A Software Tool to Facilitate Design, Assessment and Evaluation of Engineering Courses

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Abstract — Courses are building blocks of an educational system. Design of a course involves identifying the program outcomes addressed, defining its learning objectives to satisfy them, determining the educational methods to infuse and assessment methods to measure the success. A utility software is developed to help the instructors to organize their courses, collect data for evaluations and analyze the results for improvements and document results. It is based on MS EXCEL electronic spread sheet where the instructor enters the course design information and student data. The program uses the facilities provided by EXCEL to manipulate the data to obtain course design and evaluation tables and graphs that ease the evaluation of a course and comparing performances in successive offerings

***Index Terms* — Computer applications, Documentation, Educational technology, Engineering education, Spreadsheet programs**

I. INTRODUCTION

Engineering education is a process in which students from high schools are taken as raw material and graduated as engineers. The steps in the process are specified as the curriculum. Courses are state variables of the system. The transfer characteristics of the overall system were modeled by the number of courses he completed and grant point average (GPA) he accumulated in them. This was called a content-based system. The new understanding by the Accreditation Board of Engineering and Technology (ABET) Inc. is stipulated as EC2000 which relies on what the student learns rather than what he has been taught. Graduates will be implementing the knowledge and skills they gain during their studies in work places. In the engineering, the half-life is around 5 years; i.e. in 5 years time only half of what the student learns at the university remains useful. The expectations of the stake holders from the graduates in this duration are defined as program educational objectives (PEO). Abilities, skills and attributes gained by students at the graduation are stated as program outcomes (POs). POs contain statements to satisfy the EC2000 engineering criteria (***3a-3k)***, and program criteria for the specific engineering program. Program outcomes are the responses of the educational system.

Courses are the building blocks of the curriculum, hence states of the educational system. Foundations of program outcomes in courses are specified as course learning objectives (CLOs) that are eigenvalues of the system. Overall system response may be affected by a single eigenvalue. Observability and controllability are two important aspects of any control system that involve defining and controlling the state variables of the system. Since the work of equipping students with attributes specified in program outcomes (POs) must be done at the individual course level, all faculty members involved in teaching required courses must now understand and be involved in the accreditation process on a continuing basis. The potential of the new system (EC2000) to improve instructions depends strongly on how well engineering faculty understand it and appreciate the intensity of their full involvement in it.

CLOs are laid out for every core course in the curriculum and assessed carefully so that corresponding program outcomes (POs) are satisfied at the end. An articulation matrix that relates the POs to CLOs is planned for each course. A Microsoft EXCEL® electronic spread sheet based utility software has been developed to assist the course design, assessment and evaluation. It is used in some departments in the Faculty of Engineering [1, 2]. The paper describes the software and its utilization. The software has worksheet that is filled out by the instructor for course design, assessment and performance criteria. Then, it generates tables and figures that are used in the course binder. Examples below are taken from EE 311 – Electronics I, a common core course in Electrical and Computer Engineering.

II. COURSE DESIGN

Course design starts with identifying of program outcomes and specifying course learning objectives. Topics to be covered, instructional methods and assessment methods are defined at the beginning of the term. The progress is monitored during the term and necessary modifications are made. The evaluation of the course is carried out at the end of the term.

