Development of Learning Taxonomy for an Undergraduate Course in Architectural Engineering Program

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Abstract

Curriculum for an undergraduate course is re-designed and educational methodology based-on active learning is formalized in Missouri S&T Architectural Engineering Program. Based-on course improvement plan, course goals, student learning objectives and assessment tools need to be classified to have better documentation of mentioned improvements. This paper outlines development of a learning taxonomy for this purpose. Reasoning of the study and preferred methodology presented herein by the help of literature review. Using a template for course blueprint enables to create targeted taxonomy. Selected course blueprint is exemplified for another Architectural Engineering course and helps outlining learning taxonomy for “architectural materials and methods of building construction” course. Higher and lower cognitive domains of learning objectives is specified by using necessary action verbs classified in Bloom’s Taxonomy. Assessment methods are linked to learning objectives to meet course goals. Consequently, learning outcomes for mentioned course can be created by this methodology.

Keywords: Curriculum development, educational model, active learning, learning taxonomy, architectural engineering

Introduction

Higher education’s quality assurance bodies around the world - such as ABET in the United States - create and maintain competency-banks as in this experiment to usher in greater clarity to all stakeholders like the; curriculum developers, students, teachers, administrators, industry.[1, 2, 3, 4] Designing degree programs around competencies would not only help demonstrate quality, but it would also support students as they move from one institution to another.[5] There is a variety of perspectives about the origin of competences, with backgrounds in diverse areas such as linguistics, cognitive psychology, business organization, management development and engineering education, thus being able to find that the terms competence and competency are used in various ways in the literature. Although these concepts are commonly used in the educative area in some European countries (such as; United Kingdom, Denmark, Finland, France, and others), there is further discussion on implementation of these concepts at course level and supporting theoretical frame. Many institutions in Europe have competence-based curriculum and learning process is also desired to be changed in practice along with changes in the curriculum.[6] Each program seeking accreditation is given latitude to develop their own systems for continuous improvement. Many programs struggle with how to institutionalize this process in a way that will gather faculty support and that will provide the documentation of the continuous improvement process. Since the purpose of the accreditation process is the continued improvement of engineering education, it makes sense to explicitly incorporate what is known about cognitive science.[7] This paper outlines development of a learning taxonomy for an undergraduate course in architectural engineering program. The research question herein is how to design an architectural engineering course syllabus to satisfy program outcomes and course objectives faculty teach. Architectural engineering program provides students with the knowledge and opportunities that prepare them for industry and to pursue further education at the graduate level. Methodology to create learning goals, objectives, outcomes and assessment for a particular course in Architectural Engineering is presented herein. Beside, contribution of course learning outcomes to meeting the requirement of program outcomes are also important. This paper focuses more on the background and reasoning of the course curriculum improvement. The study includes specific reference to the cognitive system of Bloom Taxonomy and the teaching model of Kolb and Webb's depth of knowledge, to provide structure for course organization and a foundation for faculty to seek course improvement. Learning outcome, assessment and learning styles are discussed and taxonomy of educational objectives are introduced. Writing course learning outcomes needs specific methodology based on literature review.

Learning outcome, assessment and learning styles

Learning outcomes are statements that specify what learners will know or be able to do as a result of a learning activity. Outcomes are usually expressed as knowledge, skills, or attitudes.[8, 9, 10, 11] By reviewing the published learning outcomes for a given major, students and instructors can keep in mind and discuss the larger picture of student learning within that major how the courses, projects, assessments, and other learning activities help students accomplish those outcomes. [12] Learning outcomes provide direction in the planning of a learning activity. Learning outcomes have three distinguishing characteristics [8]:

- The specified action by the learners must be observable.
- The specified action by the learners must be measurable.
- The specified action must be done by the learners.

