AC 2011-998: PAT: A PROGRAM ASSESSMENT TOOL FOR ENGINEERING PROGRAMS

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PAT: An Online Program Assessment Tool

Introduction

Over the last decade Engineering Criteria 2000 significantly changed the way in which engineering programs undertake assessment and report for accreditation purposes. Since implementation of EC2000¹, engineering programs are required to demonstrate the achievements of their program educational objectives and program outcomes by following a documented assessment plan. The sustainability of this assessment process became a problem for all those involved. Program coordinators started to look for ways of automating the process and of changing the accreditation activities from a year-long frenzy prior to the visit, to something that is ongoing and sustainable.

In the meantime, several commercial software programs became available, ostensibly to facilitate the assessment and reporting processes. Several of these were reviewed by faculty and staff in the college, including Weaveonline², TaskStream³, True Outcomes⁴, eLumen⁵ and TK20⁶. Each had strengths and weaknesses, but being a large engineering college with 18 engineering programs, it wasn't possible to converge upon a common commercial software tool that everyone agreed upon. It was decided that any tool selected would need to fit to the existing assessment plans, not the other way around, and that its main features would be flexibility, scalability and sustainability. Thus, we conceptualized and built the software for an in-house assessment tool, which was developed with active participation of engineering program assessment coordinators, faculty and administrators, as well as computer programmers, and it has found widespread support throughout the college.

The creation of the program assessment tool (PAT) and database has been a joint partnership between the college Information Technology and Engineering Computer Services (ITECS), Academic Affairs and the college assessment committee, and it demonstrates a wider college commitment to supporting and enhancing assessment processes. The purpose of the program assessment tool and database is to provide a 'one-stop' destination through which faculty can create assessment matrices and tasks, enter assessment data, generate results, interpret findings and write reports. Overall, it is a tool to manage the assessment processes of each engineering program. Also, administrators are able to monitor the progress of individual programs against their assessment plans.

Throughout the development of the tool, the authors of this paper had bi-weekly meetings with the software developers and submitted changes as they tested small portions of the tool. The programming languages behind the tool are .php and html. The tool is now functional and was used on our recent ABET accreditation visit. We will report on the current functional aspects of the program assessment tool. However, further development is envisioned and being planned for, as further outlined in the paper.

The phases of development of PAT

The development of PAT is described in a series of phases, including three phases that have been implemented, as well as two additional phases that are planned. The first phases are fully functional and the tool is used effectively as an assessment management process, but the additional phases will serve to enhance the capabilities of the tool.

Phase 0: Before programming began

- *Creation of Assessment plans*

When we started thinking about a new program assessment tool five years ago, we did not start with the people who would create this software for us, instead, we invited every program coordinator to create a sustainable program assessment plan and we looked at the common features of them. The search for a sustainable assessment plan, coincided with a half-day workshop at the Annual NCSU Assessment Symposium titled “Planning Assessment Backwards,” given by the renowned assessment expert Peggy Maki⁷. She recommended separating program outcome statements into three parts: 1) Knowledge, 2) Skills and 3) Attitudes. This separation was suggested to avoid conglomeration of the outcome statements, to simplify the connection to course instructional objectives and to allow for out of curriculum components. We had been in search of a model like this to create a new sustainable assessment plan with embedded course level assessment and chose to adopt the approach. Defining a “skills” category for the undergraduate program captured the attention of Biomedical Engineering faculty who were interested in developing a skill-set common to all students graduating from the program.

At the next Biomedical Engineering (BME) Undergraduate Program retreat, a session was dedicated to identifying the basic skills our students needed to acquire during the course of their studies. The method to conduct this session was similar to the Hoshin Kanri⁸ method where all participants contribute to the planning and become accountable for their part. Small groups of faculty members were formed, and post-it notes were given to groups to use to list the skills they considered most important for ensuring successful Biomedical Engineering careers for graduates of the program. They were not given any information about EC 2000 Criterion 3: Program Outcomes. The groups were later asked to organize their notes under common themes.

From this exercise, the following seven themes emerged.

