Course Specific Performance Indicators Based Quality Improvement by Using Bloom's 3 Domains in Information Technology Program

Dr. Arshad Ali

Assistant Professor, Coordinator of Quality and Accreditation, Faculty of Computer and Information Systems, The Islamic University of Madinah, Al Madinah Al Munawarah, Saudi Arabia - 42351

Abstract: *This paper presents the examples of the quality improvement efforts to enhance students learning in Information Technology education by employing a novel program evaluation methodology that automates ABET Students Outcomes (SO's) data measurement and analysis based on the classification of specific performance indicators per Bloom's 3 domains and their learning levels. The levels are further subdivided based on a 3 level skills grouping methodology that groups together learning levels of related proficiency. Program evaluation use aggregate values of ABET SO's as an overall performance index. These values are calculated by assigning weights to measured specific performance indicators according to the Frequency – Hierarchy Performance Factors (FCAR) scheme, which incorporates a hierarchy of measured skills, course levels in which they are measured and counts of assessments implemented for their measurement. Specific Performance Indicators (PI's) has been developed as per course outcome and each performance indicator has been assessed multiple time during the whole term and based on the weighting factor table, according to assessment type the each assessment assigned specific weight and combined all the values to the performance indicator achievement.*

The number of assessments processed for measurement of performance indicators associated with the 3 categories of skills in multiple course levels is counted to calculate percentage learning distribution in the elementary, intermediate and advanced levels for the 3 learning domains. Learning distributions obtained for measured ABET SOs are compared to ideal models to verify standards of achievement for required types of skills, proficiency levels and align information technology curriculum delivery to attain highest levels of holistic learning.

Keywords: *Bloom's Domains, Learning Domains, Outcomes Assessments, ABET, Student Outcomes, Skills, Learning Levels, Performance Indicators*

1. Introduction

A number of articles has been published by National Institute of Learning Outcomes Assessment (NILOA) [2] and others [1, 3] which noticeably state that in many higher education institutions, Continuous Quality Improvement (CQI) and accreditation efforts are minimally integrated. Preferably, CQI instead of accreditation standards should be the prime driver for outcomes based assessment method [5]. Undisputedly, digital technology is very important automate and streamline outcomes based assessment for the accreditation is mainly explained in many research papers [4].To achieve the accreditation and excellent CQI results based on outcome assessment, the state of the art digital technology system would be very helpful in this regard. This paper specifically explains the results of integration of fundamental concepts of the Outcomes Based Education (OBE) model with world-class best practices in outcomes assessment and web-based software EvalTools®6, deployed with significant customizations. Computing and Accreditation Commission (CAC) currently using 14 SO's for Information Technology Program that utilize manual processes.

The learning outcomes, as measured by most IT program, are rarely divided into three learning domains in the revised bloom taxonomy [5] and their respective categories of learning levels. In general, institutions classify courses into a curriculum at three levels: introductory, reinforced, and mastery with measurement data for measured outcomes for mastery level courses in order to optimize documentation and efforts for effective evaluation programs. This approach has major deficiency for CQI in a student-centred, OBE model, because performance information collected at just the mastery level is at the final phase of a typical quality cycle and occurs too late for implementation of remedial efforts.

Instead, the results and performance criteria of the student must be measured from the basic to the advanced level at the teaching course for all courses throughout the program [5, 6]. A holistic approach to a CQI model would require a systematic measurement of the specific performance indicators (PIs) in all 3 domains of learning of Bloom's taxonomy and their corresponding categories of learning levels, for all course levels of a given program's curriculum. As a result, a digital PI bank containing a number of precisely defined specific PIs was developed for the Information Technology programs through the three learning domains and Bloom Learning Levels related to ABET SO, Specific PIs, measured at all levels, gave the faculty members accurate information for the course and program evaluation and subsequent improvements. In OBE model, the learning quality is improved based on the formative assessment as it provide the precise information for improvement. Given the fact that assessment is an essential part of the education process and is the basis of CQI, a new technique has been implemented to assess the distribution of learning through an Information Technology program for a particular term in the three Bloom Domains and their learning levels.

