Combining Multiple Methods and Metrics for the Assessment of ABET Students Outcomes

The case of a Software Engineering Program

Noureddine Abbadeni, Abdullah Alghamdi, Mohamed Batouche, and **Ahmed Ghoneim**
King Saud University
College of Computer and Information Sciences
Department of Software Engineering
Riyadh, KSA
{nabbadeni, ghamdi, batouche, ghoneim}@ksu.edu.sa

Abstract

Accreditation of academic degree programs is becoming an important mean for many institutions, inside and outside USA, to improve the quality of their degree programs. Many programs, in particular engineering and computing, offered by many schools have adopted or in the process of adopting the outcomes-based educational philosophy. Outcomes-based accreditation is also adopted by ABET. A key problem towards the satisfaction of ABET criteria is the assessment of attainment of student outcomes stated for the program. In this paper, we relate our experience of assessing student outcomes in a Software Engineering program, discuss the methods used, and show how the combination and integration of several methods and metrics allow for a better and more relevant assessment of student outcomes. We show results based on real assessment applied on courses in a Software Engineering program.

1. Introduction

Accreditation of academic programs is a peer-reviewed and voluntary process used by academia to assess and evaluate the quality of their degree programs. In United States, and in some other countries, the Accreditation Board of Engineering and Technology (ABET) is becoming the leader in accrediting Engineering, Computing, Technology, and Applied Science programs [1, 11].

Accreditation of academic degree programs is becoming an important mean for many institutions, inside and outside USA, to improve the quality of their degree programs. Loosely stated, accreditation consists in conducting a self-assessment and a peer-review processes in order to identify potential issues and define appropriate improvement actions. The ultimate goal is to guarantee a minimum level of quality for the degree programs offered by those institutions.

Many engineering and computing schools have adopted or in the process to adopt the outcomes-based education and accreditation in USA and outside USA [10]. Outcomes-based accreditation is also adopted by ABET. A key problem towards the satisfaction of ABET criteria is the assessment of attainment of student outcomes stated for the program. In this paper, we relate our experience of assessing student outcomes in a Software Engineering program, discuss the methods used, and show how the combination and integration of several methods and approaches allow a better assessment of student outcomes. We show results based on real assessment applied on courses in a Software Engineering program.

2. Student outcomes for software engineering programs

Student outcomes defined by ABET for all engineering programs (including Software Engineering) are as follows [2]:

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 "*

In the Software Engineering program in our University, we adopted these a) to k) student outcomes. In addition we added four student outcomes inspired from the program criteria defined for Software Engineering programs [2]. These four additional student outcomes, labeled l) to (o) are as follows [2]:

l) *The ability to analyze, design, verify, validate, implement, apply, and maintain software systems*
m) *The ability to appropriately apply discrete mathematics, probability and statistics, and relevant topics in computer science and supporting disciplines to complex software systems*
n) *The ability to work in one or more significant application domains*
o) *The ability to manage the development of software systems "*

Each course in the Software Engineering Program covers some of the a) to o) student outcomes. Obviously, when combining all courses in the program, all student outcomes must be covered.

Note that the definition of ABET student outcomes has several shortcomings and is lacking precise specification. But this issue is out of the scope of this paper. The reader interested in this should refer to [11, 7].

3. Assessment methods and metrics

3.1 Methods and metrics

In order to tackle and view the assessment from different angles, three methods (3) and two (2) metrics were used.

The methods are:

- **Direct assessment** of student outcomes covered by each course. Direct assessment reflects the opinion of the teacher through exams, assignments, homeworks, etc.
- **Indirect assessment** of student outcomes covered by each course. Indirect assessment reflects the opinion of students through a survey on course learning outcomes.

- **A complementary online survey**. This survey does not address directly student outcomes. It addresses general questions related to the course, the teacher, the classroom, etc. It is however a kind of indirect assessment as it reflects the opinion of students.

The metrics are:

- The **average score** achieved by students in each student outcome covered by each course.
- The **percentage of students achieving the satisfactory level and above** in each student outcome covered by each course (the satisfactory level is defined at a specific threshold, e.g. 70%).

