

8. A CASE STUDY OF CONTINUOUS IMPROVEMENT PROCESS IN THE DEPARTMENT OF CIVIL ENGINEERING AT QASSIM UNIVERSITY

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- Note:** 1. The author is a faculty in an Engineering College under Qassim University of Saudi Arabia.
2. The exercise of Continuous Improvement Process (CIP) undertaken here, is commendable. Do we, in India, carryout such exercises?
3. Has a Technological University any role in such exercises?

Editor

Abstract

This paper presents a continuous improvement process developed and implemented for the B.Sc. Program in Department of Civil Engineering (DOCE), College of Engineering, Qassim University, Saudi Arabia. The continuous improvement plan is based on an integrated set of strategies aimed at establishing and implementing a structured process that translates educational objectives into measurable outcomes, and specifies feedback tracks for corrective actions. As a result of setting some direct and indirect measures, the program success is assessed and the level of achievement of the educational outcomes is evaluated. This assessment process relates to the personal soft skills as well as the technical knowledge that the students acquire throughout their course of study. The documentation of the continuous improvement process describes two intersecting assessment loops; slow and fast. The slow loop refers to the process by which the program executives examine the achievement of educational outcomes. The fast loop refers to the process by which we assess the degree to which the program graduates achieve the developed program objectives.

The stages of developing and implementing the program educational objectives, outcomes and the assessment plan for the engineering programs are presented. Preliminary results from a pilot implementation are also discussed. Improvements are already evident in the areas of teaching effectiveness, assessment of student learning and involvement of all the constituencies. Based on these procedures, the ABET visit to the DOCE had achieved great success and the program was fully accredited in August 2010. The next visit to the department is going to be in 2016.

Keywords: Accreditation, Self Assessment, Program Educational Objectives (PEOs), Program Outcomes (POs), Continuous Improvement, Soft skills, ABET.

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Introduction

Engineering education play a vital role in the social and economical development of the nation. Ensuring quality engineering education results in great benefits for students, communities as well as job market by ensuring the quality of the engineering graduates who shall be responsible for leading the society development. One way of ensuring the quality of engineering education process and maintaining it, is through evaluation carried out by accreditation bodies like the "Accreditation Board for Engineering and Technology" or ABET. Therefore, the Engineering College at Qassim University, seeking to achieve quality engineering education process, initiated the process of accreditation by the ABET for all its undergraduate programs. This process was planned initially to make sure that what the programs offer, is equivalent to their peer programs worldwide. Moreover, this ABET accreditation shall lead to satisfying the graduates and societal needs.

Accreditation, as it is known, is a voluntary certified mechanism for engineering programs, administered by recognized professional bodies [5]. The engineering programs in Middle East have their particular challenges for accreditation, [2, 13]. It is also a positive move towards securing professional legitimacy, granting accredited engineering programs their deserving honor and esteem through continued professional development. Internationally, ABET has been recognized as one of the highly respected bodies that sponsor this process.

In a major shift influenced by pressure from industry and global competition, ABET has introduced a new Engineering Criteria 2000 [6] which address the effectiveness of engineering education programs by focusing on an assessment and evaluation process that assure the achievement of a set of educational objectives and outcomes. An important element of these criteria is the establishment of a continuous improvement process that is based on the educational outcomes assessment. The old system of counting course credits has largely

been replaced by an outcomes-based process. Outcomes based assessment process focuses on what the students actually learned or the skills they gained; i.e. what the students can actually do at the time of graduation. In its accreditation criteria, ABET reaffirmed a set of "hard" engineering skills while introducing a second, equally important, set of six "professional or soft" skills. These latter skills include communication, teamwork, and understanding ethics and professionalism and engineering within a global and societal context, lifelong learning and knowledge of contemporary issues. Engineering schools must present evidence that their graduates achieve reasonable levels of these skills, in addition to technical discipline-specific knowledge content [11]. Measuring student outcomes and understanding the learning experience is critical for continuous improvement and satisfying accreditation agencies. Furthermore, the design and implementation of the educational programs should be harmonized to achieve the departments' mission and the programs educational objectives and outcomes. Additionally the educational program promotes continuous improvement to: enhance its ability to satisfy the program's constituencies by meeting their needs and enhance the students' achievement of the program objectives and outcomes [1].