Measuring learning outcomes provides information on what particular knowledge (cognitive), skill or behavior (affective) students have gained after instruction is completed. Quantitative measurement includes numerical data. The data can be analyzed using statistical methods and results can be illustrated using tables, charts, histograms and graphs. Qualitative measurements consist of data collected that is not numeric such as grading of written work using a rubric, results from group discussions, interviews, case study evaluations and artistic portfolios.[13] Written measurable outcomes involves describing the first three components: outcome, assessment method, criteria for success, in the assessment cycle. Grades alone do not provide adequate feedback to students' performance. However, if grading is tied to rubrics, it can be a useful tool to identify strengths and weaknesses of student performance. Two methods of assessment can be categorized [9]:

a) Direct method used: Standardized exams
b) Indirect method used: Survey

Much of the effort associated with the accreditation process is focused on direct measurements of student learning and relating these data to program outcomes.[7] Direct measures of learning are based on actual student performance and the artifacts of their learning activities. Student performance results as evidence only if it satisfies the initial intention, such as a stated learning outcome declared in a project assignment or in the course syllabus. Examples of direct measures are written assignments, classroom assignments, presentations, test results, research projects, logs, portfolios or e-folios, and direct observations (e.g., architectural critiques, review or juries). Indirect measures of learning are those that evaluate students' feelings and perceptions with regard to their learning experience and environment. Examples include surveys, exit interviews with graduating students, focus groups, and reflective essays. Assessment results contribute to planning by promoting further examination of curricular activities and helping in making adjustments or revisions of the curriculum.[13] Traditional assessment methods, such as quizzes and tests, are effective for measuring the acquisition of facts, concepts and discrete skills. Assessment of analysis, synthesis, and evaluation skills often require a typical methods such as essays, research papers, advanced design problems, and complex take-home examinations plus more detailed rubrics for feedback.[7]

Students characteristically use different ways to take in and process information. Understanding what those ways are is a good first step toward designing instruction that can accommodate the learning needs of all of the students in a class. Three instructional approaches are defined as learning styles [14]:

a) *active learning* (getting students to do things in class that actively engage them with the material being taught),
b) *cooperative learning* (putting students to work in teams under conditions that promote the development of teamwork skills while assuring individual accountability for the entire assignment), and
c) *problem-based learning* and similar approaches (teaching material only after a need to know it has been established in the context of a complex question or problem, which increases the likelihood that the students will absorb and retain it).

In order to integrating technology into the design in construction technology and environment programs, it is recommended that to study carefully on the structure of the curriculum, the teaching methods and the instructional tools. The most widespread theory of learning is called experimental learning, which is associated with David Kolb, who developed ideas from earlier models of experimental learning.[15] The objectives assist the instructor with developing a set of activities that correlate to each quadrant in Kolb's learning cycle. Teaching in each quadrant promotes retention, encourages recognition of applications, and serves the diversity of students' learning styles.[7] Kolb [16, 17] developed a system of selecting classroom activities based upon his research related to adult learning. There are four "quadrants" (Kolb's learning cycle) of ways that people learn: concrete experience, reflective observation, abstract conceptualization, and active experimentation.[7]

Taxonomy of educational objectives and levels of thinking

The taxonomy of educational objectives is a scheme for classifying educational goals, objectives, and, most recently, standards. It provides an organizational structure that gives a commonly understood meaning to objectives classified in one of its categories, thereby enhancing communication. Based on this examination, teachers can decide where and how to improve the planning of curriculum and the delivery of instruction.[14, 18] Engineering education research is a broad-based, rapidly evolving, diverse, interdisciplinary, and highly international field. One solution that would allow engineering education researchers and practitioners to best take advantage of this diversity is to establish a standardized terminology and organizational system – a taxonomy of terms – to map the field and to communicate and connect research initiatives. It could serve as a framework for researchers and members of the engineering education research community to situate their individual research initiatives in the broader field, see connections and synthesize ideas, better access the research of others, and plan future work. A taxonomy, specifically the preferred terms, can help researchers search the literature by linking and suggesting related terms and by offering a hierarchical structure that aids in navigation.[19] Several taxonomies were developed to be used in higher education presented some of them as follows;