The comprehensive assessment strategy for each ABET SO and the estimation of program level is provided in the three-phase, SO's, PI's and learning domain evaluation modules' term summery. The term "summary" contains detailed information about the nature of the assessments used, their course levels, counts, learning distributions and skill levels of the associated performance indicators measured and can be referred to in our previous work [5]. All deficiencies in the current assessment models for the measured ABET-SO are identified by a detailed procedure for reviewing the 3 phase program term review process conducted by the faculty members. The alignment of student teaching and learning processes, by implementation of outcomes assessments to cover the 3 broad skills levels in all of the 3 Bloom's domains according to pre-set target percentage distribution levels presents an exciting, new frontier in holistic quality improvement methodologies to achieve the highest education standards for Information Technology program.

2. Material and Method

This section explains the assessment method which is used to measure the performance indicators which is more holistic with specific performance criteria for the cognitive, affective, and psychomotor domains.

2.1. Cognitive Domain

The cognitive domain refers to how a student acquires processes and uses knowledge. This is the 'thinking' domain which focuses on intellectual skills and is known to educators. Bloom's taxonomy cognitive domain further subdivided as (**remembering, understanding, applying, analyzing, evaluating and creating**) is often used to describe the increasing complexity of the cognitive skills, students move forward from a beginner to more advance level in their knowledge. The cognitive domain is core of the learning domain. The cognitive domain is well suited for the online assessment environment. As we move further the cognitive domain, especially in the synthesis and evaluation, we have collaborative tasks where the students solve the problem or the project-based activities are an important means of determining whether or not students have reached this level of learning. Moreover, higher cognitive abilities give students the opportunity to develop interpersonal learning skills. Figure 1 shows the further division of the psychomotor domain

Fig. 1. Various levels of cognitive domain

2.2. Affective Domain

The affective domain is crucial for learning, but is often not specifically addressed. This domain specifically focuses on attitudes, motivation, willingness to participate, values that are learned and ultimately integrate disciplinary values into reality. Bloom's taxonomy further sub divided as (**receiving phenomena, responding to phenomena, valuing, organize values into priorities, internalizing values**) is often describe is not as sequential as the cognitive domain is often used to describe. Figure 2 shows the further division of the psychomotor domain

Fig. 2. Various levels of affective domain

The instructor expects the student willingness to patriciate in teaching- learning activities, to spend some effort in their classes and to support the efforts made during the course. Students go to the next higher level course in the curriculum because they appreciate what they have learned. The affective domain is not just handled by using only lecture slides, it need class meetings to support to enhance the skills further. While designing the CO's for the courses to address affective domain, the instructor should the input from the alumni, academic advisory panel members, industry advisory panel members, lecturers, and other stakeholders.

2.3. Psychomotor Domain

The psychomotor domain focuses on the execution of practical activity with a certain level of skills in networking, graphical programming, etc. and the subject of kinetic activity is cognitive understanding. In the context of higher education, psychomotor learning may be included in the following contents:

- Course with Lab
- Summer training
- Networks courses
- Term projects

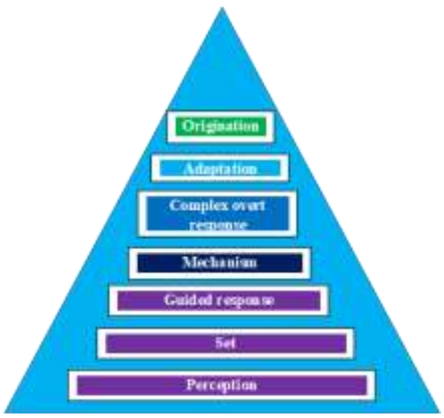


Fig. 3. Various levels of psychomotor domain

Bloom's taxonomy further sub divided as (**perception, set, guided response,**

mechanism, complex overt response, adaption, and origination). The psychomotor domain is better evaluated in a face to face environment. Figure 3 shows the further division of the psychomotor domain.However, the student must ultimately complete the competency with an instructor or assess whether the competency has been performed according to a defined standard.

