Structured Assessment of Student Outcomes "a" and "e" in Mathematics and Science Courses for Engineering Students

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Abstract*: Skills, performance, and ability attributes are known as student outcomes that are gained during graduation. In order to evaluate quality assurance of these outcomes, a set of specific and targeted curriculum and extra-curriculum activities must be used for precise as-assessment. Meeting the required outcomes, a set of desired courses have to be selected to insure that the desired outcome is highly satisfied. "Highly" covered can be identified using Bloom's levels, number of covered hours, weight of its assessment and others. Student outcomes are directly linked to course goals that are identified using a set of measurable verbs. In this paper, we will be using two outcomes "a" and "e" to structurally assess both direct and indirect outcomes in mathematics and other scientific courses using a partial differential equation method by defining appropriate measurable course goals. The strategy to assess the outcome is also explained.

***Index Terms*: Accreditation, assessment, students' outcomes, Bloom's Taxonomy, computer science.**

I. INTRODUCTION

Academic Accreditation is an authorized process of validation in which higher educational institutions and universities are assessed and evaluated using a set of standardized academic criteria. The accreditation standards are controlled by peer review board members from different faculties of accredited universities and colleges. Their mission is to evaluate a newly developed colleges programs or renew previously accredited colleges based on two categories of academic accreditation: institutional and specialized accreditations. The first type is directed towards accrediting the institution as a whole and not evaluating any academic programs offered in that particular institution as the as the specialized type does. Each college is typically assessed using academic criteria based on specific research specialized study undergone by the second accreditation type. An important factor of the accreditation program during the assessment process is dependent on different stakeholders and the community including student parents and employers. Accreditation benefits not only the institution, however its positive impacts serve students, faculty members and the community. Obtained accreditation for a specific program is illustrated by an official degree that has met certain academic standards essential to deliver graduates with potential professions. Graduated students would have higher opportunities in the employment market, accredited certifications, licensure, higher global graduate education, local and international student transfer acceptance.

Accreditation Board of Engineering and Technology (ABET) is considered as a non-governmental and non-profitable organization agency that assesses and accredits post-secondary education programs in four disciplines: applied and natural sciences, computing, engineering, and engineering technology [1]. As of November 2014, almost 3,500 academic programs in more than 700 international colleges and universities in 28 different countries worldwide have been accredited by ABET organization [2]. Moreover, individual study programs of a given institution are evaluated using specialized, programmatic accreditation

Located in the United States, ABET is recognized by CHEA, Council for Higher Education Accreditation, and by mutual agreements with multiple countries including Australia and Canada. The accreditation process is fully offered in an online format and is totally voluntary achieved though peer review, providing assurance for a higher educational institutional program offered by a college or a university and meeting the quality standards established by the profession for which the program prepares its students. The organization also provides workshops and mutual recognition international agreements for professional academic degrees such as Washington Accord. Recently, the author [3, 4] developed a systematic process to assess student outcomes in mathematics courses. Our paper will mainly focus on two outcomes and discuss a new approach to develop an assessment methodology in mathematics and other science courses that conform with ABET accreditation standards.

II. STUDENT OUTCOMES

For every program seeking ABET accreditation, a clear and well-defined set of student outcomes should be developed (referred as criterion 3) and a set of assessments (both direct and indirect) data collection via several courses and surveys need to be collected. Moreover, the results of each evaluation must be used for future program improvement in order to determine a degree to which the outcomes are fulfilled. Based on ABET website, many assessment documents can be followed as a guide sample by institutions.

Student outcome for criterion 3 of the ABET Criteria for accreditation lists, is a set of characteristics containing documented student outcomes that insures graduating students to fulfill and accomplish the educational objectives offered by the institution.

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As explained previously, attributes, skills, and abilities that students perform prior to graduation are known as students' outcomes. According to ABET definition [5], these outcomes are reflected by "a" to "k" letters and are listed below in table 1 below. A specific set of course goals for each core course are linked to the student "a" to "k" outcomes. At the end of each semester, instructors via direct and indirect course assessment should measure these outcomes:

No	Student Outcome
(a)	An ability to apply knowledge of mathematics, science, and engineering
(b)	An ability to design and conduct experiments, as well as to analyze and interpret data
(c)	An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d)	An ability to function on multidisciplinary teams
(e)	An ability to identify, formulate, and solve engineering problems
(f)	An understanding of professional and ethical responsibility
(g)	An ability to communicate effectively
(h)	The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i)	A recognition of the need for, and an ability to engage in life-long learning
(j)	A knowledge of contemporary issues
(k)	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Table 1: ABET outcomes reflected by "a" to "k" letters.

