

An Eloquent Approach to Assess and Comprehend the Program Learning Outcomes in a Higher Educational Setting

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ABSTRACT

An outcome based educational setting is immensely recognized by the quality of delivered educational attributes aligned to the institutional core initiatives such as vision, mission and core values. These educational attributes basically represent a general terminology called learning outcomes. The learning outcomes are commonly formed and shaped through various academic categories such as graduate attributes, program learning outcomes and course learning outcomes and are specifically aligned to fulfill the institutional initiatives. Though institutions struggle hard to achieve these structural constituents, but do not mostly fulfill the desired outcomes. There have been various instances of failure leading to critical evaluation of the entire institutional setups. The major reason to these failures is the lapse of a systematic, authentic or rationally measurable approach which if available could perfectly solve the deal. In view of these issues, we have come up with a unique approach which is very logical and helps to resolve the problems. Our approach measures the attainment of educational attributes through an evident, structured, measurable and calculated terminology. The outcomes produced through our approach will validly support the educational process to further enhance the quality of education and reflect the true evaluation of institutional initiatives in all aspects. In addition to determining the strengths and weaknesses, the proposed methodology would produce effective progression to the students, courses, academic programs and assessments, promoting legitimate educational processes.

Keywords

graduate attributes; program learning outcomes; course learning outcomes; assessment of attributes; attainment of attributes

Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

Higher Educational Institutions (HEIs) draw on its success by validating mission as a set of frameworks to develop their objectives and assess them through the academic programs they operate. Along the mission, higher education leadership establish core values and Graduate Attributes (GAs) brought together by the institution with concerned stakeholders (Aithal, 2016). The leadership works harmoniously together to sustain and steer the institution. Strategic leadership is positioned at the helm of the institution and has by far the most complex role to play in developing the mission and its core values. The ability of the strategic leader to engage almost all members of the university community in the strategic planning process and to instil a sense of ownership of the supposed shared values that impact the degree to which the institutional mission and goals are carried through. Principally, the entire strategic and operational plan along with the organizational policies, aligned and are in line, initiated and launched and up to periodic reviews. At the core of this activity are GAs embedded in the learning outcomes of a program of study. Generally building GAs in higher education focuses on career building outcomes including dispositions and skills that allow for lifelong learning commensurate with industry and stakeholder needs (Ruth, 2009). HEIs generally uphold

the observation, the delivery and attainment of the GAs to their curriculum (Felder and Brent, 2003). The overall purpose of the development of GAs is to ensure that students successfully come out from a university or college with these attributes attesting the execution of predefined institutional objectives at the completion of a program of study. Scholarship in this area have shown that the skills of the graduating students sometimes do not match with the requirements of a job, thus a complete alignment of outcomes to the institutional mission to the job needs-closing the loop allows for feedback and continuous improvement (NACE 2011). Nevertheless, key to the success of achieving the institution's mission and vision is embedded in the teaching and learning strategies and curriculum delivered. The university tries to ensure the attainment of GAs through student achievement of the relevant knowledge and skills and these might be expressed in statements in form of learning outcomes (Jones et al., 2007).

All the HEIs ensure the delivery of their academic programs and courses to fulfil the achievements of its GAs in their curriculum. Concurrently, though the delivery of GAs as well as the learning outcomes is quite common, but the measure of actual attainment of these attributes is somewhat lacking and not really accurate in the measurements of their attainments. One of the normal procedures to measure the delivery of learning outcomes and GAs is using indirect

measures as questionnaires, whereby the students on completion of a program is required to evaluate their learning experiences and whether they perceive that they have reached the course learning outcomes (Bath et al., 2004). The derived data from the indirect measures or the questionnaires is then collected to identify the attainment of outcomes through observed strengths and weaknesses of a delivered course or a program (Uchiyama and Radin, 2008). But these indirect methods are based mostly on the judgement of a given criteria.

This paper reports on the establishment of a patented method where direct measures of delivered curriculum is measured. This method is generalized to calculate the achieved curriculum which could indicate the degree of the achieved learning outcomes for a program. The method focuses on a computational technique, gained through assessments of the students, towards the attainment of Program Learning Outcomes (PLOs) likewise the GAs. The direct measures also provide evidence of the delivery and attainment of those learning outcomes (Bakker et al., 2015).

Statement of the Problem

Learning outcomes are statements of the knowledge, skills and abilities that individual students should possess and can demonstrate upon completion of a learning experience (Anderson et al., 2001). Academic programs at HEIs are formed and designed to achieve its key PLOs, and if achieved they confirm the success of the program. In principal, the PLOs with the GAs would reflect the vision, mission, objectives and core values of the institution. GAs are the key attributes that a student possesses upon graduation of any academic program (Barrie, 2006).