Preparation for the Accreditation Process

In fulfilling ABET criteria for the Civil Engineering (CE) undergraduate program, many hurdles were faced. The most difficult ones were the establishment of Program Educational Objectives (PEOs) and Program Outcomes (POs). This went through number of trials and modifications made by the different Programs Committees (PCs) that were formed to prepare for the accreditation process. The CE department council started the process by establishing the necessary program committees. This includes the main CE Program Committee (CEPC), headed by the Civil Engineering Program Director (CEPD), whose task is to administrate the

program affairs with regard to curriculum changes, coordinate with instructors; review feedbacks from all stockholders, suggest and implement necessary corrective actions. Three Subjects Committees (SC) headed by a committee coordinator were established to overview the different curriculum courses which were divided among the three subject committees. The tasks of these committees include; assuring the quality of learning and teaching process of the courses; suggesting appropriate actions, when necessary, towards improving the education process; reviewing the syllabi of the transferred courses and guiding the new faculty. Analysis Committee (AC) was established whose tasks include receiving feedbacks; conducting the statistical analysis and reporting the results; and coordinating the different program assessment tools. A Students' Advisory Board (SAB) of the program students at different stages of their study was established as an important constituent for the CE program. A Professional Advisory Board consisting of three members of the industrial community in addition to two CE faculty members was established as another important constituent of the CE program. These committees are frequently updated and reappointed by the CE department in order to keep up the high standards of the program and help in pushing it forward.

The ABET defines objectives as "broad statements that describe the career and professional accomplishment", and educational outcomes as "narrower statements that describe what students are expected to know and be able to do", [6]. The PCs along with the program constituencies, in consultation with the Professional Advisory Boards (PABs), kept revising and rephrasing the objectives and outcomes several times until they reached final forms of both which satisfy the two ABET criteria [10]. Professional expertise from industry and the program alumni were involved in the assessment of PEOs and POs, while faculty and senior students assessed only the POs. Assessment of PEOs and POs shows the

strengths and weaknesses of the whole educational process. Subsequently, continuous improvement strategies were set to elaborate on the strengths and to overcome the weaknesses. The improvement process should also include and describe the available documentations and the necessary process used in making decisions regarding program improvements. The implementation of these strategies was made by revising the curriculum, teaching methods, lab facilities etc [10]. In this paper, the development process of the PEOs, POs and the continuous improvement process for the CE undergraduate program, are presented. The difficulties encountered as well as the result of the continuous improvement process conducted for the CE program are discussed.

Program Educational Objectives (PEOs)

The CE department has established a procedure for reviewing, evaluating and continuously improving the CE Program. The CE Program Objectives are assessed and evaluated periodically to demonstrate the degree to which the PEOs are attained and how well they meet the needs of the programs constituencies. As a result of the evaluation process, suggestions for improvements or changes to the program objectives may arise in any academic year. Nevertheless, it is not planned to change/update the program objectives before four years from their final approval. This is to ensure a suitable period to evaluate the validity and appropriateness of the program objectives. But, in special cases and under certain circumstances, changes/updates may be applied if the CE Program committee is certain that the changes are necessary.

In 2006, the Faculty of the DOCE had revised the PEOs of the undergraduate program and finalized them to take a final form that was published in various capacities such as the student handbook [12] and college website [3] and on the student notice boards in the department building. This process occurred through a series of faculty meetings along with the available program constituencies including:

expected employers of our graduates, Faculty of the CE department, Professional Advisory Boards, and University Council, and work of several committees and sub-committees on program development. In addition, the pioneer engineers in Saudi Arabia were asked for their inputs on the suggested objectives.

The PEOs are developed to be consistent with the mission of the College of Engineering, Qassim University, that stated "The College of Engineering seeks to meet the needs of the society and the region with outstanding engineering programs in education, research, and community service" [3,10] and in accordance with the ABET accreditation criteria. The CE Program Committee has finally formulated the following objectives for the CE program as follow. The CE graduates should:

1. Possess comprehensive knowledge in Civil Engineering fundamentals.
2. Apply analysis and design, management, and construction methods in Civil Engineering projects.
3. Demonstrate ability with effective communication skills and teamwork in multi-disciplinary projects.
4. Engage in life-long learning and gain skills to promote professional development and career planning based on social, environmental and professional ethics.

Closing the loop on the objectives is done via the program evaluation and improvement process that is explained later. More consultation, feedback collection and analysis are carried out through the following years to quantitatively evaluate such achievement and make any changes, if required. Reviewing the needs and getting feedback from the program constituencies regarding the program educational objectives, are done according to a regular schedule. It is worth mentioning that the most important process here is documenting all the steps so that all the information will be there when needed.

Program Outcomes (POs)

The CE program outcomes describe knowledge, skills and ability students acquire by the time of their graduation from CE department. These relate to the skills, knowledge, and behavior that students acquire in their matriculation through the program. The POs of the CE program support the PEOs and the College mission. In 2006, the CE department established the educational outcomes for the program recommended by the faculty in consultation with the available constituencies. Then, the DOCE council formulated the POs to be closely aligned to the ABET Criterion 3 (a) to 3(k) outcomes, Engineering Criteria, (2000) [6]. The POs were presented to various constituent groups to get their comments and review. The outcomes of CE program were published on the college website [3] and listed in the student handbook [12]. The outcomes of the CE Program are listed below.

