Specific, Generic Performance Indicators and Their Rubrics for the Comprehensive Measurement of ABET Student Outcomes

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Dr. William G. Spady, International Network for OBE

Dr. Spady has been a leading pioneer in Outcome Based thinking and implementation for 45 years. As a Ph.D. graduate of the U. of Chicago in 1967, he was introduced to the seminal work of Benjamin Bloom in 1968 and transformed its fundamentals into a comprehensive paradigm-shifting system of educational transformation that he has shared through his 8 books, dozens of published papers, and countless presentations and workshops to educational institutions on 4 continents. He regards OBE as a powerful, future-focused ever-evolving approach to learner empowerment, and regrets that it has been so badly misunderstood and misrepresented across the world.

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***Abstract*:** In this research, we present the essential principles of an authentic outcome based educational model related to the development of learning outcomes, performance indicators and their rubrics with a focus on measurement of specific skills related to Bloom's 3 learning domains and their learning levels for engineering specializations. An analysis of culminating ABET Engineering Accreditation Commission student outcomes is made with reference to Bloom's 3 learning domains and their learning levels. A hypothetical model is presented for this analysis. The correlation of ABET student outcomes, course learning outcomes and performance indicators is clearly outlined. The necessity of the use of performance indicators is highlighted especially in reference to the measurement of course learning outcomes, development of assessments, teaching and learning activities. The importance of scientific constructive alignment of learning outcomes, performance indicators, assessments, teaching and learning strategies is discussed. A novel hybrid rubric for accurate assessment and scoring of student performances is also presented. Actual examples of implementation of this theory to program, course and student level performance evaluations using state of the art web based digital technology are shown. In summary, the benefits of specific performance indicators over generic ones are explained in detail with respect to support of authentic OBE principles, scientific constructive alignment, accurate measurement of student performances in specific engineering learning activities, performance failure analysis and continuous quality improvement.

I. Introduction

Several established accreditation and quality assurance agencies both international and regional such as International Engineering Alliance (IEA), Washington Accord [1], European Commission, Bologna Process [2] , Accreditation Board of Engineering Technology (ABET) [3], Middle States Commission of Higher Education (MSCHE) [4] and National Commission of Academic Accreditation and Assessment (NCAAA) [5] are based on an Outcome-Based Education (OBE) model and require higher education institutions and engineering programs to show student achievement in terms of established learning outcomes. It is clearly stated in multiple research papers published by the National Institute of Learning Outcomes Assessment (NILOA) [25,26] and others [6,28,29] that in many higher education institutions, actual Continual Quality Improvement (CQI) and accreditation efforts are minimally integrated and that ideally CQI instead of accreditation standards should be the prime driver for outcomes assessment. Unfortunately, accreditation was the prime driver for outcomes assessment and the topic of more than 1,300 journal articles between 2002 and 2004 [6]. To substantiate this finding, Mohammad and Zaharim stated in their 2012 research [38] that engineering education in Malaysia underwent a major transformation starting in 2004 due to the requirement imposed by the Washington Accord agreement. Assessment and evaluation of program outcomes (PO) became mandatory for all engineering programs in Malaysia. However, the typical PO assessment model practised by many engineering programs resulted in vague assessment methods that failed to produce effective CQI. The major issue was the lack of clear performance criteria to measure the POs. They proposed a new model based on measuring each PO using specific performance criteria. The new model is expected to allow objective evaluation of whether the students have achieved the criteria and subsequently facilitate CQI implementation within the programs. Kalaani & Haddad in a 2014 work [37] presented the CLO form in Table 6 of their paper measuring 36 specific performance criteria for just one typical electrical engineering course. A glance at open courseware from the Massachusetts Institute of Technology for a typical circuits and electronics course indicates 16 Course Outcomes (COs) [60] which naturally imply the necessary standards in current engineering education of specialized knowledge and student skills which can be measured by a corresponding number of their specific Performance Indicators (PIs). The several references indicated strongly suggest that performance criteria should be specific to collect precise learning outcome information related to various topics, phases of a curriculum while addressing various levels of proficiency of a measured skill.

Additionally, the learning outcomes data measured by most engineering institutions are rarely classified into all three learning domains of the revised Bloom's taxonomy [52] and their corresponding categories of the levels of learning. Generally, institutions classify courses of a program curriculum into three levels: introductory, reinforced, and mastery, with outcomes assessment data measured for the mastery level courses in order to streamline the documentation and effort needed for an effective program evaluation [48,49]. This approach presents a major deficiency for CQI in a student-centered OBE model because performance information collected at just the mastery level is at the final phase of a typical quality cycle and is too late for implementation of remedial efforts. Instead, student outcomes and performance criteria progressing from the elementary to advanced levels should be measured at the course level for all courses spanning the entire curriculum [56,57]. McGourty, Sebastian and Swart, in their 1997 [28] and 1998 [29] research work have explained the critical nature of course level outcome assessments. The accreditation and quality assurance agencies listed here do not explicitly establish requirements for implementing specific PIs to measure varying levels of students' skills in all course levels and learning domains. Whereas holistic approach for a CQI model would require a systematic measurement of specific PIs in all three of Bloom's domains of learning and their corresponding categories of learning levels for all course levels of a program's curriculum. Some major reasons why specific PIs are not specified as essential assessment criteria for accreditation are the requirements of detailed processes for their implementation using digital technology and established widespread use of primitive, but lengthy manual assessment models such as the traditional rubric based Gloria Rogers' (GR) model [48] employing generic PIs which is supported by popular Learning Management Systems (LMS) such as Blackboard [33]. By not specifying the implementation of both specific and generic PIs in outcomes assessment processes, accreditation would be at odds with the basic philosophy of authentic OBE and result in dramatically negative effects on CQI. In the coming sections of this paper we will present generic and specific PIs, their necessity, hybrid rubrics, the methodology and technology required for their implementation, effects on CQI.

II. Outcomes Assessment Methodology and Automation Technology

The Figure 1 shows a process flow for a FCAR + specific PIs classified per Bloom's 3 domains and 3-levels skills assessment model adopted by the Faculty of Engineering at the Islamic University of Madinah, Saudi Arabia. ABET criteria for program accreditation have been implemented in the assessment model, which requires that programs make decisions using assessment data collected from students and other program constituencies, thus ensuring a quality program improvement process. Quantitative and qualitative methods are developed to ensure students have satisfied the COs which are measured using a set of specific PIs/assessments and consequently the program level ABET SOs [20]. The noteworthy aspect of this model is that course faculty are involved in most CQI processes whether at the course or program level.