University courses or modules for a specific program are amalgamated through the development of the PLOs; the aim of a program would be delivering the curriculum that student attain specific knowledge and skills that the curriculum renders the learning outcomes established for the program. To assure that learning has been achieved, the learning outcomes are formed as a prevailing base towards the formation of the curriculum (Harden, 2009). Every course has a set of reference known by the term syllabus. The syllabus has the description, course learning outcomes, and assessments which are the key components that describe what the course or module is about and the what outcomes the students need to achieve (Lam & Tsui, 2013; Plaza et al., 2007). The course instructor, generally has the autonomy to design the course and write the syllabus in line with the PLOs. HEIs are obligated to ensure the delivery of attributes such as GAs inevitably incorporated in all its courses. (Moalosi et al., 2012) perceptibly suggest that the course syllabus is the document that allows to see the elements encompassed within the program. It is also a document that underlines the institutional policies and procedures, with a perspective to enhance the quality and structure of the course to be delivered. Most of the course curriculum is also prepared, apart from the technical and subject competencies, it allows the student to acquire the skills and attributes that are socially relevant (Bowden et al., 2000). Along with other key indicators being related to the instructional delivery of the course. The course syllabus also contains the assessment strategy where each assessment

measure is aligned with Course Learning Outcomes (CLOs). The CLOs course are the key ingredients to the attainment of PLOs (UORI, 2018). Thus, many key indicators, are fundamentally needed for the Course Learning Outcomes (CLOs) which are carefully designed and marked by the course instructor, in which they ensure the GAs and PLOs are delivered and achieved. As specified by (MDC 2009) the development of the course assessments should have association with cognitive goals to measure student achievement. Thus the PLOs are benchmarked through various methods of assessments in a course often to measure the progressive performance of a student in a program thus measured towards the achievement of CLOs (Ronald, 2009). The course instructor has the autonomy to set the outcomes for the course, ensure its delivery, teaching and learning activities and produce the assessment to measure the outcomes set for the course (Bakker et al., 2015).

The development of GAs occurs much ahead of the course delivery, but the practicability to assess its achievement takes place only after the course is delivered and at the end of the term, where the instructor evaluates by assessing whether the CLOs cover the degree what students achieved. Traditionally higher educational providers measure through indirect methods in analyzing students' feedback and survey on the course have instructors and students judge whether the CLOs have been achieved. Student's feedback on the attainment of the curriculum is vital it may not be truly direct, valid and objective. The major concern is that these methodologies provide an indirect measure to the instance of achieved PLOs and GAs. It does evidently demonstrate the measurable quantification and comprehensive statistics of PLOs and CLOs, attained in the course. In other words, the indirect methods may work out from the point of course delivery but do not illustrate, specifically, the measurable attainment of the GAs and PLOs by the students. Not only that the instance through such survey and feedback just reflects the stakeholders view which could also impact the direct or indirect influence of an individual.

Despite putting up all the required efforts, the course instructor may not be aware of the true challenges faced in the course. At most of the educational institutions, though the instructors have full autonomy to deliver and assess the course contents, within the institutional framework, they also hold the responsibility to make sure that learning outcomes are funneled from the mission of the university. The instructors or the program planner are usually unaware of the core issues and unable to effectively overcome those challenges.

In order to tackle this critical situation, through this study, the authors have demonstrated a patented rational and measurable technique to identify the attainment of PLOs, through all conducted assessments, for a computer science course. Similar strategy can be effectively applied to achieve the GAs. With further burden of designing, developing and writing the course learning outcomes, through the application of our approach, the course instructors could further improve or develop or review the course within context and will be aware of the challenges faced at the completion of a course. The approach will also allow to address and identify, if the curriculum was delivered across all the courses in an academic program with concrete statistics of the percentage of outcomes covered and as well

attained. The program planner, instructor, program reviewer would be aware of those serious challenges or deficiencies in a program. The approach, in our view, will help identify the gaps needed for further development of the entire cycle of educational process from the mission to the achieved outcomes. Consecutively, the key stakeholders, the students would also be able to identify their strengths and weakness and address those in a language defined by the higher educational institution in the form of learning outcomes and GAs.

Mapping the Curriculum

The proposed work suggests an authentic, patented and rational method to calculate the level and degree of PLOs achieved. The system starts with preparation of master matrices outlining the mapping of the PLOs as well as the GAs with all the courses delivered in that program. Since an academic program contains various category of courses, the authors selected few categories such as university requirement and major core courses to illustrate the purpose. Table 1 shows a sample program of study demonstrating the PLOs being mapped for each course.

Table 1: A sample program of study with courses mapped to the corresponding PLOs.

Course Information		PLOs						
Category	CourseID	a	b	c	d	e	f	g
UR	C001	1		1	1			1
UR	C002		1		1	1	1	
UR	C003		1	1				1
UR	C004	1		1				1
UR	C005		1	1		1	1	
MC	C006	1			1		1	
MC	C007			1		1		1
MC	C008			1		1	1	
MC	C009		1		1			
MC	C010		1		1	1	1	
MC	C011	1	1	1				1
MC	C012		1			1		
MC	C013	1		1				1

As seen in Table 1 there are 7 PLOs for the program symbolized by the letters a, b, c, d, e, f and g. The PLOs are cross-referenced by each course to indicate its coverage. This mapping is done at the unit level which is generally known as the owner of the program. In this case it would be a department or a faculty. This process is an evidence that the curriculum is reflected in the program of study (Cecilia et al., 2007). As seen in Table 1, all the courses in the program are crossed with the PLOs for an academic program. Mapping is the operation used to demonstrate various components of the curriculum. An aligned curriculum constitutes the sequence of all the courses to forming the information of a program; hence all the courses within a program should have clearly defined learning outcomes (Manogue & Brown, 2007). This master matrix demonstrate that all courses in a program have clearly defined attributes and outcomes fitting the framework established for the programs. Need to mention that each course in an academic program is required to be mapped with corresponding PLOs and GAs to complete the loop.

