A Systematic and Quantitative Method to Measure the Achieved Program Learning Outcomes in Higher Education

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Abstract **– This study calculates the level of academic program learning outcomes achieved through a course/module/unit within a higher education institution. The study draws on hypothetical data (secondary data), of a computer science course. The approach of the study demonstrates an empirical, reliable, and robust method to measure the level of program learning outcomes delivered and achieved. The method to calculate the level of learning outcomes uses a graded hypothetical assessment, charted in a specification table. The percentage covered is the ratio of the course learning outcome covered by the assessment then multiplied by the probability of a course learning outcome to occur in program learning outcome. The method is based on several specification table alignments between course learning outcomes and program learning outcomes. Embedded in the specification tables is assessment data that reflect what is covered and achieved of the curriculum. The originality of this study is that it posts a robust methodology to calculate objectively the achieved learning outcomes. The findings lead us to think in new ways to reconceptualize how students are assessed in higher education.**

Thus, rather than assess students on how they achieve on course tests and other tasks; students can be assessed on the learning outcomes they have achieved.

Keywords **– course learning outcomes, program learning outcomes, delivered curriculum, attained curriculum, specification tables, curriculum maps.**

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1. Introduction

Over the past two decades, increased attention has been given to outcome-based education, motivated by standards and quality assurance initiatives in higher education. The emphasis on outcome-based education has increased the demand for accountability by stakeholders, staff, students, parents, regulative and accrediting agencies. Historically, the outcome-based movement was imputed in the 1980s by the American Association for Higher Education which ran its first conference on higher education assessment and established a platform in terms of methods and shared language [1]. In the early days of the outcome-based education system, evaluation of programs within higher education was promogulated through institutional indicators. Specifically, through institutional measures as in the programs offered, financial support, faculty data, student background data, enrollment, graduation rates, stakeholder perceptions, and other key institutional indicators. Until much later, interest in teaching and learning imputed the need to obtain program information linked to the effectiveness of higher education learning, and thus leading to fiscal or academic decisions [2]. More recently, institutional assessment approaches focus not only on key facts but also on teaching and learning, and the outcomes of the intended learning. Current methods of the outcome-based education underline the activities pertinent to curriculum coverage direct method and assessment tools. This frame and understanding have changed the landscape of higher education, from being a place where knowledge is translated and imparted to a place where knowledge is acquired, developed, and mastered.

One of the results of the outcome-based movement was the creation of an accountability system. Universities now show evidence of what they say they offer and in what they claim they want to achieve [3]. Universities are accountable to stakeholder and accrediting agencies to produce the evidence of student learning through data and information on assessments of the learning outcomes. The assessments are used to uncover whether students learned because of teaching, whether in knowledge, skills, and competencies. The learning is demonstrated in student work for a course or module to complete their degree. It is now accepted and practiced that the achievement of the learning outcomes are culminations of learning [3]; they ensure what students should know and be able to do at the end of the course, program, or unit.

2. Learning Outcomes

What are learning outcomes and why are they significant to a program of study? Learning outcomes demonstrate the learning behaviors and competencies purposefully produced through a period of study in an educational program [4]. Learning outcomes can be framed through knowledge, skills and competencies acquired and demonstrated when student completes a program. Certainly, there are several reasons to why learning outcomes are significant, when they are achieved in a course or a program, it means the academic goals of the program have been fulfilled. Faculties in higher education design instructional activities, and curriculum-based assessments, then gather information through the tools they design to measure student achievement, providing evidence of whether the desired curriculum has been covered and achieved [5]. One common exercise is when the curriculum is aligned to all set outcomes, allowing for judgements to be made on the curriculum and whether the learning prescribed could be achieved.

Generally, the course objectives of a program provide a logical and interpretable basis to establish, categorize and define the associated learning outcomes of a course [6]. Once the curriculum is covered through teaching, it can facilitate for the instructor the opportunity to design and develop assessment tools aligned to the curriculum covered and course learning outcomes. Significantly, the program learning outcomes are the frame that could chart the teaching process and assessments. The more specific the learning outcomes, the clearer the assessment items i.e., questions, and artifacts assessing student learning, whether in knowledge, skills, or competencies.

