Advanced application for direct assessment of course and program learning outcomes in engineering higher education

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A B S T R A C T

Problem solving curricula form an essential part of the higher engineering education, which is in line with the nature of the profession, skills and attitudes of engineers. This fact renders direct assessment of learning outcomes in the engineering education an indispensable process, although not completely sufficient by itself. Consistent with the problem solving nature of the discipline, direct assessment of learning outcomes in this instance ought to be quantificational, as this paper in fact aims to contribute considerably to the overall process of assessing learning outcomes, compared with indirect assessment tools. The research method of this paper offers a set of three EXCEL-VBA applications that have been precisely designed to assess learning outcomes at course and program levels for engineering university students. The paper also describes the comprehensive algorithm of the applications and formulas used, so that other educational institutes and academics can readily reproduce. The results of the research applications provide a platform of input and output that is easy and quick to use, flexible, versatile and comprehensive in nature. Numerous assessments in the form of assignments, quizzes, major exams, projects, presentations, portfolios and final exams can be accommodated, with flexibility in the critical input parameters, such as criterion of achievement and weight of each assessment instrument. As soon as learning outcomes of all courses can be assessed, the output can readily be fed into a second application to determine the performance of students at a program or departmental level. As a conclusion, applications can be implemented by instructors to determine the performance of their students, both numerically and graphically, against established learning outcomes.

1. Introduction

The accreditation process by national NCAAA (2015) and international ABET (2015) seeks strong, trackable evidence of assessment records at both course and program levels. Apparently, this requirement is now compulsory for all engineering programs (Mohammad and Zaharim, 2012). Accordingly, streamlining the assessment process across all courses within an engineering program will significantly assist in producing assessment data that reflect consistency, transparency, versatility and accountability; these elements are certainly conducive to a successful accreditation journey. And this will particularly benefit those programs that seek accreditation for the first time (Sriraman and Stapleton, 2013)

One critical element of successful assessment that can benefit from streamlining and standardizing the assessment process across a program is to eliminate subjectivity that may inevitably be exercised by a teaching faculty, which can have adverse effect on accreditation reviews. Therefore, the assessment process requires a clear model that must be carefully discussed by faculty before being endorsed and adopted at a departmental or a program level. In the absence of an assessment system that employs a clear modelling process it would be almost impossible to eliminate undesired subjectivity, thereby hampering collection of real data that can effect concrete continual quality improvement, a strategic requirement for accreditation (Felder and Brent, 2003).

In the course of accreditation, it should be noted that the criterion of assessing the learning outcomes of a program (e.g., ABET's Criterion 3) normally

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represents the most demanding and daunting task, and it could be quite burdensome and time consuming. This is the reason behind much of the efforts exerted to date to streamline the process and reduce the associated workload (DeLyser and Hamstad, 2000; Blandford and Hwang, 2003; Yamayee et al., 2005; Essa et al., 2010).

It follows from the discussion above that development of efficient assessment tools for both course and program outcomes is instrumental in earning accreditation and collation of reflective data for further evaluation and improvement of learning.

Based on the direct assessment method, this paper presents three programed EXCEL spreadsheets that have been developed by the authors and can be used by higher education institutes (engineering or otherwise) to streamline assessment of both course and program outcomes. Full description of these applications including the algorithm adopted is presented in the following sections.

2. Application # 1: Course outcomes assessment tool (COAT)

2.1. Description of the COAT application

The course outcome assessment tool (COAT) is a hybrid platform combining EXCEL and the programming language Visual Basic for Application (VBA). COAT enables teachers to assess the performance of students against a predetermined set of course outcomes, and this can in turn be readily used to assess the overall program outcomes via a mapping process (refer to Application # 3 in this paper).

The COAT application consists of several tabs (EXCEL worksheets) as depicted in Fig. 1. In any assessment exercise, there is a minimum of 5 worksheets that include at least one assessment instrument, as follows:
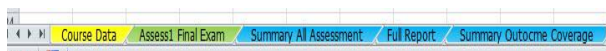

Fig. 1: Snapshot showing the various worksheets in the application COAT

1. Worksheet "Course Data": This worksheet includes general information on the course (code, name, etc.), the course outcomes to be assessed and their corresponding program outcomes. This worksheet also contains data about all the students that passed the course successfully (student number and name). Snapshots from the "Course Data" worksheet are presented in Fig. 2.

