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Developing Effective Assessment of Student Professional Outcomes*

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As engineering programs continue to prepare for evaluation under EC 2000, faculty members are experiencing concern over the less well-defined outcomes of Criterion 3 that address lifelong learning, the global and societal context of our profession, and contemporary issues. Designing and implementing assessment for these outcomes might appear to be a time-consuming and ill-defined endeavor. This paper suggests several straightforward classroom strategies that faculty may use to begin to develop these outcomes in their students and describes an effective assessment method that may be realistically implemented and maintained for the long-term.

INTRODUCTION

AS IMPLEMENTATION of the requirements of the Engineering Criteria 2000 (EC 2000) [1] becomes the standard for all accredited United States engineering programs this Fall, faculty members and administrators justly raise concerns over the costs associated with this effort. Faculty members already carry substantial workloads and, in most institutions, it is ultimately the efforts of these busy individuals that will lead to successful implementation of the assessment processes required by EC 2000. This paper addresses one example of imbedded assessment as a straightforward means by which to minimize some of the costs associated with the sustainable implementation of EC 2000.

This article focuses specifically on a few of the 'student professional outcomes'. Often colloquially referred to as the 'soft skills', they are included in the ABET-designated Criterion 3 outcomes as:

- outcome h (global and societal context);
- outcome i (lifelong learning);
- outcome j (contemporary issues).

These less familiar outcomes in particular raise some concern among those responsible for their program assessment processes. What meaningful learning experiences can contribute to the development of these outcomes in our students? How do we substantiate attainment of these soft outcomes in our graduates? What are some reasonable ways to assess them, even while students are still on campus? The purpose of this article is twofold. First it will briefly describe the 'outcomes vision' approach used for the development of the assessment process in the chemical engineering program at Michigan State University as we prepared for a 1998 ABET EC 2000 visit. Second, it will demonstrate the application of an imbedded assessment tool for the evaluation of two of these professional outcomes.

DEALING WITH CONSTRAINTS AND TENETS

As a busy faculty, our primary criterion for an 'effective' assessment tool was that it should require low faculty effort to develop, administer, and maintain. In accord with this tenet and after reviewing the literature, our faculty was reluctant to conduct assessment at all taxonomy levels as described by Bloom [2]. Further, we endeavored to include the consideration of the constraints on student time and motivation and desired at least a portion of the assessment to be virtually invisible to the students.

One solution was to imbed the assessment in our courses, blending it as seamlessly as possible into the normal classroom activities. The specific approach we used was to define performance indicators for each outcome, refine the indicators into a set of scoring rubrics, and then incorporate the rubrics into classroom grading sheets. By combining the assessment tool with a course grading sheet and by providing the sheet to the students, we minimized both faculty and student effort. The grading sheets set expectations for students, and were used by faculty both for the purposes of grading and for outcomes assessment [3].

GLOSSARY

It is reasonable to expect that the assessment and evaluation processes will differ from one program to the next. Similarly, the use of assessment terminology is likely to vary from one reader

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to the next. The following section provides definitions of some of the terms used in this article.

- *Assessment*: a system of gathering, analyzing, and interpreting evidence to determine how well actual performance matches set expectations and standards [3]; the main purpose of assessment as required by ABET is to determine the performance of the engineering program [1].
- *Program educational objective*: a broad statement or statements that describe the goals of the educational program and the expected accomplishments of graduates during the first few years of graduation [4].
- *Program outcome*: what the department faculty intend for students to be able to think, know or do when they have graduated from the program; attainment of the outcomes helps realize the achievement of educational objectives.
- *Performance indicator*: evidence that the desired outcome, or aspects of the desired outcome exist [5]. It is what a faculty member can observe and evaluate to judge achievement of an outcome by a student.
- *Practice or strategy*: the classroom practice designed to achieve a specific outcome [6].
- *Rubric*: an analytical scoring scale in which the observable performance indicators are divided into different levels of achievement
- *Benchmark*: a standard of aggregate student performance against which measured outcomes are compared; a level of expectation.

PROCESS DEVELOPMENT APPROACH

This section describes the general plan that we used for the design of the assessment process for all of our program outcomes, and is provided largely to set the context for the results that relate specifically to the soft outcomes. The first step was to mobilize key faculty members in order to achieve the 'buy-in' necessary to maintain the processes in the long-term. The departmental curriculum committee and an emeritus faculty member became the strategic players in the process. The results of their work were regularly reported at faculty meetings to maintain level of awareness and to gather additional input and suggestions. Student input was obtained through their membership on the curriculum committee.