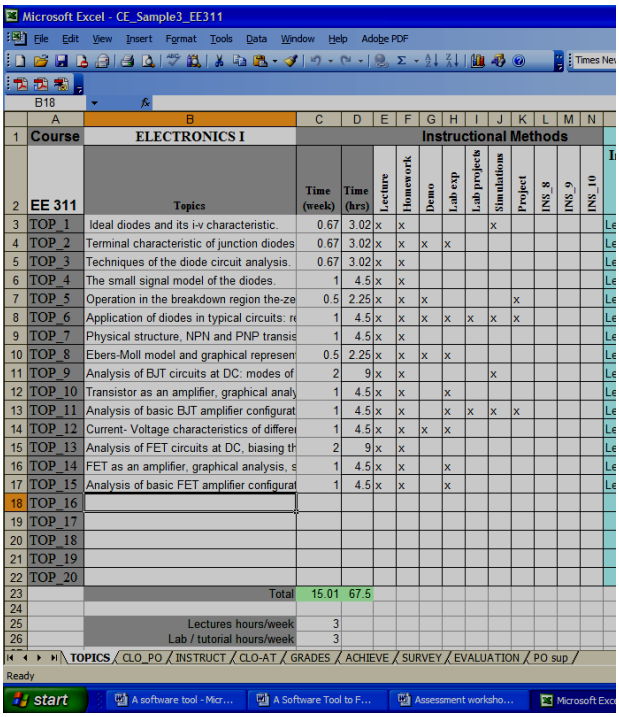


Figure 1 TOPICS worksheet

The first worksheet is the TOPICS where the instructor enters the course name and number, topics covered, teaching time for each topic (in weeks), lecture and lab/tutorial hours per week. He selects the instructional methods used to infuse each topic. 20 topics and 10 instructional methods are supported. The program generates "topics versus instructional methods" matrix and list of instructional methods for each topic.

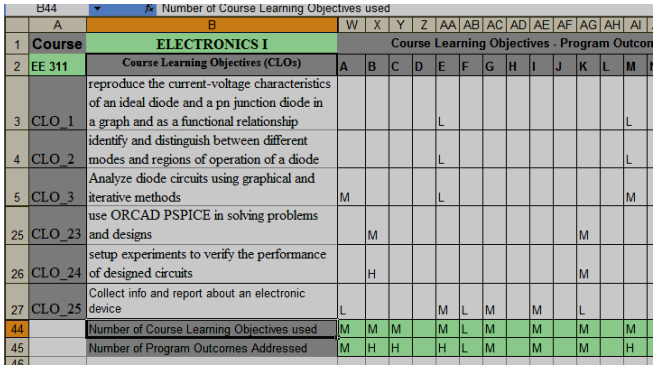


Figure 2 CLO – PO articulation table

Next the CLO-PO worksheet is prepared by describing course learning objectives and linking them to the program outcomes addressed. Satisfaction of program outcomes are defined according to the Bloom's taxonomy that is expressed in three levels as Low (L) for knowledge and comprehension, Medium (M) for application and analysis, and High (H) for synthesis and evaluation. The CLO-PO coefficient matrix is generated. The average and maximum levels of satisfactions expected for each PO are determined. Program supports 40 CLOs and 17 POs which is sufficient for all courses except one in the biomedical engineering program.

The third worksheet is INSTRUCT that relates CLOs to topics. Table 1 illustrates part of the CLO-Topics mapping. Here, topics are distributed into CLOs and numbers indicate relative weight of the CLO coverage. The program normalizes the topics, i.e. the weights are adjusted to have total of unity for each topic and a CLO-Topics coefficient matrix is generated.

Table 1 CLO-Topics mapping

EE 311	TOP_1	TOP_2	TOP_3	TOP_5	TOP_6	TOP_8	TOP_9	TOP_10
CLO_1	1							
CLO_2		1						
CLO_3			1					
CLO_13								1
CLO_21		0.5				0.5		
CLO_22					0.5			0.5
CLO_23			0.5		0.5		0.5	0.5
CLO_24								
CLO_25				0.5	0.5			

CLO-Topics and Topics-Instructional Methods coefficient matrices are multiplied to obtain the CLO-Instructional Methods articulation matrix. The course design matrix is generated from this matrix, and CLO-Assessment Tools coefficient matrix that will be seen in the next section. It contains instructional methods, assessment methods and teaching time allocated to cover each CLO.

III. Assessment of the Course

Assessment is a process to identify, collect, use, and prepare data that can be used to evaluate achievements. It involves analysis of data to inform changes that will improve an outcome. Assessment of the course and assigning grades to the students is a challenge for the instructor. Various assessment methods are currently dwelled upon [3]. Traditional assessment tools such as homework, quizzes, major and final exams, interim and term projects are still the key elements. In addition, performance appraisals such as lab performance, lab reports, and lab project reports, written and oral presentations, self and peer assessments, reflective journals and portfolios are important contributors. Performance surveys (i.e. cross/delta checks) and opinion polls are used to monitor the progress. Rubrics are prepared for assessment tools that can't be graded directly.