2. Worksheet "Assessment Instrument # 1": In this worksheet, the user enters details of one assessment instrument (e.g., Assignment, Quiz, Major Exam, Project Report, Final Exam, etc.) in terms of the number of questions covered in the assessment and the COs covered by each of the questions, assuming that a particular question can cover more than one outcome.

(a) Course outcomes (1 to 5) and corresponding program outcomes (a to k)

(b) Student information

Fig. 2: Snapshot showing input data in the "Course Data" worksheet

An option exists to account for the strength of a particular assessment instrument by assigning a value to a weight factor in this worksheet. The user also enters the mark obtained by each student in each question in the assessment, out of the maximum mark allocated for that question. A snapshot of this input is presented in Fig. 3.

A second, third, etc. assessment instrument can be added by simply cloning this worksheet (into the workbook) and changing the name to indicate the new assessment. Obviously, a new full set of data will be required for the new assessment as described here. The application does not limit the number of assessment instruments that can be used. However, it is recommended to consider only those assessments that do not repeat a specific outcome. It is also advisable to use assessments that are conducted near the end of the semester, since they will truly reflect how the students matured academically during the course and learned the various lessons before those assessments, including learning from their own failure in prior assessments.

For every student, each assessment instrument worksheet calculates the mark obtained in each course outcome as follows:

$$M_{Lj} = \frac{1}{N_{Qi}}\left(\sum_{i=1}^{N_{Qi}} M_{Qi}\right) \tag{1}$$

where: M_{Lj} is the average mark obtained in course outcome number L (from all questions) in assessment instrument j; M_{Qi} is the mark obtained in question Q_i (as a percent of the maximum mark allocated to Q_i), if and only if Q_i covers outcome L, and N_{Qi} is the total number of questions that covers outcome L.

A snapshot of the calculated mark for each of the outcome per student is shown in Fig. 3.

3. Worksheet "Summary All Assessment": This worksheet scans all assessment instruments and calculates the average mark (out of 100) achieved by

each student in each of the listed course outcomes, and use this mark to determine whether the student has achieved the outcome (by comparing the mark achieved in a specific outcome with a mark entered by the user). A snapshot of this spreadsheet is presented in Fig. 4.

(a) Assessment questions (up to 10) and corresponding course outcomes (1-8)

(b) Student information

Fig. 3: Snapshot from worksheet "Assessment Instrument # 1"

4. Calculation of the average mark of a course outcome is performed as follows:

$$M_{Lj} = \frac{1}{N_{ins}}\sum_{i=1}^{N_{ins}}\left(\frac{1}{N_{Qi}}\left(\sum_{i=1}^{N_{Qi}} M_{Qi}\right)*W_j\right) = \frac{1}{N_{ins}}\sum_{i=1}^{N_{ins}} M_{Li}*W_j \quad (2)$$

where: M_L is the average mark across all assessment instruments achieved by a particular student in course outcome number L, N_{ins} is the total number of assessment instruments used in the calculations, and W_J is the weight used to factor the impact of Assessment # J on the overall assessment.

Fig. 4: Snapshot showing output from the "Summary All Assessment" worksheet

5. Worksheet "Full Report": This worksheet presents the final results of the assessment exercise, both numerically and graphically in the form of a histogram.

The results are shown for both course and program outcomes (Fig. 5 and Fig. 6). The vertical axis in the histograms of Fig. 5 and Fig. 6 represents

the percentage of students that achieved the outcome based on a predetermined value (mark) entered by the user. A mark of 70% was considered in the example represented by these two figures Based on the formulation of the assessment method, the number of students (and hence the percentage) that passes a certain course outcome is straightforwardly counted from the number of "Yes" shown in the snapshot of Fig. 4 (i.e., counting those students who achieved the mark for the outcome).
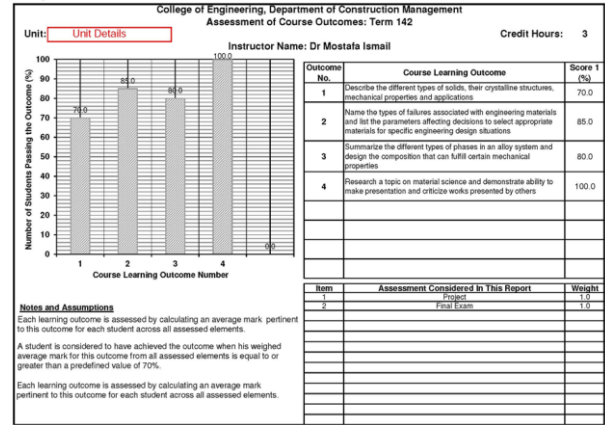

