GE Standard V: Scientific Standard

Courses seeking to meet the Scientific Standard must:

(i) Require students to engage in particular activities, and
(ii) Use direct assessment to demonstrate improvement of student skills in particular areas

To meet the Standard, courses must address *each* of the first three areas below (Areas 1, 2, and 3), and must address *one of* the last two areas (either Area 4 or Area 5). Direct assessment must be used in *each* of the four areas chosen.

The specific requirements for addressing and assessing each Area follow, and are listed under the Area headings themselves. One page is devoted to each of the five Areas.

Physics 161: Physics I

Area 1: Understanding Science as a Process

Briefly describe contexts in which your course will require students to do one or more of the things listed in the following bullet point:

- Recognize how areas of research are identified, how research problems are defined, and how research programs are designed to test hypotheses.

1. A class contest is held around the sixth week of the semester (after Unit 4), in which the optimal angle in a particular experimental set-up must be predicted. Students make various hypotheses while performing their analyses, and then test these by competing in the contest.
2. In studying Newton's Universal Law of Gravitation, students are asked to explain the implications for objects orbiting the Milky Way galaxy. When presented with data regarding such objects, students are asked to interpret the implications and thereby "discover" the idea of Dark Matter (built into Unit 9). Students are asked to determine how various dark matter distribution models might be tested.
3. During the tenth and eleventh weeks of the semester, students are presented with hypotheses regarding the conservation of various physical quantities. They are then required to design experiments capable of testing these hypotheses (laboratory activities within Unit 7).

Your course is asked to demonstrate improvement in one or more of the following student skills:

- The ability to describe key features that distinguish the scientific process from non-scientific ones
- The ability to describe the process by which science is used to answer questions
- The understanding that science relies upon observations of the physical universe, and that all scientific ideas are provisional
- The ability to distinguish questions that may be addressed scientifically from those that cannot be so addressed

Describe what direct assessments you will use in order to demonstrate improvement of such skills among your students.

Bullet 2: Students are given pretest (day 1) and post-test (end of term) questions involving scientific scenarios and are asked "What could be done next?" in order to test a particular hypothesis. Overall class performance (pre/post/gain) on these questions is reported.

Bullet 2: Student "Methodology" sub-scores are reported for three different scientific papers that students write on four laboratory experiments that they perform throughout the term (Week 2, Weeks 7/8, and Week 14). Percentage of students improving Week 2 to Week 14 is reported. Average class score on Methodology subsection is reported for each week.

Bullet 3: Students are asked to predict the sizes of errors induced by using classical mechanics in various scenarios. This is done using questions on pretest (day 1), and using analogous questions appearing throughout the term on Quizzes (Week 3 – Week 14). Pretest and Quiz average scores are compared and reported. Percentage of students improving is reported.

Bullets 2&3: In the context of a laboratory on motion, students are asked to determine whether there is any evidence for the presence of air resistance. Students take experimental data, and use this data along with the associated uncertainties to make their cases. A similar question is included on the Final Exam. Average class score is reported, as is percentage of students improving.

Area 2: Scientific Knowledge

Briefly describe contexts in which your course will require students to do one or more of the things listed in the following bullet point:

- Explore and discuss major concepts, theories, historical milestones, and contemporary methods in at least one scientific discipline.

Physics 161 is a course devoted to the study of classical mechanics (Newtonian mechanics). Nearly every homework problem, laboratory exercise, quiz question, and exam question in the course requires students to explore and utilize Newtonian Mechanics. A substantial understanding of Newtonian Mechanics is required to pass the course, and near mastery is required to earn an "A" in the course.

Your course is asked to demonstrate improvement in one or more of the following student skills:

- The understanding of major contemporary concepts in at least one scientific discipline
- The ability to describe key theories in at least one scientific discipline
- The ability to describe critical steps in the historical development of contemporary concepts or theories in at least one scientific discipline
- The ability to describe specific methods by which scientists in a particular scientific discipline collect empirical data

Describe what direct assessments you will use in order to demonstrate improvement of such skills among your students.

Bullet 1: The course is divided into 12 Units, each of which has associated Quizzes. Initial Quiz grade and final Quiz average are reported for each student for each Unit. Percentage of students improving (by Unit) is reported. Average % improvement is reported (by Unit).
Bullet 1: Initial Quiz grade vs. associated Final Exam pull-out questions sub-grade is reported for each Unit. Percentage of students improving (by Unit is reported). Average % improvement is reported (by Unit).
Bullet 1: Subset of FCI pre-test questions is included on Final Exam. Pre/Post/Gain reported for each question.

Area 3: Communicating Scientific Ideas

Briefly describe contexts in which your course will require students to do the following:

- Effectively communicate the results of scientific investigations in a format appropriate to the task.

> Every formal laboratory report requires this, as do several of the less formal laboratory activities.

Your course is asked to demonstrate improvement in one or more of the following student skills:

- The ability to effectively communicate scientific ideas
- The ability to defend and/or criticize conclusions drawn from scientific data by using the data itself
- The ability to communicate the assumptions, approximations, uncertainties, and limits of applicability inherent in a given scientific analysis

Describe what direct assessments you will use in order to demonstrate improvement of such skills among your students.

> Bullet 1: Students submit Unknown Element (Week 4), Conservation Law (Weeks 7/8), and Moment of Inertia (Week 14) reports. Overall scientific report scores are recorded using common rubric (shared with students). Percentage of students improving reported. Average improvement percentage reported.
> Bullets 2 & 3: Day 1 pre-test includes a "Does this data support this conclusion?" question. On quizzes (Weeks 3-14), similar questions appear (typically including experimental uncertainties) and similar questions are asked. Pre-test scores vs. quiz average scores reported vs. time. Average improvement % pre-test to Week 14 reported.
> Bullets 2 & 3: Appropriateness of uncertainties/conclusions sub-scores reported for the three reports mentioned above.

Area 4: Participation in the Scientific Process

Briefly describe contexts in which your course will require students to do one or more of the things listed in the following bullet point:

- Collect scientific data using appropriate tools and techniques, analyze and evaluate scientific data, and use scientific data to formulate and/or test scientific hypotheses.

Every laboratory activity requires this.

Your course is asked to demonstrate improvement in one or more of the following student skills:

- The ability to collect, analyze, or evaluate scientific data
- The understanding of the sources of uncertainty in empirical data, and the ability to estimate the sizes of such uncertainties
- The ability to formulate hypotheses based upon observational data
- The ability to determine ways by which scientific hypotheses might appropriately be tested

Describe what direct assessments you will use in order to demonstrate improvement of such skills among your students.

Bullets 1 & 2: Eight laboratory activities, spaced throughout the term, have data collection sub-scores, in which the quality of student data and uncertainties is assessed. Course average score by activity is reported.

Area 5: Science and Society

Briefly describe contexts in which your course will require students to do the following:

- Explore and discuss the impacts, potential or realized, of scientific research on society

Your course is asked to demonstrate improvement in one or more of the following student skills:

- The ability to identify societal problems for which the application of science could be beneficial, and the ability to discuss cogently ways in which science could be of benefit in such cases
- The ability to evaluate scientific information relevant to contemporary issues, the ability to identify the sources of such information, and the ability to assess the credibility of such information
- The ability to describe how scientific inquiry can contribute in meaningful ways to political, social, economic, or ethical discussions
- The ability to use scientific reasoning to make informed, data-driven decisions on contemporary issues that require scientific literacy

Describe what direct assessments you will use in order to demonstrate improvement of such skills among your students.