3. Information Technology Program Evaluation

3.1. Assessment Methodology

The Faculty of Computer and Information System at the Islamic University of Madinah has studied various options for developing its assessment methodology and systems for the Information Technology Program [8,9] to establish actual CQI and not just to fulfil ABET accreditation requirements [7]. After long discussion jointly with the Faculty of Computing and Information Systems at the Islamic University of Madinah. The following points summarize the essential elements chosen by the faculty to implement state-of-the-art assessment systems for achieving realistic CQI in computing education [5]:

1. OBE assessment model is followed in the assessment method

2. ABET, CAC outcomes assessment model employing Program Educational Objectives (PEOs), 1 CAC SOs and PIs to measure Course Outcomes (COs)

3. Measurement of outcomes information in all course levels of a program curriculum: introductory, reinforced and mastery.

4. The Faculty Course Assessment Report (FCAR) utilizing the Excellent, Adequate, Minimal, and Unsatisfactory (EAMU) performance vector methodology [10]

5. Well-defined performance criteria for course and program levels

6. A digital database of specific PIs [12] classified as per Bloom's revised 3 domains of learning and their associated levels (according to the 3-Level Skills Grouping Methodology)

7. Unique Assessments mapping to one specific PI [11]

8. Integration of direct, indirect, formative and summative outcomes assessments for course and program evaluations

9. Calculation of program and course level ABET SOs, COs data based upon weights assigned to various types of assessments, PIs and course levels

10. Course, program, and student level measurement and analysis of ABET SOs [11]

11. The Program Term Review module of EvalTools® 6 consisting of 3 parts a) Learning Domains Evaluation b) PIs Evaluation and c) ABET SOs Evaluation [13]

12. A student academic advising module related to measured outcomes data

13. Electronic integration of Action Items (AIs) generated from program outcomes term reviews with the Faculty of Computing and Information Systems standing committees' meetings, tasks, lists and overall CQI processes (CIMS feature).

3.2. CO's Specific PI's and Associated Assessments Classification Based Upon the Revised Bloom's 3 Domains and Their Learning Levels

COs are assessed directly using the performance of students in Performance Indicators (PIs). PIs are course outcome specific learning outcomes that define the key articulation for each one of the Course Outcomes (COs). Course outcomes are defined and their performance indicators along with the curriculum mapping. In each academic year data were collected and evaluated from all courses that were offered in each term. Student Outcomes directly evaluated by using the assessment of course specific PIs one for CO and it is clear that all PIs for each course are assessed directly using the performance of students. Each faculty member must prepare an

FCAR for each course he is teaching. FCAR contains the achievements levels of each PI's their COs and the associated SOs. In the FCAR, the faculty must propose action items according the achievements of PIs.

Therefore COs would be measured by PIs and assessments strictly following the 3-Level Skills Grouping Methodology

Skills Level	Cognitive Domain (Bloom, 1956; Anderson & Krathwohl, 2001)	Affective Domain (Krathwohl, Bloom & Masia, 1973)	Psychomotor Domain (Simpson, 1972)
Elementary	1. Knowledge 2. Comprehension	1. Receiving phenomena 2. Responding to phenomena	1. Perception 2. Set 3. Guided response
Intermediate	3. Application 4. Analysis	3. Valuing	4. Mechanism 5. Complex overt response
Advanced	5. Evaluation 6. Creation	4. Organizing values into problems 5. Internalizing	6. Adaptation 7. Origination

Fig. 4. 3-Level skills grouping methodology of Bloom's revised taxonomy

4. Weighting Factor Scheme for Multiple Learning and Course Levels

Different weight has been assigned to the various. Assessment based on the importance of the assessment.

