A robust method for calculating the course learning outcome achievement in the outcome-based education model

Tarig Faisal, Moath Awawdeh, Bashir Mojeed-Sanni & Anees Bashir

Higher Colleges of Technology
Ruwais and Madinat Zayed, Abu Dhabi, United Arab Emirates

ABSTRACT: Outcome-based education (OBE) emphasises the results yielded from the learning process by ensuring that students or graduates achieve the required learning outcomes (LOs) by the end of their subjects or programmes. Outcome-based education is accomplished by measuring learners' achievement of learning outcomes. The main component in determining learning outcomes achievements is course outcomes. However, the computation process to measure this element is not very elaborate, even with the establishment of computation procedures. There is a paucity of studies which have attempted to review the efficacy or otherwise of the various methods of measuring and calculating achievement of course outcomes; for the few available, the computation process does not sound scientific nor systematic. Hence, the authors of this article developed a mathematical model that evaluates the learning outcomes achievements by systematically measuring the level of students' accomplishment of the course and students' outcomes of any subjects in their programme, using a mathematical engineering approach.

INTRODUCTION

The adoption of outcome-based education (OBE) is becoming a global phenomenon as it has been widely accepted and successful across continents and countries; it is termed as the renewal of education model from the conventional perspective [1]. It requires the specification of learning outcomes (LOs), which is unlike the traditional education model that specifies the teaching content. Due to various reasons, there were reports of unsuccessful adoption of OBE in some countries. However, it is found to be successful when implemented in medical and engineering technology schools, especially in the United Kingdom and the United States. The notable success of the implementation of the OBE model has even led more universities to follow suit. The adoption of OBE is also generally practiced in the higher education sector in many developed and developing countries [2-4]. Additionally, the continuous quest for international recognition and accreditation of institutions and programmes run by higher education institutes (HEIs) has led many universities and colleges to gravitate towards partial or wholesome adoption and implementation of OBE.

Although there has been wide popularity in using OBE for enhancing the teaching practices around the world, it has also been facing some resistance from time to time. HEIs are battling with differential and contextual issues in the implementation of OBE. Eldeeb and Shatakumari opined that in the medical education field it is acknowledged that HEIs are confronted with the problem of lack of consideration for students' capabilities and competencies while determining the expected learning outcome of a course [5]. They further highlighted other, peculiar, issues that did arise during the implementation of OBE, including a lack of knowledge or improper knowledge of the teachers or students regarding the outcome of the course; or assessment tools that were not mapped and aligned to the course [5]. Thus, it is suggested that there have to be appropriately outlined *outcomes* to ensure a successful implementation of OBE [5]. One that the students need to demonstrate at the end of a course programme, while teachers need to be engaged and committed to ensuring the successful implementation of this practice, and provide a regular update/follow-up on the assessment practices.

It is suggested that the outcomes to be achieved as a part of OBE place some constraints on the teaching and learning system, i.e. education needs to be imparted freely without any predetermined outcome. Education ought to be a long journey of exploration and discovery, but the inquisitiveness for searching is being lost, because outcomes bound it. The emphasis on *outcomes* in OBE causes a change in the attitude of the educators [6-7]. The need for inclusive, system-wide, standardised assessment, especially for students with learning difficulties posed another challenge. Also, there has been significant opposition to the tremendous workload as a course of OBE [8].

The ultimate aim of OBE models is to measure the achievement of a learner in demonstrating the specified LOs, which can be achieved by identifying a set of achievable LOs, measurement tools and the continuous quality improvement (CQI) system. The teaching content has to be planned and organised by defining the knowledge needed for a learner to

