THE EVOLUTION OF CURRICULUM ASSESSMENT WITHIN THE PHYSICS PROGRAM AT AMERICAN UNIVERSITY

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Abstract

Whether a physics department is situated within an engineering program or within a liberal arts program, assessment can play an important part of overall program development and curricular enhancement. Regardless of the accrediting agency, assessment is of critical importance at the institutional level as well. At the 2007 ASEE conference in Honolulu, we reported on a complete redesign of the curriculum for the physics major at American University. Since our earlier report we have continued with annual assessments, focusing each year on one or two of the courses within our overall program. These annual assessments have allowed us to pinpoint the strengths and weaknesses of our redesigned curriculum, and have led to additional curricular revisions and changes. In this paper, we report on these curricular revisions and changes, with an emphasis on our efforts from 2007 forward. With a focus on the learning outcomes for our program, we will share how we have used an assessment-based framework to support our curricular revisions. In addition, we will discuss the goals and objectives we have created to help us achieve the intended learning outcomes. As appropriate, specific examples of our assessment plan, featuring strategies and tools used for individual physics courses will be shared. With each example a discussion of how our plan provides us with critical and timely information about *what*, and *how*, our physics students are learning will be presented. While assessment is often not viewed as a favorite item on the "to do" list of any faculty member or administrator, we have found enormous value in the continued attention we place on our annual assessment efforts. We hope that by sharing the evolution of our curricular efforts, others will find useful ideas and strategies that could be adapted to an existing assessment plan; or, that could be used to help build the foundation for a new one. The overarching goal of this paper is to share successful techniques that we've used to assess student learning. We hope these techniques will be useful for others as well.

I. Introduction

In our 2007 paper[1] we reported on an assessment study we had conducted that resulted in a significant change and reorientation with the curriculum and subsequent course progression of our physics program. At that time, our physics program was integrated with a single department along with two other disciplines in the department of Computer Science, Audio Technology, and Physics (CAP). Shortly after our study was conducted, each of these programs separated and 3 independent departments were created.

As part of our study, we looked at comparative data from 22 national undergraduate programs focusing on those that were in universities without graduate programs in physics as well as those in liberal arts colleges. The results of our study indicated to us that the number of required courses our physics majors were taking was lower than those of our comparison group. In addition, we learned that the number of credits required of our majors for graduation was substantially lower than many in our comparison group. Oftentimes our students would find the need to take a physics course at another local institution to satisfy their personal academic goals. As a result of our efforts we were able to make significant modifications in our program and extend the number of course offerings to help us create a more robust and well-rounded program for our students.

One of the outcomes of our assessment was an increase in the number of courses offered as well as an increase in the frequency in which we can offer them. As a result of our assessment efforts we have been able to expand our physics program by adding the following upper-level courses:

- Astrophysics
- Mathematical and Computational Physics
- Physics Capstone Seminar
- Statistical Mechanics
- Waves and Optics

Prior to 2007, the physics program included two "tracks" that students could follow as they progressed through the curriculum. These tracks were in computational and applied physics. Since our initial assessment, we've added a traditional physics track and the applied physics track is now a track in chemical physics. We have also been able to increase the number of credit hours required for the major from 51-53 (depending on track) to 63. This increase puts our department in-line with those of comparable institutions as well as to those of our science cohorts at American University.

To support the increase in the number of courses in our core physics curriculum, we were able to add one tenure-line position to our faculty. In fall 2011, we brought in an experimental physicist and with that have come a major overhaul of our experimental physics course. One facet of our department's assessment plan (not to be covered in this paper) was our experimental physics course. Through our ongoing assessment efforts we were able to identify the many weaknesses that existed within this course. The hiring of an experimental physicist was one outcome of these efforts. The addition of the experimental physics position has increased the number of tenure-line faculty in the department to 5 (1 full professor, 3 associate professors, and 1 assistant professor). We also have two full-time faculty members in term positions as well as a full-time director of our physics labs.

One of the fundamental purposes for engaging in our original study was that we had been seeing a decline in our enrollments (e.g. we had just one physics major graduate in the 2001 – 2002 academic year, three in the 2002 – 2003 academic year, and two in the 2003 - 2004 academic year). As a result of the changes made in our program since 2007, we have seen a steady rise in our enrollments. At present, we have approximately 25 undergraduate physics majors in our program with a comparable number of physics and applied physics minors. We presently graduate approximately 5 – 8 students each year.

