AC 2010-1378: COST OF ASSESSMENT IN ENGINEERING TECHNOLOGY PROGRAMS

Alberto Gomez-Rivas, University of Houston-Downtown

Alberto Gomez-Rivas is Professor of Structural Analysis/Design Engineering Technology. Dr. Gomez-Rivas received Ph.D. degrees from the University of Texas, Austin, Texas, in Civil Engineering and a Ph.D. from Rice University, Houston, Texas, in Economics. He received the Ingeniero Civil degree, with Honors, from the Universidad Javeriana in Bogotá, Colombia. He also served as Chief of Colombia's Department of Transportation Highway Bridge Division. Dr. Gomez-Rivas has published over 40 journal articles and is a Registered Professional Engineer.

Lea Campbell, University of Houston, Downtown

Lea Campbell is the Director of Academic Assessment at University of Houston Downtown. Dr. Campbell received her PhD from the University of Texas, Austin, Texas, in Higher Education Administration and a BA and MS in Mathematics from Eastern New Mexico University, Portales, New Mexico. Prior to joining University of Houston Downtown, Dr. Campbell was the Associate Vice Chancellor for Developmental Education at City Colleges of Chicago. She has published articles and text books on developmental mathematics, technical communications and strategies for improving student success.

George Pincus, University of Houston, Downtown

George Pincus, Ph.D., P.E., is Dean of the College of Sciences and Technology, and Professor of Engineering Technology at the University of Houston-Downtown (1996-date). He earned a Bachelor of Civil Engineering (with honors) and Master of Science in Civil Engineering degrees from the Georgia Institute of Technology, the Master of Business Administration degree from the University of Houston, and the Doctor of Philosophy degree from Cornell University. Dr. Pincus is a Life Member of ASEE and a Life Member of ASCE. He is currently registered in Texas, New Jersey and Kentucky. He is the author or co-author of 3 books and has published over 50 refereed papers.

Costs of Assessment in Engineering Technology Programs

Abstract

Assessment of outcomes recently became a critical activity for engineering technology departments after TAC/ABET changed from compliance of their traditional requirements to assessment of learning outcomes. ABET started requiring outcomes assessment at the engineering level earlier and only later implemented the same requirement for engineering technology programs.

Engineering technology departments began by trying to meet the new TAC/ABET requirement by copying assessment models used at engineering departments of universities with several decades of assessment experience. However, this was usually done without careful consideration of resources availability; and what is more important, the total costs associated with outcomes assessment. Description of assessment methods is plentiful in the literature but on the other hand, the literature is also rather poor on determining the true cost of assessing learning outcomes at institutions of higher education. The few available studies on this subject reveal costs that are usually a complete surprise to many faculty and administrators.

The cost factor is especially critical for engineering technology programs trying to adapt assessment methods used by larger and wealthier departments. On the other hand these departments can assess their outcomes by methods that are not available to other disciplines due to the specialized mission of engineering technology programs. The paper looks at the costs of assessment activities and the alternatives available for engineering technology taking in consideration the cost factor that is critical for the success of the development and implementation of continuous assessment of outcomes. The results of this study should yield useful information and suggestions for engineering technology departments seeking positive accreditation action under current TAC/ABET guidelines.

Introduction

Assessment of academic outcomes and objectives is a new activity for most engineering technology departments. The activity referred to as "assessment" in this paper is the academic version of industrial quality control familiar to engineers working in industry. This view of assessment helps faculty members with an engineering background and industrial experience to better understand costs, goals, and operative requirements of assessment. Faculty of engineering technology departments working on assessment should keep in mind the relationship with quality control in order to evaluate resources, costs, goals and other hidden details of assessment.

Assessment of outcomes became a critical activity for engineering departments in 2000 when ABET changed their traditional requirements for accreditation to outcomes-based which requires assessment of learning outcomes (or quality control). The Technology Accreditation Commission (TAC) of ABET also started requiring outcomes assessment of programs soon thereafter.