Combination of two critical factors: (a) to implement a hierarchy of skills by giving prevalence to those assessments that measure skills of the highest order over others. For example, mastery- advanced level PIs will have a higher prevalence than those for the reinforced-advanced level; and (b) to consider the counts of assessments implemented in a certain learning level due to the fact that outcomes assessment is directly equivalent to learning. Table 1 shows the calculation of weighting factors for various learning levels of the reinforced and introductory courses, which are then applied to measured PIs in given course the hierarchy of the skills levels.

Table 1 shows the *Learning Distribution % (LD)* column (refer Equation (1) shows percentage of total assessments actually implemented in all courses for various learning levels. Table 2. Shows that for ABET SO 'a' (SO_1), all assessments were implemented in introductory and Reinforced Elementary level courses measuring PIs for all domains composite, which accounted for 14.3% of learning

$$LD(i) = \frac{count(i)}{Total\ count} \times 100 \qquad (1)$$

Table 1: Weighting Factors calculation for various learning level introductory and reinforce courses

Course level- PI level	Counts(i) in term 371	%Learning Distribution [LD(i)]	% Progressive Distribution [PD(i)]	% Relative Distribution [RD(i)]	Weights WF(i) = LD(i) x RD(i)
	DATA FROM EVALTOOLS	{counts(i)/total}×100	∑ LD(i)	{PD(i)}/Min{LD(i)}	{LD(i) × RD(i)}
MASTERY-ADV	2	0	100	7.94	0.00
MASTERY-INTER	8	0	100	7.94	0.00
MASTERY-ELEM	39	8.6	100	7.94	68.25
REINFORCED-ADV	2	0	91.4	7.25	0.00
REINFORCED-INTER	8	9.1	91.4	7.25	66.01
REINFORCED-ELEM	39	65.1	82.3	6.53	425.22
INTRODUCTORY-ADV	0	0	17.2	1.37	0.00
INTRODUCTORY-INTER	14	4.6	17.2	1.37	6.28
INRTODUCTORY-ELEM	10	12.6	12.6	1.00	12.60
TOTAL	122				

The *Progressive Distribution % (PD)* (refer Equation (3)) column values are calculated by summing *LD* values according to the hierarchy of the skills levels (with reinforced-advanced assigned the highest value in this case since mastery level courses were not offered in term 371).

$$PD(i) = \sum_1^i LD(i) \qquad (2)$$

The *Relative Distribution % (RD)* (refer Equation (4)) column values are calculated by dividing the *PD(i)* value with *LD(m):* the non-zero minimum value (learning level *'m'*) of the set of *LD* values corresponding to all the learning levels *1 to i.*

$$RD(i) = \frac{PD(i)}{Min{-}non{-}zero\,\{LD(1),LD(2),\ldots.LD(i)\}} \qquad (3)$$

The *Weighting Factors WF(i)* for the various measured learning levels (refer Equation (5)) for ABET SO 'a' (SO_1) are calculated by multiplying *LD(i)* with *RD(i).*

$$WF(i) = LD(i) \times RD(i) \qquad (4)$$

5. Results and Discussions

Steps Employed By EvalTools® to Calculate the EAMU Vectors

1. Faculty use EvalTools® *Assignment Setup Module* to identify an assignment with a set of specific questions, or split an assignment to use a specific question or sub question for outcomes assessment with relative high coverage of a certain PI mapping to CO, ABET SO (for EAMU calculation).
2. EvalTools® calculates for each student the weighted average percentage on the assessments, a set of questions selected by faculty. Weights for assessments are set according to the product of their percentage in the course grading scale and multiplication factor based on the course format and are entered in the weighting factor section of the *Assignment Setup Module*.
3. EvalTools® uses the average percentiles to determine how many students fall into the EAMU categories using the pre-selected EAMU assessment criteria.
4. EvalTools® calculates the EAMU average rating by rescaling to 5 for a weighted average based on a 3 point scale as shown in Equation (1).

