An Advanced Assessment Tool and Process

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ABSTRACT
In this paper we describe a tool developed as part of the assessment process used at our university. The tool allows the automatic determination of the degree to which individual students meet the learning objectives that indicate how well students meet both course objectives and program directives. We also describe a portion of our assessment process that helps us perform the difficult step of "closing the loop" to make sure that the results of our data analysis are used to insure continuous program improvement.

Categories and Subject Descriptors
K.3.2 [Computer and Information Science Education]: Accreditation

General Terms
Measurement

Keywords
ABET, assessment

1. INTRODUCTION
In the Computer Science and engineering communities, the term "assessment" is often used to describe the evaluation of educational programs. We have developed some new evaluation techniques that will serve the Computer Science field, and perhaps the larger engineering field, well.

ABET accredits many undergraduate programs; Computer Science accreditation is done under a sub-organization known as the Computer Accreditation Commission, or CAC [1]. Many programs, especially at smaller colleges and universities are struggling under the load of the assessment process. It appears that a major factor in this difficulty is the lack of automated tools to help with the data collection and analysis process. The ABET accreditation process has become increasingly complex because it is heavily based on the creation of goals and objectives for programs. The assessment of these goals and objectives is often a time-consuming process [2, 3, 4, 5].

Our department has developed a process for assessment that includes the creation of automated software tools to help with the very difficult task of collecting and coordinating assessment data in a way that makes meaningful analysis feasible.

How effective is our process? During an ABET accreditation visit last year, preliminary discussions were begun between the department and ABET with the goal of partnership to extend our software to all ABET schools. ABET currently has no tools that provide the aggregation capability of our assessment tools. The faculty reflections process (discussed in section 2) is being considered by ABET for being promulgated as a "best practice."

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2. ASSESSMENT
The assessment process begins with the setting of desirable program outcomes, and the setting of learning objectives for each course. The department as a whole, set the program outcomes, and developed a mapping of the department's program outcomes to the ABET requirements commonly known as "A through K." With the special input of its curriculum committee, the individual instructors set the learning objectives for each course.

We also developed a rubric for retrospective analysis of their courses by the faculty who have taught them. (This rubric is in addition to some other standard rubrics that have been obtained from other universities for the purposes of measuring student's performance in written and verbal communications, as a member of a project team, and on design projects.) These retrospective reflections of faculty members provide considerable guidance to other faculty members teaching the course in subsequent years.

It should be noted that, as in most colleges and universities, the development and alignment of program outcomes is heavily affected by inputs from the major stakeholders: students alumni, recruiters, advisory board, etc., as well as external inputs from the mission, vision, and core values statements and policies of the encompassing college and the university itself.
Reflections of the faculty in the most recent self-study included the following:

- Reduce or eliminate the coverage of parsing and grammar issues in a computer languages course, especially since it was covered elsewhere in the theory of computation course.
- Spend additional time in the fundamentals of algorithms course to reflect the apparent weakness of the students in their entering knowledge of statistics.
- Include more project management and estimation in the software engineering course.

The ABET accreditation visiting team was so impressed by the department's process of using faculty reflections for course improvement that they recommended that the faculty reflections process be considered as a "Best Practice" by ABET.

3. THE ASSESSMENT TOOL

The initial deployed version of the assessment tool is a set of macros in Microsoft Excel to facilitate the measurement of the success of each course in achieving a course's learning objectives, which are then used to measure the effect on the entire program's outcomes. The common set of macros is used for every course.

A Microsoft Excel spreadsheet with a portion of the course learning objectives for a junior-level software engineering course is shown in Figure 1. All figures have been cropped.

The learning objectives for each course must be created in the context of the program's overall objectives. Mapping of this particular course's learning objectives to the overall program outcomes is shown in Figure 2.

The small subset of learning objectives shown in Figure 1 exemplifies the course's coverage. The bottom row of Figure 1 lists some of the individual sheets in this spreadsheet using separate tabs. Clicking on any of these tabs brings up a sheet showing the particular learning objective and the student's performance on this particular learning objective.