Engineering technology departments began trying to meet the new TAC/ABET requirement by copying assessment models used by engineering departments of universities with several decades of assessment experience. However, this was usually done without careful consideration of resource availability and what is more important, knowledge of all of the total costs associated with assessment. Description of assessment methods is plentiful in the literature but on the other hand, the literature is rather lacking in determining the true cost of assessing learning outcomes at institutions of higher education. This lack of information may be due in part to the fact that costs can vary dramatically from institution to institution. Factors which impact the cost of assessment include differences in faculty salaries, the structure used to manage assessment within the academic unit, size of the student population in the engineering or engineering technology program, the assessment strategies which are selected, and the degree to which technology is used to automate data collection and analysis. In addition, institutions that assign the administrative tasks associated with data collection to lower-paid graduate students or administrative staff while leaving the analysis and interpretation of data to faculty will have lower assessment costs than those institutions that use faculty to conduct all aspects of assessment. The few available studies on this subject reveal costs that are usually a complete surprise to many faculty and administrators.

The parallel with industrial quality control can provide guidance regarding assessment to department chairs of engineering technology departments. Consider that you are in a plant mixing concrete and that you want to implement a quality control program for the product of your plant. To consider that implementation and continuous verification of the quality of the product can be performed at no cost is unreasonable. Research on this subject indicates that the cost of quality control in this type of facility is about six percent of the total cost of the product[1]. Standard practice in construction engineering is for the owner to hire an engineering firm that will be in charge of quality control to assure that the finished product meets contractual specifications. The fees for these engineering services are typically seven percent of the cost of the contract[2].

This paper describes some of the assessment aspects that have developed in engineering technology departments. Engineering technology departments are considered high cost departments due to several factors: Laboratories for educational practices, relatively high faculty salaries, and low enrollments that are in most cases limited by the available facilities. Considering this cost environment, it is necessary to implement new activities with detailed consideration of the full cost of the activity. This is the case for assessment. Assessment is necessary but its satisfactory implementation also requires evaluation of the required costs and resources.

The cost factor is especially critical for engineering technology programs trying to adapt assessment methods used by larger and wealthier departments. On the other hand, such programs can implement assessment methods that may not be available to other disciplines due to the specialized mission of engineering technology programs.

Attention is called to the comparative advantage that engineering technology departments doing assessment under ABET guidelines have in comparison with other departments such as Natural

Sciences and Social Sciences. ABET provides criteria for each program that can be used as assessment goals for the programs. Natural Sciences and Social Sciences do not have criteria guiding them in the development of their assessment plans.

This paper looks at the costs of assessment activities and the alternatives available for engineering technology programs taking into consideration the cost factor that is critical for the success of development and implementation of a continuous outcomes assessment plan. The results of this study should yield useful information and suggestions for engineering technology departments seeking accreditation or reaccreditation under current TAC/ABET guidelines.

Engineering technology departments taking the position that academic assessment follows the same process as quality control and enhancement use a single and unified activity for accreditation under different agencies, which allows the same assessment plan to be followed in order to successfully comply with TAC/ABET and institutional regional accreditation requirements.

Industrial experience of the faculty in quality control and its cost

Engineering technology departments have a comparative advantage in assessment in relation to other departments because faculty with industrial experience often have practical experience in quality control and allocation of resources for product development and improvement. Motivating faculty participation in assessment is sometimes difficult because they consider that grades provide sufficient information for measurement of the attainment of educational goals and preparation of students for professional lives. However, when the relation of assessment with industrial quality control is considered by the faculty member, the need for establishment of criteria and related tests becomes clear and also show that grades are not an appropriate assessment tool.

Faculty members with industrial experience are frequently familiar with the need for continued periodic testing, short control loops, and other concepts related to quality control. Many industrial organizations function under the standards of ISO 9000 and faculty members that have worked in these organizations understand the spirit of the standards that can help them understand and practice academic assessment. It should be observed that the requirements of ISO 9000 are very similar to the requirements of academic assessment. The ISO 9000 requirements listed below are remarkably similar to corresponding academic program assessment activities.
Some of the requirements in ISO 9001:2008 (which is one of the standards in the ISO 9000 family) include

- a set of procedures that cover all key processes in the business;
- monitoring processes to ensure they are effective;
- keeping adequate records;
- checking output for defects, with appropriate and corrective action where necessary;
- regularly reviewing individual processes and the quality system itself for effectiveness; and
- facilitating continuous improvement

A company or organization that has been independently audited and certified to be in conformance with ISO 9001 may publicly state that it is "ISO 9001 certified" or "ISO 9001 registered". Certification to an ISO 9001 standard does not guarantee any quality of products and services; rather, it certifies that formalized business processes are being applied. Although the standards originated in manufacturing, they are now employed across several types of organizations. A "product", in ISO vocabulary, can mean a physical object, services, or software so why not higher education? [3] On the other hand, one basic requirement for successful accreditation by ABET is that a viable academic assessment program is being implemented at institutions seeking such accreditation.