The program supports up to 20 assessment tools. Grading and assessment are two different things and each assessment tool may contribute differently to each one. Table 2 illustrates generation of the CLO-AT worksheet. Weights are the marks assigned to the tool out of 100. The distribution of marks into CLOs for a given

assessment tool is according to their respective shares. The CLO-AT coefficient matrix is generated by normalizing the distribution of assessment tools into CLOs.

Table 2 CLO – Assessment tools mapping

EE 311	Q1_2	Q3_4	Q9_10	HW1	HW2	HW3	Major1
% weight in course grade	**1**	**1**	**1**	**1.7**	**1.7**	**1.7**	**8**
% weight in assessment	**1**	**1**	**1**	**1.7**	**1.7**	**1.7**	**8**
CLO_1	1			1			1.5
CLO_2	0.5						0.5
CLO_3		0.5		0.5			
CLO_4	0.5	0.5		2			1
CLO_5				0.5			
CLO_6							1

IV. Grades

Each assessment tool can be marked out of any value that the instructor prefers. Table 3 shows a part of the marking table. The program normalizes the grades according to weights specified in Table 2 and generates two tables; one for grading and one for assessment.

Table 3 Part of the marking table

SSN:	Q1_2	Q9_10	HW3	Major1	Major2	Major3	Final_q1
Out of	20	20	10	8	8	8	12
1	9.0	0.0	0	1.3	1.5	3.8	7.5
2	0.0	0.0	0	0.0	0	0.0	
3	20.0	0.0	5	5.8	4.5	6.3	10.0
4	10.0	1.0	8	4.7	2.9	5.3	7.0
5	18	7	7.7	4.7	5.3	6.4	7.0
6	14	3	4	3.9	3.9	3.2	9.7
7	0	0	0	0.0	0	0.0	
18	19	3	5.2	6.1	3.3	6.9	4.0
19	8	10	7.7	2.9	7.1	7.6	4.5

The grading table is used to assign the course grades. The program also calculates the letter grades to help the instructor. Accordingly, the student either passes the course or he repeats it. There are three types dropouts as failure (F), incomplete (IC) and denial (DN). The instructor enters F, IC or DN into the dropouts' column against the failing students. Then, those students are not included in computing the assessment table.

The matrix in the assessment table is multiplied by the transpose of the CLO-AT coefficient matrix to obtain the CLO satisfaction matrix. Then, the CLO satisfaction matrix is multiplied by CLO-PO coefficient matrix to obtain the PO satisfaction matrix. Accordingly, students' grades are expressed in terms of CLOs and POs rather than the assessment tools respectively by the last two matrices.

V. Evaluation of the Course

Evaluation is a process of reviewing the result of data collection and analysis, and eventually making a determination of the value of findings and action to be taken. Specific, measurable statements identifying the performances required to meet the outcome are called the performance criteria. Surely, they must be confirmable through evidences. A course binder is prepared for every course containing the course design information, indirect and direct assessment tools and students' samples. The course is evaluated via the data collected using the assessment tools and predetermined performance criteria to find out:

- Achievements of Course Learning Objectives
- Achievements of Program Outcomes addressed, and
- Achievements of Program Outcomes addressed by individual students

The performance criteria have been set as:

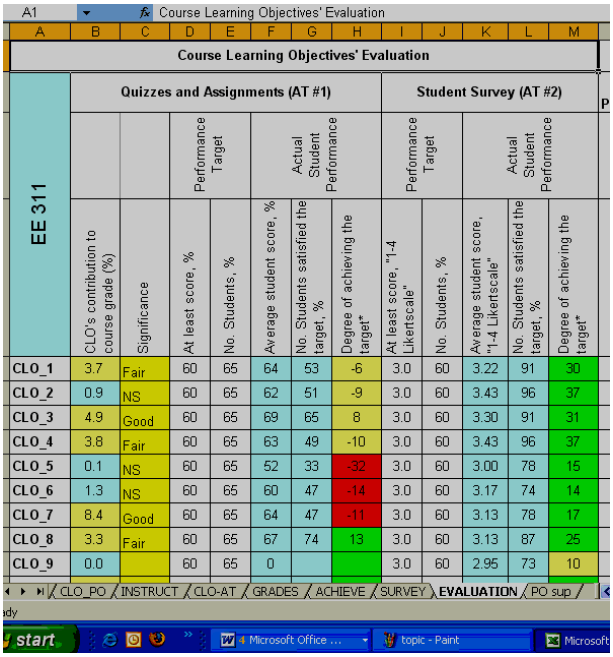
1. 65% and 70% of the class students' score over 60% and 70% in each CLO and each supported PO respectively;
2. At least 65% and 70 % of the total number of outcomes should be greater than or equal to 60% and 70% on average for CLOs and supported POs respectively.