In Table 1, it is recognized that on the far left there are various categories of courses that constitutes the program of study, offered as University Requirement (UR), Major Core (MC), Major Elective (ME), General Elective (GE), Humanities/Social Sciences Elective (H/ScE) and Physical and Natural Sciences Elective (Phy/NScE) making up the program. Though in this study the authors considered just the UR and MC courses which basically forms a backbone of any academic program and simultaneously illustrates the intended purpose of the research. In a similar way the GA matrix is prepared at the unit level.

The master matrices are prepared in conference with the curriculum specialists, program coordinators or even instructors. Feedback and support from respective course instructors is necessary for the review cycles. Though varied from an institution to another, the review cycle of the PLOs is generally done on 5-year cycle at HEIs, whereas the CLOs have the flexibility to be changed regularly through revision of courses or modules. Further program developments and enhancement are considered based on the outcome of the student's attainment of the CLOs, followed by relevant analysis of the attained PLOs.

Course or module development allows the instructor to develop and select the CLOs, content, sequencing, delivery, assessment strategies and teaching methodologies. Significantly during the development of the assessments; in tandem, the CLOs are mapped to the assessments. In form of "good" practice, the instructor draws from the curriculum and topics the CLOs of the course which are then aligned with the PLOs. In most cases the instructor prepares the course description or syllabus with an aim to achieve all the applicable PLOs and GAs. The teaching operation allows for content delivery, subsumed in this is knowledge and skill transfer achieving the CLOs. For the instructor to map the assessments to the CLOs, draws on those aspects of the assessments that directly target the learning outcomes. Once students take the assessments, the results or graded work may reflect whether the CLOs have been fulfilled.

Student achieved outcomes specifically those evidenced through course or module assessments are significant to further detail the level of achievement of PLOs and GAs (Philip et al., 2009; Barrie, Hughes and Smith, 2009). Facing this challenge, inevitably comes from various methods and practices currently used, in the form of self-appraisal, instructor opinions and peer analysis. Inexorably, it posits to the different approaches leading to quality maintenance and allowing latitude for measuring the level of attainment of the PLOs and GAs. Convincingly there are few indirect methods to evaluate the outcomes but with advanced systems as in course management and information systems in place, our approach helps in the development of an appropriate software application system, to track every individual student's performance through course assessments. Student's performance, through a course is trailed through a set of assessment marks, allowing us to identify the outcomes achieved in a course, thereby accumulating the outcomes of every course, it identifies the outcomes achieved in the whole program. In this study we intend to address assessable statistics regarding the delivery or coverage and attainment or achievement of the PLOs. The method should be easily generalizable to well-

established and accurately defined GAs, thus in this study we will:

- ✓ Demonstrate the mapping process of the PLOs with its courses;
- ✓ Demonstrate the mapping process of the CLOs with PLOs;
- ✓ Demonstrate the mapping process of the assessments to the CLOs;
- ✓ Demonstrate the calculation at some percentage level of the CLOs and PLOs, delivered;
- ✓ Demonstrate the calculation the at some percentage level of the CLOs and PLOs attained;
- ✓ Develop a set of robust equations prescribing the underlying method;

Methodology

At the beginning of an academic term, a course instructor prepares the course syllabuses that would entail all the vital information such as the course code, title, credit hours, course pre-requisite, co-requisite, delivery venues, along with the core defined information such as the course description, CLOs, reading materials, teaching and learning strategies, topics to be covered, assessment information and other key information related to the institutional policies. The CLOs are prepared in reference to the course description and with reference to the PLOs. The course syllabus could also show the PLOs and GAs covered in the course, as well as the matrix mapping the module's CLOs with PLOs and GAs. The course instructor delivers the course with the aim to achieve the maximum CLOs. The assessments are key to measure the attainment of CLOs. The course instructor prepares the assessments with an expectation to logically and interpretably reflect the CLOs. Generally, for any course, within a higher education provider, undergoes an internal as well as external moderation oversight to ensure that the syllabus have the constituent parts and mainly that the assessments challenge

the CLOs. In addition, the moderator's also review other technical components of the assessment including, ambiguity of questions, weightage on the assessment items, logical sequence of questions, language, marking scheme and time limits. The moderation process ensures that the delivery as well the attainment of assessments is professional, consistent and upholds the expected quality and standards and are in line to the intended institutional attributes.

The instructor corrects student assessments whether the tests or class work (i.e. projects, assignments or other out of class work). The assessments are aligned to the CLOs. When the instructor corrects the exams, he/she in fact is assessing whether the CLOs have been achieved through the class work assessments. The development of this method focuses on the actual measurable CLOs delivered as well as attained. We will tabulate the course work against the CLOs against PLOs through establishing matrixes and cross-referenced tabulations. Specifically, a table will be used to mark on all assessments at the end of the course or module. At the end of the academic term, the instructor prepares the matrices to tabulate and measure the attainment of key indicators through the course assessments.