Industrial Advisory Boards

Internal assessment should be complemented by review of all procedures by an external organization familiar with the goals and objectives of the department while it is highly desirable that this external organization be familiar with the academic discipline of the program. Industry Advisory Boards properly selected constitute ideal organizations for peer review of assessment plans. The Industrial Advisory Board for the engineering technology programs at our institution was selected and organized to provide a peer review function. At the end of each academic year, the Board meets with the faculty to review the results of all assessment methods and comments on the corrective actions taken as a result of assessment.

Course-Embedded Assessment

An interesting aspect of the new assessment criteria is that old dependable grades are not a sufficient acceptable measure of performance because they are not related directly to the achievement of specific program outcomes. However, instructors must continue grading as usual while at the same time being involved in development and implementation of assessment plans that include performance measurements. C. A. Palomba and Trudy W. Banta in their book *Assessment Essentials* state: “In a move that is all too rare in higher education, faculty at Rivier College is working to integrate goals described in the institution’s mission statement and the standards on which grades are based. That is, individual college grades should reflect that a student has achieved specific course objectives and college wide general education goals and competences at a level considered appropriate for the course and subject matter” [4]. Our engineering technology department faculty communicated earlier with Professor P.F. Cunningham, Assessment Director at Rivier College, and are currently developing what Professor Cunningham defines as “Course-Embedded Assessment”[5].

In course-embedded assessment,
(1) You identify a primary course objective that you can logically link to an institutional goal stated in your mission or general education program,
(2) Select one or more course-embedded assignment or classroom test which would provide evidence about the learning outcome,
(3) design a rubric to assist in evaluating the student learning outcome,
(4) collect the exam or assignment,
(4) Using the rubric, score the artifact and review the results,
(5) Use the results for program improvement.

The advantages of course-embedded assessment are multiple and diverse: (1) it is a process of using student activities, rather than nationally normed tests or surveys to assess skills and knowledge, (2) it builds on the daily work (assignments, tests, projects) of students and faculty, (3) it gets students to participate more fully as this is not a voluntary activity but part of their course work, (4) it is not "added on" to faculty work but is a part of their normal teaching activities since it is faculty designed, and faculty implemented, (5) provides a more systematic way of doing what is already an important activity to the faculty, (6) more clearly links assessment data to the relationship between teaching and learning and what is actually occurring in the classroom, and (7) promotes the practice of reflective teaching.

To illustrate the concept of Course-Embedded assessment one example of an assignment in ENGR 3311 Structural Analysis I is discussed. Figure 1 presents an assignment that involves the design of a truss of minimum weight. The course outcome and its relation to a Program Outcome are included. The rubric for evaluation of the assignment is as follows:

<u>Course Outcome:</u>
Achieve a firm grasp of the analysis of structures using modern applications of linear algebra. Considering that all structures today are designed using these methods [Structural Analysis-Design (SAD) Program Outcome # 1].

<u>Program Outcome:</u>
Perform standard analysis and design of structural systems following codes and modern practices.

<u>Program Objectives:</u>

Graduates will become proficient in applying their knowledge (in mathematics, science and engineering) and standard tools, specially computer hardware and software, to technical problem solving.

<u>Rubric for the Assignment:</u>
Individual Students, Grades and numerical grade (0-4) assigned as follows:
Incorrect Procedure: D=1; Correct Procedure not meeting conditions: C= 2; Structure too heavy: B=3; Optimal structure, minimum weight: A= 4. Note: Six percent of the students received an “F” because the work was late yet these same students could very easily have created an optimal structure, thus meeting the competency standard of the learning outcome. Timeliness of submitting work is not the learning outcome which is being measured so students who received an F have been removed from the summary of assessment data in Figure 2.

<u>Global Evaluation for Course Assessment:</u>
Satisfactory Performance: Class average greater than 2.3; Good Performance: Class average greater than 2.5; Outstanding Performance: Class average greater than 3.0. These criteria were selected by faculty and apply across all courses so that subsequent evaluations and changes by course, semesters and years is simplified.