Fig. 5: Snapshot showing example output of the assessment for course
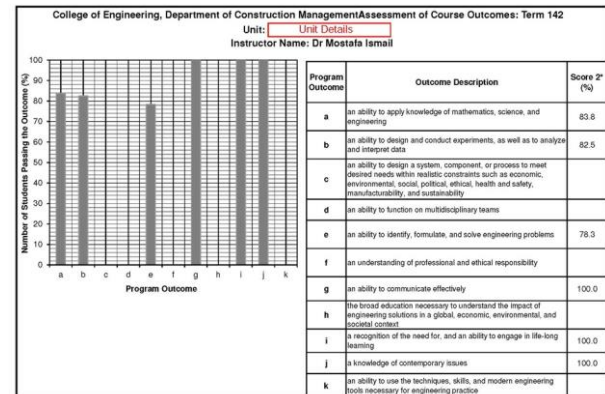

Fig. 6: Snapshot showing example output of the assessment for program outcomes

Although the number of students achieving the program outcomes can be explicitly calculated in a similar manner, the current application considers the following formula:

$$N_{s(POi)} = = \frac{1}{N_{OC}}\sum_{n=1}^{N_{OC}} N_{S(COj)}*OC_i \quad (3)$$

where: $N_{s(POi)}$ is the percentage of students who achieved program outcome number i (program outcomes a to k in the case presented here), $N_{s(COj)}$ is the percentage of students who achieved course outcome number j (arbitrarily, j = 1 to 8 in the case presented here, following ABET definitions for engineering outcomes), OC_i is a code indicating coverage of POi by COj: (Note: OC_i = 1 if COj covers POi or OC_i = 0 if not), and N_{OC} is the total number (frequency) the programme outcome POi is covered by all course outcomes.

6. Worksheet "Summary Outcome Coverage": This worksheet provides the necessary evidence (for

auditing, accountability and accreditation) on coverage of the course outcomes (and hence the program outcomes) by the various assessment instruments used during the course. It basically reports how and where exactly in the assessment instruments each of the course outcomes is examined. This worksheet is designed to print A4 pages of the nature shown in Fig. 7. In that figure, a blank cell indicates no coverage, while a cell populated with "1" indicates that the course outcome was covered by the corresponding question number.

The algorithm that underlies the performance of the COAT application is depicted in Fig. 8.
The COAT application readily enables assessment of all course outcomes at once. This advantage is extremely useful in reducing the workload and associated documentation whilst covering all outcomes. This advantage can be appreciated in light of instances in the literature where educational institutes opt to select only a fraction of the outcomes for assessment (Blandford and Hwang, 2003; Yamayee et al., 2005) or a small number of assessment instruments (DeLyser and Hamstad, 2000) as a way to cope with the workload. Naturally this advantage also applies to program outcomes according to the mapping process explained above. According to this advantage, there is no need for departments to be concerned with the question of which specific outcomes should be selected for assessment or how often should the assessment be performed.

Fig. 7: Snapshot showing coverage of course outcomes by various assessment instruments