The focus of the remainder of this paper will be to provide an overview of our department's current assessment plan. We'll begin with a basic discussion of the "language of assessment" and then move on to provide a look at the key components of the assessment plan for our overall physics program. Once these components have been identified, we'll provide two examples of how we have developed assessment strategies at the course level. For our two examples, we've chosen one introductory-level, General Education physics course (Physics 100, Physics for the

Modern World) as well as one upper-level physics course (Physics 331, Modern Physics). Included within these examples is a presentation of some conceptual assessments that are available within the disciplines of physics and astronomy. Our thought is that a department looking to start or enhance their assessment efforts might find this presentation useful. Finally, we will include a discussion of how we make use of the assessment results we've obtained, and how these results help us frame the next assessment cycle.

II. The "Language" of Assessment

As we well know, at the institutional level, assessment is an often-dreaded word for many of us. Institutions are responsible for providing assessment data, results, etc. to whatever assessment agency or body is applicable. As faculty member, it is easy to sometimes think of assessment as "something we have to do for accreditation purposes." While this is certainly a true statement, assessment should be much more than that. It has been our experience that, if framed properly, a departmental assessment plan can serve a multitude of purposes. The primary purpose of any assessment plan should be the ***assessment of student learning***. As part of this plan we need to ask: *Are our students learning what we intend for them to learn; and, what evidence do we have to document that this learning has actually taken (or is taking) place?* While on the surface of things this might seem like a relatively easy question to answer. In practice, however, providing evidence of student learning takes careful thought and planning in order to create a plan that does more than just satisfy the institution's need for some data for their report to an accrediting body. Assessment need not be a thorn in our sides!

Before presenting an overview of our assessment plan, we thought it wise to provide a brief discussion of some of the commonly used terms related to assessment. As you look at the tables provided in the sections that follow, you might be wondering what the difference between a **learning goal**, a **learning objective**, and a **learning outcome** is. Goals and objectives are very similar to one another. They essentially describe the intended scope and expected results of a teaching activity, course, or program. **Goals** express intended outcomes in *general* terms and **objectives** express them in *specific* terms[2]. A **learning outcome** refers to a statement that describes what the learner is to have achieved and can reasonably and reliably demonstrate by the end of a teaching activity, course, or program.

Measures to assess student learning typically fall into one of two categories: *direct* or *indirect*. A **direct measure** is one that "directly" evaluates student learning[3]. Direct measures include the use of actual student work and include items such as an

- exam or quiz,
- class assignment, project, report, etc.
- work-related task,
- interaction with a client (perhaps as part of an independent study or cooperative learning experience), or
- musical or other performance.

It is not sufficient to simply use grades alone as a measure of student learning. Instead what is needed is a set of criteria used in the assessment, a clearly-framed analysis and discussion of results, and a feedback loop that can be linked to a specific department's program, general education, and/or the decision-making process at the institutional level. Simply reporting that X% of your students got A's, Y% got B's, etc. is not a sufficient direct measure of student learning.

An **indirect measure** of student learning is based on a report of perceived student learning[4]. Indirect measures can also provide information regarding how what a student has learned is valued by a specific stakeholder or set of stakeholders. For example, this information might come in the form of a report from a supervisor on an independent study project, a cooperative learning, or other work experience. Indirect measures provide additional information but are not as strong as direct measures in terms of truly capturing what a student has learned. In addition, indirect measures often involve an interpretation of an evaluation by a supervisor or an assumption regarding just what the evaluation represents.

In developing our own assessment plan we found it useful to make use of a number of resources. In the next sub-section we offer a brief look at some resources we've found to be especially useful.

Brief Overview of Helpful Assessment Resources

At the program level, we've found that keeping things straightforward and simple is the best plan of attack. One doesn't need to have 25 learning outcomes! Instead, we recommend beginning with about 4 – 6 learning outcomes. Walvoord's guide to assessment[4] has been a particularly useful tool as we initially framed our assessment plan. In addition, Astin's book provided us with a very straightforward way of looking at assessment within higher education. At the course level, Astin's work is also very thought-provoking. Astin[5] argues that "A professor may give what he or she believes to be a stimulating and provocative lecture and yet never really know how much of it was understood by the students, how much of it will be retained, or what other effects it may have had on the students" (p. 129). Astin further argues that while examinations provide faculty members with feedback, "acting on the basis of such feedback is a little like closing the barn door after the horse has escaped" (p. 130). If one wants to know what a learner is thinking, one needs to ask them! The caveat here is that in asking students what they are thinking, one needs to be prepared to deal with their responses.