University of Houston-Downtown
Structural Analysis and Design Program

Course: ENGR 3311 Structural Analysis

Semester: Fall 2009 Instructor: Dr. Gomez-Rivas

Student Name:

Course Outcome:

1. Achieve a firm grasp of the analysis of structures using modern applications of linear algebra. Considering that, all structures today are design using these methods. (SAD Program Outcome # 1).

Analyze the structure presented in the figure and select the size of steel members meeting two conditions:

1. At node 2, the vertical global deflection should be less than 0.25 inches and the horizontal global deflection less than 0.05 inches

2. The total weight of the structure should be a minimum.

Use Excel to develop all steps of the analysis and design procedures.

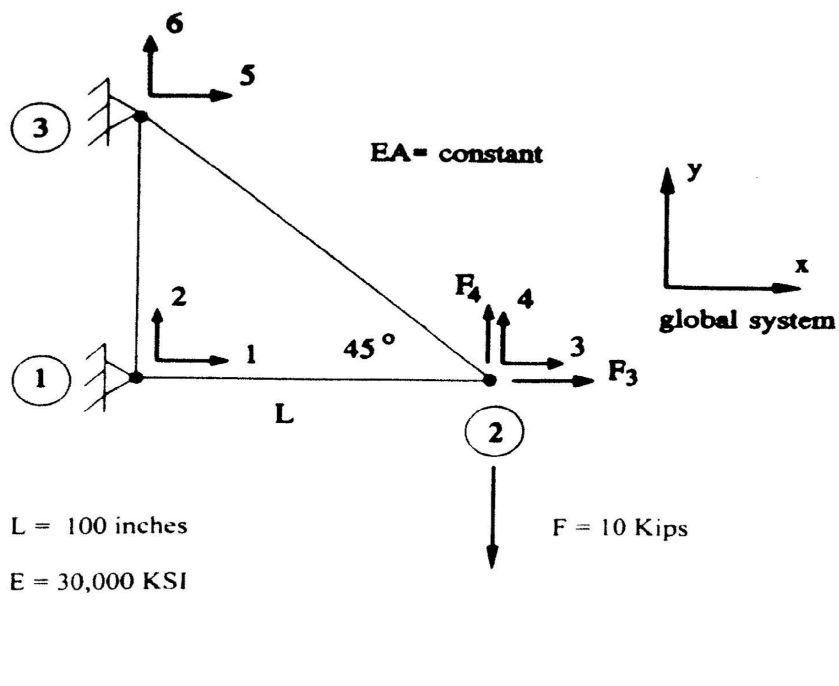

Figure 1. Course-Embedded Assignment

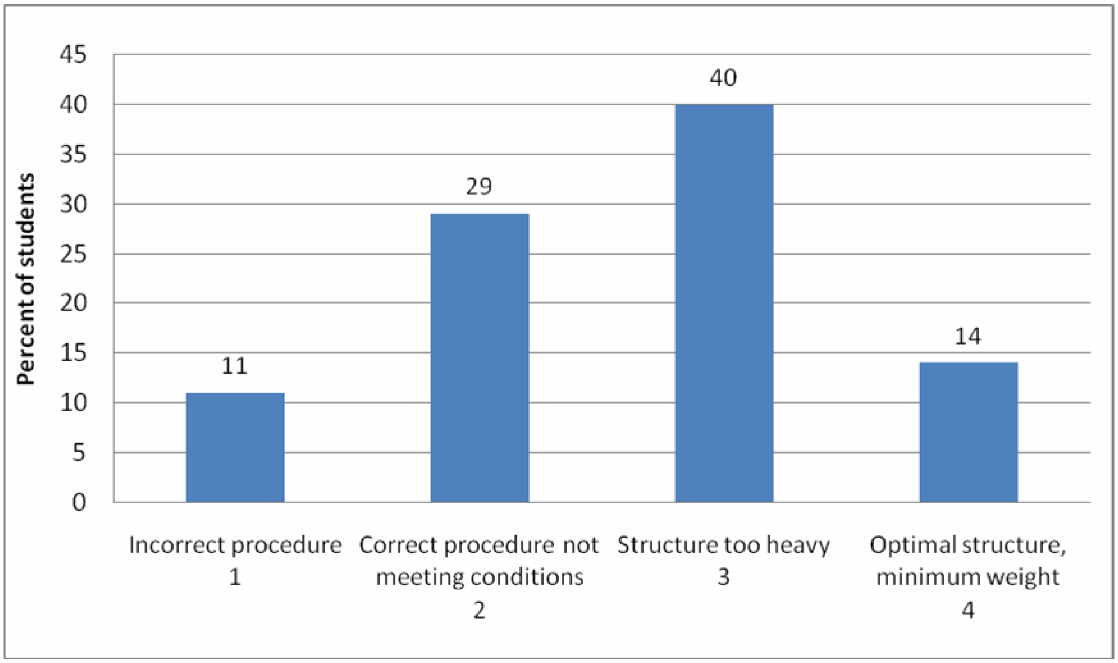

Figure 2. Course-Embedded assessment: Example of an assignment in ENGR 3311 Structural Analysis I

After the assignment is graded and the resulting data is evaluated, the results are tabulated and analyzed by two faculty members; the department then has a clear picture of fulfillment of course outcome, the program outcome, and the program objective, yielding a direct measurement of outcomes. It is important to observe that the program outcome considered is related to the items "a" and "f" of the TAC/ABET criteria:

> "a. an appropriate mastery of the knowledge, techniques, skills, and modern tools of their disciplines" and
>
> "f. an ability to identify, analyze and solve technical problems."

The information collected above is then incorporated into an "Assessment Plan and Report Summary" spreadsheet which is revised every year. Each Learning Outcome (LO) is mapped to Program Objectives (PO) for each engineering technology program. Courses where a specific Learning Objective is assessed are then listed on the spreadsheet so that information on what LO is being assessed in each course is clear with the result that several courses measure the same LO.

Portfolios

Portfolios constitute an important kind of direct performance assessment. Portfolios are samples of student work collected over time that give students the opportunity to track and document their academic progress throughout their years in college[1]. In the case of engineering technology students, many of whom receive support from their companies, the portfolio is an excellent way to show their employer what they have learned in college, course by course. Student portfolios are developed by students and evaluated by faculty following established rubrics. The Partial