The learning outcomes are generally written at the outset of the program design. They are aligned to the program courses or units in what is called a curriculum map. The curriculum map provides a chart of course sequence in a program and the loci of learning outcomes potentially to be assessed in one or more courses. Educators consider levels of learning hierarchies in which lower-level competencies come before advanced ones identified in the program. A course learning outcome could be achieved in introductory courses at the lower level of the "educational hierarchy," the learning outcome could be redundant to be repeated in more advanced courses. Thus, when learning outcomes are aligned to lower-level courses, their coverage could be redundant, in upper-level courses. However, the learning outcomes are aligned at the higher level, they cover higher cognitive learning, namely in the evaluation and synthesis, not found in courses at the bottom of the curriculum hierarchy. The exercise of aligning learning outcomes to fit a course of an academic program is a logical and rational process. If done systematically and consistently, they normatively and perceptibly give a clear picture where these learning outcomes are covered and where they are not covered, whether in content or the cognitive learning objectives.

Gagne [7], [8] who established the work of task analysis, proposed instructional unit maps as guides to learning hierarchies for a program. Gagne stated that in a learning hierarchy, super ordinate capabilities are more easily achieved when subordinate ones have been acquired and assimilated. Students can move from one level of hierarchy, (e.g., understanding) to another (e.g., application), once they have achieved the lower levels. The use of learning outcomes provides an overall picture or a hierarchy of competencies for the student to achieve through a program of study. As course hierarchy can be established for a program, it is also possible that learning outcomes can be placed in a hierarchy. Thus, if a learning outcome is covered in one course which is a prefix to another course (i.e., upper level), the learning outcome could be used again in subsequent courses at a higher knowledge objective. To obtain a conceptual/visual understanding of program plans; many universities rely on what is known as specification tables, program maps or matrices [9]. These maps are used as guidelines and thus draw closer the courses to a cohesive whole with clear overarching set of learning outcomes that define the program.

3. Curriculum Maps and Specification Tables

The program map contains courses in sequence from introductory to more advanced levels. The curriculum map is collected in several courses organized in a hierarchy of skills and competencies.

The map has a tier system in which the learning outcomes of first year courses are introduced. Subsequently, in higher level courses, the learning outcomes are developed and mastered.

Generally, the complexity of the curriculum map is found in the cross-referencing of learning outcomes placed in different levels of a program chart. A course in a program can be connected to other courses in form of prerequisites. More than one course can also be aligned to program learning outcomes at different levels of program hierarchy [10]. Mapping the learning outcomes through a different level of competencies, to a larger network of alignments and links is a complex task in the education sphere. However, if such a system is in place where for each course it is identified whether a learning outcome is aligned, we can bring closer the course learning outcomes to program learning outcomes and draw closer the delivered curriculum to what the student has learned [11].

A curriculum specification table lists the learning outcomes written against a set of curriculum units. [5], [12]. The curriculum specification table is composed of columns listing the program learning outcomes crossed by the rows, listing the curriculum units (see Table 1.). Usually, a program coordinator or instructor for a course will identify the learning outcomes in each course and check the cells in the specification table that align to the program learning outcomes. However, unrefined his method is, it has course instructors identify course learning outcomes to align with program learning. Through replication and rounds of checks the inter-rater agreement gives some validity to the mapping. This process is based on a rational interpretation, and consensus driven where there is usually more than one judge whether the course learning outcomes align with program learning outcomes. This process follows from Hasson and Keeney's [13] "validity" concept in which numerous rounds take place; whereby specialists in the area review and re-review the outcomes reflecting the course objectives.

The curriculum specification table shown in Table 1. has an example where learning outcomes are given in small letters: "a," "b," "c," … crossed by the course numbers against learning outcomes. At a different level, specification tables can be built of a program learning outcome aligned to a course learning outcome and demonstrated in Table 3.

In this study we propose a method to calculate a measure of learning outcomes of both the delivered and attained; we draw on those assessments that are aligned to the curriculum (viz., course learning outcomes) to compute how much the course learning has been achieved of the delivered. The delivered curriculum is a principle where there is an intention through the academic program to deliver the material and for the students to achieve the required curriculum. Thus, can a program learning outcome be measured quantitatively? We claim that through a systematic, scientific, and quantitative approach, it could be done.

Forming a method to measure program learning outcomes through the course by linking them to assessments is essential to this field of work. The benefit of a method helps substantiate the learning outcomes in meeting the intended curriculum of the program being offered. If such method is implemented, where several program courses can contribute to achieving the learning outcomes by calculating a quantitative measure, then it would liberal to say that these courses reflect the goals of the program.