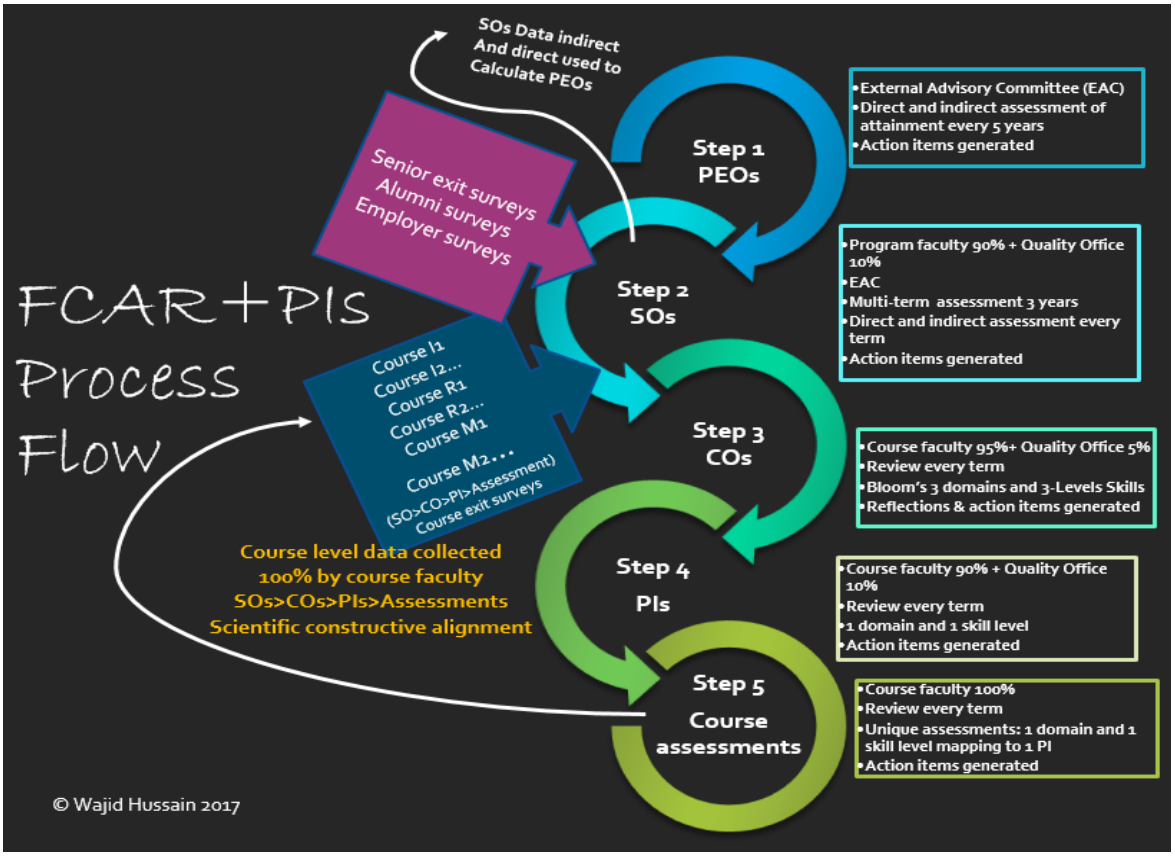


Figure 1: FCAR + specific PIs assessment model process flow indicating course faculty involvement in almost all phases of CQI cycle

Course faculty are directly involved in the teaching and learning process interacting closely with all the enrolled students. An ideal CQI cycle, would therefore include the course faculty in most levels of its process, to generate and execute action items that can directly target real time improvement in student performances for ongoing courses. Models that involve program faculty or assessment teams that are not directly involved with the enrolled students will definitely not support real time CQI which is an essential element of an authentic OBE system [7,8,10,12].

A "design down" [7,8] mapping model was developed as shown in Figure 2 exhibiting authentic OBE design down flow from goals, PEOs, SOs, course objectives, COs to specific PIs. This figure illustrates trends in levels of breadth, depth, specificity and details of technical language related to the development and measurement of the various components of a typical OBE "design down" [7,8] process.

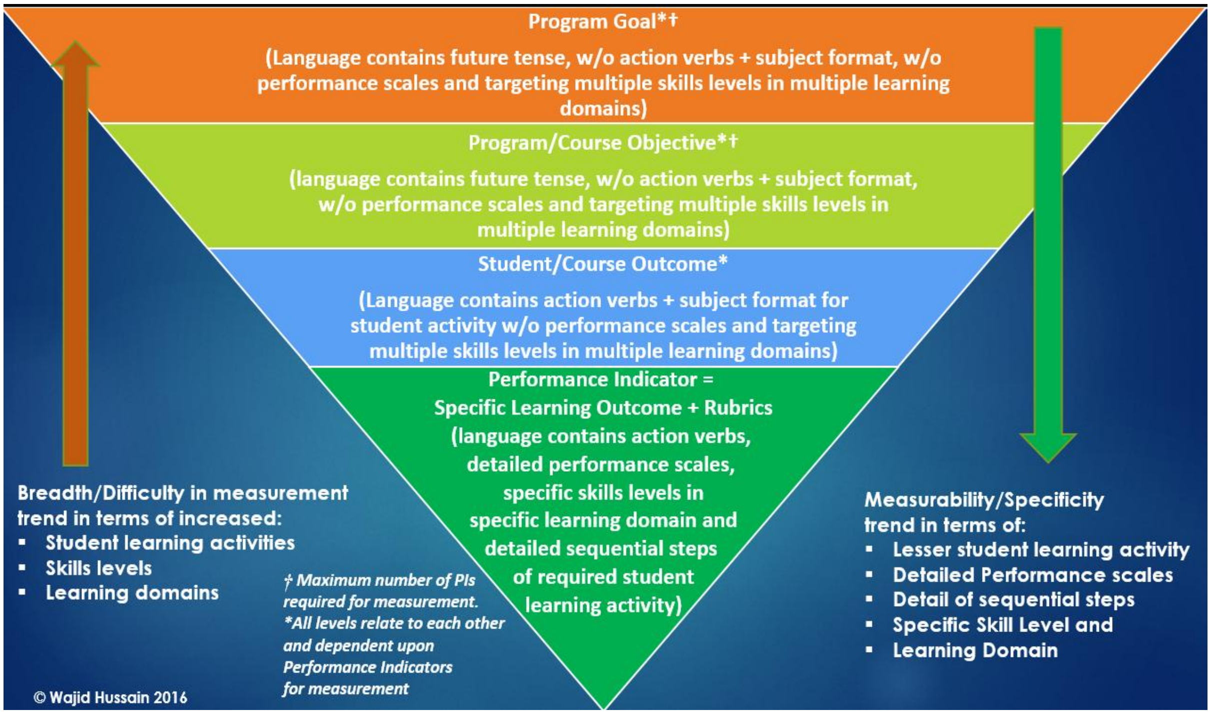


Figure 2: OBE Design down mapping from goals, PEOS, SOs, COs to PIs

FCAR, EAMU Performance Vector Methodology and Web-based Software EvalTools® 6. EvalTools® 6 [43] is chosen as the platform for outcomes assessment instead of Blackboard® [33] since it is the only tool that employs the Faculty Course Assessment Report (FCAR) and *EAMU performance vector methodology* [42,44,45,46,47,48,49,50,51]. This methodology facilitates the use of existing curricular assignments for outcomes assessment to achieve a high level of automation of the data collection process. The EvalTools® 6 FCAR module provides summative/formative options and consists of the following components: course description, COs indirect assessment, grade distribution, course reflections, old action items and new action items; COs direct assessment; PIs assessment ; student outcomes assessment; assignment list; and learning domains and skills levels assessment distribution [35,49,50,51,63,64]. The FCAR uses the EAMU performance vector, conceptually based on a performance assessment scoring rubric, developed by Miller and Olds [59], to categorize aggregate student performance. Heuristic rules and indicator levels for EAMU performance vector have been explained in research work related to the FCAR [44,45].