1. Problem solving skills
2. Communication skills
3. Business/professional skills
4. Design skills
5. Experimental biology and modeling skills
6. Programming and computer skills
7. Information gathering skills

These categories were re-assigned to groups to be converted into outcome statements and to be tied to the courses in the curriculum. At the end of this exercise, we had specific sub-outcomes listed under each of the seven categories that spanned all of the A-K ABET program outcomes. The BME assessment committee consisting of faculty in the program met and distributed these sub-outcomes under the ABET outcomes and then created a matrix of these sub-outcomes vs. courses in the curriculum, added the knowledge and attitude components, and submitted the plan to College of Engineering. This plan was instrumental in designing the software “Program Assessment Tool: PAT”

Table 1 shows the complete list of these sub-outcomes associated with A-K and Table 2 includes the matrix association with relevant courses. Assessment matrices are constructed by mapping outcomes to courses and this process is commonly called curriculum mapping⁹.

Table 1: Listing of sub-outcomes

a) An ability to apply knowledge of mathematics, science and engineering	
a-1	Explain basics concepts of systems and cellular biology.
a-2	Discuss the problems associated with the interactions between living and non-living materials and systems.
a-3	Critically evaluate and analyze problems at the interface of engineering and biology.
a-4	Apply knowledge of math, science and engineering.
b) An ability to design and conduct experiments, as well as to analyze and interpret data	
b-1	Design experiments for hypothesis testing.
b-2	Measurement and data interpretation skills from living systems
b-3	Basic circuit analysis and troubleshooting skills
b-4	Statistical data analysis skills
c) An ability to design a system, component, or process to meet desired needs	
c-1	CAD skills
c-2	Mechanical, fabrication and manufacturing skills
c-3	Prototyping skills
c-4	Needs assessment skills
c-5	Project planning skills
c-6	Medical devices design skills
d) An ability to function on multi-disciplinary teams	
d-1	Negotiation skills (conflict management, consensus building)
d-2	Time management skills
d-3	Self-assessment skills
d-4	Team building skills
e) An ability to identify, formulate and solve engineering problems	
e-1	Critical thinking skills
e-2	Problem identification skills
e-3	Mechanical analysis skills
e-4	Systems analysis skills
e-5	Modeling skills
e-6	Reverse engineering skills

e-7	Differential equation solution skills
f) An understanding of professional and ethical responsibility	
f-1	Comprehension of ethical codes in engineering and medicine
f-2	Financial/budgeting skills
f-3	IP, disclosure reading/writing skills
f-4	Demonstrate inter-personal skills and professional behavior.
g) An ability to communicate effectively	
g-1	Scientific paper/journal paper writing skills
g-2	Resume writing skills
g-3	Data presentation skills
g-4	Oral presentation / scientific view expression skills
g-5	Oral presentation/ power point presentation skills
h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.	
h-1	Identify and articulate impact of engineering solutions on society.
i) A recognition of the need for, and an ability to engage in life-long learning	
i-1	Demonstrate a desire for learning through post-graduate career plans.
i-2	Library skills (literature search, use of web)
j) A knowledge of contemporary issues	
j-1	Identify and discuss contemporary clinical issues and potential biomedical engineering solutions.
j-2	Assess, evaluate and reference peer-reviewed technical literature.
k) An ability to use techniques, skills and modern engineering tools necessary for engineering practice.	
k-1	MATLAB skills
k-2	Computer aided design skills
k-3	Algorithm development skills
k-4	BME data presentation skills