We begin the illustration of a hypothetical course with 5 CLOs. Table 2, illustrates 5 CLOs for an undergraduate course which are mapped against the assessments. The Table includes the course with its delivered and attained attributes, mapped with the CLOs. The first row indicates the curriculum delivered represented by "D" and the attained represented by "A." Table 2 also shows an aggregate average of a group or section scores through each assessment covering the CLOs. The specified group or section would have many students registered within it. Percentage of attained CLOs are calculated and represented as the last column in Table 2. Each cell in Table 2 has hypothetical average scores of a group or section, on a particular assessment, this being the delivered and attained average scores.

Table 2: Assessments mapped against the CLOs in the course C002

CLOs	D			A	D			A	D			A	A
	Assessment 1/20				Assessment 2/30				Final Assessment/50				% of CLO(A)
1	40%	08.00	06.50						20%	10.00	08.00		80.56
2					30%	09.00	07.00		10%	05.00	02.00		64.29
3	30%	06.00	04.00		20%	06.00	03.00		30%	15.00	13.00		74.07
4									10%	05.00	03.00		60.00
5	30%	06.00	03.50		50%	15.00	11.50		30%	15.00	11.00		72.22
Total		20.00				30.00				50.00			

In Table 3, the CLOs are mapped against the PLOs and GAs. The cell marked using a common digit "1" demonstrates the coverage of the PLOs or the GAs in the course. The cell marked with a digit "0" represents non-coverage for the particular intersecting CLO. Also the "X" marked cells represent the PLOs and GAs are not applicable in this course, hence in a way the "X" marked cells are discarded and could be regarded as "0". This is derived from the matrix prepared initially through Table 1. This also indicates that not all PLOs or GAs are covered in every course, however they could simultaneously be covered by a

number of other courses for the program. The percentage of a specific PLO delivered is equal to the total of each PLO being represented by "Count (C)" as 2, 2, 3, 4 in this illustration, divided by the total count of PLOs being represented by "Total C" as 11. Hence the calculation produces Table 3a, which shows the percentage of PLOs delivered in the course. Hence, Table 3 below shows the instance of alignment of the CLOs with PLOs. Simultaneously, Table 3a shows the percentage of each PLO delivered in the course. This is derived by dividing the count of each PLO with the total count of PLOs i.e. $2/11 \times 100 = 18.182$, $3/11 \times 100 = 27.273$ and $4/11 \times 100 = 36.364$.

Table 3: Alignment Matrix of CLOs crossed with PLOs in the course C002

CLOs	PLOs						
	a	b	c	d	e	f	g
1	x	1	x	0	1	1	x
2	x	0	x	1	1	0	x
3	x	1	x	0	0	1	x
4	x	0	x	0	1	1	x
5	x	0	x	1	0	1	x
Count (C)	x	2	x	2	3	4	x
Total C	11						

Table 3a: Percentage of PLOs delivered

	a	b	c	d	e	f	g
% of PLO	x	18.182	x	18.182	27.273	36.364	x

Table 4, Table 4a, Table 4b indicates the percentage of PLOs delivered for each CLO in each assessment in the course. Need to again specify that the tables 4, 4a and 4b are tabulated for each assessment held in the course. The figures are derived using table 2, 3 and 3a, by dividing the delivered values with the percentage of respective PLO, for each assessment, as seen in the tables below. It is vital to note that the '0' in these tables indicates that PLOs are not assessed in these intersections.

Table 4: Percentage of PLOs delivered for each CLO in Assessment 1

CLOs	PLOs						
	a	b	c	d	e	f	g
1	x	$8*18.182/100 = 1.45\%$	x	0	$8*27.273/100 = 2.18\%$	$8*36.364/100 = 2.91\%$	x
2	x	0	x	0	0	0	x
3	x	$6*18.182/100 = 1.09\%$	x	0	0	$6*36.364/100 = 2.18\%$	x
4	x	0	x	0	0	0	x
5	x	0	x	$6*18.182/100 = 1.09\%$	0	$6*36.364/100 = 2.18\%$	x

Table 4a: Percentage of PLOs delivered for each CLO in Assessment 2

CLOs	PLOs						
	a	b	c	d	e	f	g
1	x	0	x	0	0	0	x
2	x	0	x	$9*18.182/100 = 1.64\%$	$9*27.273/100 = 2.45\%$	0	x
3	x	$6*18.182/100 = 1.09\%$	x	0	0	$6*36.364/100 = 2.18\%$	x
4	x	0	x	0	0	0	x
5	x	0	x	$15*18.182/100 = 2.73\%$	0	$15*36.364/100 = 5.45\%$	x

Table 4b: Percentage of PLOs delivered for each CLO in Final Assessment

CLOs	PLOs						
	a	b	c	d	e	f	g
1	x	$10*18.182/100 = 1.82\%$	x	0	$10*27.273/100 = 2.73\%$	$10*36.364/100 = 3.64\%$	x
2	x	0	x	$5*18.182/100 = 0.91\%$	$5*27.273/100 = 1.36\%$	0	x
3	x	$15*18.182/100 = 2.73\%$	x	0	0	$15*36.364/100 = 5.45\%$	x
4	x	0	x	0	$5*27.273/100 = 1.36\%$	$5*36.364/100 = 1.82\%$	x
5	x	0	x	$15*18.182/100 = 2.73\%$	0	$15*36.364/100 = 5.45\%$	x