3.2 Indirect assessment survey

Indirect assessment is based on a survey administered in each course. This survey is based on specific course learning outcomes for that course. Course learning outcomes are mapped to student outcomes. Here is an example of questions from such survey:

At the end of this course, I am able to:

- *Understand the critical role of requirements engineering in the Software development process.*
  ☐ ***Strongly Agree*** ☐ ***Agree*** ☐ ***Neutral*** ☐ ***Disagree*** ☐ ***Strongly Disagree***

- *Distinguish between functional and non-functional requirements.*
  ☐ ***Strongly Agree*** ☐ ***Agree*** ☐ ***Neutral*** ☐ ***Disagree*** ☐ ***Strongly Disagree***

- *Specify requirements in use cases and other specification techniques.*
  ☐ *Strongly Agree* ☐ *Agree* ☐ *Neutral* ☐ *Disagree* ☐ *Strongly Disagree*

3.3 Levels of satisfaction

The levels of satisfaction are defined as follows:

- For direct assessment (quantitative):
  - **Unsatisfactory** is given to a student whose score in a specific outcome is 60% or lower,
  - **Developing** is given to a student whose score in a specific outcome is between 60% and 70%,
  - **Satisfactory** is given to a student whose score in a specific outcome is between 70% and 80%,
  - **Exemplary** is given to a student whose score in a specific outcome is above 80%.

- For indirect assessment (qualitative):
  - **Unsatisfactory**: corresponds to the percentage of students who answered “Disagree” and “Strongly Disagree” in a specific outcome.
  - **Developing**: corresponds to the percentage of students who answered “Neutral” in a specific outcome.
  - **Satisfactory**: corresponds to the percentage of students who answered “Agree” in a specific outcome.

- **Exemplary**: corresponds to the percentage of students who answered "Strongly Agree" in a specific outcome.

- For the complementary online survey: The same levels used with the indirect assessment are used with the complementary online survey.

3.4 Complementary online survey

As mentioned previously, the complementary online survey does not address student outcomes directly. It addresses general questions that might be helpful, after analysis, in explaining issues behind the non-attainment of some student outcomes.

The complementary survey contains 27 questions. Examples of questions in the complementary online survey are given in Table 1.

Table 1: Samples of questions from the complementary online survey.

Question #	**Question**
Q1	The faculty member provides students with the course plan/syllabus (objectives, topics, references, requirements, etc.) at the beginning of the semester
Q5	The faculty member uses a variety of teaching methods that enhance the understanding of students
Q14	The faculty member works on the development of thinking and creativity skills among students
Q22	Test and exam questions cover most of the course topics
Q23	The faculty member diversifies evaluation methods to assess the performance of students
Q26	The faculty member is available in his office during office hours

3.5 Attainment of student outcomes

The final judgment of the attainment of student outcomes is based on the followings (Table 2):

Table 2: Judgment of the attainment of student outcomes.

Exceeds Expectations (EE)	Meets Expectations (ME)	Progressing Towards Expectations (PE)	Does Not Meet Expectations (DNME)
80% or more of students are achieving the satisfactory level or above	70% - 80% of students are achieving the satisfactory level or above	60% - 70% of students are achieving the satisfactory level or above	Less than 60% of students are achieving the satisfactory level or above

The attainment of student outcomes must be judged primarily by using the percentage of students achieving the satisfactory-exemplary levels metric and cannot be judged by using the average score of all students in a specific outcome, as the average score gives an indication on the mean but does not give indication how results are distributed around the mean. The average score achieved by students is used as additional and informative only.

4. Results and discussion

4.1 Analysis methodology

When applying the methods and metrics in the previous section, the following eventual resulting situations should be analyzed as they indicate an eventual issue:

- Cases where an outcome is not met - Does not meet expectations (DNME).
- Cases where an outcome is not met but it is almost met - Progressing towards expectations (PE)
- Cases with an important discrepancy between direct and indirect assessment for a specific outcome; especially if the direct assessment (opinion of teacher) is much higher than the indirect assessment (opinion of students).
- Cases where some questions in the complementary online survey are not satisfactory (either DNME or PE). Analyzing these questions from the complementary survey might help to identify the reasons behind the non-attainment of some student outcomes.

4.2 Results

We report in figures 1, 2, 3, 4 the results obtained by applying the assessment methods and metrics explained in the previous section to one course in the Software Engineering program, in which the student outcomes covered are e), f), g), k), and l):

- Figure 1 shows the average score metric per student outcome using both direct and indirect methods.
- Figure 2 shows the percentage of students achieving the satisfactory-exemplary levels metric per student outcome using both direct and indirect methods.
- Figure 3 shows the average score metric per question in the complementary online survey.
- Figure 4 shows the percentage of students achieving the satisfactory-exemplary levels metric per question in the complementary online survey.