Astin's work really brought to the forefront for us the fact that assessment should include both a formative and a summative component. Perhaps one of the best resources for crafting formative assessments is a book by Cross and Angelo[6] dealing with classroom assessment techniques (CATs). This book is a treasured resource in our department! In it, Cross and Angelo describe "… an approach designed to help teachers find out what the students are learning in the classroom and how well they are learning it" (p. 4). Carefully crafted CATs can serve as a "snapshot" of where students are in terms of their learning at a particular point in time. When coupled with more traditional assessment measures a more complete picture of student learning can be achieved.

As we've worked to develop some effective measures to assess student learning, we have found it useful to make use of some of the existing concept inventories that are available at the national level. These inventories are a result of the efforts of a number of individuals conducting research in the area of physics education. In the next sub-section we offer an alphabetized list of the inventories we are aware of. A good number of these inventories can be found in Redish's wonderful book, *Teaching Physics with the Physics Suite*[7]. This book is a must-have for any physics department.

Overview of Available Concept Inventories

The following is a relatively comprehensive list of some of the concept inventories available to help uncover what students are learning in our physics classes. When used as part of a comprehensive assessment plan, these inventories can provide useful information into what students are learning in our courses.

- Conceptual Survey of Electricity and Magnetism[8] (CSEM)
- Determining and Interpreting Resistive Electric Circuits Concepts Test[9] (DIRECT)
- Electric Circuits Concept Evaluation[10] (ECCE)
- Energy Concepts Survey[11] (ECS)
- Epistemological Beliefs Assessment for Physics Science[12] (EBAPS)
- Force and Motion Conceptual Evaluation[13] (FMCE)
- Force Concept Inventory[14] (FCI)
- Heat and Temperature Concept Evaluation[15] (HTCE)
- Introductory Astronomy Survey[16] (v 2.0)
- Mathematical Modeling Conceptual Evaluation[17] (MMCE)
- Mechanics Baseline Test[18] (MBT)
- Measurement Uncertainty Quiz[19] (MUQ)
- Physics Measurement Questionnaire[20] (PMQ)
- Quantum Physics Conceptual Survey[21] (QPCS)
- Student Expectations in University Physics: *The Maryland Physics Expectations Survey*[22] (MPEX)
- Test of Understanding Graphs – Kinematics[23] (TUG-K)
- The Vector Evaluation Test[24] (VET)
- Thermal Concept Evaluation[25]
- Tools for Scientific Thinking: Mathematical Modeling Conceptual Evaluation[26] (MMCE)
- Tools for Scientific Thinking: Vector Evaluation[27]
- Views about Science Survey[28] (VASS)
- Wave Diagnostic Test[29] (WDT)

To date, we've made use of a number of these inventories as part of our overall assessment plan. How we've made use of these inventories will be evident in the assessment plan we highlight in the following section. We intend to utilize other inventories as they relate to our curriculum throughout other facets of our assessment cycle. To be as complete and thorough as possible, and to provide our readers with the most useful information, the above represents the most comprehensive list we've collected. We also note that reference to these and other assessments are listed on a number of other websites. The Physics Education group at North Carolina State University, for example, has a very comprehensive list of concept inventories and assessment tools[30].

III. An Overview of the Assessment Plan

The Physics Department at American University was one of the first departments on our campus to develop a comprehensive assessment plan. Our assessment plan is a "living document," and is one that is revised and changed according to the data and results that we collect. Our ultimate goal is the improvement of student learning in physics.

As we began the process of establishing an assessment plan, we asked ourselves the following question … *What do we want a graduate with a major in physics to look like and to be able to do after completing 4 years of study at our institution?* To help us answer this question, we developed a set of learning outcomes for the physics major. These learning outcomes are presented in Table I.

Table I.
Department Learning Outcomes

Upon completion of the BS in Physics, students will be able to:	
A	demonstrate their understanding of the foundations in physics.
B	competently solve appropriate problems in upper level physics courses.
C	demonstrate competency in experimental design and scientific data collection and analysis.
D	demonstrate competency in their understanding of scientific information, both orally and in writing.
E	integrate competently the knowledge and skills acquired in the major and have adequate preparation to succeed in post-undergraduate studies or a professional career.

Once we had established our learning outcomes for the major, we began work on developing a plan for assessment of these learning outcomes. Table II provides a summary of our assessment plan including our assessment measures, intended targets, the learning outcomes to be assessed by the respective measures along with our proposed assessment cycle.