- Bloom's Taxonomy
- SOLO Taxonomy
- EER Taxonomy
- Fink's Taxonomy

These taxonomies have been further developed but the basic ideas are still the same and particularly Bloom's Taxonomy is still very widely used. [20] Two Denmark Universities interpreted "course objectives" as "intended learning outcomes" (ILO) and systematically formulated all such as competencies using the SOLO "Structure of the Observed Learning Outcome" taxonomy that operates with five numbered progressive levels of competencies.[20] SOLO taxonomy was studied by research educators in computer science [21,22], geography[23], statistic[24], accounting[25], design and technology.[26] Development of a taxonomy of keywords for engineering educations research is published by Finelli and others in 2015 as EER taxonomy.[19] Fink's taxonomy of significant learning encompasses the ideas included in problem-based, project-based, and team-based learning. Bloom's taxonomy has been the primary reference for educational outcomes in ABET and body of knowledge documents for environmental and civil engineers. Fink's taxonomy expands on Bloom's taxonomy as it includes categories such as learning how to learn, the human dimension of learning, and the caring dimension of learning.[27] Bloom's taxonomy is a powerful tool for discussion among faculty related to teaching.[7]

Webb (1997) developed a process and criteria for systematically analyzing the alignment between standards and standardized assessments. Since then the process and criteria have demonstrated application to reviewing curricular alignment as well. This body of work offers the Depth of Knowledge (DOK) model employed to analyze the cognitive expectation demanded by standards, curricular activities and assessment tasks. The model is based upon the assumption that curricular elements may all be categorized based upon the cognitive demands required to produce an acceptable response. Each grouping of tasks reflects a different level of cognitive expectation, or depth of knowledge, required to complete the task. Webb describes his DOK levels as "nominative" rather than as a taxonomy. Depth of knowledge is identified in four levels; 1) recall, 2) skill/concept, 3) strategic thinking, and 4) extended thinking.[28, 29, 30, 31]

Bloom's taxonomy

Bloom's taxonomy has been widely accepted for engineering education with a universal agreement that engineering graduates should be competent at analysis, synthesis and evaluation.[7, 32] There are more than one type of learning which are clustered in three domains; cognitive, affective and psychomotor. Bloom developed taxonomy (hierarchy) of cognitive learning skills which allows educators to evaluate learning of students systematically.[33, 34] The original taxonomy provided carefully developed definitions for each of the six major categories in the cognitive domain. Cognitive domain is divided to: knowledge, comprehension, application, analysis, synthesis, evaluation.[15, 18, 35] The categories were ordered from simple to complex and from concrete to abstract.[18, 36] Instructors categorize the learning objectives they have constructed into either lower (knowledge, comprehension, application) or higher (analysis, synthesis, evaluation) cognitive domains, according to Bloom's taxonomy. Based on the cognitive level, they create an assessment plan consisting of three methods to assess each learning objective. Methods of assessment are specifically matched to the cognitive level of the learning objective. Collection of performance evidence becomes increasingly more difficult as increasingly higher-level thinking is required.[7] A revision of Bloom's taxonomy of educational objectives was also done due to needs manifested in the course of the time.[37] A revised taxonomy was proposed by Krathwohl by the new knowledge dimension, however contains four instead of three main categories. A fourth, and new category, metacognitive knowledge, provides a distinction that was not widely recognized at the time the original scheme was developed.[18] The Bloom's action verbs can be used to connect all areas of the curriculum and to accommodate measurement and assessment. For instance, verbs such as; remembering, understanding, applying, analyzing, evaluating, creating.[13] The use of Bloom's taxonomy as an alternative assessment method is gaining interest in science education.[38] As an example in STEM education; a Blooming Biology Tool (BBT), an assessment tool based on Bloom's Taxonomy, is developed to assist science faculty in better aligning their assessments with their teaching activities and to help students enhance their study skills and metacognition.[39] Crowe (2008) found that execution of the BBT was helpful in enhancing student learning through alterations in teaching approach to promote higher cognitive skill development.[38]