III. Specific, Generic PIs and Rubrics (Holistic, Analytic and Hybrid)

In an OBE model, assessments related to specific PIs, measure the level of teaching and learning achievement, and help outline future actions related to course delivery, syllabus, teaching and learning strategies for CQI [19,21,22,24,25,31,55]. By performing an exhaustive design and classification exercise of several hundred PIs (90% specific) related to COs and ABET SOs for the Electrical Engineering (EE), Mechanical Engineering (ME) and Civil Engineering (CE) programs, the Faculty of Engineering has observed that ABET SOs exhibit relevance and coverage of the revised Bloom's learning domains as shown in Table 1[49]. In Table 1, 'H' High; 'M': Medium; or 'L": Low; refer to the degree of relevance and coverage of an ABET SO for a learning domain, which is estimated by the type, number of activities and assessments processed in different courses of a program in a given term for the measurement of PIs related to this learning domain. Our earlier work [49] has discussed the relevance and coverage information shown in Table 1 in two phases. For the initial phase, information was hypothetically generated based on theoretical grounds as a result of semantic analysis of the language of the 11 ABET SOs and their classified PIs. In the second phase, this hypothetical information was practically confirmed with actual SOs measurement data for a given term using PIs associated to the 3 domains, assessments and their counts information from various courses. Detailed set of appendices were also attached to provide specific assessment information in 3 domains for each ABET SO [49].

Table 1: Hypothetical relevance and coverage of ABET SOs to Bloom's 3 learning domains

SO_NO.	ABET SOs	DOMAINS RELEVANCE & COVERAGE		
		COGNITIVE	AFFECTIVE	PSYCHOMOTOR
SO_1	a. an ability to apply knowledge of mathematics, science and engineering	H	L	L
SO_2	b. an ability to design and conduct experiments, as well as to analyze and interpret data	H	M	H
SO_3	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	H	H	H
SO_4	d. an ability to function on multidisciplinary teams	M	H	L
SO_5	e. an ability to identify, formulate, and solve engineering problems	H	L	L
SO_6	f. an understanding of professional and ethical responsibility	M	H	L
SO_7	g. an ability to communicate effectively	M	H	M
SO_8	h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	M	H	L
SO_9	i. a recognition of the need for, and an ability to engage in life-long learning	M	H	L
SO_10	j. a knowledge of contemporary issues	M	H	L
SO_11	k. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H	L	H

ABET explains both kinds of PIs, generic or specific, their rubrics and provides some information to differentiate between the two as shown in training presentation material publicly available on their website [3]. But, almost all of the examples of PIs and rubrics displayed are generic and target the predominantly affective domain ABET SOs for assessment. The reasons for this are firstly, there are hundreds of specific engineering activities related to any engineering specialization that would definitely require a good number of specific PIs, rubrics to adequately measure them. Secondly, appropriate technology would definitely be required to manage this vast amount of information. It would be challenging choice for ABET or any quality assurance agency to prescribe the specific PIs model, supporting technology for automation and achieve effective CQI or continue with the traditional manual GR model with generic PIs and compromise authentic OBE and CQI.

Gloria Rogers does mention that PIs should be measured in course work but their training materials do not indicate COs in the process flow charts. An obvious reason, for the COs not appearing above PIs in the process flow chart, is that the GR traditional rubrics assessment model is implemented for measurement of the PIs and SOs data by employing independent raters, who typically assess student work after courses are completed [3,48]. This process flow model, has thus mostly proposed to programs, the GR assessment model, generic PIs and an independent raters system of scoring [48]. For authentic OBE, students in the course are the focus of the faculty, and so, faculty members teaching the course must be directly involved in the outcomes assessment process. They should apply constructive alignment based on outcomes, use formative and summative assessments, conduct evaluations, choose the best teaching and learning strategies for improved performances, and provide real time feedback to students for effective CQI.

Independent raters definitely do not interact with students, cannot understand the intricacies of the teacher-student relationship, and do not support formative assessments for CQI. The argument in favor of independent raters, is to have unbiased scoring of assessments. But, the important thing to note, as per our earlier discussions, and referred research [69], was that generic rubrics have the least reliability, and therefore, keep the door open to biased scorings and human factors. On the other hand, specific PIs and hybrid rubrics, present very high reliability and when coupled with objective evidence to verify proper application of these specific hybrid rubrics, it becomes almost impossible for biased scoring to happen. Finally, independent rater scoring is an additional effort, beyond curricular scoring, and is a manual process that can never be automated. Dissecting curricular grades, to extract outcomes information is a totally automatable process, and we can effectively leave scoring in faculty hands, while not doubling the efforts or required resources for collecting outcomes data. Therefore, assessment models, supporting generic rubrics and independent rating systems do not facilitate implementation of the 4 OBE power principles of *clarity of focus, expanded opportunity, high expectations* and *design down* [7,8,10,12], and are in total conflict with authentic, student centered, OBE methodology.

The IEA confirms the necessity of measurement of graduate attributes and specific professional competencies for qualifying graduates and practicing engineers, which is expressed clearly in statements extracted from publicly available documentation on their website [2]. Appendix A.1 and A.2 show profiles listed by the IEA for practicing engineer, engineering technologist and technician detailing types of engineering knowledge and a range of problem solving activities. The profiles indicate a very complex process using specific PIs for assessment of these attributes in qualifying graduates. Problem solving and design for various engineering specializations or for even certain course content is very specific process and can vary drastically depending upon content specific factual, conceptual and procedural knowledge. McCade has also echoed a great amount of detail on the subject of problem solving being a very comprehensive engineering activity, which comprises of several sub activities not limited to design, experimentation, analysis, evaluation etc. [58].

The Faculty of Engineering has developed 290 specific PIs through a very exhaustive and elaborate ongoing process to comprehensively measure engineering activities corresponding to various skills levels related to problem solving in introductory, reinforced and mastery level courses for ABET SO ‘e’ [49]. To be exact, 100 for CE, 74 for EE, 84 for ME and 32 for General Engineering (ENGR) programs courses. In fact, all developed specific and generic PIs corresponding to ABET SOs ‘a-k’ have been classified as per the 3 Bloom’s domains and their learning levels. The PIs database is proprietary information owned by the Faculty of Engineering and therefore cannot be listed in the appendices of this paper. Therefore, just portions of these PIs lists can be shown to present concepts employed for their development, classification and implementation for outcomes measurement. Figure 3 indicates two joined portions of the list of specific PIs for the CE program showing PIs of index number [1-8] and [95-100] classified into affective, psychomotor and cognitive domains of Bloom’s taxonomy and their learning levels. An elaborate youtube video was produced by the Office of Quality and Accreditation at the Faculty of Engineering in 2016 [62] presenting the importance of specific PIs for establishing the four power principles of OBE [7,8,10,12] ; *Clarity of Focus*: clear mapping to precise student learning activity; *Expanded Opportunity*: timely remedial action; *Design Down*: from PEOs all the way to PIs; and *High Expectations*: Hybrid Rubrics [65,66,67] scales clearly defining the highest standards for student performances.