The COAT application produces a full assessment report that will serve as an integral part in accreditation and evaluation activities for future improvement of courses and programs. The output of the report includes both collective performance of a complete class as well as each individual student,

the former being the purpose of the assessment process. The report also includes the extent of coverage of the course and program outcomes and how these are achieved. The reports produced are deliberately made to be concise and informative (5 A4 pages per a course).
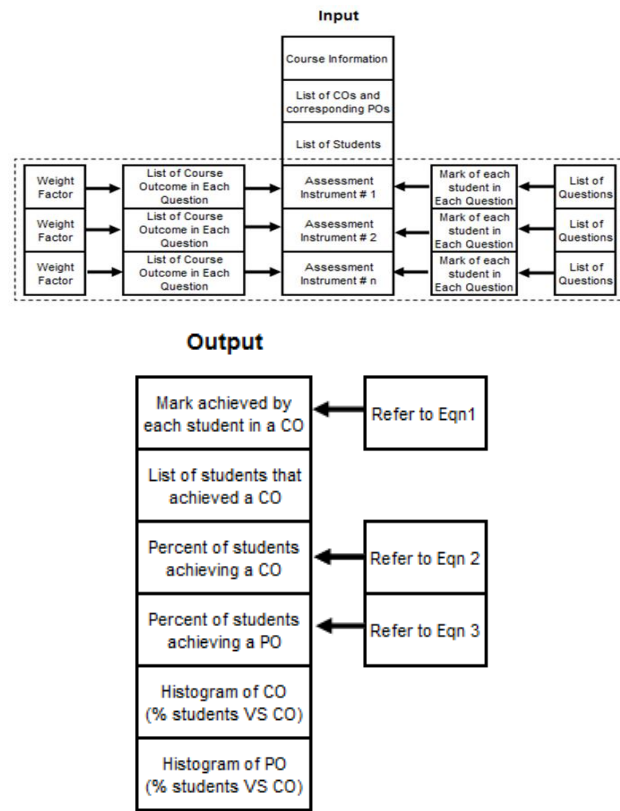

Fig. 8: Algorithm of the COAT application

3. Application # 2: Program outcomes assessment tool (POAT)

The program outcome assessment tool (POAT) is another EXCEL-VBA application that manipulates the results obtained from COAT for all the courses belonging to the program to produce a collective picture as to how the students perform across the whole program. The exercise of collecting data on the program outcomes is mandatory for accreditation. Therefore, streamlining the process towards efficiency in both undertaking and reporting is of paramount importance for departments and programs.

3.1. Description of the POAT application

The premise of the POAT application is to gather assessment data from all courses and calculate the average percentage of students that fulfil a particular program outcome across all courses of the program. As shown in Fig. 9, POAT comprises two worksheets: one for data collection and one for processing and reporting, as follows:

1. Worksheet "Data from All Units" calls the COAT files from all courses that have been stored in a

separate folder, the path of which is defined by the user as shown in Fig. 10. The user has the discretion to factor the impact of the number of credit hours assigned to each course in calculating the contribution of this particular course to the overall program outcomes. Once a COAT workbook is open, the "Data from All Units" worksheet reads of and copies the percentage of student that achieved each of the program outcomes. This process is quite fast and does not exceed 3 minutes using an average desktop or laptop computer of todays' specifications. A sample of the data after being copied into the worksheet is presented in Fig. 11.
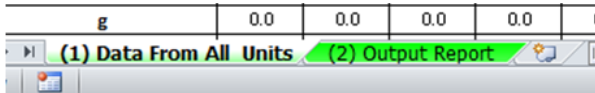

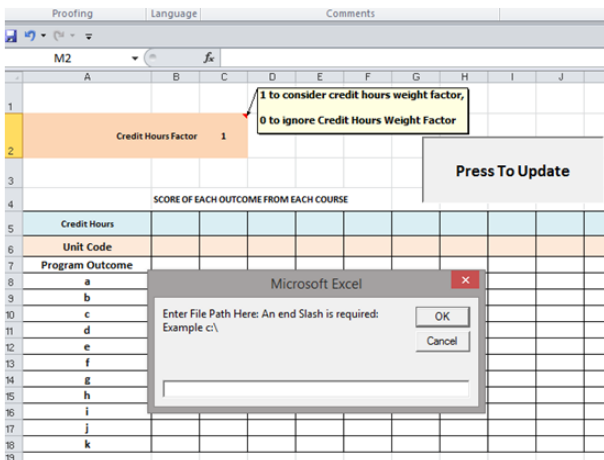**Fig. 9:** Snapshot showing the two worksheets in POAT application