Each assessment in a course contributes to the CLOs and PLOs. We can demonstrate how each assessment is mapped to each CLO as shown in Table 2. For example, "Assessment 1" covers CLO 1, CLO 3 and CLO 5. Assessment 1 delivers 8 points that are mapped to CLO 1; 6

points mapped to CLO 3 and 6 points mapped to CLO 5. With reference to Table 3, there are a total of 11 PLOs mapped to CLOs for this course (see Table 3, Total (C)). To determine the delivered percentage contributing to the PLOs, we take for example Assessment 1, which appears to cover CLOs 1, 3, and 5. As seen in Table 3, it is recognized that CLO 1 is mapped to PLO b, e and f. If we observe the points corresponding to CLO 1 in Table 2 (the row related to CLO 1), we can notice that 8 points i.e. 8% (out of 100) of CLO 1 is delivered through Assessment 1 and 10 points i.e. 10% (out of 100) is delivered through Final Assessment. Simultaneously, with reference to Table 3, PLO b is covered through two CLOs i.e. CLO 1 and CLO 3 in this course and gives the 2/11 chance occurrence i.e. Count (C)/Total C. Thus the curriculum through CLO 1 delivers PLO b, and makes 8 points out of 100 in Assessment 1 and 10 points out of 100 in the Final Assessment. We can thus treat these events as independent and draw on the multiplication rule of the possible occurrence.

As seen in Table 2, another illustration of this mapping is CLO 5 which is covered by 6 points i.e. 6% (out of 100) in Assessment 1, 15 points i.e. 15% (out of 100) in Assessment 2 and 15 points i.e. 15% (out of 100) in Final Assessment. To illustrate the PLO coverage, they are found to determine the PLOs covered by taking the percentage of CLOs covering a PLO for this specific example, PLO b has $(2/11*100)$ percentage coverage, as seen in Table 3, i.e. PLO b is covered by CLO 1 and CLO 3. However, as seen in Table 2, Assessment 1 covers CLO 1, CLO 3 and CLO 5 but the intersection of the CLOs covered by Assessment 1 and the CLOs covering PLO b are CLO 1 and CLO 3 only. It is thus recognized that CLO 5 does not cover PLO b and hence discounts it from the calculation. As described earlier, Table 3a shows the percentage of each PLO delivered in the course. This is derived by dividing the count of each PLO with the total count of PLOs i.e. $2/11*100=18.182\%$.

As seen in Table 4, in order to calculate the coverage of PLO b through CLO 1 in Assessment 1, the formula used is $8*18.182/100=1.45\%$ and summed to $10*18.182/100=1.82\%$ for the Final Assessment. Likewise, PLO b covered by CLO 3 for Assessment 1 is $6*18.182/100=1.09\%$ summed to $6*18.182/100=1.09\%$ for Assessment 2 and $15*18.182/100=2.73\%$ for the Final Assessment.

Table 5, presents the values for each of the CLOs covered by the assessments for PLO b. The total percentage covered through the assessments for the course for PLO b is 8.18%. The program may have a number of courses that cover PLO b and contribute to its coverage. Cumulatively, every course can contribute to the PLOs that are mapped to CLOs for the course. The sum of the percentages of the covered PLOs would be a measure of how much a course could contribute to each PLO.

Table 5: Percentage coverages for PLO b through each assessment in the course.

PLO b				
CLOs	Assessment 1/20	Assessment 2/30	Final Assessment/50	Total
1	1.45%		1.82%	3.27%
2				
3	1.09%	1.09%	2.73%	4.91%
4				
5				
Total	2.54%	1.09%	4.55%	8.18%

In the previous illustrations we demonstrated the level of delivered curriculum through one PLO i.e. PLO b. As mentioned the delivered can be substantially different from the achieved as it reflects the attainment of students on the assessments. The data seen in Table 2 is hypothetical, the method to obtain the achieved i.e., attained has the same approach but the value is based on student achieved scores on the assessment. For example, with reference to Table 2, 06.50 is an average score gained by the group of students in Assessment 1 for CLO 1, in the course C002. Hence 06.50 is considered the achieved average score for a batch. Likewise, 04.00 and 03.50 is the average score gained by the group of students in Assessment 1 for CLO 3 and CLO 5 respectively. Similarly, 07.00, 03.00, 11.50 represents average scores gained by the group of students in Assessment 2 for CLO2, CLO3 and CLO5 respectively. Thus in order to determine the percentage of score attained, through the application of Table 3, we can therefore apply the same method which was applied to find the delivered statistics a seen in Table 6, Table 6a, Table 6b and Table 7, as seen in the next section.