At the time of graduation, our students will have:

- a) An ability to apply knowledge of mathematics, science and engineering principles to solve civil engineering problems in practice.
- b) An ability to design and conduct experiments, and to analyze and interpret data in major recognized civil engineering areas.
- c) An ability to analyze and design a system, civil engineering structure or component to meet desired goals in civil engineering applications economically viable, sustainable and acceptable socially, politically and ethically.
- d) An ability to function on teams.
- e) An ability to identify, formulate and solve civil engineering problems.
- f) An ability to understand professional, social and ethical practices and responsibilities.
- g) An ability to communicate effectively in oral and written forms.

- h) An understanding of the impact of engineering solutions in a global, economical, 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 in civil engineering.
- k) An ability to use modern tools, techniques and skills necessary for civil engineering practice.

The program educational outcomes from (a) to (k) are in full consistence with the stated ABET outcomes Criterion 3 [6]. It is planned to periodically evaluate the POs and revise them, if needed, in order to continuously improve their compatibility with the program objectives and their achievability.

Relationship between POs to PEOs

All CE courses are designed to demonstrate overall knowledge of important aspects of Civil Engineering. The major subjects include methods of analysis and design, and problem solving techniques, which develop students' abilities to analyze, design, produce and assess information and solve open-ended engineering problems, hence fulfilling the educational objective 1 and 2.

A summary of the relationship between the established program outcomes and the objectives of the CE program is shown in Table 1. In order to quantify this relationship, three correlation levels are used; 1, 2 and 3. The correlation 1 indicates the strongest correlation between a specific outcome and a given educational objective. The net level of correlation 2 represents lower level correlation. While the third level 3, indicates no correlation. As shown in the table, every PEO is correlated with at least one outcome with a strong degree of correlation.

Relationship between the Program Curriculum and POs

A summary of the relationship between a few curriculum courses and the established program

outcomes of the CE program is shown in Table 2. The data in this table indicate the level of contribution of courses in the CE curriculum to the outcomes (a)-(k). The course syllabi in the self study reports [10] and college website [3] show clearly that each course outcome fulfills part of the requirements of the program educational outcomes.

The Continuous Improvement Process (CIP)

Development and Implementation

The outcomes assessment process here means, that "systematic collection, review and use of information about educational programs undertaken for the purpose of improving student learning and development" [1]. In the CE program, the continuous improvement process was basically based on an integrated set of strategies aimed at: establishing and implementing a structured process that translates program objectives into measurable educational outcomes, performance criteria and then specifies feedback tracks for corrective actions as shown in Figure 1, [7, 9]. On basis of this understanding, the DOCE provides the necessary assessment training on the plan, creating assessment tools, and identifying and reviewing key institutional practices to ensure that they are aligned with the assessment process. The conceptual model of the assessment plan used in the department is shown in Figure 2. The process is basically an application of the methodology known as "Plan-Do-Check-Act" (PDCA). This plan describes two interacting assessment loops. These are often referred to as the "slow loop" and the "fast loop", [8].

The slow loop refers to the process by which the department examines its program outcomes. In the first two years of the assessment process (2006-2007), the DOCE reviewed its program outcomes and courses outcomes each year, after which the program and course outcomes became an accurate reflection of the current program objectives. The

program and courses outcomes will be reviewed and updated every five years to reflect changes in the curriculum.

The fast loop refers to the process by which we assess the degree to which our students and graduates achieve the program objectives developed in the slow loop. Data are collected at least once a year. For each round in the fast loop, these data are summarized by the Analysis Committee in a general assessment report. The assessment results are then reviewed by the different CE Subjects Committees and the conclusions and recommendations drawn are added to the report. These results and conclusions are then presented to the CE Program Committee and then to the CE Department council in special meeting for this purpose where recommended changes are presented discussed. Upon approval of the recommendations by the CE council, they are then presented to the Engineering council for endorsement before they are passed to the course instructor for implementation in the upcoming academic year. These steps are illustrated by the decision making tree shown in Figure 3.

It is planned to periodically evaluate the level of achievement of the Program Outcomes and take appropriate actions towards continuous improvement. This process normally has the following steps:

- a) Setting performance criteria
- b) Collecting data and measuring the program outcomes (POs)
- c) Reviewing, analyzing and identifying improvement actions
- d) Implementing the improvement actions and
- e) Evaluating the effectiveness of improvement actions and changes.

Collecting data and performance measures

A plan is drawn for collecting data and assessment measures (indicators). The plan defines the scheduled tasks, responsibilities and

timing of performing these tasks.

