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

Seifedine Kadry and Chad Zammar
American University of the Middle East, KUWAIT
seifedine.kadry@aum.edu.kw, chad.zammar@aum.edu.kw

Abstract

Student outcomes are statements that describe the attributes, skills and abilities that students should acquire by the time they graduate. For quality assurance evaluation, these outcomes must be assessed through curriculum and extra-curriculum activities. In order to evaluate the level to which an outcome is met, it is necessary to select some courses where the outcome is highly covered. "Highly" covered can be identified using Bloom's levels, number of covered hours, weight of its assessment and others. Course goals must be linked to the student outcomes and defined in terms of measurable verbs. This paper presents a structured approach, using just the two outcomes "a" and "e" as an example, to assess directly and indirectly student outcomes in Mathematics. This is done through partial differential equation course by defining appropriate measurable course goals.

Keywords
Student outcomes; course goals; direct and indirect assessment; performance indicator; rubrics; assessment; ABET.

1. INTRODUCTION

Academic Accreditation is an official recognition and validation that an institution in higher education is assessed positively or negatively against a set of standards and criteria. It's a sign of quality, continuous assessment and improvement of their programs. There are two types of academic accreditation: institutional and specialized accreditations. The first one accredits the institution as a whole and not a specific program in the institution as the specialized one does. This research study belongs to the second type of accreditation. One of the important factors of the accreditation is involving different stakeholders and the community (student parents, employers…) in the process of assessment. Accreditation benefits students, instructors and the community. Accreditation is evidence that an academic program that leads to a degree has met certain standards that are essential to generate graduates who are ready to enter their professions. Students who graduate from accredited universities have access to enhanced opportunities in employment; licensure (i.e. PE), registration and certification (i.e. IIE society membership); graduate education and global mobility (student transfer acceptance, applications for graduate schools).
Accreditation Board of Engineering and Technology (ABET) is a non-profit and non-governmental accrediting agency for academic programs in four disciplines: applied science, computing, engineering, and engineering technology. As of November, 22 2014 ABET accredits more than 3,400 academic programs at nearly 700 colleges and universities in 28 countries including USA. ABET provides specialized, programmatic accreditation that evaluates an individual program of study, rather than evaluating the entire institution.
ABET accreditation process and procedures are totally voluntary and achieved through a peer review, provide assurance that a college or university program meets the quality standards established by the profession for which the program prepares its students. ABET is recognized in the USA by the Council for Higher Education Accreditation (CHEA) and by mutual agreement with many countries like Canada and Australia.
Recently, the author [1, 2] developed a systematic process to assess the student outcomes in mathematics courses. In this paper, we focus on just two outcomes as an example, and discuss new approach to develop an assessment methodology in mathematic courses, conform with ABET accreditation standards [3].

2. STUDENT OUTCOMES

ABET requires each program seeking accreditation to develop a clear set of student outcomes (referred as criterion 3), collect direct and indirect assessment data through several courses and surveys, determine the degree to which the outcomes are achieved, and use the results of the evaluation to improve the program. The ABET web site has several documents related to assessment [3].
Criterion 3 (Student Outcomes) of the ABET Criteria -for accrediting lists- is a set of characteristics that each program must have documented student outcomes that prepare graduates to accomplish the program educational objectives of the institution. As we mentioned, student outcomes describe the attributes, skills, and abilities that students able to do upon graduating from the program. We list below the eleven student outcomes define used by ABET (well known by “a” to “k”). Every core course in the curriculum includes set of course goals, the goals are linked to the student outcomes (i.e. “a” to “k”). Instructors are expected to measure those outcomes using direct and indirect assessment for the courses they have taught at the end of the semester:

(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, formulates, and solves 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) 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.

3. ASSESSMENT TYPES

Broadly speaking, there are two types of assessment: formative and summative assessment. Formative assessment observes student learning progressively during the learning process. For example instructor ask students at the end of each class about their feedback and based on that instructor might adjust his/her teaching way of the topic in the next class. The assessment techniques of this type may include: quizzes, minutes paper, very small survey…etc.
The summative assessment evaluate student learning at the end of chapter or topics. The assessment technique of this type may include: Exams, projects, presentations…etc.

4. PERFORMANCE INDICATORS

Performance indicator is a statement includes action verb. This verb usually is taken from Bloom’s taxonomy in order to be measurable. The idea here is to use measurable verb in order to evaluate accurately and effectively if a student outcome can be judged to have been achieved or not achieved. Performance indicators are quantitative tools and are usually expressed as a rate, ratio or percentage. In ABET terminology, performance indicators are “effective assessments use relevant direct, indirect, quantitative and qualitative measures as appropriate to the outcome being measured.” However, with growing maturity in the assessment process, programs are expected to place greater emphasis on direct assessment of student learning, which is based on student demonstrated work, rather than indirect assessment, which is based on student, alumni, or employer surveys.
In this paper, we will just focus on Outcome (a) and (e), as an example, and describe our assessment methodology. We will also use direct and indirect assessment of the outcome through evaluation of student work and survey. Clearly Outcome (a) and (e) are a broad statement and its assessment requires to breaking it down to a number of simple measurable aspects that allow one to determine the extent to which the outcome is met. In ABET literature these measurable aspects are known as performance indicators. Performance indicators are written with action verbs such as define, demonstrate, discriminate, evaluate, and interpret. Performance indicators also spell out specific

subject contents [4-7]. In our case, we select partial differential equation course for assessment. The reason of select this course is explained below.