$$EAMU\ average = \frac{3*E+2*A+1*M+0*U}{E+A+M+U} * \left(\frac{5}{3}\right) \quad (5)$$

Table 2 shows an example of how EAMU vectors are computed for a specific PI. Assessments HW3 and HW8 are selected for measuring a specific PI ABET_PI_5_3. These assessments are weighted according to course grading policy and multiplication factor. Let's say the weights are 5% for HW3 and 7% for HW8. The weighted score is computed as follows:

$$\%\ \text{weighted average} = \left(\frac{20}{30} * wf1 + \frac{40}{60} * wf2\right) / (wf1 + wf2) * 100$$
$$= \left(\frac{20}{30} * 5 + \frac{40}{60} * 7\right) / (5 + 7) * 100$$
$$= 66.67$$

The PI EAMU vector (3,1,1,2) for the entire class in the last column is obtained based on the count of students belonging to each of the categories as defined by: Excellent: scores >= 90%; Adequate: scores >= 75% and < 90%; Minimal: scores >= 60% and < 75%; and Unsatisfactory: scores < 60%. In this case, there are 3 students with scores belonging to E; one student in A; one student in M; and two students in U categories. Finally the weighted average of the EAMU vector for this specific PI_5_3 is 2.86, which is obtained as given by Equation (1).

Table 2: Calculation of aggregated EAMU for a PI's

Student	abet_PI_5_3	Hw3 (30)	% weighted (wf=5%)	Hw8 (60)	% weighted (wf=7%)	Percent-weighted
student 1	M	20	3.33	40	4.67	66.67
student 2	U	10	1.67	8	0.93	21.67
student 3	E	30	5.00	57	6.65	97.08
student 4	U	26	4.33	10	1.17	45.83
student 5	E	28	4.67	60	7.00	97.22
student 6	E	29	4.83	53	6.18	91.81
student 7	A	29	4.83	40	4.67	79.17
	EAMU	(4,1,1,1)		(2,1,2,2)		(3,1,1,2)
	Average	3.81		2.38		2.86

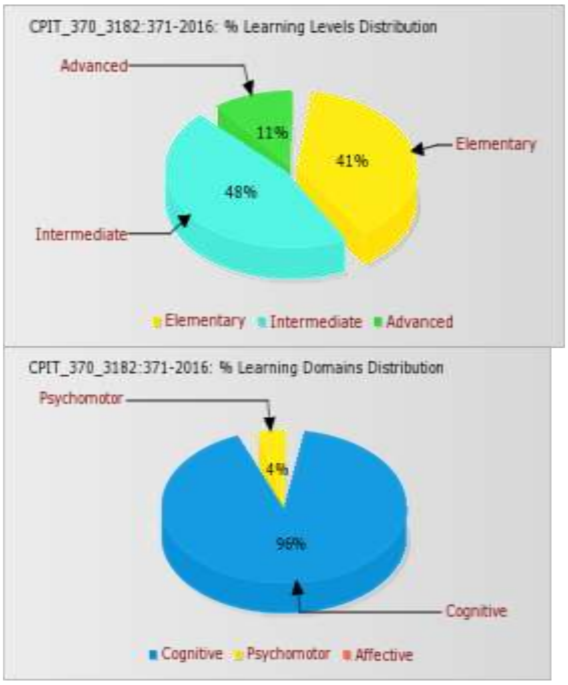


Fig. 5. % Learning level distribution in Computer Network CPIT_370_3182_ 2016-2017

Fig. 5 shows a course delivery alignment example, where a reinforced level course, Computer Networks, CPIT_370_3182, in a real-time, course-level learning domains evaluation. Figure above shows learning levels distribution achievement for CPIT_370_3182 for the term 372 in 2016-2017. It shows that affective domain is not measured at all and psychomotor just have the share of 4% due to course outcome distribution for different domains.