The ACHIEVE worksheet is used for calculating the percentile satisfactions of the CLOs and POs and makes application of the performance criteria possible.

Exit surveys are used to determine the level of satisfaction as assessed by students. They are graded using 1-4 Likert scale and used as indirect assessment tools. The surveys may also have questions in determining the students' appreciation of educational and assessment methods, and quality of teaching and teaching tools.

Figure 3 shows part of the EVALUATION worksheet related to evaluation of the course learning objectives. Column B shows the contribution of CLO's to the course grade in %. Average contribution of each CLO to the course grade is Cav = 4.348 % (out of 25 CLOs, 2 are not measured). CLOs contributions are rated as: over 2*Cav "High", between Cav and 2*Cav "Good", between 0.3*Cav and Cav "Fair" and below 03.*Cav not significant "NS". Accordingly, the CLO's are classified as in column C. Column D shows the minimum criteria for the average CLO and column E shows % of students

expected to satisfy the average. Column F and G show the average students scores and % of students scored above average respectively.



Course Learning Objectives' Evaluation

EE 311	Quizzes and Assignments (AT #1)							Student Survey (AT #2)				
			Performance Target		Actual Student Performance			Performance Target		Actual Student Performance		
	CLO's contribution to course grade (%)	Significance	At least score, %	No. Students, %	Average student score, %	No. Students satisfied the target, %	Degree of achieving the target*	At least score, "1-4 Likertscale"	No. Students, %	Average student score, "1-4 Likertscale"	No. Students satisfied the target, %	Degree of achieving the target*
CLO_1	3.7	Fair	60	65	64	53	-6	3.0	60	3.22	91	30
CLO_2	0.9	NS	60	65	62	51	-9	3.0	60	3.43	96	37
CLO_3	4.9	Good	60	65	69	65	8	3.0	60	3.30	91	31
CLO_4	3.8	Fair	60	65	63	49	-10	3.0	60	3.43	96	37
CLO_5	0.1	NS	60	65	52	33	-32	3.0	60	3.00	78	15
CLO_6	1.3	NS	60	65	60	47	-14	3.0	60	3.17	74	14
CLO_7	8.4	Good	60	65	64	47	-11	3.0	60	3.13	78	17
CLO_8	3.3	Fair	60	65	67	74	13	3.0	60	3.13	87	25
CLO_9	0.0		60	65	0			3.0	60	2.95	73	10

Figure 3 Part of EVALUATION worksheet for CLOs

Column H indicates degree of achieving the target measured as:

((Average achieved – average target)/(average target) + (students over average –target for students over average)/(target students over average))*50))

Only students who pass the course are included in evaluation. Students who fail are excluded since they are going to repeat the course and their names will appear in the evaluation for coming terms.