Table 1. Curriculum specification table of a bachelor degree of computer sciences

	Program Learning Outcomes											
Course Code	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**J**	**k**	**l**
ARAB101								1	1	1		
CMPS100B	1	1	1		1	1		1	1			
CMPS110	1	1	1		1	1		1	1		1	
ENGL101		1					1	1	1	1		
MATH199		1		1		1			1			
CMPS160	1	1	1		1	1		1	1		1	
CMPS180	1	1			1	1			1		1	
ENGL102C		1					1	1	1	1		
MATH370		1		1		1			1			
SOCS102								1	1	1	1	1
CMPS215	1	1			1	1			1		1	
CMPS240	1	1	1		1	1			1		1	
ENGL203C		1					1	1	1	1		
ENTR200							1	1	1	1		
CMPS250	1	1	1	1	1	1	1	1	1	1		
CMPS260	1	1	1			1		1			1	1
CMPS270	1	1	1		1	1			1		1	
CMPS310	1	1	1		1	1	1	1	1	1		
ENGL204		1						1	1	1		
MATH200		1		1		1			1			
CMPS350	1	1	1		1	1		1	1		1	
MATH320		1		1		1			1			
ENGL305		1						1	1	1		
CMPS405	1	1			1	1	1		1		1	
CMPS410	1	1			1	1	1		1		1	1
CMPS425	1	1	1	1	1	1	1	1	1	1		
MATH250		1		1		1			1			
CMPS490	1	1	1		1	1	1	1	1	1	1	1

4. Assessments and Their use in Course Learning Outcomes

An academic course in a program has a set of descriptors which define and characterize each course. The learning outcomes are generally aligned to each course in the program by identifying,

knowledge, skills and competencies found in the descriptors fitting the learning outcomes. Stakeholders evaluate the appropriateness of the learning outcomes in their alignment to the course. More importantly, knowledge, skills and competencies are embedded in the assessment tools, and matched to the specific learning outcomes. The alignment of the assessment is an exercise where a match between course learning outcome and assessment tools is performed by the instructor of the course or moderated by other stakeholders. When students are assessed through the aligned tools, they provide a sensible accurate measure of whether the student has learned what was intended in the course delivered.

There are different assessment tools instructors use to evaluate student performance. Thus, the assessment method whether in-class activities, tests, or projects are inseparable and usually aligned to the outcomes of the course, and the intended curriculum (viz., includes the documents by education authorities which specify how much, how often and what should be taught in an educational setting) for the course [14]. The alignment of the assessment to the course learning outcomes augments the evidence needed to assure that the academic program is consistent with its mission and graduate attributes [15]. Students undertaking a set of courses or modules, produce a trail of achieved learning [16]. If attained, it could demonstrate student proficiencies that the program set forth.

The assessment of the curriculum consists of the type and content in each course which may be in form of tests. One way to fulfill what the planned curriculum is, is to understand what is being assessed. This is done through a quality control process where stakeholders running the program go through a process of moderation i.e., evaluating whether the course learning outcomes align with the program learning outcomes. Agreement around the learning outcomes fitting the curriculum is consensus driven where faculty and other stakeholders place emphasis on the curriculum and its coverage. There are constant revisions and calibrations made to the alignment match until consensus is reached. Once this is achieved, the course learning outcomes guide the designing and writing of assessment items which are developed to match the curriculum, specifically the content to be attained. The general overarching element of learning outcomes is that it provides a framework where the teaching and course assessment are guided. One of the persistent issues in the review of a program is to assess what has been learned. Thus, to ensure that learning outcomes are achieved, the assessment items or tools are judged to align with course learning outcome. A challenging aspect in this approach is to objectively, assess the delivered curriculum through classroom assessments. And the extent which the student has reached or attained the learning outcomes established for a module or course. The attainment of the learning outcomes is explicitly embedded in the course or unit assessments and can be evaluated through formative, summative or continuous assessments [17].

5. Method and Analysis

To develop this method, one course/module was used from the computer science program. The method could be scaled to other courses or modules intended to cover the curriculum or cover a specific program. As in every course or module at this private university, course learning outcomes are mapped to program learning outcomes. Typically, it is assumed that a committee or a course instructor develops the course learning outcomes and maps to the prescribed program. Once the assessments are created in a course, they are also aligned to the course learning outcomes and content and thus linked to the program. Student assessments might not completely cover the course which then may call for further action. Also, in some cases, the learning outcomes will not be completely covered by the instruction which then draw for redesigning the course as to fulfill the alignment between the curriculum and the course learning outcomes.

The method will demonstrate at a quantitative level how much of the program outcomes is covered and attained through the assessments. Two important measures can be calculated through this method. A calculation for the intended (i.e., covered) curriculum and the second for the attained (i.e., achieved). The intended curriculum gives a measure of how much the course learning outcome has been covered through the curriculum. The desire is to achieve the intended course learning outcomes, faculty and stakeholders have only to draw on those assessments that are aligned to the program course and calculate how much of the course learning has been achieved. The achieved course learning outcome can be measured quantitatively by how much it is covered in the assessment.