[abet_SO_5] an ability to identify, formulate, and solve engineering problems

- [abet_PI_5_1] Cognitive: Applying Apply concepts, governing math or physics equations and methods to solve a technical problem
- [abet_PI_5_2] Cognitive: Analyzing Demonstrate effective problem solving techniques
- [abet_PI_5_3] Psychomotor: Adaptation Conduct site investigations
- [abet_PI_5_4] Cognitive: Analyzing Conduct lateral earth pressure and slope stability analysis
- [abet_PI_5_5] Cognitive: Evaluating Apply momentum conservation concept to evaluate forces of moving bodies
- [abet_PI_5_6] Cognitive: Creating Model the hydrological processes
- [abet_PI_5_7] Affective: Organize values into priorities Outline traffic flow characteristics, including capacity, speed and safety considerations
- [abet_PI_5_8] Cognitive: Analyzing Compute the internal and external forces and/or deformations, slope, deflections for beams, frames and trusses for determinate structures
- [abet_PI_5_95] Cognitive: Analyzing Determine the type of stress by examining loading conditions and compute the tensile and compressive stresses developed due to axial and bending moments
- [abet_PI_5_96] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute shear stresses developed due to transverse loading and/or torsion.
- [abet_PI_5_97] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute normal strain, and expansion/contraction due to axial loading
- [abet_PI_5_98] Cognitive: Analyzing Determine the type of strain by examining the loading conditions and compute shear strain, and angle of twist developed due to torsion
- [abet_PI_5_99] Cognitive: Analyzing Determine principal stresses and maximum shear stress for a given state of stress at a point by apply the stress transformation equations
- [abet_PI_5_100] Cognitive: Analyzing Calculate the maximum deflection of a beam and its location for various cases of loadings using integration techniques

Figure 3: Faculty of Engineering CE program Specific PIs for comprehensive measurement of SO 'e' on problem identification, formulation and solving

Adelman's thorough work strengthens our argument that the required language of learning outcomes for the cognitive and psychomotor learning activities should be specific [27]. He assertively states that verbs describing a cognitive or psycho-motor operation act on something, i.e. they have a specific nominal context. The nominal context can be discipline/field-specific, e.g. error analysis in chemistry; an art exhibit in 2-D with 3 media. Field-specific statements are endemic to learning outcome statements in Tuning projects. Finally, without a specific nominal context you do not have a learning outcome statement.

ABET talks about rubrics being an assessment scale that describe the levels of achievement for each PI and allow setting up thresholds for acceptable student performance [3]. Specific or generic rubrics are used for assessment of activities that are either task specific as in the cognitive, psychomotor domains or general as in the affective domain [3].

The reasons for rubrics in general are given as:

1. Formative and Summative application to assessments
2. A medium to define expectations for students, faculty and program
3. Increase inter and intra-rater reliability for assessments
4. A feedback process for learning performance for students, faculty and program

Holistic rubrics relating to a certain SO or PI do not contain individual dimensions but rather a set of performance criteria which are applied in parallel for scoring assessments by seasoned raters. On the other hand, analytic rubrics relating to SOs contain specific dimensions which are in fact the PIs needed to adequately measure the SO. Both rubrics contain descriptors for all scales, but the difference is again that the analytic rubric has descriptors for each PI or dimension. Analytic rubrics can specifically indicate areas of weakness in performance for the various dimensions or PIs corresponding to a certain SO. In both cases of rubrics, the nature of examples provided by ABET as shown in Figure 4 are very simplistic, addressing affective domain SOs like team work, while expressing the dimensions such as *research and gather information* or *listening to other teammates* with descriptors containing extremely superficial, vague and non-technical language without actually providing details steps of what students have to demonstrate to accurately assess these dimensions or PIs. The *research and gather information* PI/dimension contains one descriptor for each scale like *does not collect any information that relates to the topic:* for the *Unsatisfactory scale;* and *collects a great deal of information, all relates to the topic:* for the *Exemplary scale.* The point to note is that the engineering activity related to the PI *research and gather information,* PI *Listen to other team mates* and two other PIs is not as trivial as is represented by the descriptors in Figure 4. Actually, even the language of these 4 PIs needs improvement as per the "*clarity of focus"* power principle of authentic OBE. But, we will leave this issue for the sake of brevity and continue our discussion on the topic of rubrics.

SO: Function effectively in multidisciplinary teams Dimension/PI	**Unsatisfactory 1**	**Developing 2**	**Satisfactory 3**	**Exemplary 4**
Research and gather information	Does not collect any information that relates to the topic	Collects very little information--some relates to the topic	Collects some basic information--most relates to the topic	Collects a great deal of information, all relates to the topic
Fulfill team roles duties	Does not perform any duties of assigned team role	Performs very little duties	Performs nearly all duties	Performs all duties of assigned team role
Share in work of team	Always relies on others to do the work	Rarely does the assigned work--often needs reminding	Usually does the assigned work--rarely needs reminding	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking – never allows anyone to speak	Usually does all the talking – rarely allows others to speak	Listens – but sometimes talks too much	Listens and speaks a fair amount

Figure 4: Analytic rubrics showing different dimensions/PIs and 4 scales for measuring ABET SO ''d' Function effectively on multidisciplinary teams [3]

Let us consider some typical engineering activities required for the proper assessment of just one dimension/PI *research and gather information.* Figure 5 shows some detail of engineering activities such as methods used for locating information; number of professional citations; engineering consultants contacted; engineering data collected from site/field visits; selection and assimilation of appropriate research information into team project efforts etc. Each of these five complex engineering activities is expressed with several descriptors in all 4 scales containing specific and clear technical language required for the comprehensive assessment and scoring of the PI *research and gather information*. This added detail in rubric development is a necessary requirement without which the rubrics actually lose the reliability and validity needed to precisely assess specific engineering activities. It shall be ironical, if for the new proposed ABET EAC SO, such as "an ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge" we still resort to few simplistic and generic PIs to comprehensively complete its assessment.

SO: Function effectively in multidisciplinary teams Dimension/PI	**Unsatisfactory 1**	**Developing 2**	**Satisfactory 3**	**Exemplary 4**
Research and gather information	1. Only one method used for locating information	2 methods used for locating information	3 methods used for locating information	5 or more methods used for locating information
	2. Less than 2 professional citations	3 professional citations	4 professional citations	5 or more professional citations
	3. No engineering consultants contacted	No engineering consultants contacted	1 engineering consultant contacted	2 engineering consultants contacted
	4. No site/field visits	No site/field visits	No site/field visits	Engineering Data collected from Site/field visits
	5. Inaccurate selection and assimilation of appropriate research information	Partially correct selection and assimilation of appropriate research information	Accurate selection and partial assimilation of appropriate research information	Accurate selection and complete assimilation of appropriate research information

Figure 5: Analytic rubrics showing just one PI research and gather information with 5 descriptors as performance criteria for each scale for measuring ABET SO 'd'

Now, as the discussion for assessment of several hundred engineering activities in any specialization continues and the conviction of the need for implementing a combination of a majority of specific and a minority of generic PIs deepens, we see more clearly that neither the holistic nor analytic rubrics can actually apply to accurately assess engineering student learning activities. Since the purpose of rubrics as stated earlier is validity: precise alignment with assessments; and reliability: accuracy of scoring details of student performance; Holistic rubrics will create major issues for reliability and analytic rubrics need several PIs, specific and generic, plus each PI or dimension, in fact should contain several descriptors for each scale as shown in the example of Figure 5.

To elucidate this point further let's take an example of two introductory, 200 level, courses from the Faculty of Engineering, EE program, *EE_261: Digital Logic Design* and *EE_282: Electromagnetic Field Theory*. An assessment for course *EE_261: Digital Logic Design* is related to implementing a Boolean function using specified logic gates, creating the truth table and expressing the same Boolean function in sum of min-terms form. To solve problems for this assessment, students need fundamental knowledge of Boolean algebra, creating truth tables, understanding of logic gates and knowledge of implementing digital circuits using logic gates. The other assessment for course *EE_282: Electromagnetic Field Theory* is related to computing the potential at various coordinates with given charge placed in free space. Problem solving for this assessment requires fundamental knowledge of electromagnetic theory coupled with basic math skills. The problem solving mechanisms for these various topics in the two 200 level EE courses are completely different, involving varying types of factual, conceptual and procedural engineering knowledge.