III. ASSESSMENT TYPES

There are to well know types of assessments, formative and summative assessment. The first type of assessment observes and monitors student's learning progressively during the learning period. At the end of each lecture, the instructor can ask about students' feedback in order to adjust the teaching methods in the next upcoming class. The assessment techniques for this assessment method can be done using quizzes, short questions and surveys. The second type of assessment, the summative assessment, evaluates student understanding and learning at the end of each chapter or topic and not per class. The assessment techniques used of this assessment include exams, projects, oral presentations.

IV. PERFORMANCE INDICATORS

Performance indicator is a statement identifying an action verb that is taken from Bloom's taxonomy in order to be measurable. The main target behind this indicator method is to judge whether a student's outcome has been achieved or not. Performance indicators are quantitative tools that are presented in a rate, percentage or ratio value. According to ABET terminology performance indicators are "effective assessments use relevant direct, indirect, quantitative and qualitative measures as appropriate to the outcome being measured". Programs are expected to show more attention on direct assessment by focusing on demonstrated, applicable and analytical work of student learning, rather than using the less efficient indirect assessment, which is based on employer surveys.

This paper highlights the importance of outcomes (a) and (e) using our assessment methodology procedure. Both direct and indirect assessments of these outcomes are studied through student evaluation work and surveys. These selected outcomes are broad statements and their assessments require simplifying them to a number of simplified measurable aspects that allow one to establish the extent to which the outcome is met. IAs previously defined, the performance indicators are measurable aspects that are written using specific and unique action verbs that include: define, demonstrate, evaluate, discriminate, and interpret. Performance indicators also spell out specific subject contents that are under study [6-9]. In our case, we selected a partial differential equation course for assessment that will be explained in the below section.

V. BLOOM'S TAXONOMY IN MATH CONTEXT

In the below table, we described Bloom's taxonomy and related measurable verbs where math assessment can be used.

Bloom's level	Application examples	Verbs
Remember	Student remember how to: - Use number properties - Use notation of functions - Use basic formula of probability - Use basic formula for statistics - Use methods to solve equations	Use, Select, List, Locate
Understand	Student understand how to: - Convert between units - Interpret components of expression - Interpret experiments - Use existing function to build new one	Estimate, Explain, Relate
Apply	Student apply: - Solve equations - Solve inequality - Perform polynomial operations - Draw functions - Perform operations of vectors - Perform operations of matrices	Solve, Perform, Draw
Analyze	Student analyze: - Compare different solutions - Categorize differential equations - Differentiate different functions - Interpret graphical solution	Compare, Classify, Categorize, Interpret
Evaluate	Student evaluate: - Problems solve with different models - Interpret and predict result - Describe geometrically different models	Solve, Describe
Create	Student create: - Proof of theorems - Model problem - Design problems	Design, model

Table 2: Bloom's taxonomy using related measurable verbs.

It's strongly recommended to use the verbs from table 2 while preparing the course goals of mathematics and scientific courses. This method will insure that assessments of the outcomes are straight forward.

VI. OUTCOMES "A" VERSUS "E"

In order to differentiate between these two selected outcomes, we will need to break them down into different factors so the assessment of each one becomes more accurate and deeply understood.

Outcome "a": An ability to apply knowledge of mathematics, science, and engineering.

a1: apply knowledge of mathematics to distinguish between dependent and independent variables. Describe derivative and integral of functions. Select appropriate model.

Use analytical and numerical techniques to solve equations. Apply concepts of integral and differential calculus and linear algebra to solve problems
a2: apply knowledge of science and engineering to describe the principal of physical, chemical or biological systems. Apply thermodynamic principles. Apply materials principles. Analyze data using statistics principles. Analyze models of systems.
Outcome “e”: An ability to identify, formulates, and solves engineering problems.
e1: Identifies and understands all problems associated with current methods.
e2: Uses knowledge to construct models of physical systems.
e3: identifies and analyzes potential solutions to engineering problem.
e4: assess the effectiveness and accuracy of different approach.
e5: indicate how theory can be used in practice.
e6: select appropriate solutions to the engineering problem.