To illustrate the method, an assessment of a course is demonstrated as a hypothetical example. The assessment tools are two tests and combination of quizzes and assignments (aggregated under one score) and a final exam. The items of all the assessments were judged by the course instructor(s) to align with course learning outcomes. Likewise, the course learning outcomes are also judged to align to the program learning outcomes. Typically, before the assessments are administered, pre-moderation practices allow instructors and other stakeholders to judge the items in the assessments to align with the learning outcomes.

A quantitative measure of the course learning outcome can be calculated by identifying its specific assessment. For instance, for course learning outcome-1, course learning outcome-5 and course learning outcome-8 all are covered in test-1. Some items of test-1 can for instance, cover learning outcome-1, while other items could cover learning outcome-5 and so on. These items have different weights based on the difficulty of the items and the cognitive level they demand as judged by the assessor. So, an assessment can have different weights to cover the course learning outcomes.

Table 2. Course learning outcome crossed with the delivered and attained assessment

CLO No	Test 1/20 Delivered		Test 1 /20 Attained	Test 2 /30 Delivered		Test 2 /30 Attained	CA/10 Delivered		CA/10 Attained	Final/40 Delivered		Final/40 Attained	% of CLO Attained
1	50%*20	10	6.20							10%*40	4	3.50	69.29
2				40%*30	12	8.40				25%*40	10	7.30	71.36
3				20%*30	6	4.30				15%*40	6	3.60	65.83
4										15%*40	6	4.15	69.17
5	25%*20	5	2.90				20%*10	2	1.35				60.71
6							10%*10	1	0.80	15%*40	6	4.30	72.86
7							50%*10	5	2.55				51.00
8	25%*20	5	3.60							15%*40	6	3.55	65.00
9				20%*30	6	4.00							66.67
10				20%*30	6	4.20				5%*40	2	0.65	60.63
11							20%*10	2	1.45				72.50

Table 3. Course learning outcomes mapped against assessments and program learning outcomes

CLO No	Test 1/20 Delivered		Test 1/20 Attained	Test 2/30 Delivered		Test 2/30 Attained	CA/10 Delivered		CA/10 Attained	Final/40 Delivered		Final/40 Attained	% of CLO Attained	Program Learning Outcomes Delivered								
														a	b	c	d	e	f	g	h	i
1	50%*20	10	6.20							10%*40	4	3.50	69.29	0	1	0	X	1	1	X	0	0
2				40%*30	12	8.40				25%*40	10	7.30	71.36	1	0	1	X	0	0	X	1	1
3				20%*30	6	4.30				15%*40	6	3.60	65.83	1	0	1	X	0	0	X	1	1
4										15%*40	6	4.15	69.17	1	0	1	X	0	0	X	1	1
5	25%*20	5	2.90				20%*10	2	1.35				60.71	0	1	0	X	1	0	X	1	1
6							10%*10	1	0.80	15%*40	6	4.30	72.86	0	1	0	X	0	1	X	0	0
7							50%*10	5	2.55				51.00	0	1	0	X	1	0	X	1	1
8	25%*20	5	3.60							15%*40	6	3.55	65.00	1	0	1	X	0	0	X	1	1
9				20%*30	6	4.00							66.67	0	1	0	X	1	0	X	1	1
10				20%*30	6	4.20				5%*40	2	0.65	60.63	1	0	1	X	0	0	X	1	1
11							20%*10	2	1.45				72.50	0	1	0	X	1	0	X	1	1
		20	12.7		30	20.9		10	6.15		40	27.05	66.80	**5**	**6**	**5**	X	**5**	**2**	X	**9**	**9**

Table 4. Calculation of the delivered and attained program learning outcome

	A	B	C	D	DxB		E	DxE
Course Learning Outcome	Number of course learning outcome in program learning outcomes	Probability of occurrence of course learning outcome in program learning outcomes A/41	Delivered points from a 100 to appear in the course learning outcomes	Probability of assessment occurring in a course learning outcome C/100	Joint probability of delivered assessment of course learning outcomes occurring in program learning outcome	Hypotheti-cal student attained points from a 100 to appear in a course learning outcomes	Ratio of Hypothetic-al student attained points from a 100 to appear in a course learning outcomes	Joint probability of hypothetically attained course learning outcomes occurring in program learning outcome
1	3	0.073	14	0.14	0.01024	9.7	.097	0.007081
2	4	0.098	22	0.22	0.02146	15.7	0.157	0.015386
3	4	0.098	12	0.12	0.01171	7.9	0.079	0.007742
4	4	0.098	6	0.06	0.00585	4.15	0.0415	0.004067
5	4	0.098	7	0.07	0.00683	4.25	0.0425	0.004165
6	2	0.049	7	0.07	0.00341	5.1	0.051	0.002499
7	4	0.098	5	0.05	0.00488	2.55	0.0255	0.002499
8	4	0.098	11	0.11	0.01073	3.55	0.0355	0.003479
9	4	0.098	6	0.06	0.00585	4	0.04	0.00392
10	4	0.098	8	0.08	0.00780	4.85	0.0485	0.004753
11	4	0.098	2	0.02	0.00195	1.45	0.0145	0.001421
	41	1	100	1	0.091	63.2	0.632	0.057012

