AC 2007-1259: COURSE LEVEL ASSESSMENT AND IMPROVEMENT: APPLYING EDUCATIONAL PEDAGOGY TO ABET ACCREDITATION

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Course Level Assessment and Improvement: Applying Educational Pedagogy to ABET Accreditation

Abstract

The Accreditation Board for Engineering and Technology's (ABET) revised criteria for the accreditation of engineering programs, Engineering Criteria 2000, focuses on continuous improvement of program educational outcomes. Programs seeking ABET accreditation must use an assessment strategy in which students demonstrate achievement of clearly-defined, designated criteria. Much of the effort associated with the accreditation process is focused on direct measurements of student learning and relating these data to program outcomes. As such, a large portion of the accreditation process involves assessment in the individual courses within the curriculum and is thus administered by the faculty. This paper describes a novel approach based on educational pedagogy applied at the course level in the programs in the Chemical, Biological and Environmental Engineering programs at Oregon State University.

An effective assessment is built on a model of cognition that describes how students become competent in a specific subject domain. Therefore, it is useful to make sure such cognitive models are explicitly defined in the ABET process. Casting course level assessment in terms of cognitive models can also help guide faculty in course improvement. To address this issue, modifications of two well-established cognitive models are used, Bloom's taxonomy and Kolb's learning cycle.

The center of the course level assessment is a *course summary* that each instructor fills out every time he/she teaches a course. The two cognitive models form an integral part in the course summary. 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. For each learning objective, instructors plan 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.

The course summary culminates in an improvement plan based on the instructor's analysis of the assessment data. As part of the improvement plan, instructors are encouraged to articulate their own preferred model of learning. This process leads to a revised set of activities for the Kolb learning cycle that provides specific changes to improve the course the next time it is taught.

Introduction

The evaluation of engineering programs under the Accrediting Board of Engineering and Technology (ABET) has at its center the continued improvement of engineering education. The structure of this evaluation involves the formation of broad program educational objectives (PEOs) that are supported by both common ("a through k") and program-specific learning outcomes (LOs). The LOs are supported primarily by a series of course learning objectives (CLOs) developed by faculty for their particular courses. The CLOs form a complex web of expectations for students that weave the entire curriculum together to produce professionally competent engineers.

Assessments are used for both LOs and CLOs to determine success in meeting the CLOs, LOs, and PEOs and to determine specific changes that can be instituted to result in continued improvement. Assessment tools can include tests, reports, exit surveys, alumni surveys, portfolios, and professional exams[1]. An *assessment loop* consists of defining the outcome or objective, activities to inculcate the outcome or objective, a quantitative assessment of success, and identified alterations in activities to improve success in the future. The assessment process must result in a "closing of the loop," and each step must be documented.

Each program seeking accreditation is given latitude to develop their own systems for continuous improvement. All 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. A survey of the literature shows reports on the development of assessment plans[2,3,4,5]. The match between the program's assessment practices to the PEOs and LOs and the resulting improvement cycle has also been described[6,7]. Other papers have covered specific aspects covered by ABET 2000. One such paper presents the implementation and assessment of the "professional" skills component[8]. The use of portfolios in the Biological Engineering Programs at Ohio State and Louisiana State Universities were rated by students for perceived learning effectiveness and correlated to the Myers-Briggs Type Indicators for those students[9].

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. This paper outlines a system developed at Oregon State University to help faculty organize their courses and the subsequent assessment around CLOs and LOs to meet ABET requirements. However, the system seeks much broader objectives of improving faculty teaching and involving faculty in course planning that is based upon accepted educational approaches and theories. The system includes specific reference to the cognitive system of Bloom[10] and the teaching model of Kolb[11,12] to provide structure for course organization and a foundation for faculty to seek course improvement.