Achievement of Program educational outcomes:

Assessment Process

Over the course of every academic year, substantial data are generated through our assessment processes using the available assessment tools. The methods used for measuring the achievement of the program outcomes are classified into two categories in which each one of the program outcomes must be assessed by at least one direct and one indirect of the following measures [10]:

Direct performance measures

- a. Student performance evaluations (exams, quizzes, assignments, reports etc.)
- b. Instructors evaluation report
- c. Evaluation of the Graduation Project
- d. Evaluation of the summer/co-op training and
- e. Outcomes Achievement Exam.

Indirect performance measures

- a. Surveys: students' surveys, exit students surveys, and training surveys
- b. Reports from the Professional Advisory Board
- c. Reports from the External Visitor
- d. Reports from the Student Advisory Board
- e. A comprehensive exam, administrated by the Engineering College that comprises questions which covers all the courses in the curriculum and graduate should pass it just before their graduation, known as "Outcome Achievement Exam".

Level of achievement for the program outcomes (Assessment Criteria)

In the CE program, the level of achievement for the program outcomes from (a) to (k) are assessed and then evaluated against the following criteria [10]:

1. For each of the specified courses in Table 3, these specified courses are highly correlated

- to the specified outcome, the percentage of student passing the course is not less than 60% and average final grade is not less than 60%.
2. Mean rating of the responses from the student surveys regarding each outcome is not greater than 2.5 out of 5 for the courses specified in the previous item "1".
 3. Mean rating of the responses from the senior exit surveys regarding each outcome is not greater than 2.5 out of 5.
 4. No negative comments are reported regarding each outcome from the course instructors and exam committees.
 5. No negative comments are reported regarding each outcome in the reports of the Students Advisory Board, Professional Advisory Board and Eternal Visitor.
 6. The average grading of the students based on Outcomes achievement Exam regarding the questions related to each outcome is not less than 60%.
 7. The feedback from rubrics analysis of Graduation project and summer training for the graduated students regarding each outcome are not less than 2.5 out of 4.
 8. For the recent batch of graduate, the average rate (based on the credit hour and grade of each course) calculated using rubric analysis of the specified courses in Table 7 is not less than 2.5 out of 4.
2. As shown in Figure 4, mean rating of the responses from the senior exit surveys regarding each outcome are at least 3.0 out of 5 for the courses specified in Table 3.
 3. No negative comments were reported regarding the program outcomes from the course instructor and graduation project exam committees.
 4. No negative comments were reported regarding the program outcomes from the Students Advisory Board Report and Professional Advisory Board report. On the other hand the Eternal Visitor had some comments regarding the written reporting.
 5. Figure 5 shows the rubrics analysis applied to the outcomes achievement exam regarding the program outcomes.
 6. Figures 6 and 7 show the rubrics analysis of graduation project and summer training for the graduated students regarding the program outcomes.

Closing the Loop on Outcomes:

The CE Program Committee evaluated the previous assessments and found that most of the outcomes assessment results met or exceeded the stated criteria. Since this was the first semester of the year the Department used these criteria, the CE Program Committee felt that no immediate action should be taken on the basis of these assessments. These results will be compared with the net round of assessment, semester or survey sequence, to determine the best course of action.

ABET Visit

The CE Program Committee prepared the self study report (SSR) for the program that describes the current status of the education process as well as their plans to keep on improving it. The SSR is submitted to ABET on July 2009. In December 2009, ABET team visited the college and evaluated the programs and inspected the documentations and facilities of the college and the university. In their ext

Sample Results of the Assessment Process

To measure the achievement of the program outcomes, the previous assessment criteria were applied on the collected data. Following are sample of results that show that the CIP is capable of measuring the program outcomes. It is found that significant achievement of the program outcomes was obtained [10]:

1. The percentage of student passing the courses are more than 60% and average final grades are more than 60% for all the courses except for the courses CE 112.

statement, the ABET evaluating team stated that no observed weaknesses were found and just two concerns were observed regarding the wording of the Program Educational Objectives, and the working hours of the main university library. Corrective actions were made to fix the raised concerns in the following semesters after the ABET visit [4]. As result, the CE Programs was successfully accredited by ABET in their official board meeting in August 2010.

Summary and Recommendations

This paper presented the experiences gained in developing and implementing a strategic plan that include objectives, outcomes and continuous improvement process that based on outcome-based assessment for the engineering programs at the College of Engineering, Qassim University. The results of the application of both direct and indirect measurements have provided significant evidences of the improved teaching and learning. The above detailed assessments gave good impression regarding the achievement of the program outcomes. The implementation of this outcome-based assessment process has effected a definite change in curricular content, facilities activities and assessment practices that the students are experiencing. Corrective actions have identified to address key issues such as program objectives, facilities and increasing the math and basic sciences in the curriculum. The application of these strategies have achieved a significant success as evident by a successful ABET site visit.