The next step was to establish an 'outcomes vision'—our own perspective on the outcomes and their assessment in their role in accomplishing our program educational objectives. The outcomes vision approach included five phases as follows:

1. Definitions
2. Prioritization
3. Review
4. Measurement
5. Implementation

In the **definition phase** we considered the meaning and significance that the ABET-designated outcomes had for our students and our program. Using a brainstorming approach, we sought answers to the basic questions, 'What does this outcome mean to us? What behaviors or traits will be observed in our students who have achieved this particular outcome? How can these outcomes be developed? What are their performance indicators?' Answers to these questions had considerable value in customizing the definitions of the outcomes for our program.

Once we had an initial understanding of the meaning of the outcomes, our faculty and our departmental advisory board (alumni and employer constituencies) **prioritized** to the entire set of eleven outcomes. As the gatekeepers of the educational program, our faculty felt that not all eleven outcomes contributed equally to the achievement of our program objectives. Consequently, not all eleven outcomes would be weighted equally in our assessment processes. This understanding affected several features of the assessment strategies including the frequency at which each outcome was assessed and the weight that assessment results carried in deciding upon program improvements.

The third step, the **review phase**, was key in enabling the development of a sustainable process and in limiting the time that faculty and students invested in assessment. In this step, we reviewed the entire curriculum to inventory existing points of contact with students, i.e. learning opportunities and classroom practices, in which some type of data was already being collected or where student work could be used to contribute to both the achievement and evaluation of an outcome. Our interpretation of the requirements of Criterion 3 led us to believe that the assessment must be in large part performance based. Therefore, we were sure to look for projects and student work that required students to apply fundamental knowledge and skills and where the nature of the work required that the application of these skills be clearly demonstrated and measurable.

This resulted in a mapping of each outcome into courses in our curriculum in which course material and student learning contributed to the achievement of that particular outcome. As predicted by Ewell [7], review of the course outcomes was a valuable exercise in suggesting improvement even before any assessment data had been gathered.

When the links between outcome and courses were established, we attempted to identify specific projects and student work that could be used for assessment. In the case of outcomes h, i and j, more thought and research were required to find practical opportunities for assessment. In some instances, appropriate learning and assessment opportunities did not exist, and additional development was required. Examples of both cases—where practices existed and where they did not—are presented in this paper.

The next step was to identify **measurement** tools that, for the purposes of efficiency, could serve the dual purpose not only of assessing outcomes but could also be used in grading. These tools were used to provide measurable results that could be traced back into the curriculum to identify possible weaknesses in the development of specific outcomes in our students.

Weaknesses can only be identified relative to a baseline, so the measured achievement was to be compared to the expectations set for each outcome. These expectations, or benchmarks, were first established by faculty and set at levels that seemed compatible with our program educational objectives and the prioritization of the outcomes. The first iteration carried with it some measure of uncertainty about the suitability of the chosen levels. Appropriate adjustments could be made after the subsequent cycles of the assessment process were completed.

For example, for the lifelong learning outcome, the faculty committee suggested that at least 50% of our students should demonstrate a 'high' level of lifelong learning skills, 40% should exhibit at least 'average' skills, and the remainder should achieve the minimal acceptable level. The meaning of these levels of achievement and their quantitative measurement in relation to rubrics will be described in a later section of this paper. Although setting of these particular levels of expectation might be arguable, they seemed to represent reasonable initial targets for our student body. After the first evaluation of assessment results, these benchmarks were not achieved, and were left as a target for program improvement.

During the **implementation phase**, we gained additional insight into the route that our assessment process was taking. We were concerned over the potential for large amounts of data that would require analysis in order to properly close the loop on our assessment processes. Because of the time constraints on faculty, we agreed that assessment could justly be done on the basis of a sampling of the student population. This was a critical decision for our program because our class sizes are typically large (>60 students). Evaluation of assessment results by sampling was another timesaving feature that helped ensure the sustainability of our assessment processes.