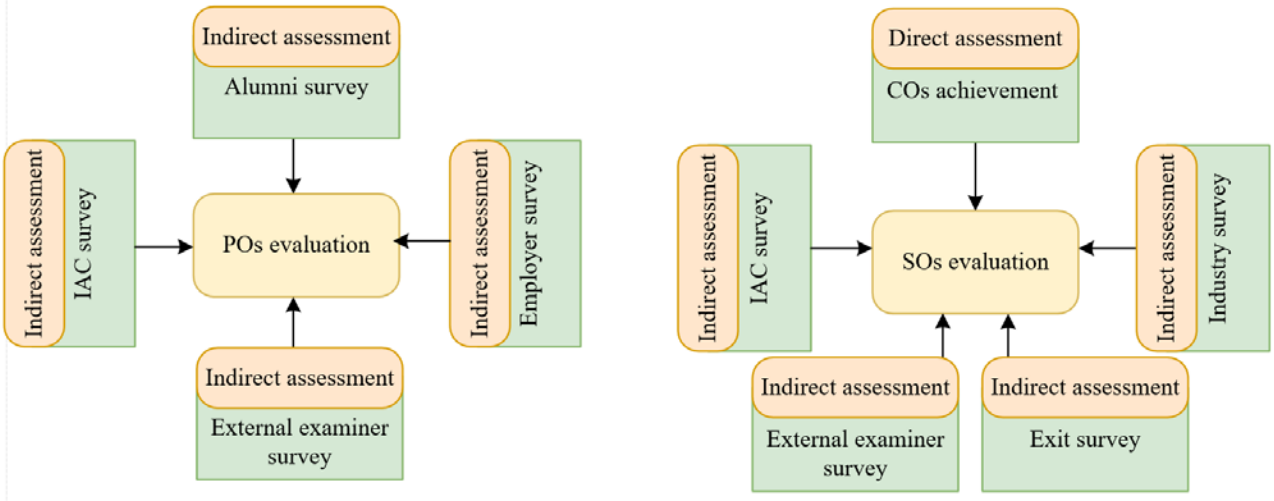
achieve the specified LOs. The fundamental element to determine the LOs achievements is to determine the course outcomes (COs) achievements. The empirical measurement of the COs achievements is not simplistic and requires a systematic approach to ensure sound evaluation of these achievements. There have not been many studies that have attempted to review the efficacy or otherwise of the various methods of measuring and calculating attainment of COs, especially in OBE focused on HEIs and programmes [9-19].

Even though some scholars have attempted to recommend tools and means of measuring the accomplishment of COs, these studies have not given full scientific details on measurement techniques used. Aside establishment of the methodology of assessing the achievement of the LO, its purpose is not well served until it is efficiently employed. The computation process involved is tedious, and therefore, is a potential hindrance for educators to apply it accordingly. These issues bring forth a need for an assessment tool that ensures that the assessment process can efficiently be deployed. Given these lacunae, this research aims to develop a robust mathematical model that calculate the level for the COs and student outcomes (SOs) attainment systematically in each subject and for each student in any programme.

OBE - ASSESSMENT MODEL

The OBE model proposed by Spady emphasises the results yielded from the learning process by ensuring that students or graduates achieve the required LOs by the end of their subjects or programmes [20]. Generally, the framework of the OBE model contains three elements: programme objectives (POs), student outcomes (SOs) and course outcomes (COs) [2]. The POs are a broad statement that describes graduates' expected attainments a few years after graduation [6]. SOs are generic outcomes that describe what the learners are expected to attain by the time of graduation, they are related to the knowledge, skills and behaviours that students should acquire during their studies [21]. Finally, the COs describe what the students should be achieving by the end of each subject. In another words, the COs are developmental outcomes assessed in the subjects during the programme; POs are summative outcomes evaluated at the end of the programme [1]. Notably, developing those outcomes can be achieved in two stages: the design stage and assessment stage [22]. Often, a top-down approach is used in the design stage in which the POs are developed based on the faculty mission and vision, and then they are used to set the SOs. The SOs are then used to build and drive the COs. In some cases, HEIs use similar SOs stipulated by an accreditation body in their country. However, the bottom-up approach design can be deployed during the assessment stage, in which the COs are used to assess the achievement of the POs.

