Abstract - This research project examines using a taxonomy-based survey to permit engineering programs to self-assess whether students are given a broad spectrum of learning opportunities. An engineering taxonomy, designed to be compact and simple, identifies seven key engineering “skills”; one conceptual, one factual, and five process oriented skills based on the engineering design cycle. Four levels of mastery are defined, compared to the six originally defined by Bloom. The taxonomy survey has been piloted in an electrical engineering program at a land-grant research university. This paper discusses the validation process and initial results.

Index Terms - Bloom’s Taxonomy, engineering program evaluation, survey instrument, engineering taxonomy.

BACKGROUND

Engineering departments are required to assess how well students are meeting self-defined learning outcomes in order to obtain accreditation under ABET. These learning outcomes, defined primarily by ABET’s (a)-(k) [1], are not specific to any engineering discipline or content. Rather the outcomes are broad statements of the types of experiences and abilities students develop in acquiring an engineering degree. Students’ ability to meet a program’s outcomes at graduation depends on the experiences they have during the program. While ABET increasingly emphasizes learning outcomes, it is also important that faculty evaluate the program that produces those outcomes.

To evaluate whether a broad spectrum of learning opportunities are available to students in an engineering program this research project examines a method for program and course self-assessment. A survey instrument, based loosely on updated versions of Bloom’s Taxonomy, is used to evaluate whether course and/or program goals are reflected by the work assigned to students. Bloom’s Taxonomy has previously been adapted to measure ABET outcomes in engineering programs by Besterfield-Sacre et. al. [2]. The taxonomy developed by these researchers addressed each of the (a)-(k) outcomes on the six cognitive process dimensions originally defined by Bloom [3] and also added a seventh valuation level. The four knowledge dimensions were replaced by the ABET (a) – (k) outcomes. While this taxonomy directly assigns levels of ability to the requisite ABET outcomes, the comprehensiveness comes with a high level of complexity. The complete taxonomy is over thirty pages in length. Here we develop a simplified taxonomy based on the assumption that the work students perform in the program is the primary factor contributing to their development as engineers. Rather than use the ABET criteria as the knowledge dimension, knowledge dimensions are adapted from a current revision of Bloom’s original taxonomy [3].

The Engineering Taxonomy

Current versions of Bloom’s Taxonomy [3] are expressed as a four by six table. The table columns represent the cognitive process dimension, hierarchically ordered into six levels of increasing difficulty from remember (lowest) to create (highest). The four rows of the table correspond to different aspects of “knowing”, i.e. the knowledge dimension. The four elements of the knowledge dimension are factual knowledge, conceptual knowledge, process knowledge, and metacognitive knowledge. The six cognitive levels combined with four knowledge dimensions results in twenty four separate elements. The taxonomy table is used to classify courses and programs by measuring their relative emphasis on each of the twenty four elements.

To create an engineering taxonomy, Bloom’s Taxonomy was modified by reducing the cognitive process dimension from six to four elements. The four elements of the knowledge dimension were also adapted for engineering. The metacognition element is still being developed and is not included in this WIP paper. Factual and conceptual dimensions were retained unchanged. The process dimension was expanded to five separate aspects corresponding to sequential steps in the engineering design process: researching, modeling or calculating, fabricating, testing, and communicating. The expansion of the process dimension, drawn loosely from [4] and references therein, reflects the importance of experience in engineering education and the idea that in order for students to develop as engineers they need to practice being engineers. The knowledge and cognitive process dimensions of the engineering taxonomy are shown in Figure 1.

A survey was developed to determine the relative emphasis different elements of the engineering taxonomy have in degree programs. For each of the twenty eight elements of the four by seven taxonomy, examples of student work that focus on developing skills on that element were listed. From this list two questions for each element ask faculty about the extent to which work students turned in impacted the overall course grade. Faculty members
were also asked to rate the relative importance of each element of the cognitive process and knowledge dimensions to their course outcomes. A five element Likert scale was used for all responses.

RESULTS

The survey was piloted by two faculty whose teaching spanned electrical and computer engineering topics. Feedback from these individuals was used to make the survey questions did not presuppose specific course content. Faculty participation was solicited by e-mail for the web-based survey. The response rate for the survey was 67% corresponding to 19 undergraduate courses, most at the junior and senior level. As of the date of this paper the survey has been given in one electrical engineering program at a land-grant research university as a web-based instrument.

Data from the survey was analyzed at both the course and program level. At the course level, faculty beliefs on the importance of each element of the cognitive process and knowledge dimensions were compared to the mean score on each of the 28 taxonomy elements that self-reported the work assigned students. A short report was generated for each participating faculty member from the survey data. For program evaluation the mean of the scores on each element in the taxonomy of all courses in a particular year (freshman through senior) of the program was determined. The mean score permitted comparison of program emphasis on both the knowledge and cognitive process axes of the engineering taxonomy to faculty beliefs.

Analysis of the survey data resulted in several interesting observations. Of the seven elements on the knowledge dimension researching—i.e. techniques and methods for learning about a problem before or during solution—was the aspect least reflected in student work. This was particularly true in the sophomore and junior years. The second least represented was communicating, particularly in the early years of the program. Communication also had the largest discrepancy between what faculty reported as important and what they had students turn in for a grade. Skills in the two knowledge dimension elements that faculty reported students performing the most work on were conceptual knowledge and modeling/calculating. Along the cognitive process dimension “apply” was consistently rated the highest followed by “analyze”. “Design” was rated lowest consistently except in the senior year. Somewhat surprisingly, emphasis of courses on the four levels of the cognitive process dimension did not show much change between the freshman and senior years.

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REFERENCES


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