Assessment Portfolio Summary in Figure 3 shows how a select group of assignments are collected from the portfolio and linked to specific program-level learning outcomes. The table also indicates the course in which the student work is produced and how the work will be evaluated.

While portfolios can be extremely rich sources of data, they are also potentially one of the most expensive assessment strategies. Portfolios require an extensive amount of student time to organize and maintain and faculty time to evaluate. Portfolio management software can ease the burden of managing assessment portfolios but subscriptions to these server-based systems can be both expenses to purchase and expensive to maintain. The move to portfolio management systems can also place added burdens on support departments like the help desk who are typically tasked with helping students learn the software thus driving up indirect costs. Finally, evaluating the contents of the portfolio can be extremely time-consuming for faculty. For all these reasons, portfolios should be carefully planned and only used when the need for rich, multi-dimensional data about student performance outweighs the expense or when less-expensive assessment strategies are not appropriate for measuring the student learning outcome.[6]

Learning Outcome	***Assessment Assignment***	***Course Where Assignment is Produced***	***Evaluation*** `
LO1: Perform standard analysis and design of structural systems following codes and modern practices.	Project: Minimum weight analysis and design of structural truss.	ENGR 3311 Structural Analysis	Faculty evaluation using rubric
LO2: Determine deformations and stresses in structural systems under the action forces: gravity, wind, fire, earth pressure and flood.	Project: Optimum analysis and design of a frame structure	ET 3322 Finite Element Analysis	Faculty evaluation using rubric
LO3: Apply basic technical concepts to identify, analyze and solve technical problems involving structural, geotechnical, and material behavior under forces and fire.	Laboratory Report 1: Soil Classification	ET 3321 Soil Mechanics	Faculty evaluation using rubric

Figure 3. Partial Assessment Portfolio Summary

Student participation in assessment

A survey of students in the engineering technology department at our institution indicates that their average age is thirty-two, and that their studies are paid for by either their companies or themselves, with most students holding full-time jobs. Furthermore, these students then apply state-of-the-art or advanced technologies at their workplace. Thus, we feel our student body should be deeply involved in all assessment activities such as testing, focus groups, and interviews, even more than traditional full-time non-working students.