The program level ABET SO evaluations employ a weighting scheme, which considers the frequency of assessments implemented in various courses for a given term to measure PIs associated with specific learning levels of Bloom's domains. Figure 2 shows the IT program term First Semester (2015/2016) composite (cognitive, affective and psychomotor) learning domains evaluation data for 14 ABET SOs.

Fig. 6. Learning domains evaluation for IT program

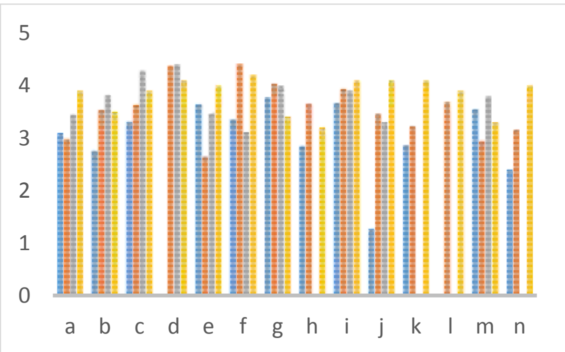
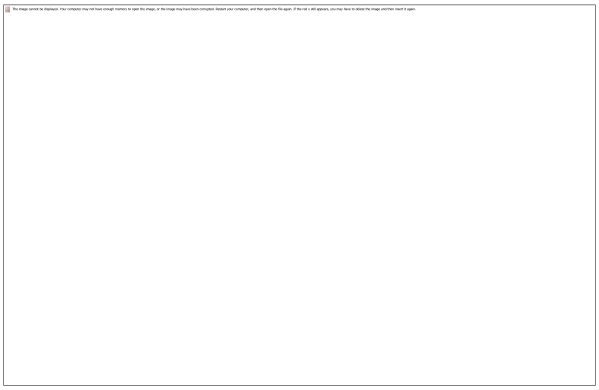


Fig. 7. Evaluation Results of SOs for Academic Years 2015-2016 and 2016-2017

The below bar chart depicts the achievement levels of SOs ('a' to 'n') for the past four academic semesters. The figure shows that student outcomes'd', 'f', and 'i' performed better than the remaining SOs.

The figure 8 shows learning domain % contribution the Information Technology program assessment for the term 371(1st Semester 2016-17) and the achievement level of each domain.



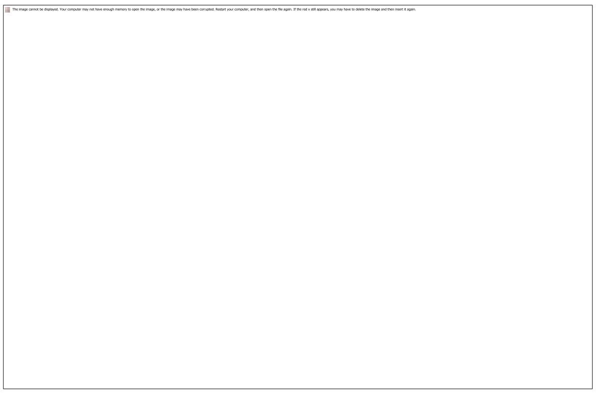


Fig. 8. %Learning domain distribution and the achievement

Several PIs were developed for the lab experimentation and design work to cover all 3 domains. Special equipment containing PI's and assessment strategies with a focus on analysis of final design to fulfil realistic constraints are in the developmental phase for measurement of various skills levels in all 3 learning domains in the senior design courses.

All skills levels in the affective and psychomotor domains are difficult to measure for a computing curriculum since they require specific, complex equipment with significant amounts of resources allocation for implementation of valid assessment processes. An important observation is that the comprehensive coverage of all the Bloom's learning levels for each ABET SO is not a trivial process and requires multi-term measurement and analysis of all courses and relevant assessments processed in a complete cycle of any computing curriculum.