Taking into consideration that the goal of the OBE model is to ensure the achievement of each one of the above frameworks, there should be a mechanism for assessing and evaluating them; in general as shown in Figure 1, the LOs achievements are assessed using either direct or indirect methods [10][22]. The grade obtained from a formative or summative assessment can be used for the direct methods, while surveys, questionnaires and observations based on perception are used for the indirect methods [9]. The POs are generally assessed indirectly through surveys and feedback in which stakeholders infer alumni's performance [5]. An example of a model for evaluating POs achievements is shown in Figure 1a. The figure shows that four types of surveys can be used to assess the POs. The alumni survey assesses the level of preparedness provided by the programme that helped the graduates to achieve the POs. The second survey is directed at industry stakeholders (employers) to evaluate alumni performances. The other two surveys are distributed to the industry advisory committee (IAC) members, and the external programme examiner based on the industry needs, as well as the accreditation needs.



a) b)

Figure 1: LOs evaluation model; a) POs evaluation model; and b) SOs evaluation model.

The SOs can be assessed through two methods, the direct and indirect assessment, as shown in Figure 1b. The COs achievements are used as a direct assessment method to evaluate attainment or otherwise of the programme's SOs. And this is because there is a direct relationship between the SOs and the COs through the mapping matrix. Therefore, collectively, the achievement of the COs for all subjects is used for the evaluation of the SOs. The indirect

assessment method entails students, upon the programme completion, filling out feedback forms and exit surveys assessing the LOs achievement or not. The industry/external stakeholders' survey is conducted by the industry practitioners to assess the SOs achievement through the student's performance during their industrial training. Finally, feedback from the external examiner and IAC members is based on the industry needs, as well as the accreditation needs.

As it is shown in the above process, the fundamental element to evaluate the LOs achievements of students or programmes in any OBE system is the accuracy and the robustness of assessing the COs achievements, since it will directly affect the SOs achievements and indirectly the POs achievements. The following section reviews the implemented methods for determining the COs achievements.

ESTABLISHED METHODS FOR ASSESSING THE COs ACHIEVEMENTS

Many methods and scenarios were used to assess the COs of subjects; these methods include the questioner, average, threshold, performance vector, Rasch model and fuzzy logic; these methods were used to determine the attainment of COs and students' grade in assessment correlation matrixes [9-19].

The questioner traditional method was used to evaluate the COs achievements and compare the results with the direct measurement [14]. In this study, as mentioned above, indirect measurements and direct measurements were conducted. The indirect measures involve a Likert scale survey given to the students at the beginning and end of each semester. Relating each question to grades by the students in the assessment, including examinations, projects and the quiz with the dedicated CO was used in the direct measurement. The results of two programmes, chemical and biochemical engineering courses were used in this study. The study concluded that the results obtained from the indirect measurements were closely related to the final grade obtained by the students for these courses.

Alzubaidi [15], Alzubaidi et al [16] and Mustaffa et al [9] used a combination of three approaches (average, threshold and performance vector) to evaluate the CO achievement. The average score relies on identifying whether the average score of students in the assessment exceeds the success criteria. In contrast, the threshold approach relies on determining the number of students, whose grades exceed the success criteria. Both of those methods were used in the assessment of CO matrices to obtain the results. The performance vector approach aggregated results of the assessment into four performance level classification categories: excellent, adequate, minimal and unsatisfactory. The results of these three methods were compared to conclude whether the COs were met or not.

The combination of the average and threshold methods was used by Yan and Lin, where each CO achievement was calculated in two stages [17]. The first stage is based on adding all the grades obtained by the student in each assessment mapped to the CO and dividing them by the maximum marks in each evaluation (average method). The second stage is to identify the number of students whose grades exceed the threshold (threshold approach). Mohamad et al utilised a similar approach to calculate COs achievements [10]. The significance of this study is the segregation of COs into three domains that reflect cognitive, psychomotor and affective skills.

Sudheer et al [18] and Rajak et al [19] also used the two-method approach to calculate the achievement of the CO. However, the calculation of the internal course assessments was carried out separately from the final examination, and then the weighted average was calculated. Furthermore, instead of identifying one target to either achieve or not, Sudheer et al defined three levels of attainment: level 3, if more than 80% of the students attain the target level; level 2, if more than 70% of the students achieve the target level; and level 1, if less than 70% of the students attain the target level [18]. On the other hand, Rajak et al defined level 3 for greater than or equal 60%; level 2 for greater than or equal 50%; and level 1 for less than 50% [19].