Table 6: Percentage of PLOs attained for each CLO in Assessment 1

CLOs	PLOs					
	a	b	c	d	e	f
1	x	6.50*18.182/100 =1.18%	x	0	6.50*27.273/100 =1.77%	6.50*36.364/100 =2.36%
2	x	0	x	0	0	0
3	x	4*18.182/100 =0.73%	x	0	0	4*36.364/100 =1.45%
4	x	0	x	0	0	0
5	x	0	x	3.50*18.182/100 =0.64%	0	3.50*36.364/100 =1.27%

Table 6a: Percentage of PLOs attained for each CLO in Assessment 2

CLOs	PLOs					
	a	b	c	d	e	f
1	x	0	x	0	0	0
2	x	0	x	7*18.182/100 =1.27%	7*27.273/100 =1.91%	0
3	x	3*18.182/100 =0.55%	x	0	0	3*36.364/100 =1.09%
4	x	0	x	0	0	0
5	x	0	x	11.5*18.182/100 =2.09%	0	11.5*36.364/100 =4.18%

Table 6b: Percentage of PLOs attained for each CLO in Final Assessment

CLOs	PLOs					
	a	b	c	d	e	f
1	x	8*18.182/100 =1.45%	x	0	8*27.273/100 =2.18%	8*36.364/100 =2.91%
2	x	0	x	2*18.182/100 =0.36%	2*27.273/100 =0.55%	0
3	x	13*18.182/100 =2.36%	x	0	0	13*36.364/100 =4.73%
4	x	0	x	0	3*27.273/100 =0.82%	3*36.364/100 =1.09%
5	x	0	x	11*18.182/100 =2.00%	0	11*36.364/100 =4.00%

Resulting in Table 7 for PLO b as follows:

Table 7: Percentage attained for PLO b through each assessment in the course.

PLO b	CLOs	Assessment 1/20	Assessment 2/30	Final Assessment/50	Total
1		1.18%		1.45%	2.63%
2					
3		0.73%	0.55%	2.36%	3.64%
4					
5					
Total		1.91%	0.55%	3.81%	6.27%

Table 7, presents the values for each of the CLOs attained by the assessments for PLO b. The total percentage attained through the assessments in the course for PLO b is 6.27%. Thus, the students batch achieved 6.27 % of PLO b in the course C002.

Likewise, same principle can be applied to determine the percentage of GAs. The cumulative score of each PLO in each course within an academic program would reflect the statistics of PLOs delivered and attained in the program.

We can demonstrate such approach through a set of equation, where we denote the CLOs delivered for the PLO by the following elements by X_{ji} . The indexing, suggest that j represent the PLO, and i for the number of CLOs, hence; PLO b has the CLOs covered by the following X_{b1} , X_{b3} and X_{b5} . We can also denote those assessments that cover the particular CLO by A_{ij} , where i stands for the CLO number and j stands for the Assessment. There are three assessments in this course this being Assessment 1, Assessment 2 and Final Assessment. Thus $j=1$, represents the index for Assessment 1, $j=2$ represents Assessment 2 and $j=3$ represents Final Assessment. Thus A_{11} represents CLO 1 in assessment 1, A_{12} represents CLO1 in Assessment 2 and so on. X_{b1} would reflect the $A_{11}+A_{13}$, since A_{12} do not cover CLO 1, and by default set to 0. In percentage we have $X_{b1}/n(X_{ji})$. Thus for PLO b we can start by the following:

$$Y_b = \left(\sum_{i=1}^{n \text{ of CLOs}} X_{bi} \right) / n(X_{ji}) \quad \text{where } j=a \text{ to } l, \text{ the number of PLOs,} \quad (1)$$

In our example, for PLO b, $X_{b1}=1$, $X_{b2}=0$, $X_{b3}=1$, $X_{b4}=0$, $X_{b5}=0$,

Table 8 illustrates the notations for the covered CLOs X_{ji} .

Let a stand for the delivered average score of the assessment (Table 9 illustrates the notations for the assessments).

$$A_{bi} = \sum_{i=1}^{n \text{ of assessments}} a_i / 100 \quad \text{here } i \text{ is the CLO number.} \quad (2)$$

Thus, to determine the percentage coverage of a PLO for all CLOs $\neq 0$, as in PLO b, the sum of CLOs can be demonstrated as the equation function of a PLO b:

$$f(b) = Y_b \times \left(\sum_{i=1}^{n(CLO)} A_{bi} \right) \quad \text{where } n(CLO) \text{ being the number of CLOs covering PLO b.} \quad (3)$$

The three equations (1), (2) and (3) are generalizable to the achieved

Table 8: Illustration of X_{ji} within the CLO-PLO matrix

CLOs	PLOs Delivered						
	a	b	c	d	e	f	g
1	-	X_{b1}	-	0	X_{e1}	X_{f1}	-
2	-	0	-	X_{d1}	X_{e1}	0	-
3	-	X_{b3}	-	0	0	X_{f1}	-
4	-	0	-	0	X_{e1}	X_{f1}	-
5	-	0	-	X_{d1}	0	X_{f1}	-
Total	-	2	-	2	3	4	-

Table 9: Illustration of the Assessments notations covered by a specific course

PLO b			
CLOs	Assessment 1	Assessment 2	Final Assessment
1	A_{11}	A_{12}	A_{13}
2	A_{21}	A_{22}	A_{23}
3	A_{31}	A_{32}	A_{33}
4	A_{41}	A_{42}	A_{43}
5	A_{51}	A_{52}	A_{53}