Table 2: Association of sub-outcomes to courses in the curriculum

Expected Outcomes	BIO183	BME 201	BME 203	BME 204	BME210	BME 252	BME 301	BME 302	BME 311	BME 312	BME 352	BME 451	BME 452	ENG331	MA341	ST370	Co-Curriculum
Outcome (a)																	Graduating Senior Survey (GSS) 2009
Sub-Outcome a1	x						x	x									
Sub-Outcome a2							x	x									BME Seminars
Sub-Outcome a3				x			x	x	x								
Sub-Outcome a4			x		x				x						x		FE Exam
Outcome (b)																	GSS 2009
Sub-Outcome b1							x										UG Research
Sub-Outcome b2				x			x	x									UG Research
Sub-Outcome b3				x	x					x							
Sub-Outcome b4							x	x								x	
Outcome (c)																	GSS 2009
Sub-Outcome c1											x						
Sub-Outcome c2											x						
Sub-Outcome c3												x					
Sub-Outcome c4													x				
Sub-Outcome c5													x				
Outcome (d)																	GSS 2009
Sub-Outcome d1												x					
Sub-Outcome d1													x				
Sub-Outcome d1													x				
Sub-Outcome d1												x					
Outcome (e)																	GSS 2009
Sub-Outcome e1				x	x		x	x	x								
Sub-Outcome e2			x		x							x					
Sub-Outcome e3								x									
Sub-Outcome e4					x				x								
Sub-Outcome e5								x	x								
Sub-Outcome e6					x						x						
Sub-Outcome e7															x		
Outcome (f)																	GSS 2009
Sub-Outcome f1												x					Ethics Modules
Sub-Outcome f2												x					
Sub-Outcome f3													x				
Sub-Outcome f4													x				BME Events
Outcome (g)																	GSS 2009
Sub-Outcome g1												x					
Sub-Outcome g2														x			
Sub-Outcome g3				x	x		x	x		x							
Sub-Outcome g4					x							x	x				
Outcome (h)																	GSS 2009
Sub-Outcome h1												x					BME Seminars
Outcome (i)																	GSS 2009
Sub-Outcome i1																	Senior Survey
Sub-Outcome i2							x					x					

Outcome (j)																	GSS 2009
Sub-Outcome j1					x								x				BME Seminars
Sub-Outcome j2																	
Outcome (k)																	GSS 2009
Sub-Outcome k1		x			x				x								
Sub-Outcome k2						x							x				
Sub-Outcome k3		x															
Sub-Outcome k3					x					x							

Note: Each x in the matrix indicates a course in which that particular outcome is **taught and also assessed**. There will be other intersections for teaching of each sub-outcome that are not assessed as part of the assessment plan, and are hence not shown in this table.

Phase 1: The start of programming

During phase 1 the following features were developed and programmed into the tool.

- *Syllabus and CV generators,*
- *Levels of access by different roles,*
- *Creation and revision of assessment matrices,*
- *Articulation of program sub-outcomes associated with A-K,*
- *Association of program outcomes and sub-outcomes with courses.*

The syllabus and CV generators provide blank text boxes based on the syllabus and CV fields required by ABET in the self-study template. Syllabuses and CVs can be edited and viewed online, a word version downloaded, as can a comprehensive document of all syllabuses and CVs.

There are three levels of access to the program. Administrators see the listing and all information for all programs in the college (see figure 1). All buttons on the main page lead to additional layers in the tool. The second level of access is for program representatives, who only see the information relevant to their particular program. The third level of access is for faculty who only have access pertaining to the courses they teach and their own CVs. The program representatives are responsible for creating the matrix that includes the association of sub-outcomes to A-K and the association with the courses, as shown in table 2.

Figure 1: Layout of PAT administrator's view

Phase 2: The next phase in programming

The following were features developed and programmed in phase 2.

- *Creation of assessment tasks for specific program sub-outcomes,*
- *Specification of performance criteria as benchmarks for student performance,*
- *Uploading of assessment data by faculty responsible for particular assessment tasks,*
- *Uploading of samples of student work (excellent, average, poor)*
- *Data analysis against performance criteria summarized for every academic year*

Programs choose the size of the matrix based on the number of courses they use to do program level assessment and the number of program outcomes they assess in a given timeframe. To avoid the lumpiness associated with program outcome statements addressing many sub-outcomes at once, the matrix allows entries of sub-outcomes (also known as performance criteria¹⁰), each of which focuses on one desirable student learning attribute at a time. Rogers¹⁰ states that, "The expected performance criteria should be specified by name, using an observable action verb which defines the level of learning expected (e.g. list, interpret, discriminate, or define)." Performance criteria are not specifically referred in the ABET EAC criteria, "but it is what ABET is expecting and what reviewers are being trained to look for"¹¹.