Cognitive Models

<u>Bloom's Taxonomy</u>. Bloom[10] divided the cognitive domain into six levels that form a quasi-hierarchy of cognitive development. In general, mastery of lower levels are required for student success at higher levels; however, engineering students typically have varying degrees of

abilities in all six levels. The six levels, their corresponding demonstrable skills, and verbs that can be used to form learning objectives are presented in Table 1:

Table 1. Levels in Bloom's taxonomy of learning

Level	Skills	Verbs
Lower level cognitive domain:		
Knowledge	**The student can recall information.** Ability to recall facts, definition, jargon , technical terms, classification, categories and criteria; recall of methods and procedures, principles, and theories	arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, reproduce state.
Comprehension	**Information is understood or can be interpreted.** Understanding of meaning including ability to verbalize in individual's words, interpretation of experimental data, extension of trends and tendencies.	classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, translate,
Application	**Concepts are employed to solve problems in new situations.** Use of abstract ideas in a concrete situation, selection of appropriate equations for particular problems, ability to solve typical textbook homework problems.	apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, write.
Higher level cognitive domain:		
Analysis	**Material that defines a problem or idea is broken into parts. The individual parts are understood, along with the relationships between them.** Breaking down complex problems, deciding upon the correct idea, principle, or skill to apply, and maintaining proper relationships between the parts of the problem.	analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, test.
Synthesis	**Concepts formed in previous experiences are combined with new material to create ideas that integrate all of the information.** Taking the many parts of a complex problem and forming as a quality whole	arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, write.
Evaluation	**New ideas are compared to existing theories and evaluated accordingly.** The ability to determine quality in a solution, process, design, or report, determination whether the results meet the internal and external engineering design criteria, multidimensional analysis such as economic versus environmental concerns.	appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, evaluate.

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.

The American Society of Civil Engineering[13] has used Bloom's taxonomy as the fundamental foundation of their move to require competency equivalent to a fifth year of engineering education for professional registration.

From a pedagogical view, students are seen to develop the higher level cognitive skills by being challenged with situations requiring the higher level skills for success. Unfortunately, most textbook-type homework problems are constrained enough in the approaches needed for solution that only an application cognitive level is required for success. Higher level skills (analysis, synthesis and evaluation) are often not included by faculty into quizzes or examinations (mid-term or final) because of time constraints and difficulty of grading. Moreover, students have the opinion that such testing requirements are "tricky" and "unfair," since they are asked to reformulate the fundamental principles in new ways. It has been our observation that faculty who require higher level cognitive skills on examination have less student satisfaction and lower student-teaching ratings than faculty who primarily requires lower level skills. We believe this is a fundamental issue in all of engineering education that must be directly dealt with in course planning.

Bloom's taxonomy is a powerful tool for discussion among faculty related to teaching. This strength comes from its ability to:

- Relate closely to faculty's experiences related to students not being able to successfully solve real world problems and their difficulty with engineering design.
- Lead to examination of what activities (lectures, discussions, recitations, laboratories, out-of-classroom activities) are best suited to challenge students into engagement at higher cognition levels.
- Clearly show what testing or assessment methods are needed to identify success at higher cognitive levels.
- Improve the quality of course learning objectives to foster higher level cognitive abilities required for success in the engineering profession.

<u>Kolb's Learning Cycle</u>. Kolb[11,12] developed a system of selecting classroom activities based upon his research related to adult learning. As schematically shown in Figure 1, there are four "quadrants" of ways that people learn: concrete experience, reflective observation, abstract conceptualization, and active experimentation. Two of these stages, concrete experience and abstract conceptualization, operate in the realm of knowing (how they perceive) while the other two, reflective observation and active experimentation, involve transformation of knowledge. It is by perceiving and then transforming knowledge that people learn. Much has been written about Kolb's system and its success in engineering education[14,15,16,17].

Kolb's system has many applications to engineering education from identifying the particular learning style of students and faculty to counseling students towards certain professions or job types. Our interest is related to the use of the Kolb learning cycle as a method to organize classroom activities, an approach primarily developed by McCarthy[16] for the K-12 system and applied to engineering education by Svinicki and Dixon[17]. This approach's basic claim is that maximum inculcation of new concepts, ideas and skills occur when learning activities give full attention, in order, to each quadrant of this cycle.

