Measurement of Course Learning Outcomes for Data Structure Using the Combination Approach

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Abstract
Data Structure is an important and compulsory course in the computer science and engineering. The topics of the course require detailed view for various algorithms such as queues, stacks, sort, search, trees and graphs. Due to the complexity of teaching and understanding of this course, we are focusing in measuring the student performance and the course learning outcomes. This paper describes methodology for providing a quantitative measurement of data structure course. The methodology uses a combination of three approaches (average, threshold, and performance vector) to assess course learning outcomes. The method utilizes data obtained from students' marks in exams, tests, projects, and other formal assessments. A computerized system has been developed based on this method to expedite the analysis process.

Keywords
ABET; Data Structures; Assessment tool; Course Learning Outcomes; Faculty Course Assessment Report; Key Performance Indicators; Program Learning Outcomes.

1. Introduction

Teaching and learning Data Structure is not an easy, according to several researches, students face problems in understanding the algorithms and the implementation, it remains a challenge in Computer Science education [1].

Over the past two years the College of Computer Engineering and Science at PMU has adopted new methodology in its teaching and learning processes. The principle of this approach has been adapted from the American Accreditation Board of Engineering and Technology (ABET) and The Saudis National Commission for Academic Accreditation & Assessment (NCAAA). The learning outcomes for each course need to be measured and used for continual improvement in course quality [2]. The methodology focuses on outcomes that are identified and measured with different attributes such as knowledge, skill, or attitude, which prepares the graduates for their professional practice [3]. This paper describes a method that is used to analyze and evaluate the attainment of data structures learning outcomes (CLOs). CLO is the attribute that students are expected to have after completing a course. The evaluation of whether CLO is attained is essential in determining a student's grasp of a particular course.

The result of CLO attainment will also be used to evaluate the attainment of computer science/engineering program learning outcomes (PLOs). The outcome of the analysis will be used to improve the teaching and learning experience in the data structure course.

2. Background

As defined by ABET, both CLO and PLO describe what the program graduates are expected to know and be able to do at the time of graduations. These relate to the learning domains such as knowledge, cognitive skills, interpersonal skills, and communication that students acquire as they progress through the program [4]. Assessment is one or more processes that identify, collect, and prepare data to evaluate the attainment of PLOs. Different types of assessment being used to measure the Program and courses outcomes like direct, indirect, quantitative and qualitative measurements [5]. In order to measure an outcome, a set of key performance indicators (KPIs) are used. KPIs are measurable attributes identifying the performance required to meet an outcome [6], [7]. CLOs are linked to PLOs via the KPI. Ideally, an assessment process should measure the extent to which student outcomes are being attained, as explicitly specified by ABET. Today the different approaches being used for CLO assessments include the average approach, threshold approach, and performance vector approach.

In the average approach the score average of students should exceed the success criteria (such as the average of scores should exceed 70% for a specified assignment). This approach is not ideal for classes with two different levels of students (high score group and low score group), as illustrated in Table 1, the average score of the student class in is 78%, which is above the success criteria, but the number of students failing reaches 50% (based on 66 being the passing score). Such an approach fails to capture the goal.

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Table 1. Student scores using the average approach

#	Score	Achievement of CLO based on Average
student 1	96	Average78%
student 2	96	
student 3	96	
student 4	96	
student 5	96	
student 6	60	
student 7	60	
student 8	60	
student 9	60	
student 10	60	

In the threshold approach a high number of the students should exceed the success criteria; for example, 75% of the students are expected to achieve a score of 70% or above for a specified assignment. This approach is not ideal when the majority of the students pass the assignment with a low score (between 70 and 75), as illustrated in Table 2.

Table 2. Student scores using the threshold approach

#	Score	% of students above the Threshold
student 1	70	80% With Average 62.2
student 2	70	
student 3	71	
student 4	71	
student 5	72	
student 6	72	
student 7	73	
student 8	73	
student 9	25	
student 10	25	

The percentage of students above the threshold reaches 80%, but the average of the class is 62.2, which is very low. The threshold approach, therefore, also fails to capture the goal.