Entering the data for each learning objective on a separate sheet is far too time-demanding to be useful for faculty to use it willingly. Faculty members use a special sheet named "Grade Sheet Broken Down by Problem" (shown in Figure 3) in which each assessed item is listed, together with the total number of points for it. Items such as examinations will ordinarily have several questions; each question will have one or more associated learning objectives with it, as shown in Figure 3. Faculty members make sure that the learning objectives for the course are all in place in the spreadsheet, and must enter the data. Once the spreadsheet is created, the effort to record grades is only slightly greater than simply entering grades into a spreadsheet or commercial grade book software package.

A "Calculate" button (not shown) on this sheet enables a large set of macros to run. These macros create and fill out individual sheets for each of the learning objectives in the course as well as summary data that can easily be aggregated across the entire curriculum. The following sheets are created using the macros:

- Assessment sheets (not shown) for each item evaluating a specific learning objective.
- A grade sheet summary (not shown) that includes means and standard deviations of the grades.
- A graph (not shown) of the course overall grade totals.
- A summary of course outcomes (shown in Figure 4) in the form of measurements of the performance of the students on the specific learning objectives.
- A summary of performance on the program outcomes. This is shown in Figure 5 below for another, small class.
- Suggested grades for the class and a grade distribution (not shown).

It is easy to see from these and other sheets when students are in need of additional assistance.

In Figure 4, the light gray background color (yellow on the original spreadsheet) in cell G18 indicates that a student did not perform at a satisfactory level on the learning objectives for this course. A row entirely in yellow would indicate that the entire class performance was below preset criteria for learning, thus helping to close the loop in the assessment process.

Student performance on program outcomes as measured for this particular course is shown in Figure 5. This information is similar, but not identical, to the results indicated in Figure 4, where we showed the "Course Outcomes Summary" sheet displaying this particular course's learning objectives.

The darkest background color (red on the original) in Figure 5 indicates that some of this particular course's learning objectives did not address particular program outcomes as defined by the department. (This information could have been seen by a previously discussed sheet that described the mapping of the course objectives to program outcomes.) Note that several different course learning objectives may be aggregated into a single program outcome. As was the case with Figure 4, a yellow background color (cell G17 in Figure 5) indicated that student performance was below preset criteria.

The entire collection of "Course Outcomes Summary" and "Program Outcomes Summary" sheets from the individual courses can be aggregated into a single sheet (not shown here) to provide a complete assessment of the department's effectiveness in meeting its educational objectives. This information can, in turn, be used to improve the curriculum and the rest of the department's education process, using our assessment process, much in the same manner that the CMM and CMMI models are intended to improve the software development process [6, 7].

4. FUTURE WORK

The first generation of this copyrighted tool, which produces accurate results, will be revised to improve the user interface, and provide stress testing to make sure that our software can handle larger class sizes than we currently have. We will also improve our overall system by interfacing the spreadsheets with a database.

Since the department's undergraduate programs had to undergo the ABET assessment process, and the entire collection of graduate programs at our university will be undergoing a university-wide graduate program review, we have decided to use our tools for the assessment of its beginning graduate courses. We expect this approach will strengthen the department's course offerings and allow greater continuity when different instructors teach these beginning graduate courses.