This approach is supported by Nichols [3] who suggests that the aggregated accomplishments of the students in the program outcomes are the primary available reflection of our programs and their results. He further states that '. . . not all students or graduates need take or respond to all means of assessment, since a representative sample is sufficient for evaluation of the program.' The sampling approach appears to be indirectly supported by ABET policy as well [8] which clearly states that ABET accredits *programs*. This implies that its role does not include accreditation or evaluation of individual student performance, but rather the aggregate outcome.

HANDLING THE ASSESSMENT CHALLENGE FOR SOFT SKILLS

The outcomes vision approach proved to be an effective method for developing assessment strategies for all of our program outcomes. The remainder of this paper describes specific results for the lifelong learning outcome and broad approaches for the outcome addressing the impact of engineering solutions in a global and societal context.

Lifelong learning

Assessment of lifelong learning skills is a logical candidate for alumni surveys and the tracking of continuing education courses that alumni have taken. Although valid, these methods do not specifically evaluate the learned skills and behaviors that motivate this outcome and, therefore, provide little guidance for improvement efforts. How could we assess this outcome in our students? The performance indicators that were developed in the definition step of our process provided the answer. Below is an example of our initial list of performance indicators. It represents a relatively broad interpretation of the outward appearance of this outcome in our students:

Performance indicators

In order to be lifelong learners, students should:

1. Be proficient in the use of a variety of informational and educational media such as traditional textbooks, scientific and technical journals, the library system as a whole, the World Wide Web, and educational software.
2. Have an understanding of and exposure to the breadth and structure of the professional and technical support system that will be available to the students upon graduation; this includes professional and technical societies, the continuing education needed to maintain professional relevance, and professional registration systems.
3. Have an awareness of the dynamic, evolving nature of science, engineering, technology, and industry, and an understanding that learning does not end with the B.S. degree.
4. Have the ability to learn on their own.

Admittedly these are rather diffuse statements, and some are not easily assessed. However, as a first step, they provided a foothold for identifying possible classroom practices with which the lifelong learning traits could be developed and evaluated. Possible opportunities for learning and subsequent demonstration of the outcome were identified as part of the **review** step described earlier with the following results.

Possible classroom practices/strategies:

1. Assign problems and projects that require analysis, synthesis, and evaluation of information gathered from a variety of resources including

traditional textbooks, scientific and technical journals, the WWW, communication with other professionals, and database software.
2. Engage students in the discussion of the professional support system that will be available to them upon graduation, including professional and technical societies, continuing education courses, and professional registration systems.
3. Provide examples and encourage active discussion of the historical progression of a scientific principle, an engineering method, or a specific technology.
4. Invite industrial representatives to meet with students to discuss current trends that are affecting their companies and industries.
5. Complete at least one problem/project that requires independent learning and the use of the tools described in #1 above.

This list helped us identify areas where practices needed to be developed; more importantly with respect to timesaving, we were able to isolate existing practices that could be used for learning and assessing. For example, for the lifelong learning outcome, we identified a project in our fluid flow and heat transfer course in which, with only minor adjustments in project requirements, student lifelong learning skills could be learned, practiced, and assessed.

Rubrics

In order to use the performance indicators in a practical way, our **implementation step** required a further refining of the list into measurable aspects of student performance. Figure 1 is a list of the rubrics developed for the lifelong learning outcome; several literature references were useful resources in their compilation [9–11]. The rubrics were grouped in a fairly simple three-level scale of '5' high, '3' average, and '1' low. Since this particular outcome did not have an exceptionally high priority in achieving our educational objectives, we felt that three levels of assessment were sufficient. The 'gaps' (4 and 2) without representative descriptions allowed the faculty members some measure of flexibility in their assessments. These levels were also consistent with scoring scales of other assessment tools used in our program evaluation processes.