Table II.
The Assessment Plan

Measures	Target	Learning Outcomes	Cycle
1. Samples of student work in 300-level and above courses (Direct)	Scores on faculty-developed rubrics	A, B, C, D, E	• Data collected each semester a given course is offered • Data reviewed semi-annually
2. Survey of graduating seniors and recent alums (Indirect)	Positive majority response	E	• Email surveys sent semi-annually
3. Telephone interviews with students in grad school (Indirect)	Positive majority response	E	• Interviews conducted annually
4. Research papers and oral presentations in Senior Capstone (Direct)	Scores on faculty-developed rubrics for paper and presentation	A, D	• Data reviewed bi-annually

5. Review of laboratory work and oral presentations in Experimental Physics (Direct)	Scores on faculty-developed rubrics for paper and presentation	A, C, D	• Data reviewed bi-annually
6. Knowledge & communication skills survey (Indirect)	Positive majority response	A, B, C, D (depending on course)	• Data reviewed semi-annually
7. Conceptual assessment surveys in 300-level and above courses (Direct)	Students score above those reported at national level. (This will vary depending on the assessment and data available)	A	• Data collected each semester a given course is offered • Data reviewed semi-annually
8. National standardized physics subject texts in lower-level courses (Direct)	Students score in the 75th percentile or higher	A, B, E	• Data collected and reviewed semi-annually

From time to time we have found it necessary (and wise) to adjust our assessment cycle as we added new upper-level courses to our curriculum. Since assessment is intended to be an ongoing activity for any department, this is perfectly reasonable. For example, we might wait until a new course has been offered once before considering a formal assessment for it. In contrast, we might set up a cursory survey or other indirect measure in a new course the first time it is taught. In that way, such an assessment might help us to smooth out the initial bumps that are often present the first time any new course is taught.

In the section that follows, we share a couple of examples of the assessments we have done. The first example is in one of our introductory-level physics courses (Physics for the Modern World, Phys 100) for non-majors that is part of the General Education core of courses at American University. In the second example, we present some of the assessment work we have done in one of our upper-level physics courses (Modern Physics, Phys 331) taken by our majors.

IV. Assessment Example: Lower-Level General Education Course

In our department we offer three different introductory-level physics sequences. The traditional course sequences are algebra-based, algebra- and trig-based, and calculus-based. For illustration purposes we have chosen to use our first-semester, algebra-based course which we call Physics for the Modern World (Physics 100). This course is typically taken by non-majors who are seeking to satisfy the university's science requirements for graduation. The content of the course parallels a traditional first-level physics course on Newtonian mechanics. Typical enrollments run from about 75 – 120 students in a given semester.

All of our introductory course sequences fall within the General Education core of courses, which on our campus is referred to as Area 5: The Natural Sciences[32]. Our General Education program has 8 overall learning outcomes. In addition, within each of the 5 areas of our General Education program there are 3 learning objectives that are unique to each area. We will begin by showing how an assessment framework for an individual course can be generated at the syllabus level. We will then highlight an example of the type of assessment data we've collected in the course as well as an interpretation of what the data actually mean in terms of how our students are learning.

Syllabus Preparation: Clarifying Course Learning Goals, Objectives and Outcomes

Within the assessment section on the Physics 100 syllabus, connections are first made to the 8 learning outcomes of our General Education program. These connections are synthesized in Table III. Each learning outcome has been coded (GE-1, GE-2, etc.) to simply the presentation and to facilitate making the connections straight-forward.

Table III.
General Education Learning Outcomes and Their Level of Connection to Physics 100

Learning Outcome	Description of Learning Outcome	Connection(s) between Learning Outcome to Physics 100 is: • Strong • Moderate • Minimal • Not Applicable
GE-1 Aesthetic sensibilities	Critical reflections on the nature and history of beauty and art	Minimal
GE-2 Communication skills	Interchanging ideas and information through writing, speech, and visual and digital media	Moderate
GE-3 Critical Inquiry	Systematic questioning and analysis of problems, issues, and claims	Strong
GE-4 Diverse Perspectives and Experiences	Acquiring knowledge and analytical skills to understand a variety of perspectives and experiences, including those that have emerged from the scholarship on age, disability, ethnicity, gender and gender identity, race, religion, sexual orientation, and social class	Minimal
GE-5 Innovative Thinking	Venturing beyond established patterns of thought in imaginative and creative ways	Moderate
GE-6 Ethical Reasoning	Assessing and weighing of moral and political beliefs and practices, and their applications to ethical dilemmas	Minimal
GE-7 Information Literacy	Locating, evaluating, citing, and effectively using information	Moderate
GE-8 Quantitative Literacy and Symbolic Reasoning	Applying mathematical, statistical, and symbolic reasoning to complex problems and decision making	Strong

Table IV represents the connections made to the 3 area-specific learning objectives. Area-specific objectives are set by our university's General Education Committee. Once again a coding scheme (A5-1, A5-2, etc.) has been employed.