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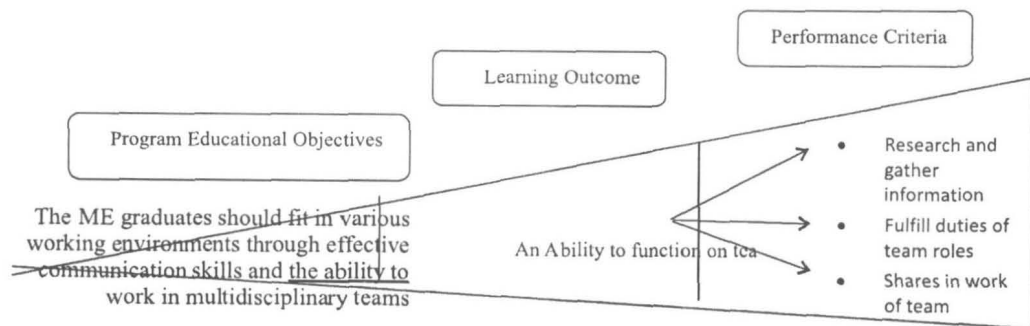


Figure 1. Transferring the educational objectives to outcomes and the to performance criteria.

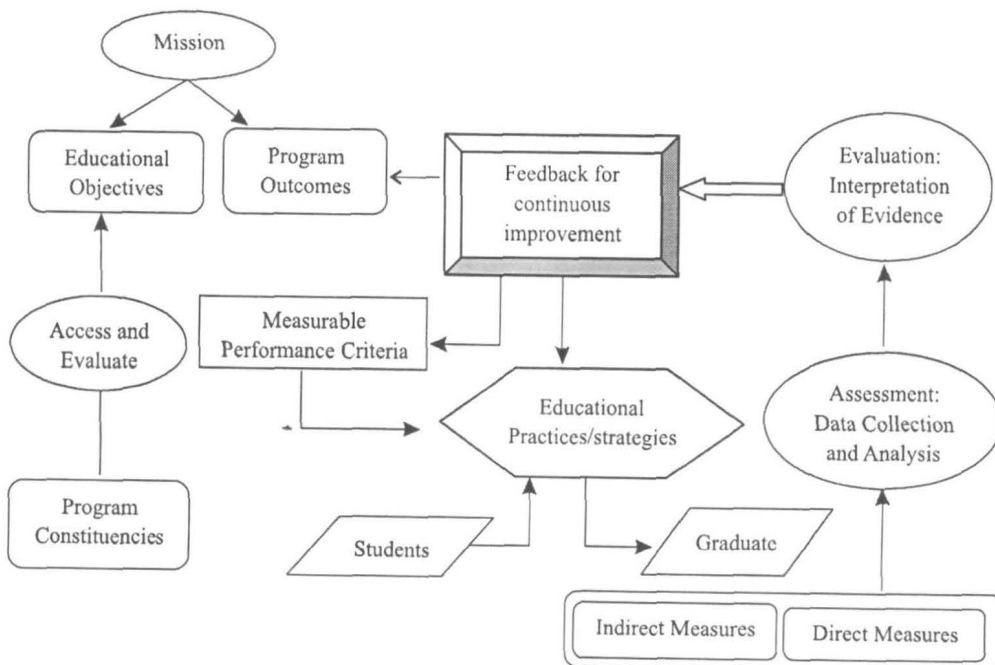


Figure 2: Flow chart of the continuous improvement process