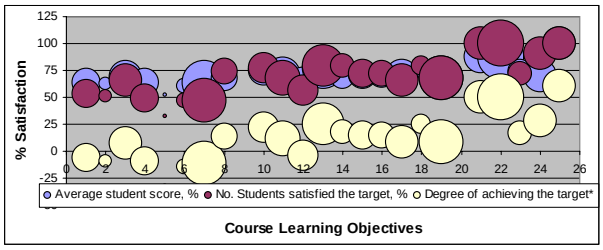
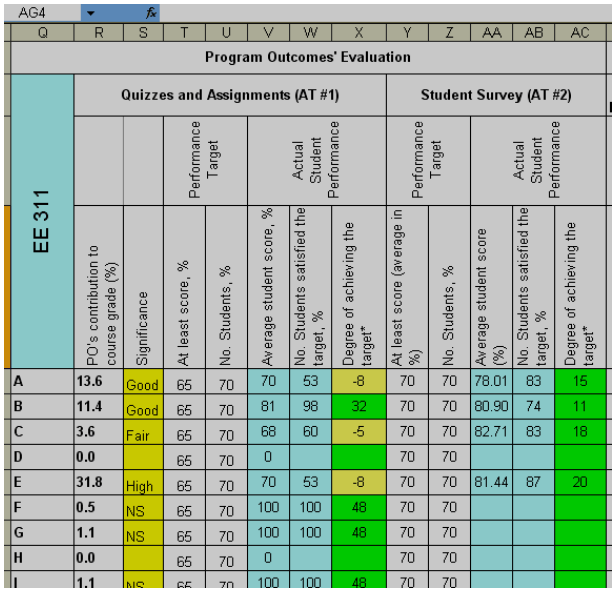


Figure 4 CLO achievement scores by direct assessment tools

The size of the bubble in Figure 4 indicates the percentile contribution of the CLO to the course grade. CLOs 9 and 20 are not addressed at all, while CLOs 2, 5 and 6 are not addressed satisfactorily. Among the satisfactory ones, CLOs 1, 4, 7 and 12 have negative scores in achieving the target. For other CLOs, all performance indices are positive indicating that the goals for those course learning objectives are achieved. More care must be given to CLOs not addressed properly and those with negative scores in the next offering of the course. Columns I-M are for the indirect assessment results. Average satisfaction is 3.3/4 (83%). Columns N and O are the same as F and G but for the previous term (not shown in Figure 3).



Program Outcomes' Evaluation

EE 311	Quizzes and Assignments (AT #1)							Student Survey (AT #2)				
			Performance Target		Actual Student Performance			Performance Target		Actual Student Performance		
	PO's contribution to course grade (%)	Significance	At least score, %	No. Students, %	Average student score, %	No. Students satisfied the target, %	Degree of achieving the target*	At least score (average in %)	No. Students, %	Average student score (%)	No. Students satisfied the target, %	Degree of achieving the target*
A	13.6	Good	65	70	70	53	-8	70	70	78.01	83	15
B	11.4	Good	65	70	81	98	32	70	70	80.90	74	11
C	3.6	Fair	65	70	68	60	-5	70	70	82.71	83	18
D	0.0		65	70	0			70	70			
E	31.8	High	65	70	70	53	-8	70	70	81.44	87	20
F	0.5	NS	65	70	100	100	48	70	70			
G	1.1	NS	65	70	100	100	48	70	70			
H	0.0		65	70	0			70	70			
I	1.1	NS	65	70	100	100	48	70	70			

Figure 5 Part of EVALUATION worksheet for POs

Figure 5 shows part of the EVALUATION worksheet used for program outcomes. The arguments and evaluation criteria are similar to those of the CLOs. We can compare the achievement in successive terms and direct and indirect assessment results.

Last critical table of evaluation is the achievement of

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	2	3	1		1	4	4		4		3		1		
2															
3	3	3	2		3	4	4		4		3		3		
4	2	3	2		2	4	4		4		3		2		
5	3	3	2		3	4	4		4		4		3		
6	3	3	1		2	4	4		4		3		2		
7															
8	1	4	2		1	4	4		4		4		1		
9	3	4	3		3	4	4		4		4		3		
10	2	3	1		1	4	4		4		3		1		
11	3	3	1		3						3		3		
12	2	3	3		3	4	4		4		3		2		

Figure 6 Individual student's achievements of POs

program outcomes by individual students as illustrated in Figure 6. Students who are going to repeat the course have been dropped from the evaluation and their names do not appear in the table. The table in the figure is generated from the PO achievement table by converting percentile achievements into 0-4 scale. 4 is exceeding expectations (E, over 80%), 3 is meeting expectations (M, 65% to 80%), 2 is needs improvement (NI, 50% to 65%), and 1 is no credible effort (NCE, less than 50%). Any student who didn't received M (3) or E (4) in any

PO didn't comply with the requirements of that PO. He must put it right somehow before graduation and his name will be reported to his counselor. For EE 311, POs A, B, C, E, K and M have been addressed satisfactorily and failure in them will be reported. Other lightly touched ones have not been measured satisfactorily, yet all students somehow secured adequate scores in them.