The measurements of learning outcomes and programme outcome in OBE is calculated by using fuzzy logic [11]. Two methods were used to calculate the CO and SO: a fuzzy system and traditional methods. The mean square error is used to compare the measurement's value between the fuzzy system and the traditional methods. The study concluded that both of the methods achieved similar results; however, the fuzzy system presents an alternative modern computational methodology.

The Rasch model was used with multiple students to calculate the COs achievements [12][13]. Ahmad et al compare the Rasch model in evaluating the COs achievements with the traditional methods, which use a questionnaire or survey that is distributed among students, where a Likert scale is being used to identify the performance measures of students [12]. The study claimed that in the traditional methods, the students themselves would provide an estimate of their knowledge and skills that they have imbibed from a course; a view not found to be accurate.

METHODOLOGY

This article is set to introduce a systematic method to calculate the attained levels of COs and SOs utilising the students' assessments grades for any programmes within the view of: 1) the mapping between the subjects' topics to the COs; 2) the mapping between the COs and SOs; 3) the coverage of COs in the subjects' assessments instruments; and 4) students' average marks or students' grade in each assessment.

Course Learning Achievements

To have an accurate calculation of the COs achievements by the students in a subject, the COs should be clearly described by a subject expert to reflect what the students should be achieving by the end of the subject. Additionally, the topics covered in the subject syllabus should be mapped clearly to the COs to identify how they contribute to the achievement of the COs. Furthermore, the assessments instruments need to determine the percentages of coverage of each topic.

The correlation between the subject's assessments and the course learning outcomes:

To determine the correlation between the subject's assessments and the COs, the mathematical representation of them needed to be identified. The following matrix can represent the relation between each CO and the topic of the course syllabus $A_{ij} \in \mathbb{Z}_{+}^{i\times j} : a_{ij} \in [1,3]$:

$$\mathrm{A} := \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2j} \\ a_{31} & a_{32} & \cdots & a_{3j} \\ \vdots & \vdots & \ddots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} \end{pmatrix} \tag{1}$$

Let $i, j := \{1,2, \dots\}$, where i is the topic number and j is the CO number. The matrix element $a_{ij} \in \{1,2,3\}$ is the coefficient value that represents the level of relation (*level weight*) between the CO and each topic which varies from 1 (low), 2 (medium) and 3 (high).

In the same way, each assessment instrument covers one or more topics, the weight of each topic in each specific assessment tool can be defined by the matrix B_{ki} for $\mathbb{R}_{\geq 0}{}^{k\times i} := \{B_{ki} \in \mathbb{R}_{\geq 0}{}^{k\times i} \mid B_{ki} \geq 0\}$ as follows:

$$\mathrm{B} := \begin{pmatrix} b_{11} & b_{12} & \cdots & b_{1i} \\ b_{21} & b_{22} & \cdots & b_{2i} \\ b_{31} & b_{32} & \cdots & b_{3i} \\ \vdots & \vdots & \ddots & \vdots \\ b_{k1} & b_{k2} & \cdots & b_{ki} \end{pmatrix} \tag{2}$$

Let $k := \{1,2, \dots\}$, be the number of assessments. The matrix element b_{ki} is the percentage weight of each topic of each assessment. Where each scalar can take a value from 0% to 100% as defined in the course assessment plan.

The contribution of each subject's assessment to the COs can now be determined by obtaining the matrix multiplication of B and A as $C = BA$

$$\mathrm{C} := \begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1j} \\ c_{21} & c_{22} & \cdots & c_{2j} \\ c_{31} & c_{32} & \cdots & c_{3j} \\ \vdots & \vdots & \ddots & \vdots \\ c_{k1} & c_{k2} & \cdots & c_{kj} \end{pmatrix} \tag{3}$$

Where $C_{kj} \in \mathbb{R}_{\geq 0}{}^{k\times j}$ represent the subject's assessment contribution to each CO, such that $C_{m,p} = \sum_{r=1}^{n} b_{mr}\, a_{rp}$ for $m = 1, \dots k$ and $p = 1, \dots j$.

