In each of these profiles, faculty developed their own authentic assessment measures and gathered meaningful information about student learning. The assessment results provided key insights regarding how well students were mastering the program-level learning outcomes.

Institutions

Doctoral and Research
Public
University of Akron; Akron, Ohio (25,000 students)
Miami University; Oxford, Ohio (14,000 students)

Master's
Private
Alverno College; Milwaukee, Wisconsin (2,600 students)

Baccalaureate
Private
Moravian College and Theological Seminary; Bethlehem, Pennsylvania (1,500 students)

Assessing Scientific Research Skills of Physics Majors

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Look for a faculty approach to developing explicit, clear learning outcomes for undergraduate physics majors and to assessing student learning using a common rubric.

Background and Purpose(s) of Assessment

In the spring of 2004, the physics department chair agreed to participate with other science department chairs and Assessment Office staff in a project to identify overarching student learning outcomes for science majors and to assess those outcomes. The science chairs met regularly for two semesters to determine expected outcomes and assessment methods.

Assessment Method(s) and Year(s) of Implementation

One of the most important skills identified for science majors was the ability to carry out an experimental research project. This ability was broken down into seven skills or traits, and a rubric was developed that described four levels of performance on each of these traits. The traits were:

- Identifies and summarizes the problem or question to be investigated
- Identifies existing, relevant knowledge and views
- Uses appropriate equipment and experiments to collect data
- Analyzes data in an appropriate manner
- Draws sound inferences and conclusions from data
- Reflects on own work to assure that conclusions are justified
- Suggests appropriate steps for further inquiry

The physics department offers a research capstone course at least once per year. Students plan and carry out a research project and write a final paper describing their project and its results. All the participating students and their faculty mentors meet biweekly to discuss progress and problems. For three consecutive offerings of the capstone (spring 2005, spring 2006, and summer 2006), faculty mentors used the rubric to assess the final papers. Each faculty member rated each paper. The scale on the rubric went from 1 (inadequate) to 4 (substantially developed). The rubric is available at the Web site given below. A score of 4 sets a high standard for an undergraduate and is in fact what one might expect of a typical master's level graduate student. In early fall 2006, the results were compiled and analyzed.

Required Resources

No monetary resources were required. Increased faculty time was devoted to examining the papers of the capstone students, as previously each faculty member had only graded the papers of his or her own students.

Findings

Table 6.1 shows the means on the seven criteria as well as the percentage of papers that were rated either "moderately developed" (rating of 3) or "substantially developed" (rating of 4).

The faculty felt that these results were quite good and indicated that on the whole our majors were prepared for the research work they would carry out in

TABLE 6.1. RESULTS FROM THE ASSESSMENT

Criteria	Mean Rating	Ratings of 3 or 4 (%)
Problem statement	3.3	88
Existing knowledge	3.1	84
Equipment and experiments	3.6	98
Data analysis	3.4	95
Inferences and conclusions	3.4	97
Reflects on own work	3.1	77
Further inquiry	3.1	76

graduate school. However, there were some individual scores that were much lower than desired. The most problematic areas were reflecting on one's work and suggesting steps for further inquiry.

Use of Findings

The department faculty identified PHY 293, Contemporary Physics Lab, a course required of all physics majors, as the appropriate place to begin trying to help students develop these skills in a more organized way. During spring 2006, the two faculty members who usually teach this course planned revisions to specifically address the experimental inquiry skills. New pre-lab questions on existing knowledge were used for all experiments and three experiments were modified to include post-lab extended discussion sessions that focused on data analysis and drawing conclusions from data, as well as reflections on the experiments. The revised course was taught for the first time during fall 2006. The assessment rubric for experimental science was utilized to score student lab reports from the earliest lab and then compared to a lab write-up from the end of the semester. At the outset, students generally scored from "inadequate" to "minimally developed" on the seven criteria; later in the course they scored from "inadequate" through "minimally to moderately developed."

As with the seniors, the areas of most concern in the assessment of students enrolled in PHY 293 were the last two rubric items about reflecting on their work and considering further steps. Students simply did not provide this information. In the fall of 2007, we changed the requirements for the lab report to include more questions that lead students to consider their work more critically, and we provided more class time for discussion and reflection. This time we assessed a total of four experiments throughout the semester rather than just two. In this second round of revision, the rubric was changed to reflect the level of work required in the class in one of the areas ("uses appropriate instruments and

experimental procedure"). Because this course provides the instruments and the procedure, we changed that rubric element to "Student conveys understanding of how instruments work and in what form data are provided by the experiment."

Physics students begin to learn experimental skills in PHY 183, Physics Laboratory, so modifications were also made to the rubric to adapt it for this course and an assessment was carried out. The rubric was modified to reflect the tasks and level of understanding expected of students in this course. The traits were rearranged and grouped under the same headings found in the formal laboratory reports: Introduction, Apparatus and Procedure, and Results and Discussion. Some of the traits that would not be expected of student reports at the first-year level were eliminated from the rubric.

Students in PHY 183 write three formal lab reports; the second and third reports from fall 2006 were analyzed with the modified rubric. Students often have trouble with the first report, which in many cases is the first lab report they have ever written. Even after the extensive modifications to the rubric to make it appropriate to the expectations of this course, students performed poorly, often scoring at the lowest level on the last three traits ("draws sound inferences and conclusions," "reflects on own work," and "suggests further inquiry"). Further, students did not notably improve their scores on the rubric between the second and third reports.

Impact of Using the Findings

The first students to take the revised PHY 293 course have not yet taken their research capstone, so we do not yet have data to show the impact of the changes. However, input we have received via exit surveys of the PHY 293 students suggests that we should reduce the number of experiments the students conduct, while increasing the discussions about data analysis and drawing conclusions. In fall 2008, the course will be radically modified to make this possible with three focus areas of experiments, discussions with each experiment, and fewer lab reports so that students may use their time for more in-depth analysis of each of the three required reports.

In PHY 183 the instructions the students receive about how to write the lab report have been changed to reflect the student learning outcomes that are embodied in the rubric. We have improved the training of the teaching assistants who deliver the course. The teaching assistants now better understand the importance of encouraging students to find answers for themselves as they are doing the activities; rather than always answering students' direct questions, teaching assistants now have the skills to lead the students to the answers by

asking questions of their own. In addition, we realized that the PHY 183 lab manual itself needed to be changed in order to give students the chance to do more critical thinking. As the course stood in the fall of 2006, students had few opportunities to make choices and were not asked enough questions to prompt deep reflection. Some improvements have already been made, and more are coming. The plan is to have each lab activity require a bit more from the students than the one before.

Success Factors

The physics department at Miami is strongly committed to students and their scientific education. As a result, faculty members were willing to participate in the assessment process despite the fact that it required an additional time commitment on their part. Also, members of the department were eager to act on the results of the assessment in order to improve student learning. The project would probably not have taken place without the initial invitation from the Assessment Office.

Relevant Institutional Web Sites Pertaining to This Assessment Practice

Scientific Inquiry Rubric:

www.units.muohio.edu/led/Assessment/Assessment_Basics/Sample_Rubrics/Scientific_Inquiry.pdf

Department of Physics:

www.cas.muohio.edu/physicsweb

E-Portfolios and Student Research in the Assessment of a Proficiency-Based Major

Steven C. Myers, Michael A. Nelson, Richard W. Stratton, The University of Akron

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Look for economics faculty assessing student learning using portfolios and rubrics to determine student achievement of key program-level learning outcomes.