The performance vector approach is based on a performance assessment scoring rubric developed by Miller and Olds [8]. A performance vector is constructed by processing data obtained from an assignment into a packet of information presented in the form of a 4-tuple vector that relates the aggregate results of the assessment to four performance level classification categories, As stated by Miller and Olds, "excellent (student applies knowledge with virtually no conceptual or procedural errors), adequate (student applies knowledge with no significant conceptual errors and only minor procedural errors), minimal (student applies knowledge with occasional conceptual errors and only minor procedural errors), and unsatisfactory (student makes significant conceptual and/or procedural errors when applying knowledge)". This vector is generally referred to as an "EAMU" performance vector and is presented in Table 3. In our paper we introduce a new approach using a combination of average, threshold, and performance vector approaches.

Table 3. Specification of performance vector classification levels

CLO - Performance vector		
Category	Nominal Levels	Points
Excellent	> 90%	3
Adequate	>75%	2
Minimal	>66%	1
Unsatisfactory	<66%	0

3. Course Assessment Methods

Assessment is usually classified into summative or formative for the purpose of considering different objectives of course assessment methods [9-11]. A "grade" is a summative assessment of a student's aggregate performance within the context of a particular course [12]. This letter grade represents the extent to which that student has successfully met the instructor's course requirements and it will be reported on the student's transcript. A "score" is a formative assessment of an assignment completed and submitted during a period. This numeric score, if it can be directly linked to a specific KPI, can be used as evidence in support of student outcomes.

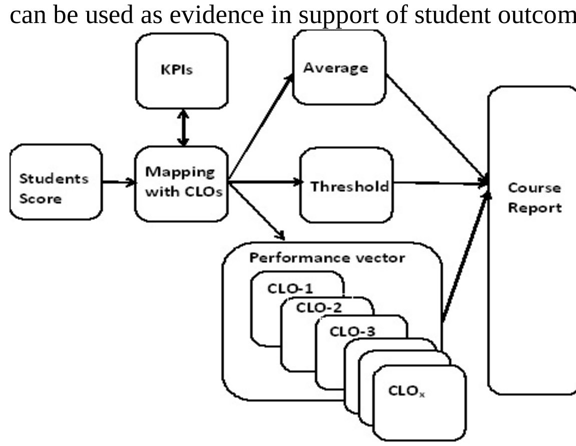

Figure 1. Processes in the combination approach

As stated by Hatfield, "virtually any assignment can potentially be used to assess student achievement of the program outcomes" [13]. Combination of average, threshold, and performance vector can be constructed from nearly any directly assessed item of classroom activity, such as homework assignments, quizzes, reports, presentations, or exams. As each item contains multiple questions focused on a specific topic, the question will be mapped to the CLO; the score of each question will be used in the measurement of CLO achievement. Figure 1 shows the processes of the new approach that consist of mapping, measurement, and report.

A. Mapping

Mapping describes the relation between classroom activity items and the CLOs.

1. To describe the usage of various data structures. These include lists, stacks, queues, dictionaries, and graphs.
2. To describe the usage of various data structures algorithms such as Sorting and Hashing.
3. To analyze the performance characteristics of algorithms using mathematical and measurement techniques.
4. To explain and summarize the advantages and disadvantages of various data structures implementations.
5. To Design and apply appropriate data structures for solving computing problems
6. To develop improved communication and collaborative skills.

In this example assignments are mapped to the CLOs. Assignment 1 (A1) covered CLO-1, assignment 2 (A2) covered both CLO-1 and CLO-3, and assignment 3 (A3) covered CLO-1 and CLO-4, as shown in Table 4.

Table 4. Mapping of CLOs and assignments

7	Outcomes	Assignments			
8		A1	A2	A3	A4
9	CLO - 1	1	1	1	
10	CLO - 2				
11	CLO - 3		1		
12	CLO - 4			1	
13	CLO - 5				
14	CLO - 6				

Mapping between CLOs and KPIs is also necessary in measuring student outcome achievements.