VII. COURSE GOALS

Example of course goals of partial differential equation:

- CG1: Model engineering systems using PDE(e)
- CG2: Solve linear first and second order PDE(a)
- CG3: Find Fourier Series of function(a)

Note: The letter between parentheses represents the student outcomes.

VIII. OUTCOMES ASSESSMENT

In order to assess outcomes “a” and “e”, both direct and indirect assessment are used. For the direct assessment, we will conduct the following exam problem:

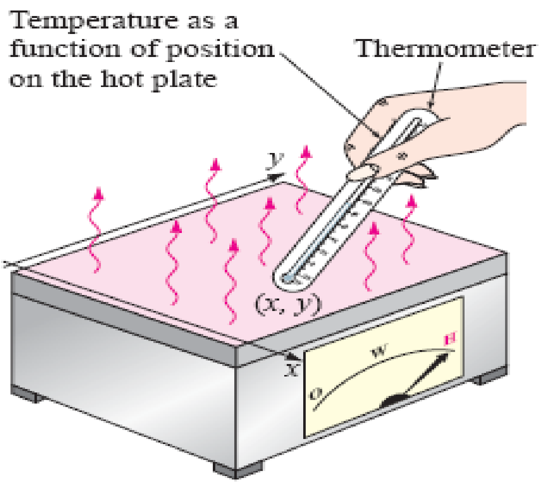

Figure 1: Steady-state temperatures in a rectangular plate

Exam Problem: A thin rectangular plate coincides with the region defined by 2<= x <= 8, 1<= y <= 5. Both left and bottom ends of the plate are insulated. The top plate is held at temperature zero, and the right end of the plate is held at temperature f(y)=y (Figure 1).

Q1: Model the problem using partial differential equation.

Q2: Solve the partial differential equation obtained in Q1, using appropriate technique.

As seen, Q1 addresses CG1 and covers outcome “e” (in particular “e2”), whereas Q2 addresses CG2 and covers outcome “a” (in particular “a1”) (Table 3). In order to validate whether the outcome is achieved or not, we need to define a specific threshold. For instance, if 70% of students get 70 and above on Q1 then outcome “e” is achieved in this course. Otherwise improvements need to be done for the CG1 in the following semester.
For the indirect assessment, the below survey will be used by both students and instructor are at the end of the term.

Rate(X) how well this class addressed each one of the following course learning outcomes (4:excellent, 3:good,2:average,1:poor,0:N/A)							
Course goals	student evaluation						
	4	3	2	1	0	Avg	%
CG1: Model engineering systems using PDE(e)							
CG2: Solve linear first and second order PDE(a)							

Table 3: Indirect assessment survey.

The outcome is achieved if the average of all students, for example, is 3 or above, same as the instructor’s evaluation. Finally, an outcome is considered to be achieved in this course if both direct and indirect assessments are targeted. We recommend that each outcome to be assessed in three different courses. In order for an outcome to be achieved, it needs to be fulfilled in at least two courses. In the below figure, outcome “e” is achieved (Figure 2).

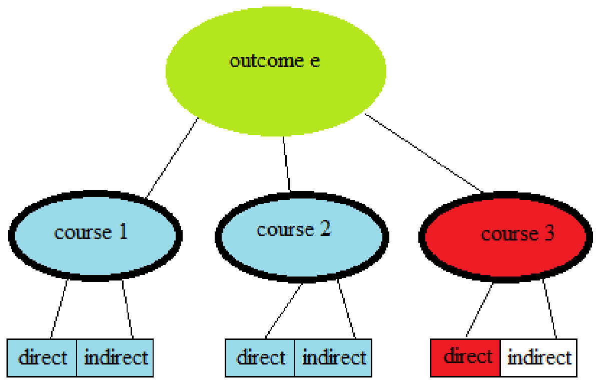

Figure 2: Outcome “e” achieved using both assessment types.

IX. CONCLUSION

In this paper, we define and explained the difference between the two ABET student outcomes "a" and "e", and how faculty can assess them through direct and indirect assessment. The proposed strategy can be extended to cover all other outcomes in many scientific courses.

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