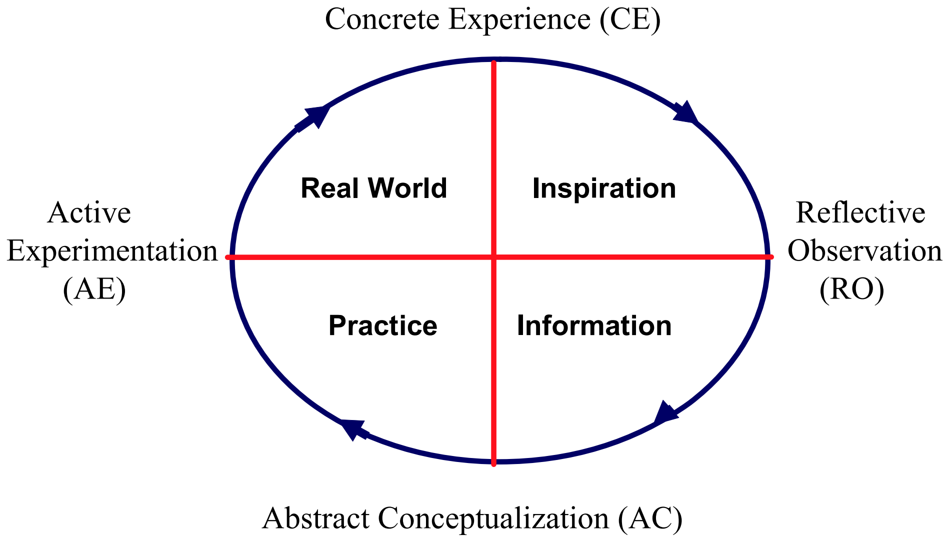

Figure 1. Kolb's Learning Cycle

As shown in Figure 1, students are taught in a defined learning cycle that involves the following fours steps:

1. **Inspiration.** This step transfers a concrete experience to internal consideration (personal reflection) through answering the "Why should I learn this?" question in a way that the student is intrinsically motivated. In engineering education, this step is accomplished through showing the students why the new material is important to real-world engineering practice and the necessity of inculcation of this new material to be a successful engineer. Common activities include telling of stories, showing concrete pictures of the application, testimony of practitioners of the usefulness of the materials, and out-of-classroom experiences such as field trips. This step is intended to be the "hook" for student learning.

2. **Information Transfer**. This step transfers the reflection of Step 1 into the logical construction of concepts, paradigms, approaches and potential skills through answering the "What do I need to know?" question. This step represents most classical education involving textbooks and lectures and tends to be information rich. Step 2 can be complex and abstract as it may require new language, concepts, paradigms, and ideas. Retention is most effectively achieved by making connections to previous students' knowledge and requires use of both Bloom's lower and high level cognitive levels.

3. **Practice under Constrained Conditions**. This step transfers the new information gained in Step 2 to practice under highly constrained conditions. The step requires active learning principles. The classical approach in engineering education is the short-answer homework problem, but discussions, laboratories and group problem solving are also successful. Obtaining laboratory data to verify predictions from the materials learned in Step 2 is another common approach for Step 3. Additionally, the emerging use of technology in the classroom can be applied in this step.

4. **Connection to the Real World**. In Step 4, the students are required to expand the analysis, synthesis, evaluation applications used in Step 3 under conditions of fewer constraints. The ideal situation is to move to a real-world engineering design that requires not only technical analysis and synthesis, but evaluation of technical, environmental and social quality. Clearly ABET's focus upon students experiencing a capstone design experience fits well with Kolb's cycle in Step 4. However, we firmly believe that this connection to the real world needs to be continuously made in classrooms across the curriculum, not relegated to the senior year, for students to understand the usefulness of their specific classes.

Course Summaries

The vehicle of the course level assessment is a *course summary* that each instructor fills out every time he/she teaches a course. The two cognitive models form an integral part in the course summary. The system contains a series of steps that are uniform for all courses, concrete in their requirements, supported by common forms, and produce a document that can be carried forward from year-to-year. These steps include:

1. **Identification of Course Learning Objectives for the Course.** Course learning objectives are identified to cover the objectives of the course. Much has been written about proper composition of CLOs[1,18,19]. We encourage faculty to limit the number of course learning objectives from five to ten.

