Rubric Development for Assessment of Undergraduate Research: Evaluating Multidisciplinary Team Projects

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Abstract

At Rowan University, all engineering students participate in clinic courses involving multidisciplinary student teams working on semester-long or year-long research projects led by an engineering professor. The difficulty arises in trying to assess student learning and performance in project-based team settings. Faced with the complexity of trying to assess the attainment of learning outcomes for each individual on a team based on an unclear blend of technical merit, communication, project planning, data analysis, and teaming behaviors, faculty members and students both fall short. It is unreasonable to expect students to achieve specific learning objectives from a series of courses, when the faculty members themselves are unclear about what the learning objectives are and how to measure them

As a first effort to address the assessment of team performance in project-based research experiences, the faculty of the Chemical Engineering Department, as a pilot study, developed four primary areas of importance for assessment. Once these areas were selected, specific indicators were developed for each, so that the students would have clearly defined goals and behaviors that reflect the desired learning outcomes. Faculty assessment of these rubrics indicate that they are very effective in demystifying the evaluation process and serve to better connect the grade in the course to the stated learning objectives.

Introduction

Experts agree on the importance of involving undergraduates in research-based learning [1-3] and teamwork [4-6]. The Boyer Commission suggested that research-based learning should become the standard for undergraduate education [7]. Many universities are responding to this challenge by introducing multidisciplinary laboratory or design courses [8,9]. At Rowan University, we have developed a method of addressing these diverse challenges, while also implementing valuable pedagogical hands-on learning experiences [10,11] and technical communications [12-14]. At Rowan University, all engineering students participate in an eight-semester course sequence known as the engineering clinics [15]. In the Junior and Senior years, these clinic courses involve multidisciplinary student teams working on semester-long or year-long research projects led by an engineering professor. Most of these projects have been sponsored by regional industries. Student teams under the supervision of chemical engineering faculty have worked on emerging topics including enhancing the compressive properties of Kevlar, examining the performance of polymer fiber-wrapped concrete systems, advanced vegetable processing technology, metals purification, combustion, membrane separation processes and many other areas of interest. Every engineering student participates in these projects and benefits from hands-on learning, exposure to emerging technologies, industrial contact, teamwork experience and technical communications.

The difficulty arises in trying to assess student learning and performance in project-based team settings. Angelo and Cross [16] provide significant suggestions for assessing the attitude of students toward group work, but provide little insight into distinguishing individual and team performances. One difficulty is that evaluating the semester long performance of teams working on projects involves a substantial number of variables. Clearly, the successful completion of the technical aspects of the project is an essential component of the demonstration of understanding by the students. However, Seat and Lord [17] observed that while industry seldom complains about the technical skills of engineering graduates, industrial employers and educators are concerned with performance skills (i.e., interpersonal, communication, and teaming). Lewis *et al.* [18] correctly observed that if students are to develop effective teaming skills, then teaming must be an explicit focus of the project.

It is unreasonable to expect students to achieve specific learning objectives from a series of courses when the faculty members themselves are unclear about what the learning objectives are and how to measure them. Young *et al*. [19] discussed the development of a criterion-based grading system to clarify expectations to students and to reduce inter-rater variability in grading, based on the ideas developed by Walvoord and Anderson [20]. This effort represents a significant step forward in course assessment; however, for graded assignments to capture the programmatic objectives, a daunting set of conditions would have to be met. Specifically,

- proper course objectives that arise exclusively from the educational objectives and fully encompass all of these objectives must be set
- tests and other graded assignments must completely capture these objectives
- student performance on exams or assignments must be a direct reflection of their abilities and not be influenced by test anxiety, poor test taking skills, etc.

There should be a direct correlation between student performance in courses and the overall learning of the students only if all of these conditions are met every time. Moreover, much of the pedagogical research warns of the numerous pitfalls associated with using evaluative instruments (grades on exams, papers etc.) within courses as the primary basis for program assessment [21].