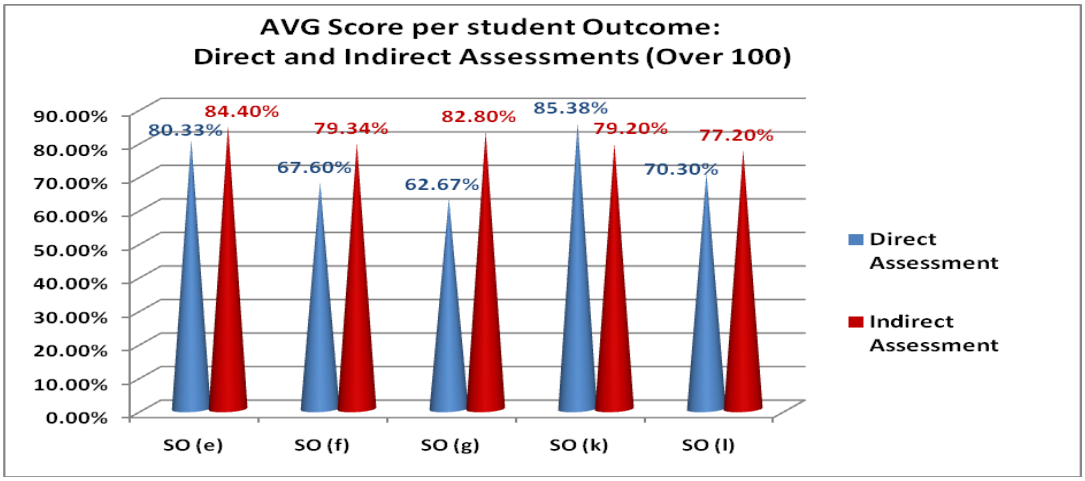

Figure 1: The average score metric per student outcome covered by a software engineering course using both direct and indirect asssessment.

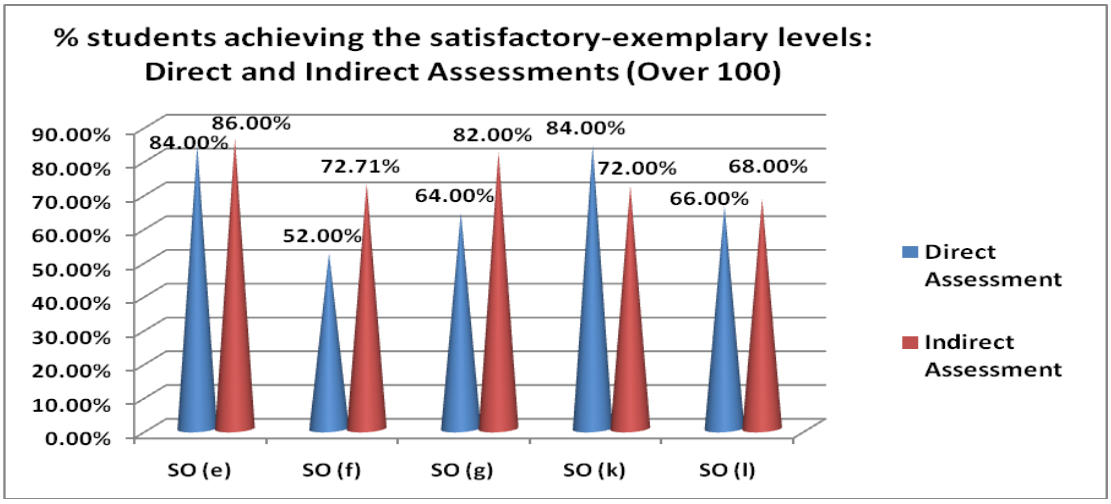

Figure 2: The percentage of staisfactory-exemplary levels metric per student covered by a software engineering course using both direct and indirect asssessment.