Courses from the university course catalog can be added to the matrix and course data are organized on a per semester basis. Then for each intersection of sub-outcomes against courses, student learning tasks are defined, and used to assess student achievement of that outcome. There may be one or more assessment tasks for each intersecting sub-outcome and course, as determined by the faculty and program representative. The tasks chosen to assess the program outcomes embedded in a particular course are entered once, and remain in the tool, to be reused if desired. Each task has an associated performance measure or performance indicator that is considered by the faculty to be the minimum acceptable level of student performance. Grades are imported from online grade books or entered by instructors (e.g. cut and pasted from excel), and evaluation results are available instantly, highlighting if the outcome has been achieved according to the predetermined metric.

Figure 2 provides an example of an assessment task, showing the outcome and sub-outcome, task description, method of assessment, performance indicator, as well as a link to the scoring rubric and links to samples of student work (excellent, average, bad), and an indication of which course sections were assessed in the assessment particular cycle.

Display Course Tasks

view information about a task

Outcome Information

An ability to design and conduct experiments, as well as to analyze and interpret data.

Suboutcome Information

Statistical data analysis skills

Department

Biomedical Engineering

Course

BME 301

Tasks

Information

Task Title
Statistical comparison of lateralization data

Description
Students were asked to make comparisons to determine significant differences between their data and class data and also comparisons within class data for students who received feedback on a task and students who did not receive feedback.

Methods
Students measured their own ability to lateralize a sound from varying angles in 10 degree increments around the head. Data from all students was compiled into class data. Class data was divided into two components: students who received feedback on the task and students who did not receive feedback. Students were asked to make statistical comparisons of their data with the class data and to compare the data for students with and without feedback.

Performance Indicator
70% of students must make 7 out of 10 on this task.

Sections

001 - F - 2009

Rubric & Examples

Rubric or Answer Key
[1257874175_rubric_lab_grading_rubric.pdf](#)

Excellent Example(s)
[1257874175_good_bme_301L](#) 1 [pdf](#)
[1257874175_good_bme_301L](#) 2 [pdf](#)

Average Example(s)
[1257874175_avg_bme_301L](#) 3 [pdf](#)
[1257874175_avg_bme_301L](#) 4 [pdf](#)

Bad Example(s)
[1257874175_bad_bme_301L](#) 5 [pdf](#)

Figure 2: One task display associated with a particular course. (Note: Student names have been removed from examples)

Course instructors set up their tasks and performance measures for the selected courses in the matrix, while program coordinators look at the overall process and to identify the places of potential improvement.

The summary of results can be viewed both according to the program outcomes and according to the courses, as shown in figure 3, which shows the courses with tasks (T) and whether the performance criteria were successfully **met or not** for sub-outcomes under outcome A. The upward arrow indicates successful attainment of the outcome, while the downward arrow shows it was not attained at the level specified by the performance criteria. There is a comparable set of numbers at the bottom of the entire table, showing assessment of each course (not shown here).

Home

Users

Reporting

Logout

You are here: Overview

Overview

Biomedical Engineering

In the overview panel, users can monitor section performance indicators as well as have quick access to task information.

● - implemented course/outcome association (no course data)

X - assessed course/outcome association (course data)

T - assessed course/outcome association that has associated tasks

↑

&

↓

- signify whether a suboutcome or course group met the course assessment.

Courses

Expected Outcomes (Knowledge, Skills, Attitudes)	BIO 183	BME 201	BME 203	BME 204	BME 210	BME 252	BME 301	BME 302	BME 311	BME 312	BME 352	BME 451	BME 452	ENG 331	MA 341	ST 370	Course Assessment
<div>A</div> <div>An ability to apply knowledge of mathematics, science, and engineering.</div>																	
<div>L</div> <div>Explain basics concepts of systems and cellular biology</div> <div>L</div> <div>Discuss the problems associated with the interactions between living and non-living materials and systems</div> <div>L</div> <div>Critically evaluate and analyze problems at the interface of engineering and biology</div> <div>L</div> <div>Apply knowledge of math, science and engineering.</div>	●						T ●	T ●									<div>↑ 4</div> <div>↓ 1</div>
							T ●	●					●				<div>↑ 1</div> <div>↓ 1</div>
				T ●			T ●	●	●								<div>↑ 1</div> <div>↓ 1</div>
			T ●		T ●				T ●						●		<div>↑ 6</div> <div>↓ 4</div>

Figure 3: Assessment display by sub-outcome.