Fig. 10: Snapshot from worksheet ""Data from All Units" in POAT: Data Entry
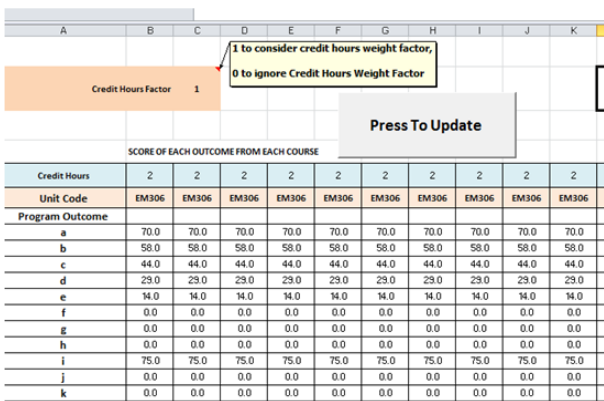

Fig. 11: Snapshot from worksheet "Data from All Units" in POAT: Date Copy

2. Worksheet "Output Report" calculates and writes the average percentage of students that achieved a particular program outcome (referred to as "score" in the dummy results shown in Fig. 12). The results are also presented in a histogram between the said percentage of students and the program outcome. The report produced by the POAT application is a single A4 page that summarizes the overall performance of the students across the whole program, as shown in Fig. 12.
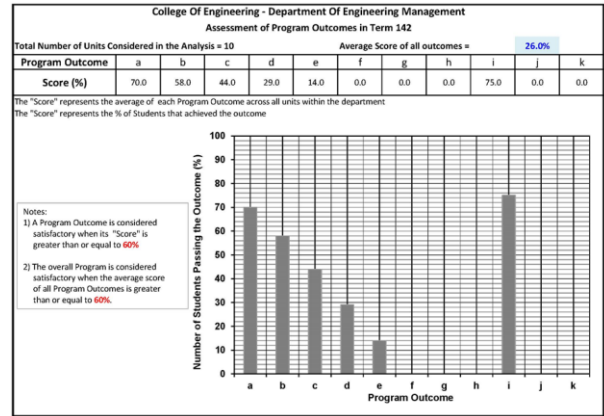

Fig. 12: Snapshot from worksheet "Data from All Units" in POAT: Final Report (dummy sample)

4. Application # 3: Mapping course outcomes to program outcomes tool

An essential part of any educational program is to ensure that the various pertinent courses will collectively cover all outcomes established for the program, with none of these outcomes being dropped out or scarcely covered. To this effect a third application has been developed using the same EXCEL-VBA combination to map the course outcomes into the program outcomes.

The input to this spreadsheet comprises the specific list of the program outcomes that are uniquely covered by each of the courses offered by the program in a matrix form similar to the one shown in the snapshot of Fig. 13.

Once entered, the spreadsheet scans through all courses (Fig. 13) and prepares a new matrix that lists all the courses that serve each of the program outcomes in accordance with the output list shown in (Fig. 14). The second part of the output from this application presents a histogram showing frequency of coverage of each of the program outcomes in the underlying courses, as displayed in Fig. 15.
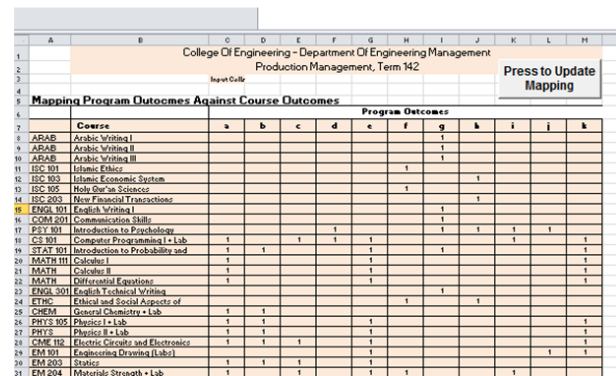

Fig. 13: Snapshot showing input to the MCTP application for course mapping

Finally a second spreadsheet in the application interprets contribution of the various courses to the program outcomes in a mosaic-like colour scheme that can be readily read and interpreted to discern distribution of each of the program outcomes among the underlying courses, as shown in Fig. 16. The colours shown in Fig. 16 are designed to reflect the

strength with which each of the courses contributes to the program outcomes according to a strength criterion entered at the user's discretion (e.g., number of credit hours or frequency of coverage of a specific program outcome in a course).