Obviously, a more comprehensive assessment method for a team-oriented, research project-based must be developed. Woods [22] listed five fundamental principles for assessment of teams:

1. Assessment is based on performance
2. Assessment is a judgment based on evidence rather than feelings

3. Assessment must have a purpose and have clearly defined performance goals
4. Assessment is done in the context of published goals and measurable criteria
5. Assessment should be based on multidimensional evidence

The Chemical Engineering department proposes the following strategy for improved assessment of student team projects: decide on the desired learning outcomes for the clinic, develop indicators that demonstrate whether the teams (and each member of the team) has achieved each of these outcomes, develop rubrics to evaluate student performance in each of these areas, and present all of this information to the students at the start of the project.

Pilot Program

In the junior/senior engineering clinic, each student team submits a final written report and gives an oral presentation allowing the communications aspects of the project to be evaluated directly. However, the remaining elements of a successful project experience had to be identified and measured. As a first effort to address the assessment of team performance in project-based research experiences, the faculty of the Chemical Engineering Department developed this list of four areas of primary importance:

- Technical Performance
- Project Planning and Logistics
- Teaming
- Laboratory Operation

Once these areas were selected, specific indicators were developed for each, so that the students would have clearly defined goals and behaviors. Table 1 summarizes these indicators.

With the specific indicators determined, the next step involved developing descriptive phrases that would assist both the students and faculty members in evaluating student performance. It became clear that specific descriptions of the level of performance in each area would be required. The goal of our rubrics was to map student work directly to the individual learning outcomes. As Banta [23] stated, "The challenge for assessment specialists, faculty, and administrators is not collecting data but connecting them." The assessment rubric also followed the format developed by Olds and Miller [24] for evaluating Unit Operations Laboratory reports at the Colorado School of Mines. The descriptive phrases are summarized in Table 2.

Area of Importance	**Specific Indicators**
Technical	Defined Objectives
	Demonstrated Technical Awareness
	Obtained and Interpreted Appropriate Results
	Formulated Supportable Conclusions
	Properly Considered Error
	Provided Recommendations for Future Work
Logistical	Organized Project
	Met Deadlines
	Executed Project Plan
	Kept Detailed Records

Laboratory Operation	Maintained Safe Practices
	Developed Hazardous Operations (HAZOP) Report
	Dressed Appropriately
	Proper Use/Maintenance of Equipment
	Performed end-of-semester Shut Down
Teaming	Division of Labor
	Professional Conduct
	Learning Experiences for All Team Members

Table 1. Summary of Specific Indicators for Areas of Importance

The decision to frame the rubrics as distinguishing the "A team," "B team" and "C or lower team" was a significant one that requires explanation. At one time, many of the other program assessment instruments used by the Chemical Engineering Department at Rowan University used a 5-point Likert scale with qualitative labels (5 = excellent, 4 = very good, 3 = good, 2 = marginal, 1 = poor), but the qualitative nature of the descriptive labels led to confusion in scoring. Some professors have different distinctions between excellent and very good and tended to use these distinctions more than the descriptive phrases that define the difference between levels for each indicator. More importantly, if the rubrics are well designed, the descriptive phrases should stand alone, without the need for subjective clarifiers like "excellent" and "good." Ultimately, it was decided to eliminate such descriptors and divide rubric elements by listing behaviors that demonstrated the level (1, 2, or 3) to which the student had obtained the desired learning outcomes. [25]

However, these previously developed rubrics were programmatic assessment tools that were seen and used only by the faculty. Part of the purpose of this pilot program was to clarify for the students the expectations in junior/senior clinic by providing specific information about their learning goals. Students tend to be more focused on grades than learning outcomes, so characterizations like "level 1 vs. level 2" would be meaningless to them, and subjective phrases like "excellent" and "good" would be subject to the same shortcomings described above. Further, if grading truly represents the measure of achievement of learning outcomes, then it is not unreasonable to present the behaviors that demonstrate successful attainment of a learning outcome in terms of grades. Consequently, the rubrics were written to be presented to the students in terms of behaviors that an A-Team would demonstrate, a B-team would demonstrate, etc. Space limitations prohibit the inclusion of all rubrics, but Table 2 provides a sample rubric.