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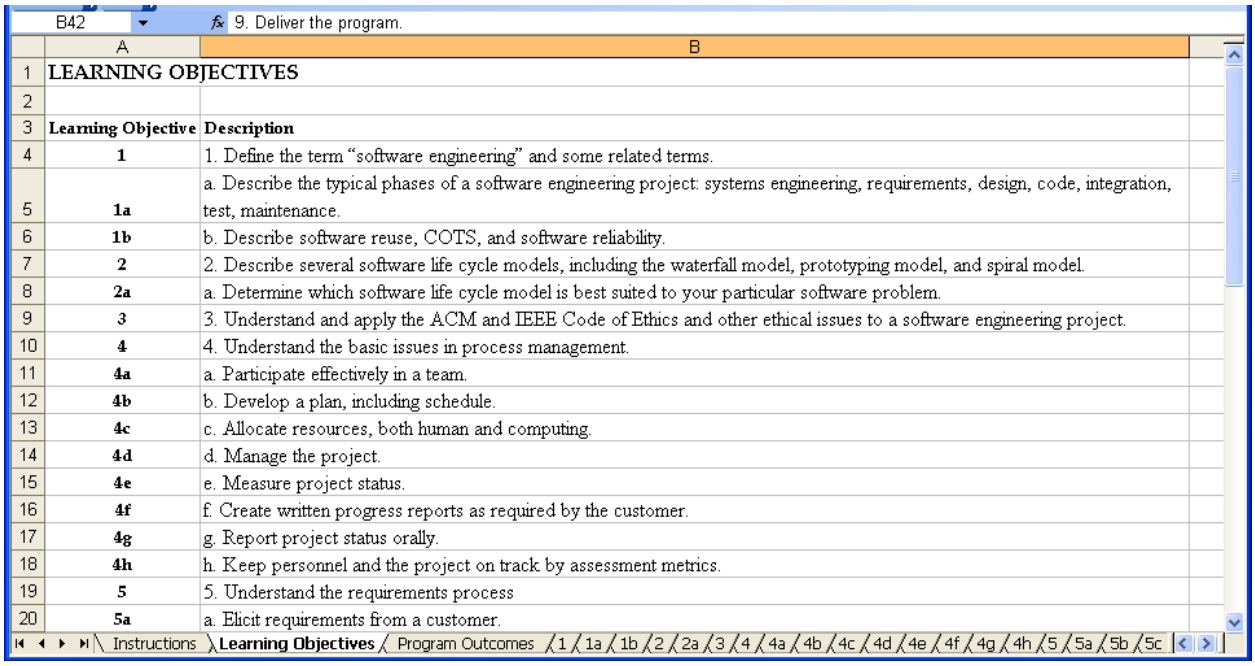
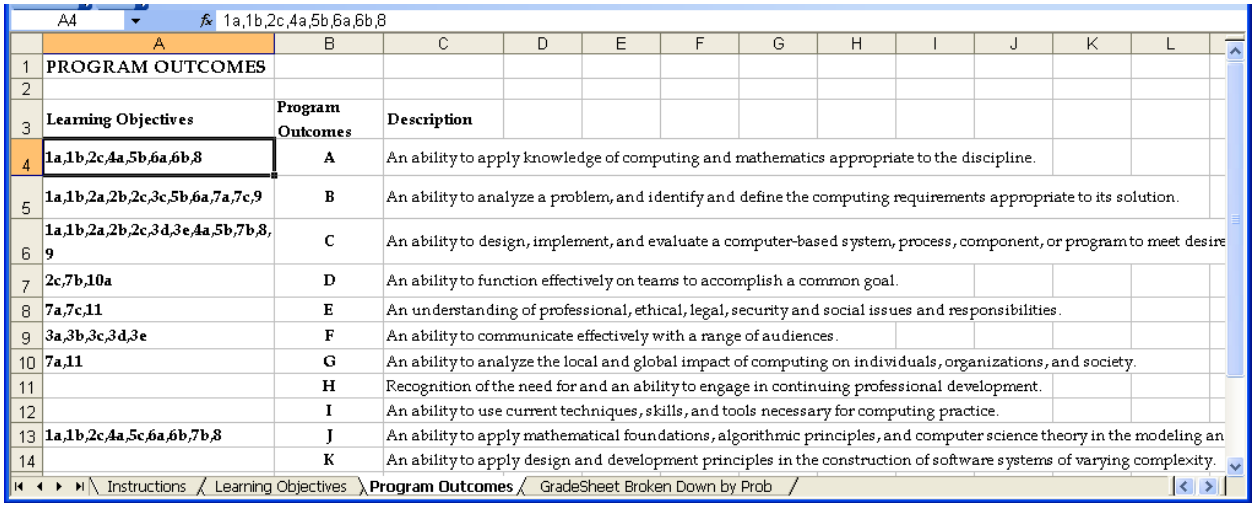


B42 | 9. Deliver the program.

	A	B
1	LEARNING OBJECTIVES	
2		
3	**Learning Objective**	**Description**
4	**1**	1. Define the term "software engineering" and some related terms.
5	**1a**	a. Describe the typical phases of a software engineering project: systems engineering, requirements, design, code, integration, test, maintenance.
6	**1b**	b. Describe software reuse, COTS, and software reliability.
7	**2**	2. Describe several software life cycle models, including the waterfall model, prototyping model, and spiral model.
8	**2a**	a. Determine which software life cycle model is best suited to your particular software problem.
9	**3**	3. Understand and apply the ACM and IEEE Code of Ethics and other ethical issues to a software engineering project.
10	**4**	4. Understand the basic issues in process management.
11	**4a**	a. Participate effectively in a team.
12	**4b**	b. Develop a plan, including schedule.
13	**4c**	c. Allocate resources, both human and computing.
14	**4d**	d. Manage the project.
15	**4e**	e. Measure project status.
16	**4f**	f. Create written progress reports as required by the customer.
17	**4g**	g. Report project status orally.
18	**4h**	h. Keep personnel and the project on track by assessment metrics.
19	**5**	5. Understand the requirements process
20	**5a**	a. Elicit requirements from a customer.