Now, the big question is, whether one generic set of problem solving rubrics could accurately apply to properly assess and precisely score both of these very different engineering activities, and deliver the validity, inter and intra-rater reliability required by the purpose of rubrics. What would happen to the quality of assessments if we should apply a generic set of PIs and rubrics to assess engineering activities from two courses, one from the senior and another from the junior levels? To expand the complexity of the problem further. How could we apply small set of generic rubrics to problem solving activities that relate to various learning levels of Bloom's cognitive domain? Activities could range from *applying*: pure and simple application of appropriate theory, math skills; *analyzing*: identify the problem, select appropriate theory and apply, derive/formulate, solve, apply math skills; *evaluating*: identify, select appropriate theory, derive/formulate, solve then interpret and evaluate the end result; or even *creating*: which involves complex combination of applying, analyzing, evaluating from the cognitive domain targeting application of theory, identification, solving problems, conducting experimentation, designing prototype, manufacturing, evaluating etc.

The ultimate level of complexity would be engineering activity that targets all learning levels in the cognitive, psychomotor and the affective domains of Bloom's taxonomy [49, 52]. Employing generic PIs and rubrics that cannot classify and assess complex engineering activity like design (see SO 'c' in Table 1.) and then finally give one score to a vast combination of skills relating to all 3 domains and several learning levels is nothing but a cocktail dessert with absolutely bad taste for CQI [10,11]. Such applications render the entire set of OBE power principles [7,8,10,11,12] void and the consequences are huge amounts of work, data collected, vague results, evaluation, feedback, CQI rendered ineffective and meaningless.

Prior to introducing the *Hybrid Rubrics,* we would like to once again reinforce the necessity of specific PIs and rubrics, with a reference to an exhaustive empirical research that reviewed 75 studies on rubrics, and summarized their benefits, with the top most benefit coming from rubrics that are *analytic, topic-specific, and complemented with exemplars and/or rater training* [69]:

The Hybrid Rubric:

The hybrid rubric is a combo of the holistic and analytic rubrics developed to address the issues related to validity: precision, accuracy of assessment alignment with outcomes, PIs; and inter, intra-rater reliability: detail of specificity of acceptable student performances; when dealing with assessment of complex and very specialized engineering activities. The hybrid rubric is an analytic rubric embedded with a holistic rubric to cater to the assessment of several descriptors that represent all the required major steps of specific student learning activity for each PI/dimension listed. Figure 6 shows an ABET SO 'e', problem solving, specific PI "*Simplify a given algebraic Boolean expression by applying the k-map and express in POS form*" and its hybrid rubric. The hybrid rubric also contains a column to indicate the percentage of total score allocation for each descriptor (major step of learning activity) corresponding to a certain PI. The scales implemented are obtained from Estell's FCAR [44,45], E, A, M and U performance vectors [59] that stand for the

Excellent: (100-90)%, Adequate: (89-75)%, Minimal (74-60)% and Unsatisfactory: (0-60)% categories respectively. The Office of Quality and Accreditation at the Faculty of Engineering has developed elaborate, step by step, instructional videos for developing hybrid rubrics for the CE [65], EE[66] and ME[67] programs. The appendix B provides a documented sample of hybrid rubrics development process from a workshop organized by the office of quality and accreditation for the CE program.

PI_5_1: SIMPLIFY A GIVEN ALGEBRAIC BOOLEAN EXPRESSION BY APPLYING THE K-MAP AND EXPRESS IN POS FORM

SCORING	UNSATISFACTORY (0-60%)	MINIMAL (60-75%)	ADEQUATE (75-90%)	EXCELLENT (90-100%)
1. 20%	1. **UNABLE/ABLE TO** Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.	1. Derive an accurate logical truth table for the given algebraic Boolean expression while properly identifying all inputs and output.
2. 20%	2. **UNABLE/ABLE TO** Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.	2. Develop the K-map representation of the information shown in the truth table with proper notations.
3. 35%	3. **UNABLE TO** Apply **OR INCORRECT** K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **MOST** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and **FAILURE IN** obtaining **SOME** prime implicants with max coverages	3. Apply K-Map simplification by mapping 0 minterms and obtaining prime implicants with max coverages
4. 25%	4. **UNABLE TO** Obtain AN UNsimplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain AN **UNsimplified** POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain **AN ALMOST** simplified POS Boolean expression by ANDing the minterms from prime implicants	4. Obtain simplified POS Boolean expression by ANDing the minterms from prime implicants

Figure 6: A specific PI and hybrid rubric for assessing ABET SO 'e' "*Ability to identify, formulate and solve engineering problems*"

The co-author's past famous work - four power principles of authentic OBE [7,8,10,12] are applied here as guidelines for the development and implementation of specific PIs and hybrid rubrics:

1. ***Clarity of focus***: Subject specialists within a program form sub-groups to select appropriate course content, topics, learning activities and their skills/complexity levels based on student standards for the development of specific PIs and their hybrid rubrics. The language of specific PIs and hybrid rubrics should have sufficient transparency in meaning to promote easy faculty comprehension and application resulting in perfect implementation of scientific constructive alignment and use of the "unique assessments" philosophy [22,24,38,35, 49, 50,,51, 63,64,70], where a single assessment does not map to more than one specific PI. The language of the specific PIs and descriptors should have an approximate correspondence with student learning activities, so both, students and faculty, can clearly understand the various scales of performance expectations.

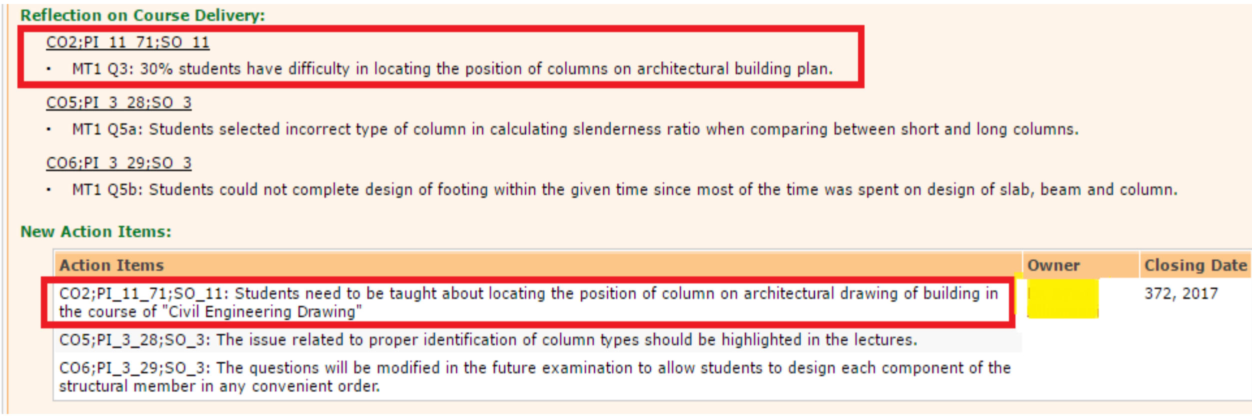
2. ***High expectations***: The Excellent scale 'E', of the hybrid rubric, should clearly identify required steps for excellent performance in using a specific *major method,* say 'M_i', for performing a certain task. A *major method* would be a complex engineering activity involving several unique steps for completing a specific task. There should be only one specific hybrid rubric designed to assess one major method or technique applied to complete a particular task. Any alternative *major methods*, say 'M_1, M_2..M_n', that complete the same task, let's say 'T', and deemed necessary curricular content by the instructor, should be assessed independently, with rubrics of their own. This would eradicate the possibility of producing "excellent" performing engineering graduates who have partial knowledge of necessary curricular content or lack required engineering skills.
3. ***Expanded opportunity***: Use hybrid rubrics and their descriptors to be consistent in rating assessments. Give the student prior notice on what is expected by rehearsing examples of problems indicated in the developed hybrid rubrics. Provide clear feedback on student graded work highlighting performance issues. Use criterion based standards and provide opportunities to improve based on some minimal required expectations. Weighted averaging should be used to scientifically score combination of assessments or performances of students [48,49,50,51]. Pure averaging to conduct quantitative evaluation of outcomes assessment should be strictly avoided [12].
4. ***Design down***: Develop PIs, hybrid rubrics in perfect alignment with institutional mission, PEOs, SOs and COs. For this mission statements and PEOs should be designed scientifically avoiding the use of vague and redundant language. Learning outcome and PIs information should be used for implementation of scientific constructive alignment to develop and align assessments, their teaching/learning strategies, scoring, evaluation, feedback and CQI efforts.