Detailed analysis of the tasks associated with each sub-outcome is also available by clicking the numbers under ‘course assessment’ on the right of the matrix. An example is shown in figure 4. This shows the actual number of students who passed or failed the task according to the predetermined performance indicator, and the overall level of attainment by students, for each task under that sub-outcome.

Suboutcome Detailed Analysis				
Engineering A 4 1 collapse all				
BME 301 1 0				
Task #130 - Nernst potentials and resting membrane potentials 1 0 (70% of students must make a 16 out of 20)				
2009 - F 1 0				
Section	Raw Pass	Raw Fail	Performance Indicator	Course Assessment
001	45	6	70% - 16/20	88.2%
BME 302 3 1				
Task #140 - Cardiovascular and Renal Systems 0 1 (70% of students must make a 100 out of 100)				
2009 - S 0 1				
Section	Raw Pass	Raw Fail	Performance Indicator	Course Assessment
001	25	19	70% - 100/100	56.8%
Task #177 - Myocardial and Skeletal Muscle Fibers with Calcium 1 0 (70% of students must make a 100 out of 100)				
2009 - S 1 0				
Section	Raw Pass	Raw Fail	Performance Indicator	Course Assessment
001	33	12	70% - 100/100	73.3%
Task #178 - Calcium Channel Blockers in Myocardial Cells 1 0 (70% of students must make a 100 out of 100)				

Figure 4: Detail of individual task scores for one sub-outcome

A further existing feature is that instructors write summary comments about what the results showed about student learning after reviewing the results of particular tasks and describe what action will be taken in the future, such as to address areas where students did not achieve the desired performance criteria. The summary comments can be viewed by individual task, by course, by outcome, or a download of all comments over the year. The latter is shown in figure 5. The program assessment coordinator then writes an annual summary of program assessment within the system.

Instructor Comments

Author	Outcome/Suboutcome	Course	Section	Semester	Year	Comment	Comment Post Date
lacartee	A - Explain basics concepts of systems and cellular biology	BME 301	001	F	2009	88% of the students met the objective	09/24/2009 (4:04pm)
lacartee	E - Critical thinking skills	BME 301	001	F	2009	84% of the students successfully completed the task	09/24/2009 (4:04pm)
lacartee	G - Data presentation skills	BME 301	001	F	2009	64% of the class successfully completed the task, but this number should rise by the end of the semester after the students receive feedback from this report	10/06/2009 (2:02pm)
lacartee	B - Statistical data analysis skills	BME 301	001	F	2009	Students successfully completed the task	10/06/2009 (2:02pm)
lacartee	B - Design experiments for hypothesis testing	BME 301	001	F	2009	All students successfully completed the task.	10/06/2009 (2:02pm)
lacartee	B - Statistical data analysis skills	BME 301	001	F	2009	Students successfully completed the task.	10/06/2009 (2:02pm)
hoo	E - Systems analysis skills	BME 311	001	F	2009	Students did an excellent job on this problem and demonstrated their FS synthesis skills.	11/07/2009 (8:08pm)
hoo	A - Apply knowledge of math, science and engineering.	BME 311	001	F	2009	These grades are from a test after a quick-refresher on the pre-req math skills.	11/09/2009 (4:04pm)
hoo	A - Apply knowledge of math, science and engineering.	BME 311	001	F	2009	While the performance indicator is still not met, this is a big improvement over the test given on the first day with only 16% satisfying the performance measure.	11/09/2009 (4:04pm)

Figure 5: Summary of instructor comments on program assessment results

The tool has additional capabilities of storing and linking course syllabi to departmental web pages and serving as an electronic portfolio for the program. The current implementation status of the tool is at the end of this phase and was fully utilized by the Biomedical Engineering program during the recent ABET accreditation visit.

Phase 3: Additional features planned

The following features are planned in the next phase of implementation.