To calculate the percentages of the subject's assessment coverage to each CO, each coefficient in the matrix (3) needs to be column-wise normalised as follows:

$$e_{kj} = \frac{c_{kj}}{\sum_{r=1}^{n} c_{kn}} \times 100\% \quad , \qquad n = 1,2, \dots j$$

Subsequently, the normalised C, which represents the percentage coverage of COs in the assessments, can be defined with a new matrix $E_{kj} \in \mathbb{R}_{\geq 0}{}^{k\times j}$,

where E is:

$$E := \begin{pmatrix} e_{11} & \cdots & e_{1j} \\ \vdots & \ddots & \vdots \\ e_{k1} & \cdots & e_{kj} \end{pmatrix} \tag{4}$$

The percentage of COs achievements: the correlation between the subjects of each assessment tool is defined by w_{1k}, where $\mathbb{R}_{\geq 0} \coloneqq \{w \in \mathbb{R}^1 \mid w \geq 0\}$ and with the condition $\sum_{n=1}^{k} w_{1n} = 100$. Consequently, a new matrix ($1 \times k\ matrix$) that represents the assessments' weight distribution in the subject is defined as $W_{1k} \in \mathbb{R}_{+}^{k}$ for $k \coloneqq \{1,2, \ldots\}$, the number of assessment is defined in matrix (2).

$$W \coloneqq [w_{11} \quad w_{12} \quad \cdots \quad w_{1k}] \tag{5}$$

The average mark obtained by the students in all assessment instruments (u_{1k}) is defined as a row vector (1 × k matrix), where $U_{1k} \in \mathbb{R}_{+}^{k}$ according to Equation (5) is written as:

$$U \coloneqq [u_{11} \quad u_{12} \quad \cdots \quad u_{1k}] \tag{6}$$

Then, the percentage of the COs achievement in the subject can be obtained using the following procedure:

1. Determine X which is the level of contribution of the students' average marks in each assessment to the COs, which can be defined by (1 × j matrix) for $X_{1k} \in \mathbb{R}_{+}^{1\times j}$.

$$X = U \times E \coloneqq [x_{11} \quad x_{12} \quad \cdots \quad x_{1j}] \tag{7}$$

2. Calculate the level of COs achievement based on the students' average marks in each assessment to the COs by normalising each element of X in Equation (7) as follows:

$$CO_{1j} = \frac{x_{1j}}{\sum_{n=1}^{k} w_{1n}\, e_{nj}} \times 100\%$$

Accordingly, the CO achievements can be represented as:

$$\mathrm{CO}_{\text{achievement}} = [\mathrm{CO}_{11} \quad \mathrm{CO}_{12} \quad \cdots \quad \mathrm{CO}_{1\mathrm{j}}] \tag{8}$$

Where $\mathbb{R}_{\geq 0}{}^{1\times j} \coloneqq \{CO_{\text{achievement}} \in \mathbb{R}_{\geq 0}{}^{1\times j} \mid CO_{1j} \geq 0\}$

Student Outcomes Achievements

The next step is to determine the SOs achievement; thus, the relation between the COs and the SOs can be represented by the matrix F_{jp} for $\mathbb{Z}_{+}^{i\times j} \coloneqq \{F_{jp} \in \mathbb{Z}_{+}^{j\times p} \mid g_{jp} \in [1,3]\}$ as follows:

$$\mathrm{F} \coloneqq \begin{pmatrix} \mathrm{g}_{11} & \mathrm{g}_{12} & \cdots & \mathrm{g}_{1\mathrm{p}} \\ \mathrm{g}_{21} & \mathrm{g}_{22} & \cdots & \mathrm{g}_{2\mathrm{p}} \\ \mathrm{g}_{31} & \mathrm{g}_{32} & \cdots & \mathrm{g}_{3\mathrm{p}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{g}_{\mathrm{j}1} & \mathrm{g}_{\mathrm{j}2} & \cdots & \mathrm{g}_{\mathrm{jp}} \end{pmatrix} \tag{9}$$

Let $p \coloneqq \{1,2, \ldots\}$, where p is the SO number. The matrix element $g_{ij} \in \{1,2,3\}$ is the coefficient value that represents the level of relation between the COs and the SOs, which varies from 1 (low) to 3 (high).