B. CLO achievements based on average

The achievement of CLOx using the score average depends on the class activity items. The summation of the average score of these items represents the achievement of a particular CLOx. For example, the achievement of CLOx for a course with assignments, LABs, quizzes, projects, major and final exams with score distribution 10, 20, 10, 20, 20, and 20, respectively, is:

$$
\begin{aligned}
CLO_x\_AVG = \; & AVG\_Assignments * 10\% + \\
& AVG\_LABs * 20\% + \\
& AVG\_Quizzes * 10\% + \\
& AVG\_Project * 20\% + \\
& AVG\_Major\_Exam * 20\% + \\
& AVG\_Final\_Exam * 20\%
\end{aligned}
$$

Table 5. Score of three assignments

	A	B	Y	Z	AA	AB	AI	AJ
2			A1	A2	A3	A4	SUM	A%
3	ID	NAME	10	20	15		45.0	10.0
4	200900699	A Alduaiji	7	15	13		35.0	
5	201001086	A Alghamdi	8	19	12		39.0	
6	200900731	A Almajid	6	20	14		40.0	
7	200900591	A Alnafisi	6	18	15		39.0	
8	201001561	A Alrashid	5	19	12		36.0	
9	200800890	A Alsayyar	10	15	14		39.0	
10	201000518	Ali AL-Madi	8	19	16		43.0	
11	200801092	H Alotaibi	6	11	11		28.0	
12	200600691	M Althabit	10	20	12		42.0	
109	Average out of 10		7.33	8.67	8.81			
110	# of students met the criteria		5	8	9			

To understand the assessment processes for one item, an example of a spreadsheet containing the scores of three assignments is used (Table 5). The process consists of three steps:

1- Calculate the average of each assignment (as illustrated in row 109 in Table 5).

2- Insert the average of each assignment in Table 6 using the assignment mapping.

Table 6. Averages of the assignments

Outcomes	Assignments				
	A1	A2	A3	A4	AVG
CLO - 1	7.33	8.67	8.81		8.3
CLO - 2					
CLO - 3		8.67			8.7
CLO - 4			8.81		8.8
CLO - 5					
CLO - 6					

3- Calculate the average of each row, which represent the AVG_Assignments for a particular CLO_x, as illustrated in AVG column in Table 6.

C. CLOs based on threshold

The achievement of CLOx using threshold also depends on the class activity items. The achievement of CLOx using this approach is equal to the summation of the average score of these items. To assess the CLOx achievement using this approach, the following steps should be done:

1- Count the number of students above the threshold for each assignment (as illustrated in row 110 in

Table 5). For Example, the number of students above the threshold for assignment 1 is:

= COUNIF (Y4: Y12, “>=”&7.5)

Table 7. The number of students above the threshold

Outcomes	Assignments				
	A1	A2	A3	A4	AVG
CLO - 1	5	8	9		81%
CLO - 2					
CLO - 3		8			89%
CLO - 4			9		100%
CLO - 5					
CLO - 6					

2- Insert the calculated number of each assignment in Table 7 using the assignment mapping.
3- Calculate the average of each row, which represents the AVG_assignments for a particular CLO_x as illustrated in AVG column in Table 7.

D. Achievement of CLOs based on performance vector

Performance vector for mapped CLOs will be computed. In our example the assignments are mapped to three CLOs (CLO-1, CLO-3, and CLO-4). To compute the performance vector of CLO-1, the following steps should be done:

1- Compute the average of the assignments for each student (as in column “BB” in the Table 8).
2- Calculate the number of students performing at excellent level (E).
= COUNIF (BB10: BB18, “>=”&90)

3- Calculate the number of students performing at adequate level (A).
= COUNIF (BB10: BB18, “>=”&75) –C118

4- Calculate the number of students performing at minimal level (M).
= COUNIF (BB10: BB18, “>=”&66) –C118-C119