Discussion

In order to sustain explicit delivery of quality education, benchmarked with international level standards and portfolios, HEIs have been persistently struggling to mark the anticipated requirements. Amidst to fulfill and attain the anticipated institutional objectives through vision, mission, objectives and values, HEIs have always been facing critical challenges to strictly evaluate the progress of such essentials, specifically through evident, structured, measurable or calculated terminologies. To overcome the lapses, various methods are adopted by different HEIs through feedback from course instructors, students and employers, but those methods are limited and restrict to equivocal processes. Certainly any institution would want their students to achieve the graduate characteristics designed by the higher education provider. Generally, after completion of an academic course or an academic program, students are unaware of their strengths and weaknesses in the completed stream. Consecutively, dynamics to track the success or failure of all involved entities and processes such as the academic programs, courses and students have also been a continuous confrontation. Our research is strictly derived from a patented methodology which follows a rational and systematic calculated approach to evidently measure the attainment of core attributes such as Graduate Attributes (GAs), Program Learning Outcomes (PLOs), applicable in any HEI. The main objective of our research is to apply a coherent and valid methodology that would assess and produce precise statistics. Thus the development of this work draws on the systemization of a methodological process. The proposed system is mathematically valid; as it rationally measures the probability of the planned outcomes for a course or program. The system is so robust that we can obtain the achieved outcomes and attributes for a student. On the other hand, the system could fit any educational system and standards to fulfil the national or international accreditation requirements. Our research aims to scale this approach as widely as possible, across programs as well to other institutions. We foresee that scaling this

method allows in fertilizing the outcome-based approach, providing a greater accountability to the methods of academic outcomes desired in higher education. The application which is under active development would quantitatively measure the probability of attainment of PLOs and GAs through empirical and a numerical calculations based on assessment grades and will help to identify this key challenge in a more effective way and in line with the strategic aims of the institution.

Declaration Note

We would like to make it clear that our research represents a very unique patented methodology to measure the assessment attributes in an outcome based educational environment, specifically to measure the probable quantity of attained value of assessments, solely created based on the factual and logical reasoning processes, followed by any authentic outcome based educational system. The patented information is listed in the next section.

Patent Information:

Filed a Patent Design titled "Computational Methodology towards Attainment of Graduate Attributes and Program Learning Outcomes in an Outcome Based Educational System".

CBR No.:14648, CBR Date: May 27 2018

Name of Inventor/Researcher: Biju Theruvil Sayed

Patent Number 201841019778, Intellectual Property, Government of India Patent Office

Online Reference:

<http://ipindiaservices.gov.in/Verify/chkCert.aspx?prm1=FzcJYOYg6oIeykt7gV5SlQ==&prm2=/Su7fa1kRYmY6p55O5yutg==&prm3=s8lZHCbhtCNk5balZ8J85w==&prm4=VkMQcHZfzCrPINYkN2G174ixOMokJaWQ1kVkpWTc/R9OpahqoyWjnJyLufB03Fh3abiqPMPY+k22aNVVW405VA==>

Conclusion

Logically this research represents a patented methodology to measure the amount of CLOs, PLOs and GAs attained in a course, it can easily be elaborated with various other emerging factors such as merging the statistics of all other courses delivered in a program to find the amount of PLOs or GAs attained within the whole program. The research will be extended with additional features by integrating indirect measures such as feedback from students, Judgment of faculty member, review from external sources to triangulate the authenticity of the outcomes. In other words, it could also be extended to benchmark and cross-verify the existing methodologies to match this measurable approach, as a form of concurrent validity.

We established a set of equations, these would be a baseline and guide, which would help us determine to produce statistical information on every student's individual achievements. With all the raw data is in appropriate matrices, the system can be easily tuned to produce statistics on individual students, programs or even the whole institution, thereby demonstrating the strengths or weakness of a student in an area. The set of equations clearly indicate a clear score in PLOs or GAs highlighting a student's

strength and could be referred to a prospective employer, looking for graduates with specific strengths who otherwise would be struggling to find the right candidates with specific strengths. The outcomes will be also helpful as a recommendation for students to continue their studies at post graduate level. Similarly referring to the statistics, a course or the whole program can be easily tracked and reviewed to meet the job market, employer's expectations and institutional accreditation processes.