- *Mapping of the program outcomes to other sources of data for indirect assessment.*
- *Adding faculty short cuts*
- *Interfacing with grades*

Outcomes assessment should include multiple methods of assessment, such as direct and indirect measures to triangulate data points¹². Surveys such as graduating senior surveys and alumni surveys provide useful feedback to the programs on a regular basis. In this phase of the tool, they will be added as new columns to the assessment matrix, mapped to the program outcomes and be utilized for indirect assessment of those outcomes. In each case, flexibility to interface the actual source (such as centralized data sets from the university office of assessment) or flexibility to add additional sources (such as FE exam data) will be considered.

Adding short-cuts for faculty will eliminate an extensive learning curve and is the next desirable feature of this tool. The syllabus generator of the tool contains a program outcomes table where the program outcomes are mapped to the course instructional objectives according to their level of coverage (major, intermediate, basic) as shown in Figure 6.

Relationship of this course to program learning outcomes:		
Learning Outcome	Level of Instruction	Course content related to outcome implementation/assessment
Outcome A	Intermediate	Calculate Nernst and Goldmann's potentials; Given a vectorcardiogram calculate the recorded EKG lead potential; Calculate ITDs and ILDs; Calculate fundamental and harmonic frequencies of speech and formants; Understand the electronic requirements to record biological potentials; apply basic optics to understand vision; Identify anatomical features of physiological systems.
Outcome B	Major	Design and conduct experiments to investigate the differences between reflexes and reaction times; the relationship between the EKG and heart sounds; the physiological response to sympathetic stimulation. Conduct experiments to measure biological potentials; characteristics of hearing; evaluate cochlear implant speech processors; and understand the basis of speech production. Use psychophysics to compare sensory perceptions. Use statistical analysis to analyze data collected in the lab.
Outcome D	Basic	Work as part of a team to conduct laboratory experiments.
Outcome E	Intermediate	Predict the behavior of physiological systems in response to changing conditions.
Outcome F	Basic	Ethical considerations of implants discussed in class.
Outcome G	Major	Write formal lab reports including Introduction, Methods, Results and Discussion presenting data recorded from laboratory experiments.
Outcome I	Intermediate	Use electronic databases to search for relevant scientific literature. Summarize and report answers to questions posed in class.
Outcome J	Basic	Explain state-of-the-art technology designed to interface with electrically excitable physiological systems.
Outcome K	Basic	Use bioamplifiers to record biological potentials.

Figure 6: Relationship of a course to program learning outcomes as displayed on the syllabus

Live links to tasks being assessed for program assessment purposes will be placed next to those program outcomes being achieved in a major way in that course. The sole duty of the course instructor will be to implement the existing task during the semester or to create a new one, and while doing so, never have to leave the syllabus page and never have to navigate through the complexities of the tool. For instance, they will not have to navigate through the detail of the outcomes matrix.

If we can also add the flexibility of interfacing directly with task scores/grades, the entry of the performance results to the assessment matrix will be instantaneous.

In this phase we will do extensive testing to remove any glitches that may hinder the performance of the tool. Participants at the ASEE presentation will be invited to obtain guest accounts to use the tool so they can provide feedback and evaluation. Ultimately, we intend to make the tool broadly available to the engineering education community.

Phase 4: The final product

The following are desired features for phase 4 of development.

- *Producing the program assessment report chapters, appendices and tables for accreditation purposes*
- *Producing annual reports for program review activities*

The ultimate goal of this tool is to produce an annual or multi-year program outcomes assessment report using the commentary provided by the instructors, the task descriptions and the performance results from all programs. At present it is only possible to download pieces of the assessment report and then to cut and paste them into one document and add additional commentary. It is the intention to improve this, so that the tool generates a complete report, integrating all the sections into a comprehensive document.

Conclusions:

In its current form, PAT has already proved to be an invaluable program assessment tool for housing data, tracking progress and generating components of reports. With the additional developments that are planned, the value will increase as a user-friendly means of gathering and tracking assessment results at the course and program level.

In the final phase, we intend to market this tool to all program representatives and faculty in the college of engineering as an effective way of doing program outcomes assessment, and to get the buy in of all faculty who have a task to complete. Ultimately the tool has the potential to be used throughout our college as well as at colleges on other campuses because of the ease of portability. Being web based, it can easily be integrated with existing computing processes. Additionally, because of the flexibility of building matrices and tasks, the tool has potential for application to other disciplines.

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