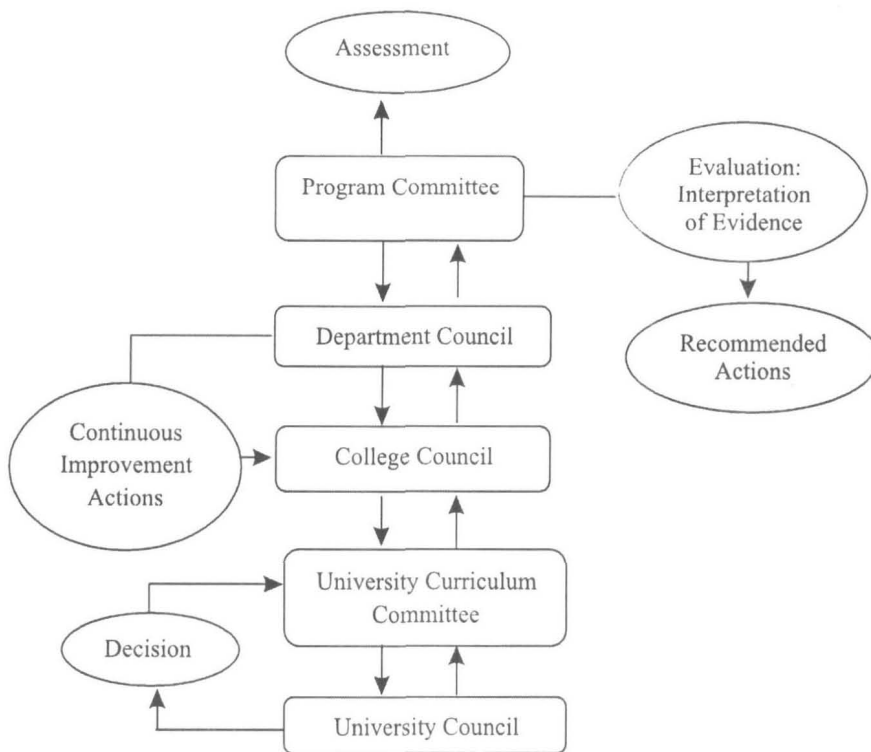


Figure 3 : Decision making tree of the continuous improvement process (CIP)

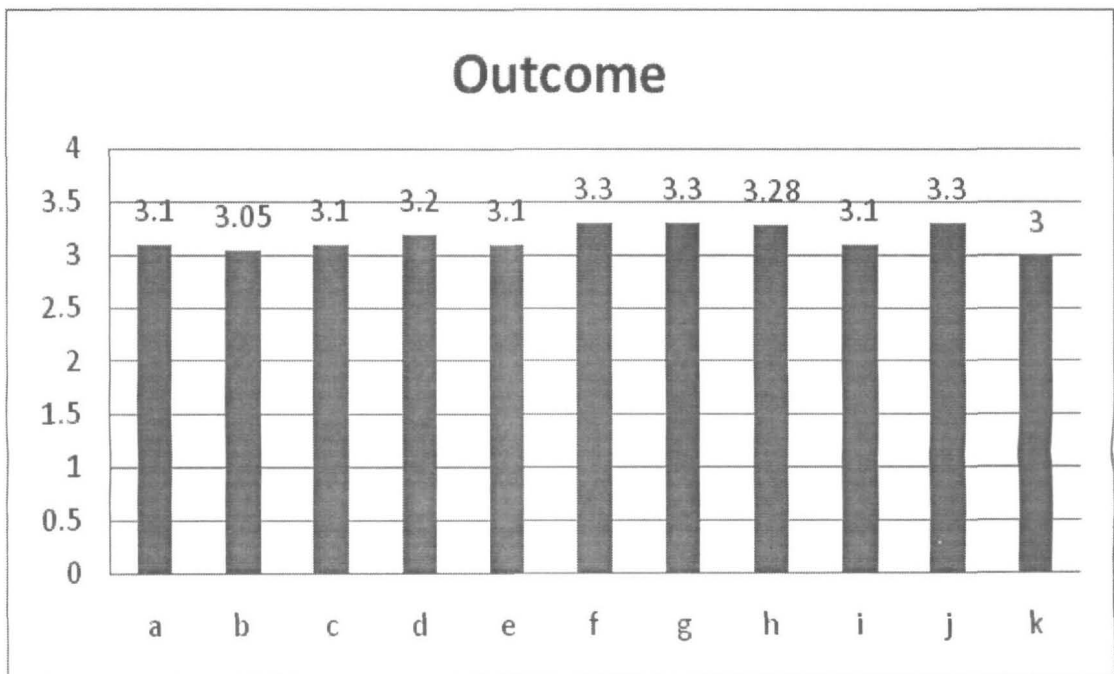


Figure 4: The mean rating of the responses from the graduating student surveys (11 students)