2. **Identification of Learning Outcomes Supported by the CLOs**. The specific learning outcome of the course are related to the program educational objectives and the program-specific learning outcomes. The faculty rate the level of correspondence as substantial, limited, or instructor-dependent.

3. **Rating of CLOs with to Bloom's Taxonomy**. The course learning objectives are rated as to the level of cognitive depth that is necessary for achievement, based upon Bloom's taxonomy that is necessary for achievement. Such identification allows faculty to select appropriate assessment tools to the specific CLO in Step 4. We believe it also increases awareness in faculty to build in a progression of student learning deeper into Bloom's taxonomy.

   The Department has expectations that the level of cognitive development required will increase with the level of the course (lower division, upper division, graduate level). Traditional assessment methods, such as quizzes and tests, are effective for measuring the acquisition of facts, concepts and discrete skills. However, educational interventions that require higher order cognitive activity, such as critical and creative thinking, are not as effectively assessed with these methods[20]. Assessment of analysis, synthesis, and evaluation skills often require atypical methods such as essays, research papers, advanced design problems, and complex take-home examinations plus more detailed rubrics for feedback. Hopefully, the correspondence of CLOs with cognitive levels will results in more sophisticated assessment methods for the higher cognitive skills.

4. **Identification of Three Assessment Methods for Each CLO.** Based upon the results of Step 3, the faculty identifies the assessment method to be utilized. Assessments of achievement of CLOs are a systemic difficulty at most universities as most assessments involve homework, quizzes, and short answer questions in midterm or finals. Such assessments are highly biased toward Bloom's levels of knowledge, comprehension, and application. The typical short answer problems that strongly resemble homework problems often only require a cognitive level of application as students make a one-to-one connections to their homework experiences for success. Improper assessment choices can result in students entering a "pattern recognition" mode of problem solving.

   We believe that it is important for faculty to fully plan assessment for the entire course to promote diversity of assessment methods.

5. **Listing of Activities for Each CLO in Kolb's Four Quadrants.** Step 5 is based upon the presumption that incremental improvement cannot be achieved without specific documentation of the activities that occur in the classroom. For each CLO, a lesson plan is developed where successive activities for each of Kolb's four quadrants ("inspiration", "information transfer", "practice under constrained conditions", and "connection to the real world.") are identified. It is assumed that faculty will choose at least one activity to support each quadrant. For each activity, times required, date conducted, and preparation needed is recorded.

   Step 5 is arguably the most radical part of the system as it basically requires faculty to make complete lesson plans for their courses. The required choices of activities are based upon the faculty's best judgment as to whether the activity will optimally lead to student success related to the CLO. Those choices can then be assessed for effectiveness. This step is foundational in shifting the education from being faculty-centered to student-centered and process-centered to outcome-centered. Moreover, it takes advantage of both subjective faculty professional expertise and objective measurement of student learning.

6. **Conduct of Assessment for Each CLO.** The assessments planned under Step 3 are conducted and the quantitative results collected and recorded. Most results are tallied by graduate teaching assistant under direction from the faculty. For triangulation, three assessment tools are used for each CLO with one assessment typically being a student self-assessment on a Likert Scale.

7. **Development of Improvement Plan.** The strength of the OSU system is that it requires faculty to reflect upon their course, review the CLO assessments, and write a course improvement plan. The course improvement plan includes a listing of changes in activities planned for the next time this course will be taught. These changes may include different activities, rearrangement of the sequence of activities, changes in time committed to various activities, and possible removal or addition of materials. These changes are then mapped again in the 4-quadrant system for each CLO. Typically, faculty only propose changes in one or two of the CLOs. This importance of this step to promote faculty reflection on their activities, teaching methods and the effectiveness of student learning cannot be understated.

The second piece of the improvement plan is to take the assessment results for the CLOs and to summarize the support of the course on the common ("a through k") and program-specific learning outcomes. A composite of these brief summaries are then used to complete the overall assessment of the curriculum to support the learning outcomes and the program educational objectives.

8. **Listing of Proposed Changes to Activities based on Course Summary.** The proposed changes are mapped again in the 4-quadrant system for each CLO. Typically, faculty only propose changes in one or two of the CLOs.