Table IV.
Area 5-specific Objectives and Their Level of Connection to Physics 100

Learning Objective	Description of Learning Objective	Connection(s) between Learning Objective and PHYS 100 is: • Strong • Moderate • Minimal • Not Applicable
A5-1	Investigate the natural world and the living forms that inhabit it by studying the systems and processes that occur at scales from the atomic to the cosmic	Strong
A5-2	Develop problem-solving skills and utilize the scientific method to describe, explain, and predict natural phenomena through laboratory experiences	Strong
A5-3	Analyze the role of science in public discourse and in addressing societal problems	Moderate

Table V represents the course-specific learning outcomes and the learning objectives specific to each one. In addition, these are linked with the General Education and Area 5 learning outcomes and objectives using the coding scheme previously identified. In the past, the course-specific learning outcomes were simply listed in bullet form on the instructor's syllabus. This is most likely the presentation format used by most of us. It is quite a simple task to turn that bulleted list into a table-style format. This adds clarity to the presentation on the syllabus and also helps to draw students' attention to it.

The important message to students is: Here are the items that the instructor hopes for you to be able to do and understand at the end of the term, and here are the different ways (i.e. measures) that you will have an opportunity to use to demonstrate your understanding.

Table V.
Course-Specific Learning Outcomes and
Associated Objectives and Assessment Measures

Learning Outcome	Objectives Specific to Learning Outcome	General Education and/or Area 5-specific Goals, Objectives, or Learning Outcomes Addressed	Learning Experiences and Assessment Measures used in PHYS 100
1. Know basic physics terms.	1.1 Writing a definition of a specified term. 1.2 Providing the term that best fits a particular context. 1.3 Selecting the best term when given a definition. 1.4 Distinguishing between scalar and vector quantities. 1.5 Identifying the appropriate usage of a specified term.	GE-2 GE-7 GE-8 A5-1 A5-2	You will have several opportunities to demonstrate your understanding of basic physics terms. These include: • Regular homework assignments that involve short answer responses to conceptual questions. • Exams and quizzes that utilize a variety of question types (multiple choice, short answer, and numerical problem solving). • Laboratory activities and reports that will require you to demonstrate your understanding of basic physics terms. • Free-writing activities.

2. Understand that units must be included when presenting or describing physical data and/or results.	2.1 Converting from the SI to the British system of units and vice versa, using learned techniques. 2.2 Distinguishing between units of various physical quantities. 2.3 Recognizing the appropriate unit for a given term. 2.4 Expressing proper units with each numerical result or data obtained through direct measurement.	GE-2 GE-7 GE-8 A5-1 A5-2	Throughout ALL aspects of this course, whether in the classroom or laboratory, the importance of units will be stressed.
3. Understand fundamental physical concepts and principles.	3.1Selecting the appropriate law or relationship given a physical description of a situation. 3.2 Writing a description of a particular law or principle. 3.3 Recognizing an appropriate concept or principle for a given task. 3.4 Citing examples which exemplify fundamental laws and principles. 3.5 Relating fundamental laws and principles to given physical situations in the classroom and laboratory.	GE-2 GE-3 GE-7 GE-8 A5-1 A5-2	You will have several opportunities to demonstrate your understanding of fundamental physics concepts and principles. These include: • Regular homework assignments. • Exams and quizzes that utilize a variety of question types (multiple choice, short answer, and numerical problem solving). • Laboratory activities and report writing. • Free-writing activities.
4. Understand appropriate problem solving techniques and methodologies.	4.1Outlining problem solving methodologies. 4.2 Recognizing appropriate uses of problem solving techniques. 4.3 Recognizing improper uses of problem solving techniques. 4.4 Explaining one's choice of problem solving methodologies.	GE-2 GE-3 GE-7 GE-8 A5-1 A5-2	Opportunities to demonstrate your understanding of appropriate problem solving techniques and methodologies include: • Regular homework assignments. • Exams and quizzes that utilize a variety of question types (multiple choice, short answer, and numerical problem solving). • Laboratory activities and report writing. • Free-writing activities.
5. Apply fundamental physical laws and principles.	5.1 Distinguishing between appropriate and inappropriate applications of physical laws and principles. 5.2 Formulating solutions to problems based on appropriate laws and principles. 5.3 Solving problems that require the application of physical laws and principles. 5.4 Applying principles to new and different problem solving situations. 5.5 Demonstrating appropriate problem solving techniques.	GE-2 GE-3 GE-5 GE-7 GE-8 A5-1 A5-2	Opportunities to apply fundamental physical laws and principles include: • Regular homework assignments. • Exams and quizzes that utilize a variety of question types (multiple choice, short answer, and numerical problem solving). • Laboratory activities and report writing. • Free-writing activities.
6. Interpret and draw motion graphs.	6.1Drawing a graph of a particular motion of interest and determining its slope and y-intercept. 6.2 Describing the motion of an object in a given graphical representation. 6.3 Making interpretations based on a given graphical representation. 6.4 Selecting the graphical representation which best illustrates a given situation.	GE-2 GE-3 GE-7 GE-8 A5-1 A5-2	The laboratory activities are designed to give you experience with graphs. You will have opportunities to create graphs using our computer-based data acquisition system. In addition, you will also be required to produce and interpret some graphs that you have created by hand.