5. 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.

Table 1. Bloom's Taxonomy

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

It's strongly recommended to use the verbs in the previous table while preparing the course goals of mathematics courses. So assessments of the outcomes become straight forward.

6. OUTCOMES "A" VERSUS "E"

In order to remove the ambiguity and understand deeply the difference between these two outcomes, we will break them down to measurable performance indicators by using measurable verbs from the previous table, so the assessment of each one becomes more accurate.
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.

7. 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)
- ….
- ….

The letter between parentheses represents the student outcomes.

8. OUTCOMES ASSESSMENT

In order to assess outcomes "a" and "e", we will use direct and indirect assessment. For the direct assessment we will include the following problem in the exam:

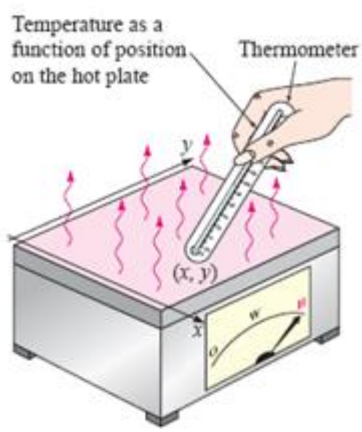

Figure 1. Steady-state temperatures in a rectangular plate

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

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

As we can see, Q1 address CG1 and cover outcome "e" (in particular "e2"), where Q2 address CG2 and cover outcome "a" (in particular "a1"). Now to decide if the outcome is achieved, we need to define threshold. For instance we can say, if 70% of students get 70 and above on Q1 then outcome "e" is achieved in this course, otherwise we need to suggest some improvements for the CG1 in the next semester.
For the indirect assessment, we use the below survey where students and instructor are required to fill in at the end of the term.

Table 2. Survey

please 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)							
…..							

The outcome is achieved if the average of all students, for example, is 3 or above, same for the instructor evaluation. At the end an outcome is achieved in this course if all assessment, direct and indirect, is achieved.
We recommend that each outcome is assessed in three courses. Hence an outcome is achieved if it's achieved at least in two courses. In the below figure, outcome "e" is achieved.

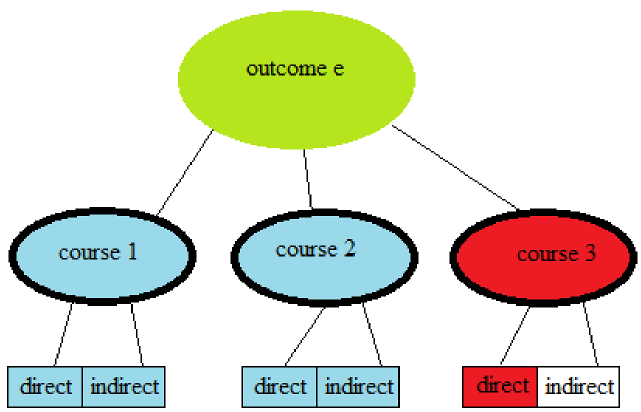

Figure 2. Outcome e is achieved

9. CONCLUSION

In this paper, we explained the difference between the two ABET student outcomes "a" and "e", and how faculty can evaluate them through direct and indirect assessment. The ability to identify and define the problem was evaluated through a modelling exercise then followed by the evaluation of the student's ability to apply his or her knowledge in order to find a solution to that problem.
The proposed strategy can be extended to cover all other outcomes.

References (12 font)

[1] S. Kadry, "Systematic assessment of student outcomes in mathematics for engineering students," 2015 IEEE Global Engineering Education Conference (EDUCON), Tallinn, 2015, pp. 782-788. doi: 10.1109/EDUCON.2015.7096060.
[2] Kadry, S. (2015). Quality-Assurance Assessment of Learning Outcomes in Mathematics. International Journal of Quality Assurance in Engineering and Technology Education (IJQAETE), 4(2), 37-48. doi:10.4018/IJQAETE.2015040104.
[3] ABET, Inc., http://www.abet.org/
[4] E. Darandari, A. Murphy. "Assessment of Student Learning". Higher Education in Saudi Arabia Higher Education Dynamics Volume 40, 2013, pp 61-71. Springer.
[5] Briedes, D. (2002). Developing effective assessment of student professional outcomes. International Journal of Engineering Education, 18(2), 208-216.
[6] KESHAVARZ, M., BAGHDARNIA, M.. Assessment of student professional outcomes for continuous improvement. Journal of Learning Design, North America, 6, Jul. 2013. Available at: <https://www.jld.edu.au/article/view/95>. Date accessed: 23 Nov. 2014.
[7] Bloxham, S., & Boyd, P. (2007). Developing effective assessment in higher education: a practical guide [electronic version]. Retrieved from http://www.scribd.com/doc/53026895/Bloxham-and-Boyd-electronic-version-of-developing-effective-assessment-in-higher-ed#page=11