The students also experience much higher learning when engaged in such processes. The conception of creativity includes an interrelated set of intellectual skills of creative thinking, critical thinking, and innovative problem solving; personal characteristics of versatility, tolerance for ambiguity, willingness to take risks, open-mindedness, confidence, and curiosity, and values of discipline, perseverance, and responsibility. Engineering students report more effective learning when they are engaged in higher order cognitive activities through active learning. Even in the opinion of professional engineers, faculty should engage students in higher level cognitive activities like analyze, design, develop, implement and so on.[36]

Writing course learning outcomes

Goals and objectives are similar in that they describe the intended purposes and expected results of teaching activities and establish the foundation for assessment. Goals are statements about general aims or purposes of education that are broad, long-range intended outcomes and concepts; e.g., "clear communication", problem-solving skills", etc. Objectives are brief, clear statements that describe the desired learning outcomes of instruction: i.e., the specific skills, values, and attitudes students should exhibit that reflect the broader goals. The differences between goals and objectives is the characteristic which distinguishes goals from objectives is the level of specificity. Goals express intended outcomes in general terms and objectives express them in specific terms. The differences between objectives and outcomes is; objectives are intended results or consequences of instruction, curricula, programs, or activities and outcomes are achieved results or consequences of what was learned.[40] Learning outcomes written at the course level should state clear expectations; learners know what they have to do to demonstrate that they have achieved the learning outcomes. When writing learning outcomes, it is recommended that to focus on student behavior and use simple, specific action verbs to describe what students are expected to demonstrate.[9] The wording should be something as follows: collect, organize, apply, articulate, use, evaluate, participate, appreciate, identify, outline, distinguish, calculate, explain, design, formulate, etc.[9, 41] Learning outcome statements may be broken down into three main components:

- an action word that identifies the performance to be demonstrated;
- a learning statement that specifies what learning will be demonstrated in the performance;
- a broad statement of the criterion or standard for acceptable performance.

Statements of learning outcomes should be detailed as much as possible instead of being general and so, it would be fairly easy to measure when using the correct assessment measure. Action verbs based on revised Bloom's taxonomy result in overt behavior that can be observed and measured. Certain verbs are unclear or relate to covert, internal behaviors that cannot be observed or measured. These types of verbs should be avoided (e.g., appreciate, become aware of, become familiar with, know, learn, and understand).[10] While writing learning outcomes, the more clear and concise the language, the greater the likelihood that students will be able to use them to structure their learning.[42]

Creating a course to achieve specified outcomes requires effort in three domains: planning (identifying course content and defining measurable learning objectives for it); instruction (selecting and implementing the methods that will be used to deliver the specified content and facilitate student achievement of the objectives); and assessment and evaluation (selecting and implementing the methods that will be used to determine whether and how well the objectives have been achieved and interpreting the results). To keep track of how and where program outcomes are addressed in the curriculum, a course assessment matrix might be constructed for each core course, with a column for each program outcome and a row for each outcome-related learning objective. Entries of 1, 2, and 3 inserted in a cell of the matrix respectively indicate that an objective addresses an outcome slightly, moderately, or substantively.[43]

Course blueprint

Active learning methodologies such as; problem-based learning, hands-on learning, are included in "architectural materials and methods of building construction" course in Missouri S&T Architectural Engineering Program. This educational method is formalized and implemented based on feedback received from student's surveys. Further improvements to the course included;

- better organization of classroom activities
- using diverse teaching methods
- better understanding of education theories
- better monitoring results of teaching activities

Due to mentioned course improvement plan, a documentation/classification method is required to follow interaction between learning objectives, instruction and assessment. Development of a learning taxonomy based-on active learning may result in a series of other positive impacts such as; improvement in faculty's ability to deliver course material and better documentation of mentioned improvements. In order to realize this goal, a template to document course goals, student learning objectives and assessment which automatically creates a taxonomy is selected as course blueprint. This template is also promoted by Missouri S&T Educational Technology, which organizes workshops to create building blocks[44, 45], in order to promote active learning at faculty level.[14] Higher and lower cognitive domains of learning objectives is specified by using necessary action verbs classified in Bloom's Taxonomy. It is also possible to produce a course assessment matrix which presents outcome-related learning objectives. A sample course template using course blueprint belong to "Building Lighting Systems" in Missouri S&T Architectural Engineering Program is depicted in Figure 1.