The SO achievement can be calculated as follows:

1. Determine the level of contribution of each CO achievement to the SO; this can be defined as ($1 \times p$ matrix) for $\mathrm{Z} \in \mathbb{R}_{+}^{1\times p}$, where:

$$Z = CO_{\text{achievement}} \times F = [Z_{11} \quad Z_{12} \quad \cdots \quad Z_{1P}] \tag{10}$$

2. Each element of matrix Z in Equation (9) is normalised as follows:

$$SO_{1p} = \frac{z_{1p}}{\sum_{n=1}^{j} g_{np}} \times 100\%$$

Accordingly, the SO achievement can be represented as:

$$SO_{\text{achievement}} = [SO_{11} \quad SO_{12} \quad \cdots \quad SO_{1p}] \tag{11}$$

Where $\mathbb{R}_{\geq 0}{}^{1\times p} \coloneqq \{SO_{\text{achievement}} \in \mathbb{R}_{\geq 0}{}^{1\times p} \mid SO_{1p} \geq 0\}$

RESULTS AND ANALYSIS

To implement the above method, the authors assume that one subject contains eight topics to be covered, five assessments to be conducted, and five COs. The relation between each CO and the course topics and its syllabus is shown in Table 1, while Table 2 shows the percentage coverage of each topic in the assessment. Table 3 shows the weight distribution of each assessment, as well as the average marks obtained by the students in the class in each assessment, and finally, Table 4 shows the relation between the COs and the SOs.

Table 1: COs and the course topics relation.

Syllabus/COs	CO1	CO2	CO3	CO4	CO5
Topic 1	2	0	0	0	2
Topic 2	3	0	0	0	2
Topic 3	0	0	3	0	2
Topic 4	0	0	3	0	2
Topic 5	0	3	0	0	2
Topic 6	0	3	0	0	2
Topic 7	0	0	0	3	2

Table 2: Coverage of each topic in the assessment.

Assessment/syllabus	Topic 1 (%)	Topic 2 (%)	Topic 3 (%)	Topic 4 (%)	Topic 5 (%)	Topic 6 (%)	Topic 7 (%)	Topic 8 (%)
Assessment 1	20	80						
Assessment 2			80	20				
Assessment 3	10	10	20	20	10	10	10	10
Assessment 4			30	30		10	15	15
Assessment 5	5	15	20	20	10	5	5	20

Table 3: Weight distribution and students' average marks.

Assessment/CLO	Weight	Class average
Assessment 1	10%	5
Assessment 2	20%	16
Assessment 3	10%	8
Assessment 4	10%	8
Assessment 5	50%	25

Table 4: Relation between the COs and the SOs.

COs/SOs	SO 1	SO 2	SO 3	SO 4	SO 5
CO 1	3	3	3	2	2
CO 2		2			
CO 3	3	3			
CO 4	3	3			
CO 5	3	3	3		3

Student Outcomes Achievements

Using the equations in the previous sections and the example given in this section, which is illustrated by Tables 1, 2, 3 and 4, one can now formulate the calculations required to obtain COs achievements as follows:

$$A=\begin{pmatrix} 2 & 0 & 0 & 0 & 2 \\ 3 & 0 & 0 & 0 & 2 \\ 0 & 0 & 3 & 0 & 2 \\ 0 & 0 & 3 & 0 & 2 \\ 0 & 3 & 0 & 0 & 2 \\ 0 & 3 & 0 & 0 & 2 \\ 0 & 0 & 0 & 3 & 2 \\ 0 & 0 & 3 & 0 & 2 \end{pmatrix}, B=\begin{pmatrix} 20 & 80 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 80 & 20 & 0 & 0 & 0 & 0 \\ 10 & 10 & 20 & 20 & 10 & 10 & 10 & 10 \\ 0 & 0 & 30 & 30 & 10 & 10 & 15 & 15 \\ 5 & 15 & 20 & 20 & 5 & 5 & 5 & 20 \end{pmatrix}, BA=\begin{pmatrix} 2.8 & 0 & 0 & 0 & 2 \\ 0 & 0 & 3.0 & 0 & 2 \\ 0.5 & 0.6 & 1.5 & 0.3 & 2 \\ 0 & 0.3 & 2.25 & 0.45 & 2 \\ 0.55 & 0.45 & 1.8 & 0.15 & 2 \end{pmatrix}$$