On the other hand, the number of students per course in most courses, especially laboratory-based courses, is statistically small. This situation requires intense motivation for the students to participate in assessment. In most cases, it is necessary to conduct measurements directly during classes rather than let students participate in online surveys at their leisure in order to get reliable data of statistical significance.

Student Projects

Engineering Technology courses involve projects that require active physical participation of the members of a group. In a joint project related to a theoretical paper it is difficult to continuously control who is working and who is not. On the other hand when students are involved in laboratory exercises such as casting a reinforced concrete beam or taking surveying measurements, all students are forced to actively participate by the nature of the project. The ABET criteria requiring training of students to work in groups is then easily achieved in typical engineering technology laboratory projects. Faculty encourage students to privately discuss failure of team member to participate in projects.

Computing Assessment Costs

There are many different ways to compute costs associated with a product or service with some methods being quite complex and exhaustive while others are rather simple and primitive. Availability of solid information is usually an indicator for selection of a particular approach in computing costs. For example, one detailed (and hopefully precise) method of calculating costs was developed by the Department of Defense where all phases in the development of a defense information system were considered[7]. On the other hand, computing academic program assessment costs is relatively rudimentary and approximate for a variety of reasons, for example: 1) there is no simple way of keeping track of faculty, administrative, and support time spent on assessment since this activity is usually bundled in with many other day-to-day activities; 2) academic program assessment takes place at many levels and many individuals participate in the process; and 3) some components of academic assessment have been part of the day-to-day activity of the institution and may not be added assessment functions. Thus, for the sake of illustration our institutional yearly investment in assessment of 3 engineering technology programs is calculated with full knowledge that these costs are far from precise and may not apply to other higher education institutions:

- Conservative estimate of faculty time spent on assessment activities = 10% Our selection of 10% of faculty time is based on the extent of activities requiring faculty time over the academic year, for example: collecting data, preparing course syllabi and course outcomes, conducting student intake and exit interviews, administering and grading specific assessment tests, evaluating and grading capstone courses, reviewing and assigning grades to student portfolios, and just plain thinking of ways to better measure outcomes, reading and becoming familiar with assessment literature, serving on a variety of faculty committees concerned with program and course assessment, meeting with industrial advisory boards and other faculty to discuss possible program improvements, attending assessment conferences and seminars, analyzing increasing volume of current and historical data resulting in improvements to courses and academic programs. Also, each academic department at our institution assigns one quarter working load to one faculty member as a "Department Assessment Coordinator", and this translates into significant cost for smaller departments such as engineering technology at our institution.

- Most higher education institutions maintain a centralized office of Institutional Effectiveness with at least one main supervisor and other personnel. Our institution includes four degree granting colleges and since Institutional Effectiveness serves all colleges, approximately one-fourth of their effort might be allocated to our college which is home to engineering technology. This office assures that all common courses required of all students receive the proper attention with regards to assessment and also serves as a centralized resource and compliance office assuring that all faculty fully participate in program assessment. Our estimate of Institutional Effectiveness effort spent on engineering technology programs is thus ¼ x 100% x 1/3 = 8.5%

- Our approximate cost computation of assessment(which we feel is conservative) is as follows:

10% of the engineering technology salaries and fringe benefits (this includes ¼ work assignment for one faculty member) =	$ 85,000
Plus 10% of staff support salaries and fringe benefits =	$ 20,000
Plus 8.5% of Office of Institutional Effectiveness Salaries plus fringe benefits =	$ 30,000
Travel, copier, miscellaneous, connected with assessment =	$ 15,000
Estimates yearly cost of assessment =	$150,000
(Or $50,000/year for each of the 3 engineering technology programs)	

It should be noted that this is a continuing yearly cost estimate and does not account for a first year start-up costs of assessment. The cost may decline somewhat over time as the faculty's assessment expertise increases, as they identify less expensive assessment strategies and as they establish systems which serve to streamline the processes and tasks within the assessment cycle. This estimate is probably low and much less than 6% industrial quality control costs for manufacturing a product.

