives at high levels in Bloom's Taxonomy. Higher level objectives are inherently more general or broader, i.e., more open-ended and can be used to provide both the stimulation and freedom of intellectual thought that may be desired. Additionally, if one feels that the exam is too narrow, one simply writes course exam questions that are at a higher level and more open-ended. In other words, when it appears that a learning objective is restricting the learning environment, then change the learning objective.

Another oft-heard complaint is that developing learning objectives requires too much preparation time. There is much that could be discussed on this point and much of that arguable. Consider this, however: this author finds that time is too precious to not be directly focused on and to be efficient about the task at hand. Learning objectives provide that direct

focus both for the teacher and the student and help make both the author's and the student's time more efficient regardless of the preparation time. The EC2000 assessment process itself practically demands the development of "measurable learning outcomes," i.e., learning objectives.

III. Writing and Using Cognitive Learning Objectives

Learning objectives, in order to be useful, must be clear and concise. Cognitive learning objectives must also be *measurable*. One way in which to think about a well-written learning objective is apply the "exam test." That is, would the learning objective as stated be a suitable exam question given sufficient time? Consider the following two learning objectives.

A. Understand the Method of Sections and how to use it to calculate member forces.
B. Use the Method of Sections to calculate member forces.

Both objectives refer to the same task: that of analyzing a truss using the method of sections in order to calculate member forces. Although Objective A is an important *goal* of a statics course, it is not *measurable*. It specifies nothing about how one would demonstrate "understanding" of the concept. Consider, for instance, what would happen if this were used for a question on an exam. A full credit response would be along the lines "Yep. Got it." Then, the student moves on to the next question. Objective A is a fine goal, but that's all it is … a goal. Its primary utility is as a guide for writing Objective B, which is inherently measurable in terms of a student's ability to successfully apply the Method of Sections to calculate member forces.

There are four basic verbs of this type that are a part of many important and valuable course goals but should be avoided when writing cognitive learning objectives: *Know, Learn, Appreciate,* and *Understand*. None of these are directly measurable. Each relies on something else to *demonstrate* the mastery of that knowledge, learning, appreciation, or understanding.

Considerable discussion about how to write learning objectives is included in previously mentioned references[1-5] and therefore the discussion here will focus more on the author's use of learning objectives. One last point of reference from the author's experience, though, is that it is often easier to learn how to write an objective for a specific *lesson* before diving in and writing one for an entire *course* or *program.*

Learning objectives may be categorized into three basic areas that take their names from their use: course, lesson, and review objectives. **Course objectives** are the task-level intellectual skills that the successful student will be able at do the end of the course. These should probably be written at a fairly high level in Bloom's Taxonomy, be included in the course syllabus, and typically number from five to seven.

Lesson objectives refer to those learning objectives for a specific lesson, e.g., a 50-minute lesson presentation. These are what the student should be able to do at the end of the lesson *including* associated text reading, homework assignments/projects, etc. Lesson objectives do not need to be fully covered within the lesson period. Indeed, they should help guide the student's learning beyond the in-class contact time. A typical 50-minute lesson has three to five lesson objectives that may span the range of Bloom's Taxonomy. It is frequently helpful to

students (particularly global and sequential learners) to have these in full view each and every lesson. Sideboards and easels provide excellent places to locate these.

Review objectives are the set of task-level intellectual skills for a block of material that will be covered on an upcoming exam. These usually number from 20 to 30 depending on how one condenses some of the lower-level Knowledge objectives into broader Comprehension or even higher level objectives. These can be given to students one to two weeks before the scheduled exam and may even include review problems.

A couple of ways to deliver these objectives to the students are mentioned above, e.g., the syllabus, in-class, and before exams. Another effective way to do this is to prepare "Study Notes.[1]" These are usually prepared before the semester if possible and typically have one page per lesson. Each page includes the associated lesson number, topic, objectives, text reading, lesson comments, and any supplementary material. The following example comes from the statics course used previously in this paper.

GE109 - Statics **Lesson 20**
Analysis of Trusses I - Method of Joints
Objectives

1. State the basic assumptions of the idealized truss model.
2. Identify truss members and joints.
3. Describe in terms that an above average high school senior would understand how a truss is similar or different to our study of concurrent force systems.
4. Define the Method of Joints.
5. Use the Method of Joints to analyze a given truss structure to find member forces.

Study Assignment

Review: Text, Section 4.1 - 4.2
Study: Text, Section 4.3 - 4.4

Although one might initially think a high level objective that requires synthesis and evaluation skills belongs only in upper division undergraduate courses, research suggests otherwise[4,5,6]. Indeed, much of undergraduate engineering education is focused on the Knowledge, Comprehension, and Application levels. If it is desired to develop students' critical thinking skills (and this always seems to be a worthwhile goal), then students should be motivated, inspired, and led at the earliest undergraduate levels to learn how to think at the highest levels in Bloom's Taxonomy. One way in which to do this is to write learning objectives at all of Bloom's levels in each and every course.

IV. Course and Program Assessment

Critical aspects of effective use of cognitive learning objectives for both course and program assessment are what this authors calls the three C's: Clarity, Concision, and Continuity. Learning objectives provide not only a focus for students and their learning, but are also critical to measuring that learning. Homework and exam questions written in a similar style as the learning objectives is a key element of that measurement.

During the delivery of a course, the teacher should continually remind the students of where the class is headed (the "big-picture"). Since the student will ultimately be evaluated on their mastery of the course objectives, these then serve as an over-all guide for the course. By consistently drawing connections between the lesson material, lesson objectives, and course

objectives, several (positive) things are accomplished. A variety of learning styles are accommodated, e.g., by providing the global learner "the big picture" or helping the inductive learner to be drawn from the specific to the general. Continuity of material within the course is also enhanced. Continuity of the course with the program outcomes is also assisted.

One cannot ensure student achievement of program outcomes unless one carefully maps out the connection between the program outcomes and the courses that are used to achieve those outcomes. This can't be accomplished until one determines what is accomplished within a course. Learning objectives do just that. They inform the instructor of both what the course is "about" and are a device to determine how well the students have accomplished those objectives. In other words, learning objectives may be a backbone for course and program assessment. With skilled use, learning objectives also ensure continuity within the courses and programs.

Although this may appear to be a top-down development process, often it is in writing the detailed lesson objectives that one more clearly understands the course objectives. Likewise, in writing course objectives, one often more clearly understands the program outcomes. Although there needs to be clarity, concision, and continuity in program outcomes, course objectives, and lesson objectives, there is not necessarily a linear path that one should use to develop these. Start with the familiar and the simplest (lesson and course objectives) in order to develop experience with writing clear and measurable objectives.

Conclusions

Cognitive learning objectives can be used to inform the instructor about course organization and delivery as well as provide an avenue for improved student-teacher communication, which inevitably enhances student learning. This paper discusses how to write clear course objectives, how they can be used to provide a focus for an instructor's lesson presentation, and be used to aid student learning as well as provide a means by which to measure student learning. Several examples of and techniques for using learning objectives are presented with an emphasis on how learning objectives provide a backbone for evaluating and assessing student learning.

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