The first row and the second cell in Table 2. indicate the number of points (20) for the assessment in the course i.e., the total points for assessment-1 i.e., test-1. Thus, the learning outcome-1 covered by 10 points through assessment-1 out of the 20 points; course learning outcome-5 covers 5 points through assessment-1 out of the 20 points; and course learning outcome-8 covers 5 points through assessment-1 out of the 20 points. Thus, the assessment makes up 20 points of what we consider as delivered. Using the assessment specification table, we can identify the delivered as well as the attained. What is attained is the measure of how much students achieved on the assessment as opposed to the delivered which is what the assessment covers of the curriculum. In Table 2., assessment-1, column 4 indicates that attained by students on the assessment i.e., test-1 (as an average score), comes to 6.20, 2.90 and 3.60 for course learning outcome-1, course learning outcome-5 and course learning outcome-8 respectively. We can also recognize what is covered and achieved for each learning outcome. We can demonstrate this through Table 2. The assessment type is in the columns and learning outcome in the rows. The learning outcome 1 is identified by the first columns of Table 2. and Table 3. If we observe the 2nd column, half (50%) of test-1 covers course learning outcome-1, 25% of test-1 covers course learning outcome-5 and 25% of test-1 covers course learning outcome-8. In this example, the average student scores of the assessments are presented. For example, the attainment of assessment 1 has the average value of 6.20 on the 4th column and the 3rd row of Table 2. is the score attained by students on test-1 covering only learning outcome-1; 2.90 and 3.60 on the same assessment, is the level attained by students for learning outcome-5, and learning outcome-8 respectively.

The last column of Table 3. shows the percentage of the course learning outcome attained by students through all the assessments for each course learning outcome. This is based on the delivered curriculum that is how much students achieved of the delivered curriculum. The percentage of attained course learning outcome-1 through test-1 and final exam (see row 3) comes to a hypothetical 69.29% of outcome-1 attained by students. This is calculated by adding the achieved on test-1 and final exam divided by 14 points (i.e., ((6.20+3.5)/14)x100). Note, 14 out of the total hundred points is the percentage of the course learning outcome covered by the two assessments—Test-1 and the Final Exam. In other words, 14 in the denominator is the total points from assessment test-1 (10 points) and the final (4 points) covering course learning outcome-1.

Table 3. shows the information as in the previous Table 2., with the addition of program learning outcomes crossed with the course learning outcomes and shown in the last 9-right columns. The "1" in the last 9-right columns of Table 3. indicates the course learning outcome aligned to the program learning outcomes. The "0" indicates that no alignment exists. As an example, the program learning outcomes-b, program learning outcome-e and program learning outcome-f are aligned to course learning outcome-1.

In Table 2. and Table 3., the fourth, seventh, tenth, and thirteenth column show the attained score by students on test-1, test-2, continuous assessments, and final exam. The probability of the attained can be calculated for each course learning outcome by taking the attained points for a particular course learning outcome and dividing by the total number of points covered for the course. Again, as mentioned earlier, the delivered curriculum, which is intended and covered by the assessments, the attained is the curriculum achieved, based on student performance on the assessment. To calculate the probability of the delivered curriculum for course learning outcome-1, we use the multiplication rule. The delivered curriculum for learning outcome-1 is 0.14, considering that 10 points allocated for test-1 and 4 points are allocated for the final exam, totaling 14 points out of a 100. The number, 14 points in ratio of 0.14 is multiplied by the probability of the program learning outcomes being covered by the course learning outcome-1. Course learning outcome-1 aligned with program learning outcomes "b", "e", "f", and thus has a probable occurrence in a program of 3/41 or 0.073. This would be the probability of occurrence of course learning outcome in the program. Thus, using the Multiplication Rule of the course learning outcome-1 and program learning outcome probability event, is 0.14 x 0.073= 0.0102. This can be explained as the delivered curriculum by course learning outcome-1 which covers 1.02% of the program through course learning outcome-1. We can calculate through the Multiplication Rule, how much each course learning outcome covers the program learning outcomes. The sum of these joint probabilities of course learning outcome-1 to course learning outcome-11, gives the total probability or percentage of how much the program is covered of the course.