VI. Support for Program Outcomes

The ultimate aim of an educational system is to achieve the program outcomes. Satisfaction of POs at the levels specified in the course design requires allotting instruction time and assessing effort for each one according to the weight proposed in the course design. The last worksheet PO Sup contains the PO-CLO articulation matrix, PO-Topics articulation and coefficient matrices and PO-AT (assessment tool) articulation matrix. From these matrices, the summary table (Figure 7) for coverage of program outcomes is generated through matrix operations.

EE 311	Lecture hrs	Lect. hrs %	Grade %	Instructional Methods	Assessment Methods
A	5.66	8.38	13.63	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Q1_2, Q3_4, Q5_6, Q7_8, Q9_10, HW2, HW3, Major1, Major2, Major3, Simul, Paper P, Final1, Final2, Final3,
B	5.19	7.69	11.43	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Simul, Lab P1, Lab P2, Lab,
C	4.66	6.9	3.592	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Q3_4, HW2, HW3, Major2, Major3, Simul, Lab P1, Lab P2,
D					
E	24	35.5	31.81	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Q1_2, Q3_4, Q5_6, Q7_8, Q9_10, HW2, HW3, Major1, Major2, Major3, Simul, Lab P1, Lab P2, Paper P, Final1, Final2, Final3,
F	0.32	0.47	0.529	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Paper P,
G	0.64	0.94	1.058	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Paper P,
H					
I	0.64	0.94	1.058	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Paper P,
J					
K	5.42	8.03	11.01	Lecture, Homework, Demo, Lab exp, Lab projects, Simulations, Project,	Simul, Lab P1, Lab P2, Lab, Paper P,
L					

CLO PO INSTRUCT CLO-AT GRADES ACHIEVE SURVEY EVALUATION PO sup

Figure 8 Summary of Program Outcome coverage

Figure 8 illustrates coverage of POs (in %) in lecturing and assessments for EE 311 in Fall 2006-2007. Both coverage data demonstrate close correlation between instructional and assessment methods. Engineering analysis (PO_E and PO_M) takes the largest share. Engineering math, science, (PO_A) experimentation (PO_B) and modern tools use (PO_K) have been tackled considerably. Students have activities outside of the classroom for the second group, hence they receive larger share in grading. The engineering design has not been covered satisfactorily this term. There are also traces for soft skills PO_F, PO_G and PO_I.

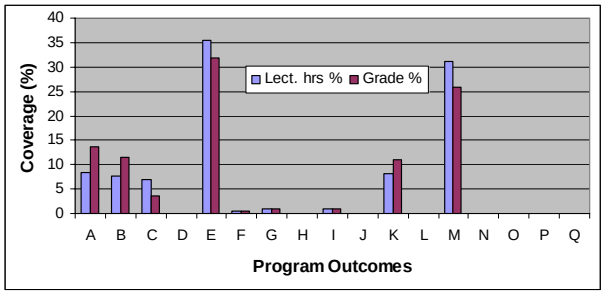


Figure 7 Coverage of POs for EE311 in Fall 2006-2007

VII. Conclusion

ABET EC2000 requires all program outcomes to be satisfied by every student at minimum level before graduation. Grades are no more accepted as evidences of achievements. Rather, evidences from students' works must be provided, properly evaluated using rubrics. Many courses may support the same program outcome. Proofs from two or three courses may be sufficient to satisfy the ABET requirement for a specific outcome. However, courses are built over each other and develop students' learning throughout the curriculum. The program developed doesn't provide ready proofs for achievement of program outcomes but it makes the educational system transparent so that the system designer can easily pinpoint the discrepancies and takes corrective measures.

In a well-designed course, there is harmony between instructional and assessment methods. Coverage of course learning objectives and program outcomes in instructions and in grades generally comes into close agreement. The program generates several pictorial presentations that ease the evaluation of a course and comparing performances in successive offerings.

Acknowledgement

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