Instructions | Learning Objectives | Program Outcomes | 1 | 1a | 1b | 2 | 2a | 3 | 4 | 4a | 4b | 4c | 4d | 4e | 4f | 4g | 4h | 5 | 5a | 5b | 5c

Figure 1. A course's learning objectives.

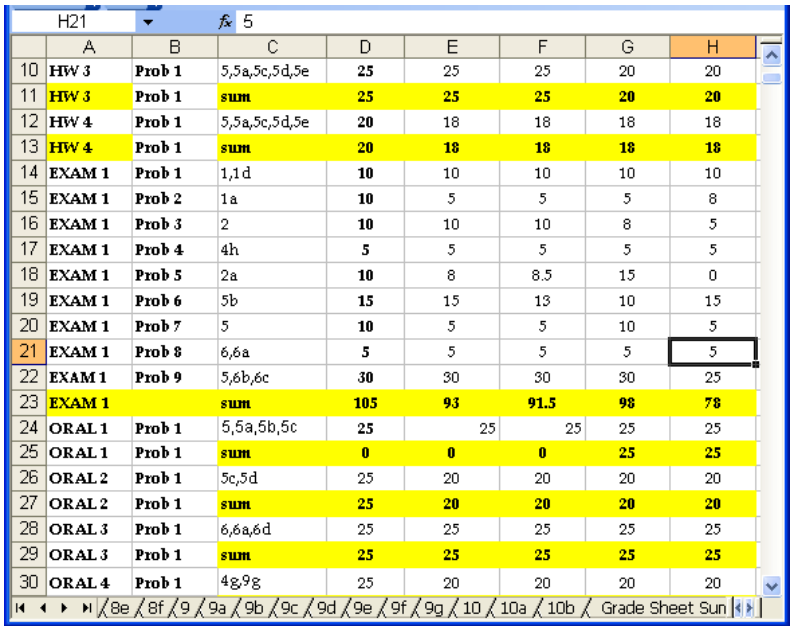


A4 | 1a,1b,2c,4a,5b,6a,6b,8

	A	B	C
1	PROGRAM OUTCOMES		
2			
3	**Learning Objectives**	**Program Outcomes**	**Description**
4	**1a,1b,2c,4a,5b,6a,6b,8**	**A**	An ability to apply knowledge of computing and mathematics appropriate to the discipline.
5	**1a,1b,2a,2b,2c,3c,5b,6a,7a,7c,9**	**B**	An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution.
6	**1a,1b,2a,2b,2c,3d,3e,4a,5b,7b,8, 9**	**C**	An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desire
7	**2c,7b,10a**	**D**	An ability to function effectively on teams to accomplish a common goal.
8	**7a,7c,11**	**E**	An understanding of professional, ethical, legal, security and social issues and responsibilities.
9	**3a,3b,3c,3d,3e**	**F**	An ability to communicate effectively with a range of audiences.
10	**7a,11**	**G**	An ability to analyze the local and global impact of computing on individuals, organizations, and society.
11		**H**	Recognition of the need for and an ability to engage in continuing professional development.
12		**I**	An ability to use current techniques, skills, and tools necessary for computing practice.
13	**1a,1b,2c,4a,5c,6a,6b,7b,8**	**J**	An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling an
14		**K**	An ability to apply design and development principles in the construction of software systems of varying complexity.