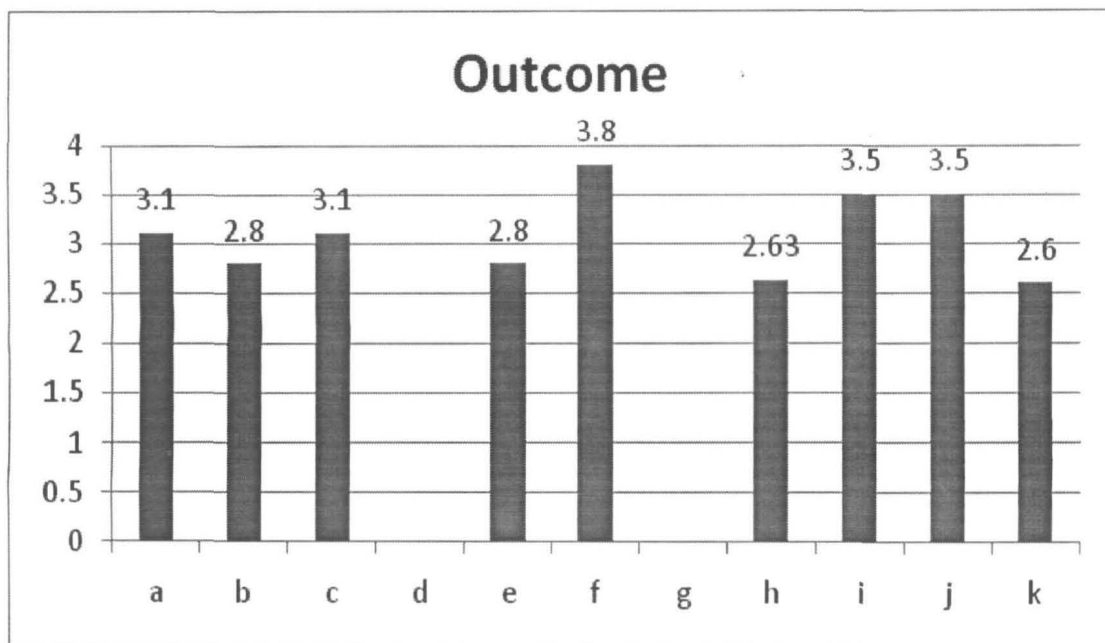


Figure 5: The average rate of the rubric analysis applied to the outcomes achievement exam (11 students)

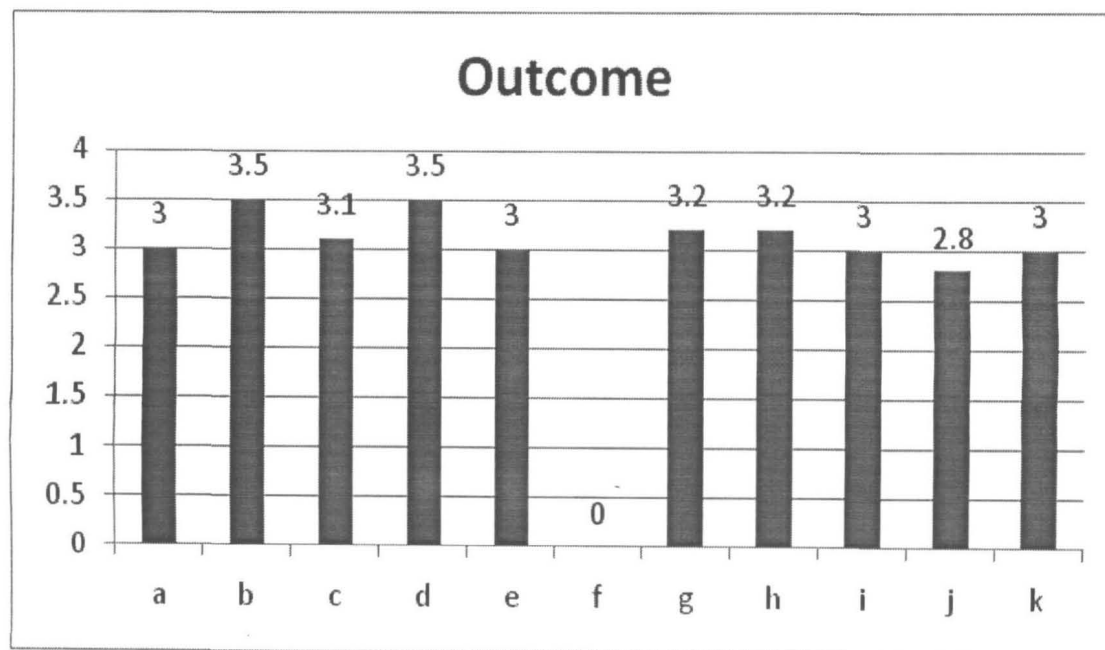


Figure 6: The average rate of the rubric analysis applied to senior design project (11 students)