Indicator	An "A" team	A "B" team	A "C" or lower team
Organized Project	Effectively organizes project tasks to minimize wasted time and effort	Identifies relevant tasks but may struggle with setting priorities and planning	Has difficulty converting broad objectives to specific tasks

Met Deadlines	Consistently meets deadlines	Misses some deadlines despite reasonable effort	Routinely ignores deadlines
Executed Project Plan	Effectively and safely executes the project plan. Makes significant progress. Modifies the plan as necessary	Executes the project plan but has difficulty overcoming setbacks	Works haphazardly with little chance of achieving project objectives
Kept Detailed Records	Keeps detailed records easily followed by others. These records include a laboratory notebook, computer files, purchase records and others	Keeps a lab notebook but records lack organization or contain omissions	Keeps poor, sketchy or no records

Table 2. Behaviors Corresponding to Project Planning and Logistics

Results and Discussion

The rubrics have two uses, each of which was piloted within the Chemical Engineering department during the 2002-03 academic year. The first is that it will facilitate grading that is more uniform, fair and clearly understood by the students. Faculty distributed the tables to the students at the beginning of the semester, refer to them throughout the semester in giving feedback on how the students are doing, and use them to aid in assigning and justifying a final grade.

The second use of the rubrics is assessment of the junior/senior clinic program as a whole. As mentioned above, simply using course grades as a primary assessment tool (even when the grades are fair and based on well-constructed criteria) has pitfalls. In junior/senior clinic, for example, a danger is that students will perform well overall but have widespread deficiencies in one or two areas. In such as case, the fact that most teams earned A's and B's for the semester would imply that students in junior/senior clinic are meeting the desired learning outcomes, when in reality there is a need for specific improvements. As part of the pilot assessment program, faculty went through the 18 indicators, one by one, and examined the level of performance demonstrated by each team with respect to each indicator. Through this process, specific problem areas were uncovered even when the overall student performance is objectively very good.

Faculty members were asked to assess the effectiveness of the rubrics. Table 3 indicates that the faculty clearly felt that the rubrics were useful in improving fairness and linking the grading to the learning objective.

Statement	Mean Response (4 = strongly agree; 1 = strongly disagree)
The grading rubrics helped me explain the expectations of my project	3.80
The grading rubrics helped me determine how my team would be graded	3.70
The grading rubrics helped me consider project issues that I otherwise might not have	3.30
I referred to the grading rubrics during the semester	3.40
I think that clinic is more fair using grading rubrics	3.70
I would like to use the rubrics again next semester	3.80

Table 3. Faculty Assessment of Grading Rubrics

Future Work

Although the development of the above rubrics represents a significant step forward, substantial work remains to be addressed. Meaningful assessment instruments must be developed to gauge student and faculty perceptions of these criteria. Are the critical learning objectives addressed in these rubrics and are the measurements accurate? Appropriate and meaningful weightings must be developed for each of the behaviors. While appropriate dress has been listed as an important part of the project, one would be unlikely to argue that it is as significant of a learning objective as "drew meaningful and supportable conclusions."

Once the rubrics have been optimized, the next major task to be addressed is differentiating the performance of individuals from the performance of the team. It is possible that a team could have one or more member who fully attains the desired learning outcomes, but whose teammates fall substantially short of achieving these outcomes. Currently, the Chemical Engineering Department at Rowan University uses a peer-assessment technique modeled after the process described by Felder [26].

Although this is a useful tool, it is somewhat over-reliant on student evaluation of their peers. Our experience indicates that reasonably successful teams generally recommend an equal distribution of points, while the recommendation of less successful teams often are clouded with personal issues and resentments. Because students tend to focus on grade rather than on learning outcomes, their responses tend to be holistic (person X should get 50% of the points) and more about evaluation and grading and less about achieving specified learning outcomes.

A major thrust of this effort is to develop evidence-based tools to complement the Felder survey, such that students could more meaningfully assess the performance of their teammates without defaulting to meaningless (everyone contributed equally), hierarchal (person X was terrible, but no reasons provided), or personal assessments. Moreover, the students will be required to cite specific evidence linking their evaluations to the specific desired learning outcomes. Ideally, in addition to aiding the faculty member in attempting to discern individual achievement from a group experience, forcing an evidence-based approach may help the students recognize the importance of the learning outcomes.

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