An ability to engage in lifelong learning

5: Student . . .
- ❑ Demonstrates ability to learn independently
- ❑ Goes beyond what is required in completing an assignment and brings information from outside sources into assignments
- ❑ Learns from mistakes and practices continuous improvement
- ❑ Demonstrates capability to think for one's self
- ❑ Demonstrates responsibility for creating one's own learning opportunities
- ❑ Is able to understand, interpret, and apply learned materials and concepts in a format different from that taught in class (e.g. different nomenclature, understand equation from different textbook)
- ❑ Participates and takes a leadership role in professional and technical societies available to the student body

3: Student . . .
- ❑ Requires guidance as to expected outcome of task or project
- ❑ Completes only what is required
- ❑ Sometimes is able to avoid repeating the same mistakes
- ❑ Does not always take responsibility for own learning
- ❑ Seldom brings information from outside sources to assignments
- ❑ Has some trouble using materials and concepts that are in a different format from that taught in class
- ❑ Occasionally participates in the activities of local professional and technical societies

1: Student . . .
- ❑ Requires detailed or step-by-step instructions to complete a task
- ❑ Shows little or no interest in outside learning resources
- ❑ Assumes that all learning takes place within the confines of the class
- ❑ Cannot use materials outside of what is explained in class
- ❑ Unable to recognize own shortcomings or deficiencies
- ❑ Does not show any interest in professional and/or technical societies

Fig. 1. Scoring rubrics for program outcome.

The next step was to imbed the rubrics into a project or presentation grading sheet (Fig. 2). This sheet was used for assigning grades for a required project in our fluid flow and heat transfer course. Not all traits described in the general list of rubrics were incorporated into the grading sheet—only those that were compatible with the nature of the project were included. In this project, student teams were asked to conduct independent research, in which the concepts learned in class were applied to the technical analysis of a device or system. A list of possible project topics was compiled from a combined list of student and instructor suggestions with the only restrictions being that the device or system must have some relationship to fluid flow, heat transfer, or both. If possible, a mathematical analysis of the operation of the device or system, including determination of key thermal or fluid properties, was to be included in the report. No class time was spent on the details of the projects other than the discussion of the report requirements. The student teams were required to present their results in a written report and as an oral presentation.

Assessment procedure

In a typical year, our fluid flow and heat transfer course serves about 80–90 chemical engineering

Group Presentation Evaluation Form
(50 points total)

1. Technical Content (25 points) ______

a. Explanation (relationship to fluid flow/heat transfer) ______
- ❑ Takes new information and effectively integrates it with previous knowledge
- ❑ Demonstrates understanding of how various pieces of the problem relate to each other and to the whole
- ❑ Is able to understand, interpret, and apply learned materials and concepts in a format different from that taught in class

b. Technical analysis ______
- ❑ Uses appropriate equations, constants, and estimates
- ❑ Includes necessary references to technical resources (handbooks, texts, etc.)
- ❑ Goes beyond what is required in completing an assignment and brings information from outside sources into assignments

2. Oral Presentation (20 points) ______

a. Preparation ______
- ❑ Speaks comfortably with minimal prompts (notecards)
- ❑ Uses proper American English
- ❑ Uses visual aides effectively

b. Effectiveness of presentation ______
- ❑ Plans and delivers an oral presentation effectively; applies the principle of "(tell them)^3"
- ❑ Thoughts are logically organized
- ❑ Presents well "mechanically" (does not block screen, doesn't exhibit nervous behaviors)
- ❑ Makes eye contact
- ❑ Can be easily heard

c. Group cooperation ______
- ❑ Material divided among group members appropriately
- ❑ Smooth transitions between group members' presentations

3. Professionalism (5 points) ______
- ❑ Professional (appropriate) appearance
- ❑ Professional language
- ❑ Professional attitude

TOTAL POINTS ______

Project Title: ______

Group members: ______

Fig. 2. Rubric-based grading sheet.