Note that A is the coefficient matrix that represents the relation between the topics of the subjects and the COs (Table 1); B is the coefficient matrix that represents the relation between the subject assessment number and its course topic shown in Table 2; and *C* is calculated as per matrix (3). From Table 3, *W* and *U* one can obtain the following:

$$W=(10 \quad 20 \quad 10 \quad 10 \quad 50),\ U=(5 \quad 16 \quad 8 \quad 8 \quad 25)$$

Now *E* and *X* can be calculated according to Equation (4) and Equation (7), respectively:

$$E\cong\begin{pmatrix} 58 & 0 & 0 & 0 & 42 \\ 0 & 0 & 60 & 0 & 40 \\ 10 & 12 & 31 & 6 & 41 \\ 0 & 6 & 45 & 9 & 40 \\ 11 & 9 & 36 & 3 & 40 \end{pmatrix},\quad X=(6.5 \quad 3.7 \quad 24.7 \quad 2 \quad 25)$$

Then, the CO achievement can be found using Equation (8) as shown below and in Figure 2a.

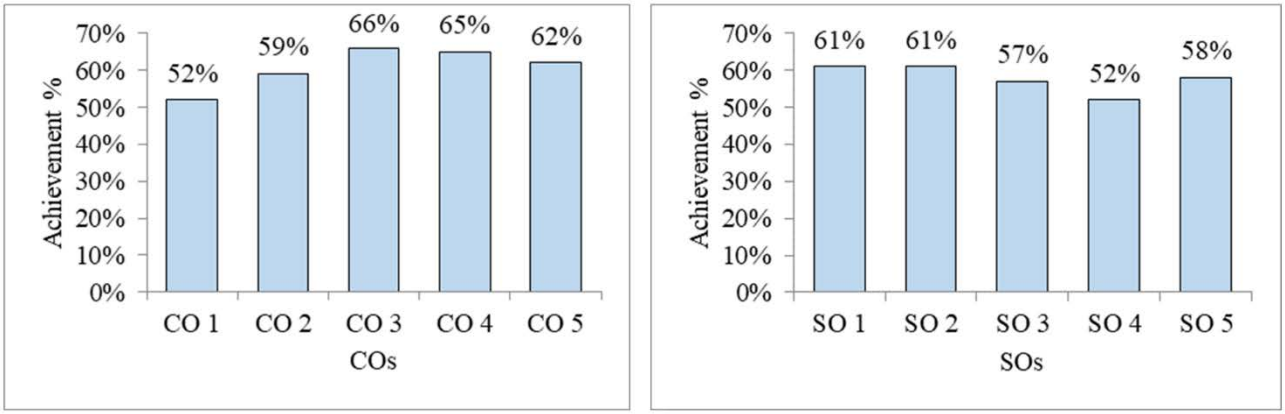
$$CO_{achievement}\cong(52 \quad 59 \quad 66 \quad 65 \quad 62)$$

One can now find the SO achievement using the previous results, by obtaining firstly the level of contribution of each CO achievement to the SO, which is defined in matrix (9) and considering the data given in Table 4:

$$F=\begin{pmatrix} 3 & 3 & 3 & 2 & 2 \\ 0 & 3 & 0 & 0 & 0 \\ 3 & 3 & 0 & 0 & 0 \\ 3 & 3 & 0 & 0 & 0 \\ 3 & 3 & 3 & 0 & 3 \end{pmatrix} \text{ and hence } Z=(7.4 \quad 9.1 \quad 3.4 \quad 1 \quad 3)$$

From Equation (8), the SO achievement can be calculated as shown below and in Figure 2b:

$$SO_{achievement}\cong(61 \quad 61 \quad 57 \quad 52 \quad 58)$$



a) b)

Figure 2: LOs achievement (average class score) - a) COs achievement; and b) SOs achievement.