When finished, the course summary includes all the information related to the ABET assessment and the instructor's best judgment on how to improve the course the next time it is taught. This documentation is available to other instructors who teach the same course, to new faculty who may teach the course the next time it is taught, and to peers for curriculum development of discipline specific course sequences. Ideally the course summaries provide documentation of course goals (CLOs), identification of cognitive levels required for success, activities chosen to support goal achievement (Kolb mapping), success of achievement of goals (assessments), relations to LOs and PEOs, identification of levels of cognitive required for success, and proposed improvements to "close the cycle."

Implementation

Faculty are required to complete the course summary for all courses taught. The course summaries are posted on our shared IT drive and are available for all faculty to review. The course summaries are used by the Department Head for annual evaluations of teaching. In the annual evaluation, each course is discussed with the faculty member with particular emphasis placed upon:

- Appropriateness of the chosen learning objectives
- Appropriateness of required cognitive levels based on Bloom's taxonomy
- Variety of activities used
- Coverage of activities to support Kolb's quadrants of inspiration, information transfer, application under constrained conditions, and connection to the real world
- Success in students' success in being able to demonstrate competency for CLOs and LOs
- Comprehensiveness of course evaluation related to prescribing specific course improvements
- Comprehensiveness of course evaluation related to a clear description of the contribution of the course to demonstrated success of the learning outcomes
- Appropriateness of the list of proposed changes to result in course improvement

Faculty are supported in these efforts by annual workshops and various faculty meetings to further describe and reinforce the ABET process and educational methods and theories. This is a continual process that allows inclusion of new faculty. Time is provided for faculty to share their personal experiences with new teaching methods and approaches and new assessment methods. We attempt to provide a supportive atmosphere for which the course summaries are an important communication tool to assist faculty in their development.

Faculty Impact

The typical assessment methods, such as quizzes and tests, more commonly measure lower level cognitive activities; consequently, a common pitfall to implementing a structured assessment system is the reduction of the curriculum to the "lowest common denominator" in the level of student learning. Perhaps the most dramatic change with our ABET approach is to counteract this effect. There has been demonstration of the simultaneous engagement of faculty to direct student learning towards higher cognitive processes and metacognition. For example, in his course summary, one instructor wrote:

> "Assessment strategies for 2006 continue to refine the assessment of high-level (H) skills. In Fall 2006, a given CLO was "tuned" to a low-level (L) or high-level (H) by adjusting the content of a given engineering problem that focused on this learning objective. For example, a problem that focused on a given CLO could be made high-level (H) by requiring multiple alterative steps in the problem solving process and evaluation of alternatives. Generally, if an engineering problem used to assess a given CLO was structured as low-level (L), then the "% pass rate" was in the 70-90% range. However, if an engineering problem used to assess a given CLO was structured as high-level (L), then the "% pass rate" was in the 50-70% range or even lower. For example, for CLO #4 and #7 structured as H, the % pass rate was only around 20%. With respect to the student survey results, for a given CLO, the difference between "agree" and "strongly agree" was about 40%, consistent with the difference between structuring the problem used to evaluate the CLO as "low-level" or "high-level."
>
> This "CLO tuning method" will be used next year, and if consistent results are obtained with Fall 2006, then more effort will be directed in class to help a student identify if an engineering problem is "high-level" vs. "low-level" and how strategies for solving each type of problem might differ."

This ABET system has resulted in a series of other positive impacts that we believe have resulted in improvement in our ability to deliver chemical engineering education. These improvements include:

- Greater planning of classroom activities
- More diverse use of activities for teaching
- Greater understanding of education theory with specific emphasis upon Bloom's taxonomy and Kolb's learning cycle
- Greater reflection by faculty upon their teaching, assessment, and classroom organization
- Demonstrated cycles of improvement

Summary

This paper describes a novel approach based that integrates documentation of course assessment loop for ABET accreditation and educational pedagogy applied at the course level. The approach requires faculty to write a course summary which is an improvement plan based on the instructor's analysis of the assessment data. As part of the improvement plan, instructors are encouraged to articulate their own preferred model of learning. This process leads to a revised set of activities for the Kolb learning cycle that provides specific changes to improve the course the next time it is taught.

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