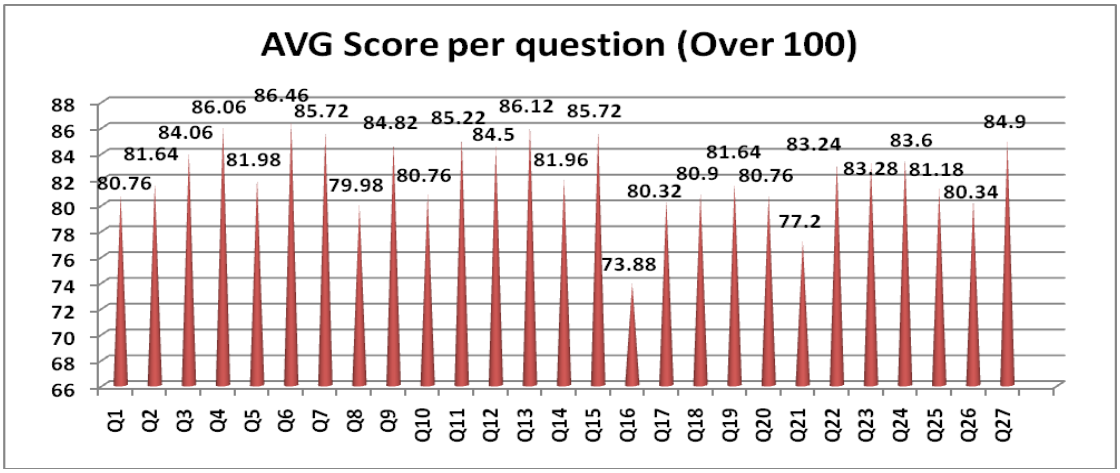

Figure 3: The average score metric per question in the complementary online survey.

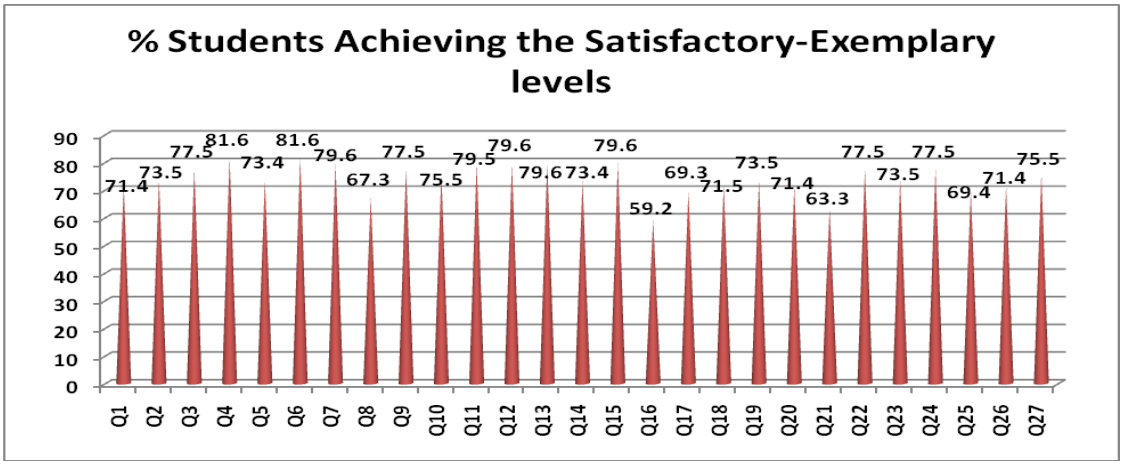

Figure 4: The percentage of satisfactory-emplary levels metric per question in the complementary online survey.

Table 3 summarizes the judgment of attainment (or not) of student outcomes.

Table 3: Summary of attainment of student outcomes.

Student Outcomes Covered by the Course	Direct Assessment		Indirect Assessment	
	When using the AVG score	When using % students achieving the satisfactory/exemplary levels	When using the AVG score	When using % students achieving the satisfactory/exemplary levels
SO (e)	EE	EE	EE	EE
SO (f)	PE	DNME	ME	ME
SO (g)	PE	PE	EE	EE
SO (k)	EE	EE	ME	ME
SO (l)	ME	PE	ME	PE

4.3 Results Analysis

When analyzing the results shown in figures 1, 2, 3, and 4, we can point out the followings:

- Outcome (e) exceeds expectations (EE) with all methods and metrics.
- Outcome (f) is met according to students (indirect assessment) while it is not met when using the opinion of the teacher (direct assessment) where the average score metric indicates PE while the percentage of students achieving the satisfactory level metric indicates DNME.
- Outcome (g) exceeds expectations according to indirect assessment while direct assessment indicates PE.
- Outcome (k) is met according to indirect assessment and it exceeds expectations according to the teacher.
- Outcome (l) is met according to the teacher and to students when using the average score metric while it indicates PE when using the percentage of students achieving the satisfactory level metric.