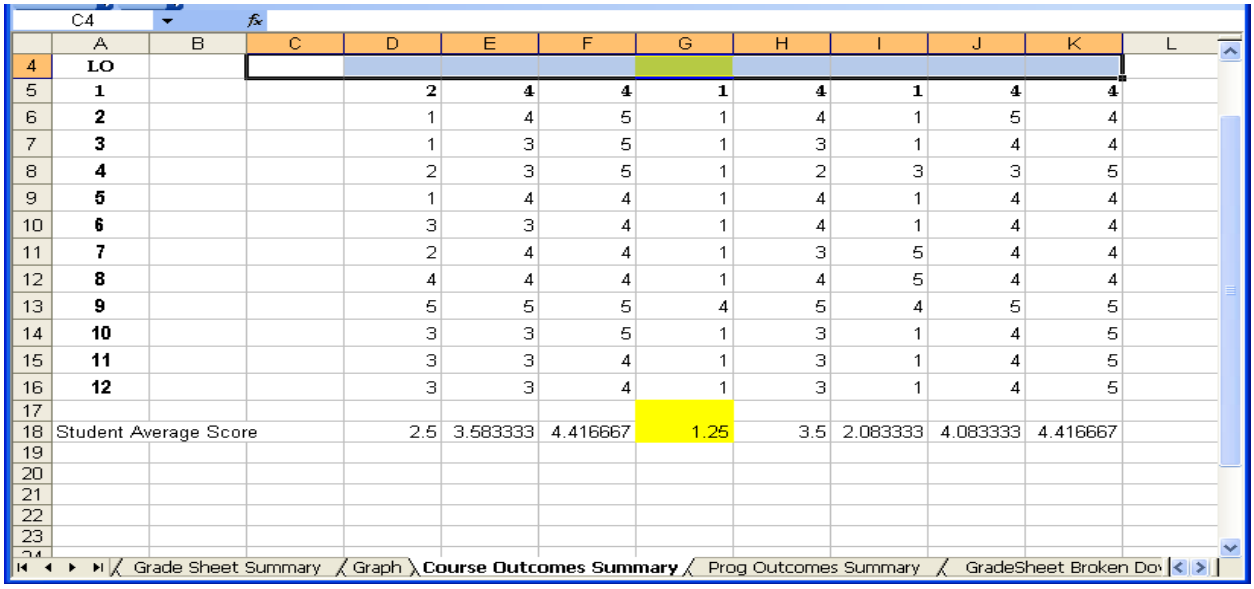
Instructions | Learning Objectives | Program Outcomes | GradeSheet Broken Down by Prob

Figure 2. Mapping a course's learning objectives to program outcomes.



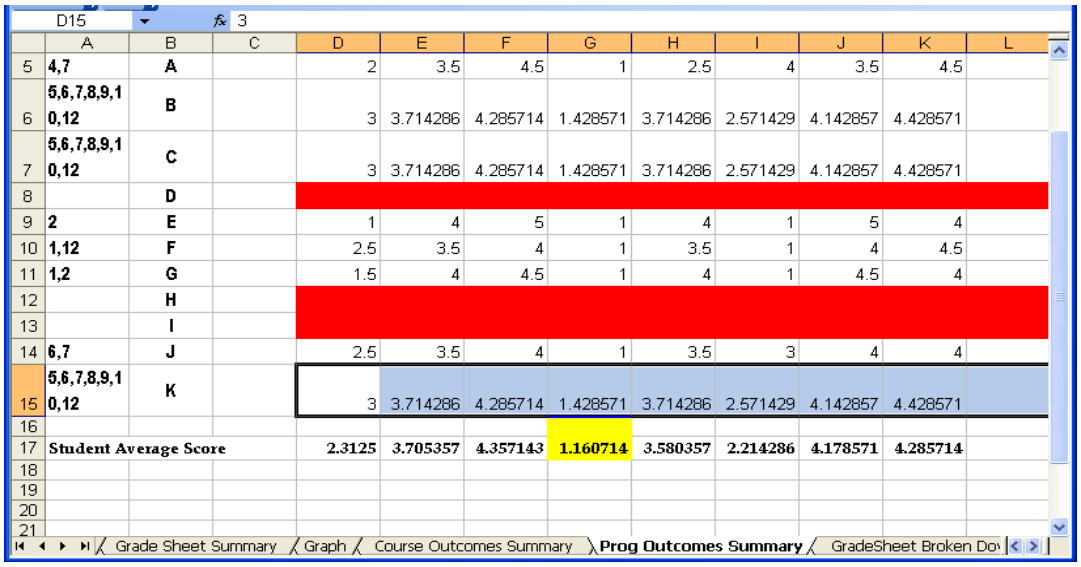
	A	B	C	D	E	F	G	H
10	**HW 3**	**Prob 1**	5,5a,5c,5d,5e	**25**	25	25	20	20
11	**HW 3**	**Prob 1**	**sum**	**25**	**25**	**25**	**20**	**20**
12	**HW 4**	**Prob 1**	5,5a,5c,5d,5e	**20**	18	18	18	18
13	**HW 4**	**Prob 1**	**sum**	**20**	**18**	**18**	**18**	**18**
14	**EXAM 1**	**Prob 1**	1,1d	**10**	10	10	10	10
15	**EXAM 1**	**Prob 2**	1a	**10**	5	5	5	8
16	**EXAM 1**	**Prob 3**	2	**10**	10	10	8	5
17	**EXAM 1**	**Prob 4**	4h	**5**	5	5	5	5
18	**EXAM 1**	**Prob 5**	2a	**10**	8	8.5	15	0
19	**EXAM 1**	**Prob 6**	5b	**15**	15	13	10	15
20	**EXAM 1**	**Prob 7**	5	**10**	5	5	10	5
21	**EXAM 1**	**Prob 8**	6,6a	**5**	5	5	5	5
22	**EXAM 1**	**Prob 9**	5,6b,6c	**30**	30	30	30	25
23	**EXAM 1**		**sum**	**105**	**93**	**91.5**	**98**	**78**
24	**ORAL 1**	**Prob 1**	5,5a,5b,5c	**25**	25	25	25	25
25	**ORAL 1**	**Prob 1**	**sum**	**0**	**0**	**0**	**25**	**25**
26	**ORAL 2**	**Prob 1**	5c,5d	25	20	20	20	20
27	**ORAL 2**	**Prob 1**	**sum**	**25**	**20**	**20**	**20**	**20**
28	**ORAL 3**	**Prob 1**	6,6a,6d	25	25	25	25	25
29	**ORAL 3**	**Prob 1**	**sum**	**25**	**25**	**25**	**25**	**25**
30	**ORAL 4**	**Prob 1**	4g,9g	25	20	20	20	20