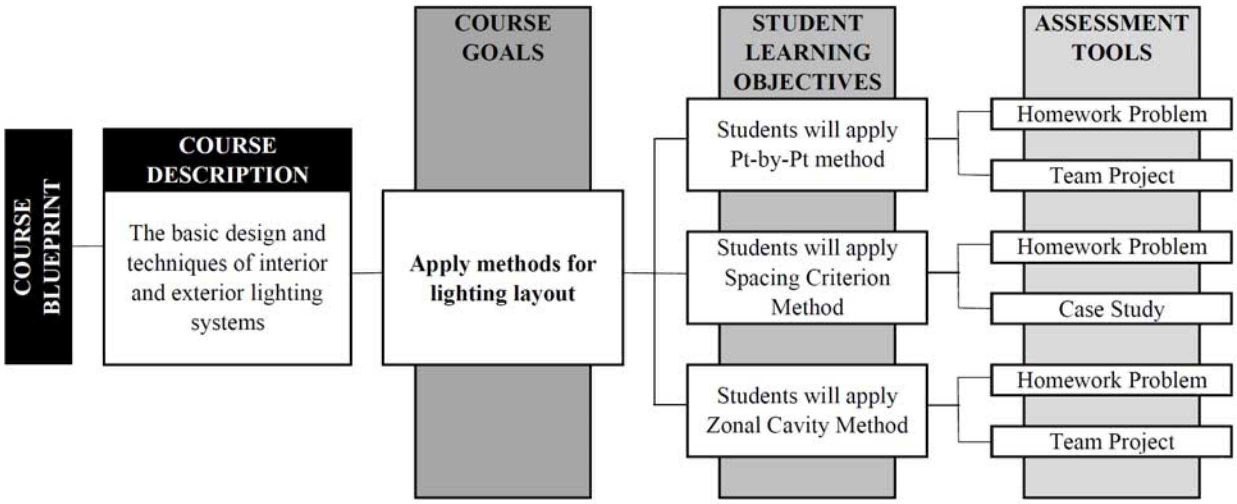

Figure 1. Sample course template belong to "Building Lighting Systems".

The figure presents the course goals, student learning objectives and assessment tools partially, because of number of course goals may vary course by course. A building design needs an interdisciplinary study including architectural, structural, electrical, mechanical majors and etc. Using engineering methods and some common assessment tools, this sample provides other Architectural Engineering courses such as; architectural materials and methods of building construction a good basis to start from.

Conclusion

The focus on teaching shifted to competencies achieved by students due to technological developments and industry needs – consequently to follow conditions of higher education accreditation agencies. Creating measurable learning objective is important to set forth course improvement plan. Taxonomy of educational objectives help instructor to re-design or improve his/her course curriculum. Increased retention of knowledge is targeted by using active learning strategies rather than traditional learning environment. Even each learning style has its own definition, most of the time those are interchangeable in the literature such as; active learning, cooperative learning and problem-based learning. Course outcomes shall support program outcomes – not all but partially – to be part of four year engineering education. Writing measurable learning outcomes is possible by using some action verbs that some of them belong to high level cognitive domain. Creating a course plan to achieve specified outcomes requires effort in three domains as; learning objectives, instruction and assessment. In order to document a previously developed course curriculum based on problem-based learning, an existing course blueprint is selected to use as an ideal template. A partial course template is exemplified for "Building Lighting Systems". By using course blueprint, instructors are encouraged to create their own preferred method of learning as part of teaching improvement plan. This process leads to a revised set of activities that maintain particular changes to improve the course. On the other hand, usage of quadrant in Kolb's learning cycle and Webb's depth of knowledge is also inspirational to create a course-based assessment quadrant based on direct or indirect methods of assessment. Consequently, discussed methodology is being used to create course building block for "architectural materials & methods of building construction" course in Missouri S&T Architectural Engineering Program.

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