The achieved measure follows the same method as the delivered but measures the extent the student has achieved the course learning outcomes. This is measured by the assessments (e.g., tests-1, assignments and so forth) in which the students demonstrate what they know of the curriculum covered.. We can demonstrate this procedure through the shown in Table 3. As mentioned in the previous example, the course learning outcome-1 is aligned

with program learning outcomes "b", "e", "f", and thus has a probable occurrence in a program of 3/41 or 0.073; the denominator 41, is the total number of times the program learning outcomes are being covered by some aspect in the course. The percentage covered by the assessments of the course is the "total" joint probability of the assessment covering the course learning outcome "crossed" by its occurrence in the list of program outcomes.

In the fourth column in the third raw, the value of 6.20 (Table 2. or Table 3.) is the average score students achieved on test-1, out of the 10 points covering the course learning outcome-1. Similarly, 3.5 is the average student score achieved by students on the final exam out of "4" points covering the same learning outcome-1. Thus, the average percentage level achieved by students of the course learning outcome-1 is (6.20+3.5)/100=0.097. Thus, using the Multiplication Rule of the achieved course learning outcome-1 and program learning outcome is 0.097 x 0.073= 0.007 which suggests students achieved the covered in the course curriculum through learning outcome-1 at a 0.7 chance of the program achieved through course learning outcome-1.

If the course learning outcomes are accounted by 100 points covered by the assessments, the ratio of achieved course learning outcome-2 of the total covered is 15.7/100. The probability that the program learning outcomes covered by the course learning outcome-2 is 4/41. Thus, the attained program learning outcomes covered by course learning outcome-2, can be calculated using the Multiplication Rules of Probability in which the "occurrence" of learning outcome-2 is crossed by the probability of the program learning outcomes is covered by the course learning outcome-2. This joint probability is the (15.7/100)x(4/41)= 0.015 which states that for learning outcome-2 students attained 1.5% of the program learning outcomes.

If we can calculate a measure of the program learning outcomes through course learning outcome-1, we can also calculate an aggregate measure of how much is covered and attained for a program being covered by a set of course learning outcomes. The approach is algorithmic and easily applicable to course or even student level, we can determine how much a student achieved of the program learning outcomes of all the courses taken. For a single course a measure of delivered or attained program learning outcomes can be calculated. The computed percentage of delivered as well as the attained program learning outcome are shown in Table 4. The 6th column of Table 4. represents the Multiplication Rule of probabilities of the delivered course learning outcome. Using the Multiplication Rules of probability, the probability of two events of delivered course learning outcomes and the ratios of course learning outcome found in program learning outcomes is the product of the respective probabilities shown in the 6th column of Table 4. The ratio of the occurrence of the delivered course learning outcome across all program learning outcomes is illustrated through in Table 4. We demonstrate an example using learning outcome-2 where program learning outcome "a", "c", "h" and "i" is aligned to course learning outcome-2 and measured by test-2 and the final exam (see Table 3.). Both assessments, test-2 and the final exam cover 22% of the total score for the course. As a repetition of the demonstration above, the program covered by the course learning outcome-2 is 4/41 (9.8%). The Multiplication Rule of probability of the delivered curriculum covered by the course learning outcome-1 for the program is (22/100) x (9.8/100) = 0.02146 (see column 6 of Table 4.). The measure of 0.022 indicates the percentage score of about 2.2% covering the program learning outcomes by the assessments of course learning outcome-2. In terms of the attained, we can calculate the hypothetical average for each assessment i.e., test-2 and the final exam being 8.4 and 7.4 respectively; their sum is 15.4, which is the average attained out of a hundred i.e., 15.4% and has a probability of 0.154. The chance of occurrence of attained program learning outcome is (15.4/100) x (9.8/100) = 0.015386 (see column 9 of Table 4.) that comes to a percentage score of 1.5% level attainment of the program outcomes per course. This can have a total score by summing up each program learning outcome attained. Every course has a measure for the delivered course learning outcomes found in the program, where an aggregate score in percentage can be calculated for courses covering the program learning outcomes. By scaling the process, it can lead to an aggregate score of the delivered courses for a program and how much each course quantitatively contributes to the delivered content of a program. In totality, a measure for the whole program can be calculated to whether the program learning outcomes have been achieved by the delivered curriculum.