References

- [1] Aithal, P.S. (2016). Creating Innovators through setting up organizational Vision,
- [2] Mission and Core Values: a Strategic Model in Higher Education. *International Journal of Management, IT and Engineering*, 6(1), 310-324.
- [3] Anderson, L.W., Krathwohl, D.R., Airasian, P.W., Cruikshank, K.A., Mayer, R.E.,
- [4] Pintrich, P.R., Raths, J., and Wittrock, M.C.. (2001). *A Taxonomy for Learning*,
- [5] *Teaching and Assess-ing: A Revision of Bloom's Taxonomy of Educational Objec-tives*. New York: Longman.
- [6] Bakker, H.P., Brouwer, N., Buckland, A., Chinomona, A., DeVos, M., Donaldson, N.,
- [7] Dukhi, N., duToit, J., Ellery, F., Fox, R., Grant, C., Guilfoyle, M., Kruuse, H., Matthews, S., Meistre, B.. Shackleton, S., Sieborger, I., Snowball, J., Vetter, S., Vice, S., Western R.. (2015). *Assessment in higher education: Reframing traditional understandings and practices*. Centre for Higher Education Research, Teaching and Learning, Rhodes University. https://www.ru.ac.za/media/rhodesuniversity/content/chertl/documents/RU%20_%20Assessment%20in%20HE.pdf. Accessed 03 December 2017.
- [8] Barrie, S.. (2006). Understanding What We Mean by Generic Attributes of Graduates. *Higher Education*, 51(2), 215-241.
- [9] Barrie, S., Hughes, C., Smith, C. D.. (2009). The national graduate attributes project: integration and assessment of graduate attributes in curriculum. Australian Learning and Teaching Council, Strawberry Hills. https://www.researchgate.net/publication/242508963_The_national_graduate_attributes_project_integration_and_assessment_of_graduate_attributes_in_curriculum. Accessed 04 November 2017.
- [10] Bath, D. M., Smith, C. D., Stein, S.J, and Swann, R.. (2004). Beyond Mapping and Embedding Graduate Attributes: Bringing Together Quality Assurance and Action Learning to Create a Validated and Living Curriculum. *Higher Education Research and Development*, 23. <https://doi.org/10.1080/0729436042000235427>.
- [11] Bowden, J., Hart, G., King, B., Trigwell, K., & Watts, O. (2000). *Generic capabilities of ATN university graduates*. Canberra: Australian Government Department of Education, Training and Youth Affairs. <http://www.clt.uts.edu.au/atn.grad.cap.project.index.html>. Accessed 17 April 2017.
- [12] Cecilia M. P., JoLaine R. D., Marion K. S., Grant H. S., and Karen A. S.. (2007). Curriculum Mapping in Program Assessment and Evaluation. *American Journal of Pharmaceutical Education*, 71(2), 20. <https://doi.org/10.5688/aj710220>
- [13] Felder, R. M., Brent, R., (2003). Designing and Teaching courses to satisfy the ABET Engineering criteria. *Journal of Engineering Education*, 92 (1), 7-25.
- [14] Harden, R.M.. (2009). AMEE Guide No. 14: Outcome-based education: Part 1 – An in-troduction to outcome-based education. *Journal Medical Teacher*, 21(1), 7-14. <https://doi.org/10.1080/01421599979969>
- [15] Jones, S., Dermoudy, J., Hannan, G., James, S., Osborn, J., Yates, B.. (2007). Designing and mapping a generic attributes curriculum for science undergraduate students: a faculty-wide collaborative project. *Symposium Presentation UniServe Science Teaching and Learning Research Proceedings*. 40.

- https://www.researchgate.net/publication/229001240_Designing_and_mapping_a_generic_attributes_curriculum_for_science_undergraduate_students_a_faculty-wide_collaborative_project. Accessed 25 September 2017.
- [16] Lam, B., & Tsui, K.. (2013). Examining the Alignment of Subject Learning Outcomes and Course Curricula Through Curriculum Mapping. *Australian Journal of Teacher Education*, 38(12). <http://ro.ecu.edu.au/ajte/vol38/iss12/6>
- [17] Manogue, M., Brown, G.. (2007). Managing the curriculum – for a change. *European Journal of Dental Education*, 11, 75-86.
- [18] MDC (Miami Dade College). (2009). Direct Measures of Student Learning. Office of The Associate Provost For Institutional Effectiveness., https://www.mdc.edu/main/images/Direct%20Measures%20of%20Student%20LearningR3_tcm6-33021.pdf. Accessed 10 February 2018.
- [19] Moalosi R., Oladiran, M. T., Uziak, J., (2012). Students' perspective on the attainment of graduate attributes through a design project. *Global Journal of Engineering Education*. 14(1). <http://www.wiete.com.au/journals/GJEE/Publish/vol14no1/06-Uziak-J.pdf>. Accessed 19 March 2017.
- [20] NACE (National Association of Colleges and Employers). (2011). Job Outlook 2012 Report. http://www.sjsu.edu/careercenter/docs/job-outlook-survey-NACE_2012.pdf. Accessed 21 April 2018.
- [21] Philip, G. A., Liz, R., Laura, E. R.. (2009). Trends in Global Higher Education: Tracking an Academic Revolution. A Report Prepared for the UNESCO 2009 World Conference on Higher Education. http://www.cep.edu.rs/public/Altbach,_Reisberg,_Rumbley_Tracking_an_Academic_Revolution,_UNESCO_2009.pdf. Accessed 16 May 2018.
- [22] Plaza, C. M., Draugalis, J. R., Slack, M. K., Skrepnek, G. H., and Sauer, K. A.. (2007). Curriculum Mapping in Program Assessment and Evaluation. *American Journal of Pharmaceutical Education*, 71(2), 1-8. <https://www.ajpe.org/doi/abs/10.5688/aj710220>
- [23] Ronald, M. H.. (2009). Learning outcomes as a tool to assess progression. *Journal Medical Teacher*, 29(7), 678-682. <https://doi.org/10.1080/01421590701729955>.
- [24] Ruth, B.. (2009). The graduate attributes we've overlooked: enhancing graduate employability through career management skills. *Higher Education Research & Development*, 28(1), 31-44. <https://doi.org/10.1080/07294360802444347>
- [25] Uchiyama, K. P., Radin, J. L., (2008). Curriculum mapping in higher education: a vehicle for collaboration. *Innovative Higher Education*, 33:271-280. <https://doi.org/10.1007/s10755-008-9078-8>
- [26] UORI (University of Rhode Island). (2018). Developing & Writing Course-Level Student Learning Outcomes. <https://web.uri.edu/assessment/course-level-outcomes/>. Accessed 16 August 2018.