6. Conclusion

This paper presents a new method of evaluating program outcomes by using web based software EvalTools® 6, to analyze the program learning distribution information in Bloom's 3 domains based on the counts of assessments processed in multiple course and skills levels of Information Technology curriculum. This learning distribution information provides information technology program with a wealth of detail on all current ABET SO's assessment plans and helps to control future changes in real time or in order to achieve optimal distribution coverage in different areas of learning and their level of learning. This CQI activities would result in alignment of the program, learning outcomes of the course, associated PI's with assessments and learning strategies aligned to produce the required skill areas, areas of learning and coverage for different technical specialties. Information Technology programs using this approach would generate and classify CO's and their PI's using 3 level skills grouping in a relatively simple process and evaluate the results for effective pedagogy as required by an ideal OBE model. The application of this methodology and digital systems would help to develop holistic processes from the delivery of the program to the learning outcomes that are the primary ingredients of all aspects of information technology education to produce quality graduates for industry with the skills needed not only for cognitive abilities but also for the affective and psychomotor domains.

References

[1]. Wergin, J. F.,Higher education: Waking up to the importance of accreditation. Change, 2005,37(3), 35-41.

[2]. Gannon-Slater, N., Ikenberry, S., Jankowski, N. & Kuh, G.,Institutional assessment practices across accreditation regions. National Institute of Learning Outcomes Assessment (NILOA).2014, www.learningoutcomeassessment.org/documents/Accreditation%20repo rt.pdf

[3]. McGourty, J., Sebastian, C. & Swart, W., Developing a comprehensive assessment program for engineering education. *Journal of Engineering Education*. Volume 87, issue 4 (pp 355-361). October 1998. 1998 American Society of Engineering Education. doi: 10.1002/j.2168- 9830.1998.tb00365.x

[4]. Eugene Essa, Andrew Dittrich, Sergiu Dascalu, Frederick C. Harris, Jr., ACAT: A Web-based Software Tool to Facilitate Course Assessment for ABET Accreditation, Department of Computer Science and Engineering University of Nevada, Reno Reno, NV.USA http://www.cse.unr.edu/~fredh/papers/conf/092-aawbsttfcafaa/paper.pdf

[5]. Information on EvalTools® available at http://www.makteam.com

[6]. Mead, P., F., Turnquest, T., T. & Wallace, S., D., Work in Progress: Practical framework for engineering outcomes based teaching assessment – a catalyst for the creation of faculty learning communities. *36th Annual Frontiers in Education Conference, 2006,* (pp.19-20). Publisher IEEE. doi: 10.1109/FIE.2006.322414

[7]. Accreditation Board of Computing (ABET),www.abet.org

[8]. Wergin, J. F., Higher education: Waking up to the importance of accreditation. Change, 2005,37(3), 35-41.

[9]. Gardiner L. F., Assessment essentials: Planning, implementing, and improving assessment in higher education (review). J. Higher Education, 2002,73(2), 302–305.

[10]. J. Estell, J. Yoder, B. Morrison, F. Mak, "Improving upon best practices: FCAR 2.0," *ASEE 2012 Annual Conference*, San Antonio.

[11]. W. Hussain, M. F. Addas, "A Digital Integrated Quality Management System for Automated Assessment of QIYAS Standardized Learning Outcomes", *2nd International Conference on Outcomes Assessment (ICA)*, 2015, QIYAS, Riyadh, KSA.

[12]. Mohammad, A., W. & Zaharim, A. Programme outcomes assessment models in engineering faculties. *Asian Social Science*, Vol . 8, No. 16. ISSN 1911-2017, EISSN 1911-2025. Published by the Canadian Center of Science and Education, 2012, doi: 10.5539/ass.v8n16p115

[13]. Hussain, W., Addas, M., F., and Mak, F. (2016). Engineering Program Evaluations Based on Automated Measurement of Performance Indicators Data Classified into Cognitive, Affective and Psychomotor Learning Domains of the Revised Bloom's Taxonomy. ASEE 123rd Annual Conference, New Orleans, June 2016.