These results indicate clearly that different methods and metrics hold different results. This justifies the use of multiple methods and metrics in order to view the assessment from different angles and maximize the chance to identify the issues.

A thorough analysis of these results may indicate the followings:

- Among the questions in the complementary survey that were not met, we cite the followings:
    - Q 21 - The faculty member prepares test and exam questions in a clear manner
    - Q 16 - The faculty member provides students with their results and grades on time
    - Q 8 - The faculty member encourages students to read from a variety of sources
- Q 8 might have an impact on outcome (l), which is the ability to analyze. Encouraging students to read from a variety of sources might improve their analysis skills.
- Q 21 might have an impact on all non-attained outcomes since an important percentage of students are finding exams not clear. Making exams clear might improve the attainment of various outcomes.

- Q 16 does not have necessarily an impact on any outcome. However, displaying the exam results of students on time, might improve the perception of students regarding the teacher. This can have an impact on their indirect assessment.

5. Conclusion

Assessment is one of the key issues for ABET accreditation. The work presented in this paper suggests and shows that using and combining properly different assessment methods and metrics allow viewing the problem of assessment from different angles as these methods and metrics do not hold the same results. This helps in understanding and analyzing the assessment results. Furthermore, the complementary online survey, although it does not address directly student outcomes, it might help in improving the understanding of the reasons or root causes behind the non-attainment of some student outcomes. Obviously the understanding of these root causes is critical towards continuous improvement.

Acknowledgements

We thank our colleagues, members of the ABET-College Committee and the ABET-Software Engineering Committee at the college of computer and information sciences at King Saud University, for the fructuous discussions during our regular meetings. We thank also the College of Computer and Information Sciences for its support.

References

1. Accreditation Board of Engineering and Technology (ABET): http://www.abet.org
2. ABET Engineering Accreditation Criteria (EAC), 2011-2012 Accreditation Cycle: http://www.abet.org/forms.shtml
3. B. S. Bloom, M. D. Englehart, E. J. Furst, W. H. Hill, and D. R. Krathwohl, Taxonomy of Educational Objectives: Handbook 1: Cognitive Domain, New York: Longman, 1956.
4. G. Rogers, “Assessment Tips”, *ABET Newsletter*, August, October, and November, 2006.
5. R. M. Felder and , R. Brent, “The National Effective Teaching Institute:Assessment of Impact and Implications for Faculty Development”, *Journal of Engineering Eduaction*, The American Society of Engineering Education (ASEE), Vol. 99, No. 2, 2010, pp. 121–134.
6. R. M. Felder, and R. Brent, “Designing and Teaching Courses to Satisfy the ABET Engineering Criteria”, *Journal of Engineering Education*, The American Society of Engineering Education (ASEE), Vol. 92, No. 1, 2003, pp. 7-25.
7. M. Besterfield-Sacre, L. J. Shuman, H. Wolfe, C. J. Atman, J. McGourty, R. L. Miller, B. M. Olds, and G. Rogers, “Defining the Outcomes: A Framework for EC 2000”, *IEEE Transactions on Education*, Vol. 43, No. 2, 2000, pp. 100-110.
8. R. M. Felder and R. Brent, “Understanding Student Differences”, *Journal of Engineering Eduaction*, The American Society of Engineering Education (ASEE), Vol. 94, No. 1, 2005, pp. 57-72.
9. Felder, R. M. And Brent, R., “The ABCs of Engineering Education: ABET, Bloom’s Taxonomy, Cooperative Learning, and So On”, *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* The American Society of Engineering Education (ASEE), 2004.
10. R. M. Felder, R. Brent, and M. J. Prince, “Engineering Instructional Development: Programs, Best Practices, and Recommendations”, *Journal of Engineering Education*, The American Society of Engineering Education (ASEE), Vol. 100, No. 1, 2011, pp. 89-122.
11. N. Abbadeni and A. Alghamdi, “A Practical Review of ABET Accreditation Criteria – the Case of Software Engineering Programs”, To appear in the Proceedings of the International Conference on Engineering Education (ICEE), The International Network for Engineering Education and Research (iNEER), Belfast, Northern Ireland, UK, August 21-26, 2011.