Column 6 of Table 4. shows the probabilities of the covered learning outcomes. The sum of the column gives a measure of the course covering the program learning outcomes. Similarly, the last column (column 9) sum provides a measure of the attained course learning outcomes covering the program or in another words the quantitative measure of achieved program learning outcomes for each course learning outcome for the course or module. We can develop a set of equations from the specification tables (see Table 3. and Table 4.) which could cover the course or program. If the values in terms of assessments i.e., covered or attained could be built into a specified data within the database, these data systems can be operational and computational.

6. Discussion

The goal of this study was to calculate how much of the program learning outcomes have been attained by the students. *We have demonstrated a method in which a unit, a college or even a teaching and learning institution can calculate the average score of the program learning outcomes as an overall measure of the program achievement.* The data used in this study was hypothetical, the method matched course learning outcomes with program learning outcomes and assessments. The delivered i.e., "declared" course learning outcomes where used as a base and example of the curriculum match to the course learning outcomes.

This study demonstrates through an empirical and scientific approach the "average" level of students attained work on course or unit assessments; with the purpose of attaining the program learning outcomes. The method allows to measure individual student or group of students (whole classes) in a course or module and whether the course curriculum delivered has achieved the intended curriculum through the course learning outcomes.

Assessments are now used widely to address student learning. Currently many accreditation institutions are using assessments to evaluate the learning outcomes. For instance, the Accreditation Board for Engineering and Technology (ABET) according to Veltri et.al. [12], has developed criteria for the course assessments which are used to determine if the program learning outcomes and course learning outcomes are aligned to the standards of the ABET and thus are benchmarked to some external standards. A common practice among universities and a case in point are the Australian universities; they provide statements of generic outcomes of a university education as a condition of national funding and that they are achieving these outcomes [11]. Australian universities also seek to have graduate attributes fulfilled and reflected in the program design through the courses and learning outcomes in the program courses. The attainment of graduate attributes is not straightforward [17]. It involves ensuring the learning outcome (program and course) are covered using indirect methods and data analysis techniques in curriculum documentation, student perceptions, longitudinal data analysis, perceptions of alumni, and faculty [17], [18].

The method developed in this study, starting with specification tables or what is known as curriculum matrixes. There are a number and types of specification tables that can be developed. A curriculum specification table which maps the courses to align with the program learning outcomes. At different level, there is what is known as the assessment specification tables, which specify the assessments and their alignment to the course learning outcomes. Within the specification table of aligned assessments to course learning outcomes, followed by the alignments course learning outcomes to program (see Table 2. and Table 3.). The curriculum of a course or module can be aligned through what is known as a curriculum matrix to check whether the curriculum is delivered [19], [20], [21]. The concept of curriculum mapping i.e., alignment is adapted from curriculum design concepts mapping the course learning outcomes to program learning outcomes [22]. Concomitantly, the assessments designed for the curriculum evaluation and planning allow to evaluate whether the learning outcomes have been achieved and determine whether cognitively and non-cognitively they assess the knowledge, skills and competencies embedded in the learning outcomes. Many higher education institutions rely on those learning outcomes that meet the college or institutional accreditation requirements, they also assure that the designed program objectives are embedded in the learning outcomes which have been delivered. The mapping of course learning outcomes to program is rather done through a judgement process where agreement is moderated by stakeholders of the course. Expanding this process to include students and employers might expand this process to objective evidence and triangulate the process. Thus, in this study, assessments were mapped to the learning outcomes and then calculated by how much i.e., quantitatively, were delivered and how much were attained. One challenge of this work is to attempt to address the delivered and assume that it has been declared, i.e., have been achieved (See English, [23] cited in Robley, Whittle & Murdoch-Eaton [24]).

The key artifact used in this process is the curriculum matrix or what is known as the alignment matrix in which it allowed us to align program learning outcomes to course learning outcomes. A matrix could be used to also map the graduate attributes to program learning outcomes allowing for closure where the loop from the mission to program learning outcomes is cycled through. In doing so the institution can claim that what the mission leading to the skills and proficiencies in students has been achieved.

More importantly, the alignment matrix presented in this study crossed program learning outcomes and course learning outcome (proxy to the designed curriculum). Within the table, the weights of the assessments were embedded in the specification table. The mapping of assessment items of a course and then to program learning is a process whereby a judge or a panel, logically and interpretably rate each item, element, or unit in a course assessment to match the course learning outcome. The course

learning outcomes are derived from the course objectives which are delivered from the program learning outcomes. The process is consensually driven in that inter-rater agreement which validates the alignments especially the alignment of the course learning outcome with assessments, in what Biggs [24] called constructive alignment model. Going up the ladder or hierarchy: course learning outcomes to program learning outcomes and program learning outcomes to graduate attributes.