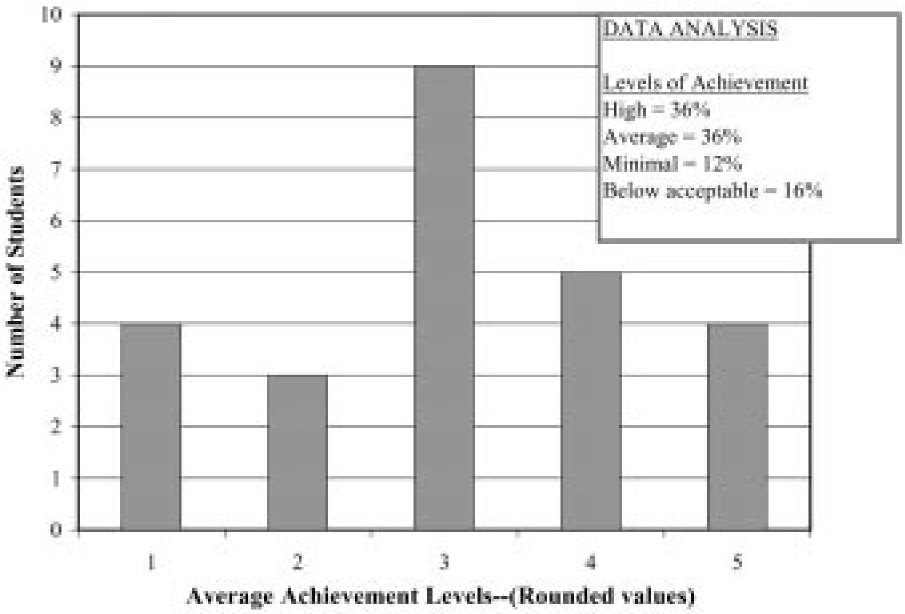

Fig. 3. Example of outcome level of achievement analysis.

students. The course is four semester credits, and includes four 'lecture' sessions and one recitation (discussion) session per week. The students are divided among several recitation sections to provide opportunities to work and learn in smaller groups; all recitation sections are held at the same time of the week. In addition, the course scheduling is conveniently arranged so that the recitation sections occur immediately following that day's lecture session, so that if needed, the instructor can utilize a two-hour block of scheduled course time by combining the lecture section with the recitations. This time was used over a two- to three-week period to accommodate all of the student presentations.

Student presentations were graded during class using the grading sheet presented as Fig. 2. The level of achievement (5 down to 1) was marked by a numeral for each performance indicator directly on the grading sheet. This system requires the instructors to be familiar with the scoring rubrics (Fig. 1). Although some element of subjectivity exists, the use of rubrics has, in fact, provided greater objectivity to the grading and assessment of these types of student projects.

For the purposes of project grading, the instructor gave a grade based on the level of achievement for each indicator. If all indicators were marked as a '5', the highest possible score (50 points) was assigned. For a mix of levels of achievement, the instructor assigned a proportional number of points.

For the *separate purposes of assessment*, a representative sample of the grading sheets was photocopied, the student names were removed, and the levels of achievement on the indicators relevant to lifelong learning (or any other outcome represented on the grading sheet) were extracted from the scoring. The levels for all relevant indicators were averaged for each student in the sample to give a set of student averages for that specific outcome (representative results are shown as Fig. 3 for a sample of 25 students). This step required some investment of time, but a student was hired to gather and compile the data. It should be noted that an improvement to this process is being developed wherein the scoring will be done in the classroom using a laptop computer, and the data will be compiled automatically, thus allowing even larger samples to be analyzed. In the meantime, student involvement is a hallmark of our assessment processes and helps develop both understanding and a sense of buy-in within this important constituent group.

The compiled data were then compared to the levels of expectation, or benchmarks. For the example results shown on Fig. 3, the averaged student scores were rounded to the nearest whole number and plotted against frequency of occurrence. The data analysis shows that the benchmarks were not achieved. Thirty-six percent of the students (not 50%, as desired) achieved a 'high' level (total of both 5 and 4 scores), 36% (not 40%) achieved at an average level, and 16% performed at levels below the acceptable minimum (>1). The results of this analysis were presented as part of an overall annual assessment report to the program faculty, the departmental advisory board, and the program review committee. Decisions on program improvements were made as part of a process described in a previous paper [12].

In order to improve student skills in lifelong learning, additional learning opportunities were provided in other courses. In the chemical engineering unit operations laboratory course, students were assigned a problem that requires them to use the Internet to understand government regulations regarding the use of chemicals in food. In our separations course, students develop a course supplement—a collection of papers—on separation processes that were not covered in the course materials. The result of these efforts is not included in this paper.

Other aspects of the lifelong learning skills were assessed through other measurements, e.g. the participation of students in professional and technical societies was assessed by student response on a web-based survey. In addition, the alumni survey, which is administered on a five-year cycle, requests responses about alumni participation in continuing education and in professional societies. Thus, other complementary assessment tools serve to add to the data that are gathered on campus and help portray the broader scope of the performance of our students in this area.

Global and societal context of engineering solutions

The definition of performance indicators for this outcome was less straightforward than for other outcomes. Since our students do not all participate in a formal international studies program, the initial enticement was to utilize some of the humanities and social science courses taken by our students to develop these outcomes. Several shortcomings were immediately identified with this plan including the wide variety of humanities and social science courses taken by our students and the resulting difficulty in maintaining systematic assessment of student performance.