Conclusions

ABET accreditation is a critical activity for engineering technology programs leading to professional recognition of the programs specially for academic programs in states such as ours where graduates of accredited engineering technology programs are allowed to sit for the Fundamentals of Engineering and the Professional Engineering examinations and possibly, to become registered professional engineers with the same professional status as graduates of accredited engineering departments. Thus, TAC/ABET accreditation is a sine qua non for these departments.

ABET accreditation is highly demanding of faculty resources for a department especially when the university is committed to other regional accreditations such as the Southern Association of Colleges and Schools. In this case, faculty may be carrying the load of two accreditation systems. The history of academic accreditation presents a transformational change from accreditation based upon credentials to current accreditation based upon quality control. This change in accreditation surprised the administration of many institutions particularly relative to new demands for faculty resources. Faculty already had a full load of activities involving teaching, research and service and suddenly a new task was imposed on them: assessment.

The senior author, after discussions with colleagues at many conferences, has determined that departments having difficulties with accreditation based on assessment is mostly due to lack of resources. In other words, the full cost of implementing a successful assessment program was not considered.

Engineering technology departments, by their nature, have alternatives to reduce the assessment load and become more efficient in obtaining and keeping their accreditation. This paper concludes that:

1. Engineering technology departments taking the position that academic assessment is no different from quality control and enhancement need to maintain a single and unified activity/center for accreditation under different agencies such as TAC/ABET and institutional regional accreditation.
2. Industrial experience of the faculty in quality control and knowledge of its true cost is valuable experience for the development and operation of a successful assessment plan.
3. Industrial Advisory Boards can act as independent peer reviewers to provide the necessary external checks on the internal assessment plan of the departments.
4. Course-embedded assessment is a powerful tool for direct assessment of program outcomes that is at the same time economical of faculty resources.
5. To obtain satisfactory measurement of student performance, students must participate in assessment in a direct manner. Surveys with small number of participants become statistically useless.
6. Engineering technology projects offer ideal opportunities to train students to work in groups.
7. Program criteria required by ABET may be thought of by Engineering Technology departments as equivalents to ASTM specifications or ISO 9000 for quality control together with ABET Criteria. It is not necessary to reinvent program outcomes, as is the case for other academic programs that lack traditional goals for their outcomes.
8. A continuing yearly cost of about $50,000 per engineering technology program was estimated for our institution. Although this approximate cost is mostly included within faculty and staff salary budgets, it should be recognized as a necessary and important expense of maintaining a high quality engineering technology program.

Comments offered by our institutional Director of Assessment offer thoughtful insight relative to cost of assessment[7]:

> "*Cost analysis is only half the analysis that needs to be done here. We also must think about the benefit that comes from assessment and how that offsets the cost. I don't see assessment as this cost that needs to be eliminated. I see assessment as an investment in the integrity of our university and the degrees we are awarding students. We want to be*

known as a quality institution. We want to be able to systematically improve our programs. At the end of the day we also want to be able to provide hard evidence that indeed we do produce well-trained competent graduates. In addition, we want increased retention, increased graduation rates, improved quality of student work, etc. Assessment is the only process that I can think of that is able to take us in that direction of quality in any sort of systematic, institution-wide manner." [8]

Last but not least, academic administrators should realize that academic assessment is the same as quality control in an industrial plant and demands new resources; and that these new resources must be allocated for successful continuous improvement of engineering technology program assessment.

A successful continuous improvement plan requires detailed analysis of the resources allocated to the activity. Engineering activities of many types imply a quality control cost of about six percent of the cost of the project and there is no reason to believe that academic institutions will implement satisfactory quality control and product enhancement at very low cost. On the contrary, for institutions with highly qualified personnel, any new activity translates into new costs. Furthermore, improving the quality of the output based on testing is a long term operation in the language of economists.

Bibliography

1. Private Communication
2. Private Communication
3. http://en.wikipedia.org/wiki/ISO_9000
4. C. A. Palomba & T. W. Banta, *Assessment Essentials*, Jossey-Bass, a Wiley Imprint, 1999.
5. Private Communication.
6. Gloria Rogers and Julia Williams, Portfolios: Proceed with Caution, http://www.abet.org/Linked%20Documents-UPDATE/Assessment/Final.pdf
7. U.S. Government Accountability Office, *Cost Assessment Guide: Best Practices for Estimating and Managing Program Costs*, GAO-07-1134SP, p. 82-84, July 200
8. Private Communication, March 5, 2010.