Not all course learning outcomes can be addressed by the assessments. As item questions or units are judged to cover the course learning outcomes, they are mere approximations of the delivered curriculum that reflect the course learning outcomes. The attained would be how much students achieved on the assessments in some units of measure. The practical implication of this process is not only that the learning outcomes achieved are measured but through the measurement it could be determined which learning may be overly stressed or achieved in a module and thus allow for correction in the coverage of the module. The approach also helps to address the paucity of the elements not covered and immediately apply corrective action by calling out for those learning outcomes that are not complete or imbalanced. Even when such coverage is distributed fairly i.e., normally; calculating what is attained provides us with some understanding of where there are gaps in teaching and learning and the needed focus in the future.

In summary, the process underlined in this paper suggests, firstly: the judgement of the assessment, specifically item level assessments being aligned to the course learning outcomes and providing the weights of each assessment covering the course learning outcome. Secondly, the alignment of course learning outcomes to program learning outcomes. Thirdly, the calculations of the joint probabilities of the delivered and attained learning outcomes through the algorithm presented in this paper. The alignments shown in the specification tables allow for the development of further work in this area to go beyond course level analysis, to program level. Thus, bringing *the possible and fundamental changes to student assessment and a new thinking and paradigmatic shift in how students are assessed, rather than have them assessed on the specific modules, the method allows to perform the calculation to the extent which students have achieved or attained the program learning outcomes. This shift would be viable and logical as it would reflect what is set forth in outcome-based learning.*

Indirect measure also plays a significant role in assessing students' knowledge of the achieved learning outcomes. When students are the ones who are assessed, it would be important for them to reflect on whether the assessments are aligned with course learning outcomes or whether the learning outcomes have been fulfilled. Any future work shall be triangulating the process to reflect and integrate student instructors or even stakeholder ratings of the assessments and whether they reflect the learning outcomes. Also, because the attainment of learning outcomes leads to the acquisition of graduate attributes, future involvement of employers in the judgement of whether the learning outcomes have been achieved will significantly increase the validity of such approach. The empirical method thus, can substantiate the attainment not only of learning outcomes but of graduate attributes and thus, fulfilling the objectives and the mission of the institution [25],[26],[27].

7. Conclusion

Bringing closer the university mission to goals and to course learning outcomes is not exactly easy. Particularly when the higher education institution, as in this study has a strong liberal arts education detached from discipline-based learning such as business or engineering. Controlling for such diversity is necessary to bring learning outcomes into some cohesive sense that reflect the mission of the institution. At the end of the line, when the students have ensured they attained the learning outcome, it is expected that they are disposed with attributes embedded mission of the institution.

Further establishing program learning outcomes is not easy and has to stem from a strong conceptual framework of the college or university. The development of these aspects is generally approached consensually where the university community review and re-review the university learning outcomes or program learning outcomes. The course mapping exercise charts the course learning outcomes with the program learning outcomes and is one of the fundamental tools to establish an empirical approach to whether the course and curriculum cover the program learning outcome. While essential elements through faculty within a program judge the alignment of a course to program learning outcomes, the approach is limited as it draws on a single stakeholder and leave students in judging whether the material they learned was covered in the learning program. Further, involvement of students and other stakeholders could bring more credible results to whether the program, course objectives and course learning outcomes are aligned.

As the assessment tasks can be derived from the learning outcomes, it is generally the faculty that generates the assessments from the curriculum to check whether the curriculum covers the learning outcomes. When teaching is done, assessments are developed based on the curriculum delivered. Once

this is all done, assessments are administered to see if the delivered curriculum is attained. The data generated, and outcomes can be reviewed to calculate the achievement level of the learning outcomes [28]. Aligning the assessment to outcomes is key to the development of this study. We see these specification tables provide a system of numerically organized data sets or specification tables of delivered and attained learning outcomes. From these tables we can develop matrices and from these matrices equations that can be scaled to courses but also programs. There will be generalized equations of programs, or at college level. We can also develop these matrices and equations for the delivered as well achieved outcome for each student and for a single course or all the courses, the student takes that account for the program. These equations can in fact be scaled such that program learning outcomes can be aligned to core values of the institution and thus allow to scale these equations to a variegated alignment matrix.

Given the limitations stated above (end of the discussion section), the empirical and objective approach of measuring the program learning outcome is so robust, particularly this being a high impact study. We believe the approach could lead to a reconceptualization of how assessment of higher education could be performed. We close this paper with this tenuto: That rather than we assess students on what was achieved in the assessment, a more viable method is to assess whether the students have achieved the program learning outcomes for a specific program.

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