Coincidentally, the results of our earlier outcomes mapping showed weaknesses in the coverage of several outcomes in our curriculum. These factors motivated the development of a junior-level seminar course, Chemical Engineering as a Profession, a new course that provides opportunity for explicit coverage of the soft outcomes and gives ample opportunity for their assessment. Additional details on this course are provided by Briedis and Miller [13].

The performance indicators that were developed for this outcome are outlined as follows.

Understanding of the impact of engineering in a global and societal context

5: Student . . .
- Describes and discusses current trends in the chemical engineering discipline
- Reads and is able to relate the content of periodicals that are relevant to understanding the global and societal impact of engineering
- Has a personal perspective on the importance of engineering in today's world
- Can relate how issues of culture impact technology development abroad (through personal experience in an international setting or through classroom discussions)
- Can analyze historically important engineering failures and their impact on society and engineering solutions of the future
- Combines knowledge of potential impacts into design and problem-solving processes

3: Student . . .
- Is somewhat aware of current events in society
- Is aware of the existence of technical periodicals – would know where to look to find them
- Is interested in engineering because of what the discipline offers him/her personally
- Is familiar with technology abroad, but does not consider the relationships between culture and technology to be different from those in the U.S.
- Can site some important engineering failures, realizes their impact on engineering solutions of the future, but does not have significant insight into their impact on society
- Shows some shallow consideration of the potential impacts in design and problem-solving exercises

1: Student . . .
- Is unaware of current events
- Is not familiar with any technical periodicals
- Isn't sure why he/she is studying engineering
- Isn't aware of cultural consideration in technology development abroad
- Has little or no awareness of significant historical engineering failures and what we have learned from them
- Does not consider potential impacts of design and problem-solving to be constrains on the solution

Fig. 4. Scoring rubric for program outcome.

Performance indicators

In order to be aware of the global and societal impact of engineering solutions, students should:

1. Recognize the impact of chemical engineering decisions on the local and global environment, community, and economy.
2. Combine knowledge of potential impacts into design and problem-solving processes.
3. Be familiar with national and international publications that describe the impact of technology on society.
4. Be familiar with and able to describe the historical development of technology in chemical engineering.
5. Have a personal perspective on the importance of engineering in today's world.

The practices and classroom strategies developed for this outcome included the following possibilities:

- Students will solve practical engineering problems in which they consider the impact of the engineering decision on the local and global environment and economy.
- Students will analyze case studies on the actual environmental, economic, and/or political impact of past engineering decisions.

The rubrics that were developed from these performance indicators are included as Fig. 4. By the same method used for assessment of lifelong learning, grading sheets were developed for the evaluation of student performance for this outcome. In this case, the assessment was done in the junior seminar course where students submitted a written discussion of the role of culture in engineering. Their discussion was based on their own reading and on two guest presentations. One guest speaker from the Michigan State University Department of Anthropology spoke on the role of culture in development of technology. A chemical engineering colleague (Professor Carl T. Lira) spoke on the cultural and scientific context of the Bhopal disaster. The written exercise also served a dual purpose in the evaluation and assessment of student writing. As in the previous example, the assessment results from the student reports were coupled with additional assessment data from student design projects (consideration of environmental and global impacts) and from alumni surveys so as to provide a more complete picture of student achievement for this professional skills outcome.

IMPROVEMENTS AFTER THE LOOP

The outcomes vision process was a valuable approach that provided our faculty with a critical review of our curriculum and led to some program improvements even before the collection of assessment data had begun. In addition, the grading sheets that resulted from this process have proven to be a convenient, consistent way of incorporating assessment into current classroom practices. They have been used extensively and successfully in an NSF-sponsored Multidisciplinary Bioprocessing Laboratory course that has been offered in the Department of Chemical Engineering over the last three years. The purpose of this course is to train students from multiple disciplines to work effectively in research teams [14]. Wherever they have been used, the grading sheets with imbedded assessment rubrics have provided the type of feedback for which they were intended, and have done so at minimal cost. Real changes have been effected in our courses as a result of the program improvement process [13]. The ultimate benefactors have been the students in our program.

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