IV. Program, Course and Student Level CQI.

Contrary to the GR model's selective sampling of few courses, students for program evaluations as highlighted [3], the Faculty of Engineering has collected outcomes assessment data for *ALL* students, in *ALL* courses, by using the automated FCAR + specific PIs methodology. The principles of authentic OBE *"success and learning for ALL"* are implemented to conduct comprehensive course, student level evaluations resulting in holistic CQI. In this section we present few samples of program, course and student level evaluations and CQI.

Program Level Evaluation and CQI: The *Program Term Review* module of EvalTools® 6 consists of three parts i) *Learning Domains Evaluation* ii) *PIs Evaluation* and iii) *ABET SOs Evaluation* as per our specific requests and requirements. The PIs and SOs evaluation is focused on failing SOs and PIs for analysis and discussions relating to improvement [35,49,50,51,63,64]. Weighted average values of ABET SOs and PIs [45] with a scientific color coding scheme as per PVT heuristic rules shown in Figure 21 indicate failures for investigation. Courses contributing to failing PIs and SOs are examined [35,49,50,51,63,64]. The Faculty of Engineering has presented elaborate *youtube video presentations* that detail the automation of outcomes assessment, showing some Continuous Improvement Management System (CIMS) features such as action items elevation from the FCAR to task lists of standing committees for actual CQI [35,63,64].

Course Level Evaluation and CQI: Faculty members electronically port old action items status details from previous offerings of a certain course into the current FCAR. Modifications and proposals to a course are made with consideration of the status of the old action items. Program faculty report failing COs, their associated PIs, ABET SOs, comments on student indirect assessments and other general issues of concern in the respective *course reflections* section of the FCAR. Based upon these course reflections, new action items are proposed by the faculty [49,50,51]. The course reflections and action items maintain headings related to format CO_*N1*; PI_*N2*_*N3*; SO_*N2*; where *N1*: CO index; *N2*: ABET SO index (1 being 'a' and 11 being 'k'); and *N3*: PI index. Additionally, course reflections have to also mention the failing assessments in abbreviated form.


Reflection on Course Delivery:

CO2;PI_11_71;SO_11

- MT1 Q3: 30% students have difficulty in locating the position of columns on architectural building plan.

CO5;PI_3_28;SO_3

- MT1 Q5a: Students selected incorrect type of column in calculating slenderness ratio when comparing between short and long columns.

CO6;PI_3_29;SO_3

- MT1 Q5b: Students could not complete design of footing within the given time since most of the time was spent on design of slab, beam and column.

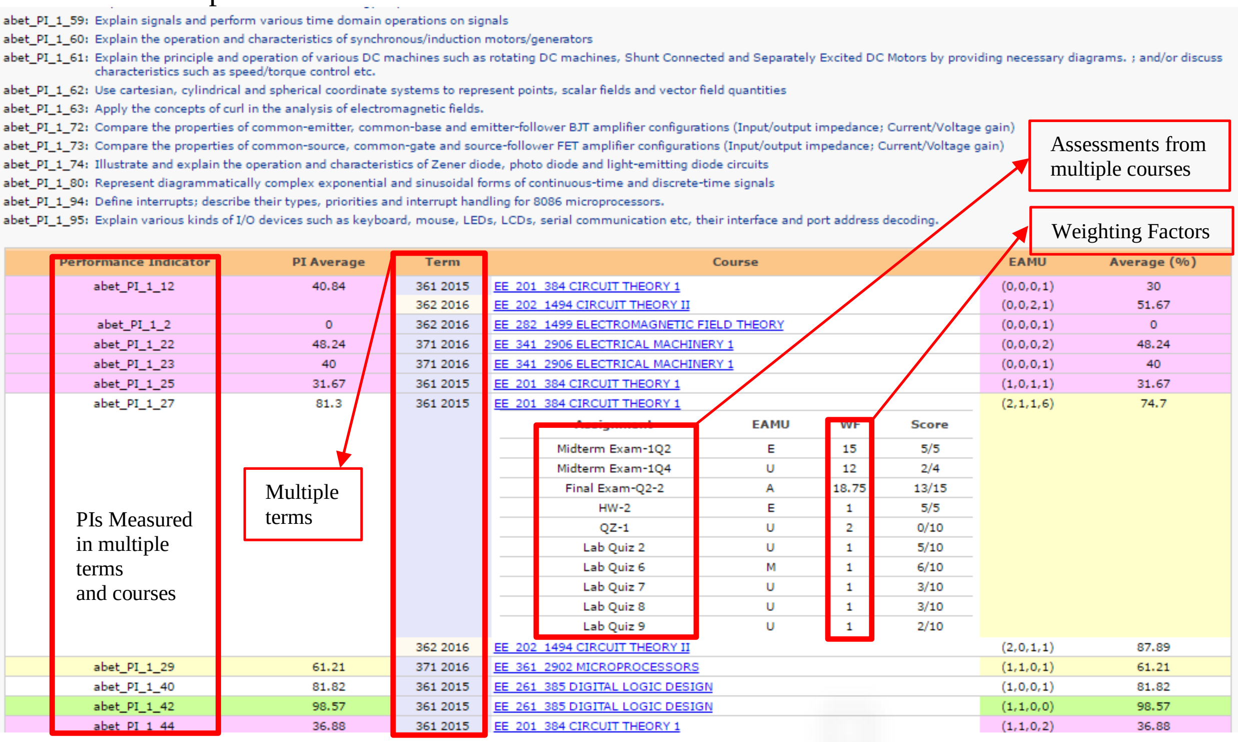
New Action Items:

Action Items	Owner	Closing Date
CO2;PI_11_71;SO_11: Students need to be taught about locating the position of column on architectural drawing of building in the course of "Civil Engineering Drawing"		372, 2017
CO5;PI_3_28;SO_3: The issue related to proper identification of column types should be highlighted in the lectures.		
CO6;PI_3_29;SO_3: The questions will be modified in the future examination to allow students to design each component of the structural member in any convenient order.		

Figure 7: Course CE_416, Reinforced Concrete Design-I, showing easy identification of root cause failures and CQI activity using specific PIs

Figure 7 shows for a CE course CE_416, Reinforced Concrete Design-I, the CO_2: *"Locate the position of columns, identify and designate the structural reinforced concrete members for the structural system"*; and PI_11_71: "*Locate the position of columns, identify and designate the structural reinforced concrete members (Slabs, beams, columns and footings) for the structural system by classifying the panel types of slabs*" is assessed using Mid Term-1 Q3 abbreviated as MT1 Q3 and corresponds to SO_11 or SO 'k': "*an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice*"; The performances in this assessment have failed and therefore, the failing CO, PI and ABET SO are headlined for reflections and action items. The reason for failure is documented in the reflections section. In this case, the reason was observed as, 30% students had difficulty in locating the position of columns on architectural building plans. It was noted, that a course offered earlier, *Civil Engineering Drawing*, never covered fundamental activity such as locating columns in architectural building plans. Therefore, the action item suggested, was to teach students about locating the position of columns on architectural drawings of buildings in course on *Civil Engineering Drawing*. However, this action item would have to be elevated to the program level since it is not the scope of faculty for redressal. Elevations are easily facilitated using CIMS technology provided by software EvalTools 6 ® [35,43,49,50,51,68].