The procedure can be summarised as shown in Table 5.

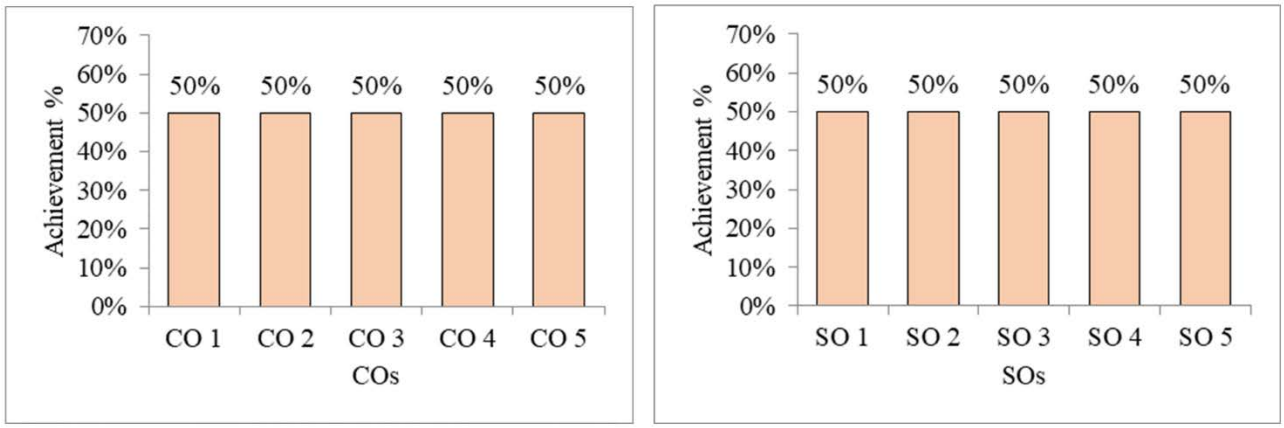
Table 5: Summarised procedure.

No.	Define/calculate	Equation	Table
1	Define A	1	1
2	Define B	2	2
3	Calculate C	3	
4	Calculate E (normalised C)	3, 4	
5	Define W	5	3
6	Define U	6	3, update
7	Calculate X	7	
8	Calculate CO (consider normalisation)	7, 8	
9	Define F	9	4
10	Calculate Z	10	
11	Calculate SO (consider normalisation)	11	

The same procedure as used in Table 5, which considered the average mark obtained by students, can also be followed (*Update Step 6*) to calculate the CO achievement for each student (consider individual student's marks). One can assume a student scored in the subject assessment as shown below:

$$U = (5 \quad 10 \quad 5 \quad 5 \quad 25)$$

With the same assessment weight *W* as before, the results can be obtained as shown in Figure 3a and Figure 3b for the COs and SOs achievement, respectively.



a) b)

Figure 3: LOs achievement (individual students) - a) COs achievement; and b) SOs achievement.

CONCLUSIONS

The results of this study pointed to the fact that there is a crucial need for a COs achievement measurement system that enables educators and universities to determine their students' level of LO achievement. The complexity of cross-relations between the LO and the subject's assessments led to the development of many generic or customised systems to ease the process.

In many cases, COs were mapped directly by educators to the assessments without going through the process of relating the COs to the subject's topics and the subject's topics to the assessments. In other cases, relations between COs and the subject topics were considered as either related or not, without taking into consideration the level of these relations. The authors of this article believe that those considerations might not reflect the accurate achievement of the LOs.

Accordingly, in this study, a systematic mathematical model was developed to determine the students' attainment accurately or otherwise, of course and programme outcomes in HEIs. This model will eliminate the tedious and time-consuming process that needs to be done by educators or institutes to calculate the LOs. The model requires only the mapping between the subjects' syllabus/topics to COs, the distribution of the topics in the subject assessment, the CO to SO mapping, course assessment grade distribution and students' grades to calculate the LOs achievements by the students or the subjects.

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