Fig. 14: Snapshot showing Program outcome coverage by the various courses
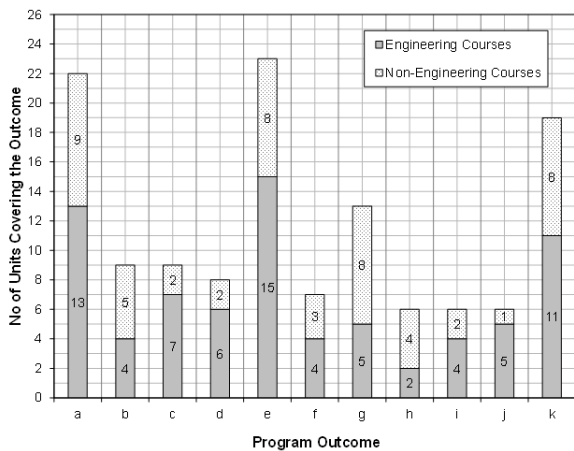
Fig. 15: Example histogram showing coverage of the program outcomes by various courses

Fig. 16: Snapshot showing a colour scheme showing course outcomes mapping to program outcomes

5. Summary and conclusions

Assessment of course and program outcomes has become a necessity in higher education as part of the mainstream efforts of collecting data for evaluation, accountability and learning improvement. While the assessment exercise is invariably a cornerstone in any accreditation program, it is normally perceived to be burdensome, subjective and very time consuming. To overcome these unpopular aspects of outcomes assessment, this paper has presented a suite of three applications that can be used to mainstream and standardize the assessment process, at both course and program levels. The applications have been recently adopted by the College of Engineering at Prince Sultan University (Riyadh) in its course towards obtaining accreditation for its engineering programs. Excellent feedback has been received from about 70 users of the applications. Fig. 17 shows results result from the Construction Engineering Program at PSU after application of POAT across the whole program in Semester 1 of the academic year 2015/2016.
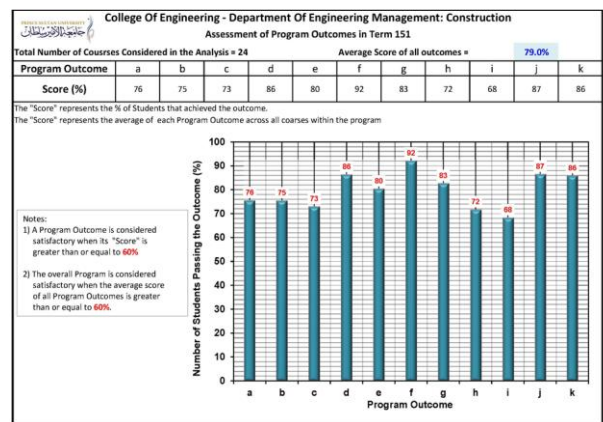

Fig. 17: Snapshot showing assessment of program outcomes using POAT at PSU

The applications presented here have been developed using EXCEL combined with the VBA programming language. The first application (COAT) is concerned with assessment of course outcomes. Every effort has been exerted to ensure the application is both versatile (by accepting an unlimited number of assessment instruments) and efficient (quick to use). A 5-page report of A4 size is produced by the application, documenting the assessment process and providing evidence as to how each of the course outcomes (and the mapped program outcomes) is being tested.

The second application presented in this paper (POAT) is for assessment of the overall program outcomes (e.g. for a department or a college). It compiles and analyzes the data prepared from the COAT application for all courses offered by the program and produce a report on the broad, average performance of the students. This application produces a single A4 summary report.

The third application developed in this paper aims at mapping the various outcomes in the courses offered by the program into the required program outcomes (MCTP) to determine the extent of coverage and highlight any scarcity and/or lack of coverage.

It should be noted that the two assessment applications described in this paper are based on the direct method of assessment. This is normally insufficient to draw a full picture of the outcomes and should be complimented with some indirect assessment methods, such as course completion survey, exit survey, employer questionnaires, focus groups, etc. The challenge with these indirect methods is that they are qualitative in nature.

However, some indirect assessment methods can be designed to be quantification, and these can be added directly to the existing application with minor modifications if needed.

Acknowledgment

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