Student Level Evaluation and CQI: The Faculty of Engineering has implemented a student advising system employing the FCAR + specific PIs classified per Bloom's domains and *3-Levels Skills Grouping* methodology, and EvalTools 6 ®. A youtube video also presents some detail of the features of this module and how individual student skills data is collected by using specific PIs, course assessments and integrated by faculty into academic advising [62]. Figure 8 illustrates a list of ABET SOs calculated from PIs measurements for a typical student evaluation. The student skills SOs data is realistic and corresponds closely with actual student performances since 15 essential elements of precision assessment [49,51,70] have been implemented to ensure outcomes data is as accurate as possible.


abet_PI_1_59: Explain signals and perform various time domain operations on signals
abet_PI_1_60: Explain the operation and characteristics of synchronous/induction motors/generators
abet_PI_1_61: Explain the principle and operation of various DC machines such as rotating DC machines, Shunt Connected and Separately Excited DC Motors by providing necessary diagrams. ; and/or discuss characteristics such as speed/torque control etc.
abet_PI_1_62: Use cartesian, cylindrical and spherical coordinate systems to represent points, scalar fields and vector field quantities
abet_PI_1_63: Apply the concepts of curl in the analysis of electromagnetic fields.
abet_PI_1_72: Compare the properties of common-emitter, common-base and emitter-follower BJT amplifier configurations (Input/output impedance; Current/Voltage gain)
abet_PI_1_73: Compare the properties of common-source, common-gate and source-follower FET amplifier configurations (Input/output impedance; Current/Voltage gain)
abet_PI_1_74: Illustrate and explain the operation and characteristics of Zener diode, photo diode and light-emitting diode circuits
abet_PI_1_80: Represent diagrammatically complex exponential and sinusoidal forms of continuous-time and discrete-time signals
abet_PI_1_94: Define interrupts; describe their types, priorities and interrupt handling for 8086 microprocessors.
abet_PI_1_95: Explain various kinds of I/O devices such as keyboard, mouse, LEDs, LCDs, serial communication etc, their interface and port address decoding.

Performance Indicator	PI Average	Term	Course	EAMU	Average (%)
abet_PI_1_12	40.84	361 2015	EE 201 384 CIRCUIT THEORY 1	(0,0,0,1)	30
		362 2016	EE 202 1494 CIRCUIT THEORY II	(0,0,2,1)	51.67
abet_PI_1_2	0	362 2016	EE 282 1499 ELECTROMAGNETIC FIELD THEORY	(0,0,0,1)	0
abet_PI_1_22	48.24	371 2016	EE 341 2906 ELECTRICAL MACHINERY 1	(0,0,0,2)	48.24
abet_PI_1_23	40	371 2016	EE 341 2906 ELECTRICAL MACHINERY 1	(0,0,0,1)	40
abet_PI_1_25	31.67	361 2015	EE 201 384 CIRCUIT THEORY 1	(1,0,1,1)	31.67
abet_PI_1_27	81.3	361 2015	EE 201 384 CIRCUIT THEORY 1	(2,1,1,6)	74.7
		362 2016	EE 202 1494 CIRCUIT THEORY II	(2,0,1,1)	87.89
abet_PI_1_29	61.21	371 2016	EE 361 2902 MICROPROCESSORS	(1,1,0,1)	61.21
abet_PI_1_40	81.82	361 2015	EE 261 385 DIGITAL LOGIC DESIGN	(1,0,0,1)	81.82
abet_PI_1_42	98.57	361 2015	EE 261 385 DIGITAL LOGIC DESIGN	(1,1,0,0)	98.57
abet_PI_1_44	36.88	361 2015	EE 201 384 CIRCUIT THEORY 1	(1,1,0,2)	36.88

Assignment	EAMU	WF	Score
Midterm Exam-1Q2	E	15	5/5
Midterm Exam-1Q4	U	12	2/4
Final Exam-Q2-2	A	18.75	13/15
HW-2	E	1	5/5
QZ-1	U	2	0/10
Lab Quiz 2	U	1	5/10
Lab Quiz 6	M	1	6/10
Lab Quiz 7	U	1	3/10
Lab Quiz 8	U	1	3/10
Lab Quiz 9	U	1	2/10

Figure 8: SO_1, 'a', individual student's skills data measured by multiple raters using several PIs in multiple courses, types of assessments, terms and applying weighting factors WF

V. Conclusion

The demand for higher education is ever on the increase, with student achievement and accountability posing the biggest challenges to improving the quality of higher education. In order to meet these challenges, an OBE model for student learning, along with several quality standards in higher education have been adopted by accreditation agencies and educational institutions over the past two decades. With thousands of institutions and programs in a tight race for rank and accreditation, the prevalent understanding and implementation of authentic OBE and CQI needs clarification. This paper has presented research detailing some aspects of traditional assessment models that are in conflict with the principles and purpose of authentic OBE models and have widened the gap between accreditation and actual CQI in engineering education. Lack of clarity, and specificity, in the language of learning outcomes, PIs, rubrics and manual processes are at the crux of the CQI problem as explained in the various sections of this paper.

Quality assurance agencies such as IEA, ABET, MSCHE etc. have achieved a great deal in terms of establishing a major paradigm shift from curricular based education systems to OBE in the United States and worldwide by reaching out to several thousands of programs and institutions. The benefits of partial and incremental implementation of OBE philosophy over more than two decades has significantly transformed the face of education today. Faculty culture, teaching and learning strategy, curriculum content and delivery, students' skills, and employers' outlook have all been reformed to a very fertile state, ready to embrace standards of authentic OBE systems. The dilemma facing ABET, and other quality assurance agencies is that they have clear intent to implement authentic OBE philosophy, for achieving student success, but due to practical limitations related to manual processes, documentation, reporting, and resources, they cannot propose measurement of outcomes, specific PIs, evaluation, feedback and CQI efforts for all students, as the gold standard for accreditation. We have currently reached a juncture, where the greatest setback to OBE implementation is the gap that exists between outcomes assessment processes and CQI efforts. The author has been in many programs' accreditation rooms that remain locked up, are given limited access, opened by assigned personnel or the independent raters and contain student objective evidence records. It is practically impossible, for CQI to be achieved, when outcomes information is not instantly accessible, remains locked up, and piled up within thousands of documents.

The purpose of quality assurance agencies and educational institutions is not fulfillment of minimum accreditation requirements, but establishing essential OBE standards that promote holistic CQI, learning and success for all. In conclusion, this is the right moment for quality assurance agencies and educational institutions to embark on a quest to seek solutions that incorporate such outcomes assessment methodology, which supports implementation of state of the art technology to streamline and automate assessment, evaluation, reporting and CQI to fulfill accreditation criteria that are fully aligned with authentic OBE. The assessment model using FCAR, specific PIs classified per Bloom's 3 domains and 3-levels skills, their hybrid rubrics integrated with state of the art, web based software, such as EvalTools 6 ®, present a viable solution to educational institutions for the implementation of accreditation requirements that fully support the principles of authentic OBE and holistic CQI.