Figure 3. A "Grade Sheet Broken Down by Problem" data sheet showing recording of learning objectives.



	A	B	C	D	E	F	G	H	I	J	K	L
4	**LO**											
5	**1**			**2**	**4**	**4**	**1**	**4**	**1**	**4**	**4**	
6	**2**			1	4	5	1	4	1	5	4	
7	**3**			1	3	5	1	3	1	4	4	
8	**4**			2	3	5	1	2	3	3	5	
9	**5**			1	4	4	1	4	1	4	4	
10	**6**			3	3	4	1	4	1	4	4	
11	**7**			2	4	4	1	3	5	4	4	
12	**8**			4	4	4	1	4	5	4	4	
13	**9**			5	5	5	4	5	4	5	5	
14	**10**			3	3	5	1	3	1	4	5	
15	**11**			3	3	4	1	3	1	4	5	
16	**12**			3	3	4	1	3	1	4	5	
17												
18	Student Average Score			2.5	3.583333	4.416667	1.25	3.5	2.083333	4.083333	4.416667	
19												
20												
21												
22												
23												

Figure 4. A "Course Outcomes Summary" data sheet for all learning objectives in a course.



	A	B	C	D	E	F	G	H	I	J	K	L
5	4,7	A		2	3.5	4.5	1	2.5	4	3.5	4.5	
6	5,6,7,8,9,10,12	B		3	3.714286	4.285714	1.428571	3.714286	2.571429	4.142857	4.428571	
7	5,6,7,8,9,10,12	C		3	3.714286	4.285714	1.428571	3.714286	2.571429	4.142857	4.428571	
8		D										
9	2	E		1	4	5	1	4	1	5	4	
10	1,12	F		2.5	3.5	4	1	3.5	1	4	4.5	
11	1,2	G		1.5	4	4.5	1	4	1	4.5	4	
12		H										
13		I										
14	6,7	J		2.5	3.5	4	1	3.5	3	4	4	
15	5,6,7,8,9,10,12	K		3	3.714286	4.285714	1.428571	3.714286	2.571429	4.142857	4.428571	
16												
17	Student Average Score			2.3125	3.705357	4.357143	1.160714	3.580357	2.214286	4.178571	4.285714	
18												
19												
20												
21												

Figure 5. A "Program Outcomes Summary" data sheet showing how particular learning objectives are met.