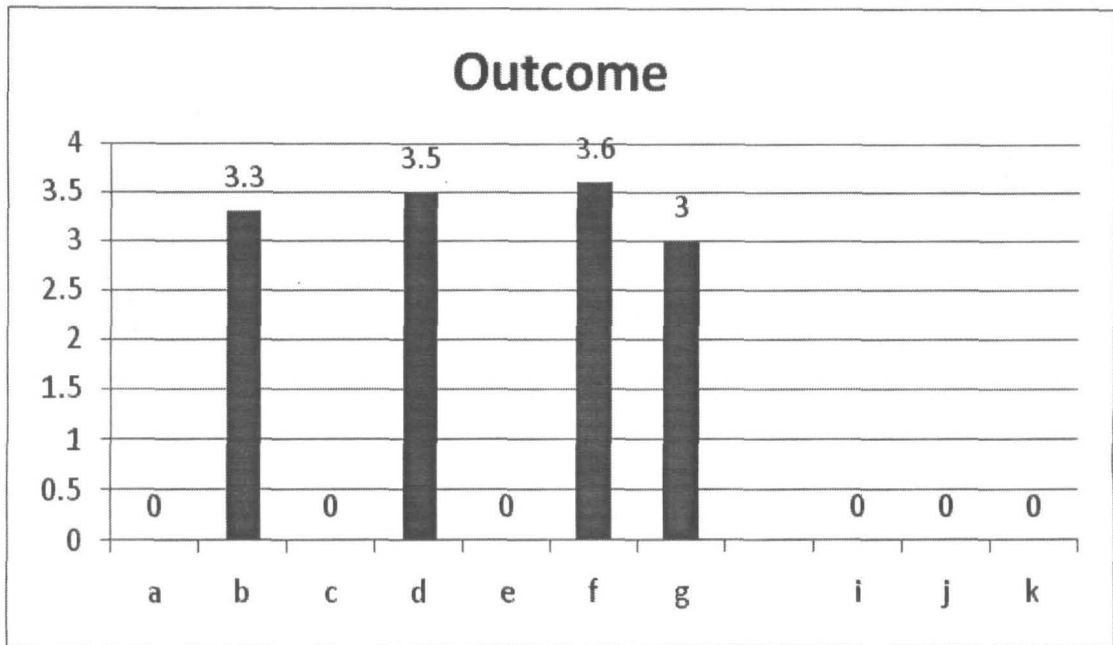


Figure 7: The average rate of the rubric analysis applied to the summer training (11 students)

CE Program Objectives	CE Program Educational Outcomes										
	a	b	c	d	e	f	g	h	i	j	k
PO-1	1	1	1	3	1	2	3	2	2	2	2
PO-2	1	1	1	3	2	1	2	2	2	1	1
PO-3	3	2	2	1	2	2	1	2	3	2	2
PO-4	1	1	2	3	1	2	1	1	1	1	1

Strongly correlated = 1 Somewhat correlate = 2 Not correlated = 3

Table 1: Mapping between the Pos and PEPs from the CE program

Course Code and Title			CE Program Educational Outcomes										
			a	b	c	d	e	f	g	h	i	j	k
Core Courses	GE 104	Basics of Engineering Drawing	2	3	3	3	3	3	2	3	3	3	2
	CE 112	Survey Basics	1	1	2	1	2	1	1	2	2	2	1
	CE 202	Mechanics of Materials	1	3	2	3	1	3	3	3	2	3	3
	CE 203	Structural Materials	2	1	2	1	1	2	2	1	2	2	2
Elective Courses	GE 211	Introduction to Engineering Design-I	3	3	1	1	1	1	1	1	1	1	2
	CE 401	Concrete Technology	2	1	2	1	1	2	2	1	2	2	2
	CE 403	Advanced Reinforced Concrete	1	3	1	3	1	2	3	2	2	2	3
	CE 406	Advanced Structural Analysis	1	3	2	3	1	3	3	3	2	3	3
	CE 406	Advanced Steel Design	1	3	1	3	1	2	3	2	2	3	3

Strongly correlated = 1 Somewhat correlate = 2 Not correlated = 3

Table 2 : Mapping of civil engineering courses to the program outcomes:
Table includes the required and elective courses

Program Outcome	Strongly correlated courses	Program Outcome	Strongly correlated courses
A	CE 112, CE202, CE285, CE305, CE315, CE 320, CE341, CE370, CE375, CE400, GE 401	g	CE 112, GE 211, GE213, CE370, CE 400, GE401, CE405
B	CE 112, CE203, CE231, CE304, CE354, CE405	h	CE 203, GE211, GE 213, CE304, CE370, CE400, GE401, CE405
C	GE 211, GE 213, CE315, CE 320, CE341, CE363, CE370, CE375, CE400	i	GE 211, GE 213, CE305, CE 370, CE 400, GE 401, CE405
D	CE 112, CE203, GE211, GE213, CE231, CE 304, CE370, CE400, GE 401, CE405	j	GE 211, GE 213, CE370, CE400, GE 401, CE405
E	CE 202, CE203, GE211, GE213, CE 230, CE 231, CE304, CE305, CE315, CE 341, CE 353, CE370, CE375, CE400, GE401, GE 402	k	CE112, GE 213, CE370, CE400, GE 401, CE405
F	CE 112, GE 211, GE213, CE 370, CE400, GE 401, GE 402, CE405		

Table 3 : Strongly correlated courses corresponding to each Program