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Appendix A: IEA profiles for graduate attributes and competencies

1. IEA knowledge profile for practicing engineers, engineering technologist and technicians

5.1 Knowledge profile

A Washington Accord programme provides:	**A Sydney Accord programme** provides:	**A Dublin Accord programme** provides:
WK1: A systematic, theory-based understanding of the **natural sciences** applicable to the discipline	**SK1:** A systematic, theory-based understanding of the **natural sciences** applicable to the sub-discipline	**DK1:** A descriptive, formula-based understanding of the **natural sciences** applicable in a sub-discipline
WK2: Conceptually-based **mathematics**, numerical analysis, statistics and formal aspects of computer and information science to support analysis and modelling applicable to the discipline	**SK2:** Conceptually-based **mathematics**, numerical analysis, statistics and aspects of computer and information science to support analysis and use of models applicable to the sub-discipline	**DK2:** Procedural **mathematics**, numerical analysis, statistics applicable in a sub-discipline
WK3: A systematic, theory-based formulation of **engineering fundamentals** required in the engineering discipline	**SK3:** A systematic , theory-based formulation of **engineering fundamentals** required in an accepted sub-discipline	**DK3:** A coherent procedural formulation of **engineering fundamentals** required in an accepted sub-discipline
WK4: Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.	**SK4:** Engineering **specialist knowledge** that provides theoretical frameworks and bodies of knowledge for an accepted sub-discipline	**DK4:** Engineering **specialist knowledge** that provides the body of knowledge for an accepted sub-discipline
WK5: Knowledge that supports **engineering design** in a practice area	**SK5:** Knowledge that supports **engineering design** using the technologies of a practice area	**DK5:** Knowledge that supports **engineering design** based on the techniques and procedures of a practice area
WK6: Knowledge of **engineering practice** (technology) in the practice areas in the engineering discipline	**SK6:** Knowledge of **engineering technologies** applicable in the sub-discipline	**DK6:** Codified **practical engineering knowledge** in recognised practice area.
WK7: Comprehension of the role of engineering in society and identified issues in engineering practice in the discipline: ethics and the professional responsibility of an engineer to public safety; the impacts of engineering activity: economic, social, cultural, environmental and sustainability	**SK7: Comprehension of** the role of technology in society and identified issues in applying engineering technology: ethics and impacts: economic, social, environmental and sustainability	**DK7: Knowledge** of issues and approaches in engineering technician practice: ethics, financial, cultural, environmental and sustainability impacts
WK8: Engagement with selected knowledge in the **research literature** of the discipline	**SK8:** Engagement with the **technological literature** of the discipline	
A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 4 to 5 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 3 to 4 years of study, depending on the level of students at entry.	A programme that builds this type of knowledge and develops the attributes listed below is typically achieved in 2 to 3 years of study, depending on the level of students at entry.

2. IEA problem solving profile for practicing engineers, engineering technologist and technicians

4 Common Range and Contextual Definitions

4.1 Range of Problem Solving

References to the Knowledge Profile are shown thus: (WK3, WK4 ...)

In the context of both Graduate Attributes and Professional Competencies:			
Attribute	***Complex Engineering Problems*** have characteristic WP1 and some or all of WP2 to WP7:	***Broadly-defined Engineering Problems*** **have characteristic SP1 and some or all of SP2 to SP7:**	***Well-defined Engineering Problems*** have characteristic DP1 and some or all of DP2 to DP7:
<u>Depth of Knowledge Required</u>	**WP1:** Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach	**SP1:** Cannot be resolved without engineering knowledge at the level of one or more of SK 4, SK5, and SK6 supported by SK3 with a strong emphasis on the application of developed technology	**DP1:** Cannot be resolved without extensive practical knowledge as reflected in DK5 and DK6 supported by theoretical knowledge defined in DK3 and DK4
Range of conflicting requirements	**WP2:** Involve wide-ranging or conflicting technical, engineering and other issues	**SP2:** Involve a variety of factors which may impose conflicting constraints	**DP2:** Involve several issues, but with few of these exerting conflicting constraints
Depth of analysis required	**WP3:** Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models	**SP3:** Can be solved by application of well-proven analysis techniques	**DP3:** Can be solved in standardised ways
Familiarity of issues	**WP4:** Involve infrequently encountered issues	**SP4:** Belong to families of familiar problems which are solved in well-accepted ways	**DP4:** Are frequently encountered and thus familiar to most practitioners in the practice area
Extent of applicable codes	**WP5:** Are outside problems encompassed by standards and codes of practice for professional engineering	**SP5:** May be partially outside those encompassed by standards or codes of practice	**DP5:** Are encompassed by standards and/or documented codes of practice
Extent of stakeholder involvement and conflicting requirements	**WP6:** Involve diverse groups of stakeholders with widely varying needs	**SP6:** Involve several groups of stakeholders with differing and occasionally conflicting needs	**DP6:** Involve a limited range of stakeholders with differing needs
Interdependence	**WP 7:** Are high level problems including many component parts or sub-problems	**SP7:** Are parts of, or systems within complex engineering problems	**DP7:** Are discrete components of engineering systems
In addition, in the context of the Professional Competencies			
Consequences	**EP1:** Have significant consequences in a range of contexts	**TP1:**Have consequences which are important locally, but may extend more widely	**NP1:** Have consequences which are locally important and not far-reaching
Judgement	**EP2:** Require judgement in decision making	**TP2:** Require judgement in decision making	

Appendix B: Hybrid Rubrics Example:
Civil Engineering Hybrid rubrics development workshop

OFFICE OF QUALITY & ACCREDITATION WORKSHOP 1Oth OCTOBER 2016, 8-9:30 AM

PROGRAM:	CIVIL ENGINEERING
PROGRAM COORDINATOR:	[redacted]
ABET COORDINATOR:	[redacted]

1	COURSE TITLE:	CE 312 STRUCTURAL ANALYSIS I
2	COURSE OUTCOME:	Explain the various classical methods used to analyze indeterminate and determinate structures
3	PERFORMANCE INDICATOR:	Use different methods for analysis of indeterminate structures
4	ABET STUDENT OUTCOME:	an ability to identify, formulate, and solve engineering problems
5	HIGHEST EXPECTATION STUDENT ACTIVITY (SEQUENTIAL WITH ALL GRADABLE MAJOR STEPS INDICATED) :	1. Determine the method for the given cases of indeterminate structural components 2. Formulate the mathematical solution for the given indeterminate structural components 3. Apply the suggested method by properly labeled free hand sketches

RUBRIC DEVELOPMENT

Score	Excellent (90-100%)	Adequate (75-89%)	Minimal (60-75%)	Unsatisfactory (0-60%)
30%	1. Explain all applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Explain applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Explain at least one of the applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components	1. Unable to explain even one of the applicable methods like slope deflection, force deformation method, moment distribution accurately for the given cases of indeterminate structural components OR
30%	2. Formulate the mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Formulate at least two of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Formulate at least one of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method	2. Unable to formulate at least one of given methods' mathematical solution accurately for the given indeterminate structural components by applying the selected method OR
40%	3. Apply the suggested method by properly labeled free hand sketches. All the labels should thoroughly indicate all parameters in the applied formula	3. Apply the suggested method by properly labeled free hand sketches. Majority of the labels should thoroughly indicate most parameters in the applied formula	3. Apply the suggested method by properly labeled free hand sketches. Some of the labels should thoroughly indicate most parameters in the applied formula	3. Unable to apply the suggested method by properly labeled free hand sketches. Some of the labels should thoroughly indicate most parameters in the applied formula