5- Calculate the number of students performing at unsatisfactory level (U).
= COUNIF (BB10: BB18, “<”&66)

Table 8. Performance vector of the assignments

	A	B	C	D	E	F	BB
8			A1	A2	A3	A4	AVG
9	ID	NAME	100%	100%	100%	0	100%
10	200900699	A Alduaiji	70.00	75.00	86.67		77.22
11	201001086	A Alghamdi	80.00	95.00	80.00		85.00
12	200900731	A Almajid	60.00	100.00	93.33		84.44
13	200900591	A Alnafisi	60.00	90.00	100.00		83.33
14	201001561	A Alrashid	50.00	95.00	80.00		75.00
15	200800890	A Alsayyar	100.00	75.00	93.33		89.44
16	201000518	Ali AL-Madi	80.00	95.00	106.67		93.89
17	200801092	H Alotaibi	60.00	55.00	73.33		62.78
18	200600691	M Althabit	100.00	100.00	80.00		93.33
116							
117	CLO - Performance vector						
118	Excellent	E	2				
119	Adequate	A	6				
120	Minimal	M	0				
121	Unsatisfactory	U	1				

4. Faculty Course Assessment Report

At the end of the semester each instructor prepares the Faculty Course Assessment Report (FCAR). Table 9 below shows the FCAR of data structures course with 26 students.

Table 9. Data structures FCAR with average, threshold, and performance vector

Outcomes	Achievement of CILOs based on average	Achievement of CILOs based on criteria	CLO - Performance vector				Met / Not Met	Need Improvement	Reasons	Improvement Action	KPI
			E	A	M	U					
CLO1	77%	84%	3	18	3	2	Met				1.a- 2.b- 3.a- 4.c-
CLO2	69%	64%	2	13	7	4	Met				1.b-
CLO3	76%	75%	2	15	8	1	Met				1.b- 4.b- 5.b- 7.a-
CLO4	76%	77%	3	17	4	2	Met				8.b- 9.b-
CLO5	65%	61%	1	10	10	5	NotMet	Yes	Weakness in solving computing problems	give the students more exercises in	10.b-
CLO6	82%	92%	9	15	0	2	Met				9.c-

The first column is the CLOs, the second column represents the achievement based on average, the third column is the achievement based on threshold, and the fourth column represents the performance vector (EMAU). Based on the results, if a CLO average or threshold scores above the success criteria and the number of students with unsatisfactory level are less than 20%, the CLO is achieved and the keyword “MET” will appear in the ”MET/NOT MET” column.

If ((Average ≥ 70% ∨ Threshold ≥ 70%) ∧ U ≤ 20%) is true

If CLO average and threshold below the success criteria or the number of students with unsatisfactory level are more than 20% the CLO is not achieved and the keyword “NOT MET” will appear in the particular column and keyword “YES” will appear in “Need Improvement” column. The instructors should provide an explanation in the “Reasons” column. Two types of suggestion may be added to the “Improvement Action”, the first type changes to be taken by the program committee, like modifications the syllabus of the course by adding or deleting a course outcome, adding or deleting topics. the second type changes to be taken by the faculty member that can be implemented next time the course is offered like offering additional lectures to cover a specific topics, update or change the software or using additional textbook.. The KPI column describes the relation between the particular CLO and the KPI, implemented for future work in measurement of PLO achievement.

5. Conclusion

In this paper a new CLOs assessment approach has been presented for direct measurement of how well students achieve the outcomes and which actions are needed for improvement to close the assessment loop. The main contribution is in proposing a methodology for providing a quantitative measurement of the level to which each course learning outcome has been achieved. In addition, this methodology provides valuable information regarding how each learning outcome is assessed by the different assessment tools, thereby giving insights into the consistency of the various tools in measuring a particular course learning outcome. Future work will investigate more appropriate techniques for assessing final year projects, internships, and professional values. Challenging task to computerizing the full process of assessing the key performance indicators and the program learning outcomes is also planned.

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