7. Synthesize processes for obtaining a solution to a unique conceptual or numerical problem or situation.	7.1 Using laws, principles, and concepts correctly and effectively. 7.2 Devising appropriate problem solving sequences leading to the solution of a unique problem. 7.3 Reorganizing given information into logical problem solving sequences. 7.4 Justifying the steps taken to solve a conceptual or quantitative problem. 7.5 Integrating various concepts learned into an effective problem solving strategy.	GE-2 GE-3 GE-5 GE-7 GE-8 A5-1 A5-2 A5-3	Opportunities to demonstrate your ability to synthesize processes used for both conceptual and numerical problem solving include: • Regular homework assignments. • Exams and quizzes that utilize a variety of question types (multiple choice, short answer, and numerical problem solving). • Laboratory activities, report writing, and assigned laboratory questions. • Free-writing activities.
8. Appreciate physics.	8.1Exploring real-world applications of the concepts, laws, and principles discussed. 8.2 Being encouraged to make connections between physics and one's individual major. 8.3 Making comparisons between various ways of looking at a given physical phenomenon. 8.4 Experiencing hands-on applications of physics, particularly through laboratory activities. 8.5 Exploring how scientists build models through which various physical phenomena can be analyzed and understood.	GE-1 GE-4 A5-3	Throughout the course you will have numerous opportunities to appreciate and value the physics you are learning. These opportunities include: • Laboratory activities that coordinate well with class material and assignments. • Free-writing activities. • Qualitative and quantitative problem solving.

In terms of our department's overall assessment plan, we want to be able to document how our students are learning. While any of the measures illustrated in Table V have the potential to be used as a tool to demonstrate student learning at the course level within our overall plan, we decided use a measure that is common to all of our introductory-level courses (Measure 8 as shown in Table II). Rather than present the data we've collected from all of our introductory courses, we present a set of assessment results from the Physics 100 course that were collected in spring 2010.

Sample Assessment Results

In spring 2010 the Force Concept Inventory[14] (FCI) was administered in all sections of PHYS-100. The FCI is a multiple-choice, survey-type instrument used to assess student understanding of basic mechanics concepts in physics. Since Physics 100 focuses on basic mechanics, we've found this inventory to be quite useful and informative. In addition, because the inventory is regularly used at other institutions, we've been able to make comparisons not only within our own program but to the data from other institutions that have been reported within the literature. The FCI was used as one measure to help us assess how our students are learning concepts in basic mechanics. The results obtained are illustrated in Table VI (below).

TABLE VI.
FCI Results by Gender for Physics 100 (Spring 2010)

Gender	FCI Pre-test	FCI Post-test	Gain <g>	Mean Grade	Mean GPA
F (n = 33)	11.45 (38.19%)	14.91 (49.96%)	0.13 ± 0.07	2.97	3.23
M (n = 49)	13.73 (45.78%)	18.45 (61.49%)	0.34 ± 0.04	2.89	3.13
Total (n = 82)	12.82 (42.73%)	17.02 (56.85%)	0.25 ± 0.04	2.92	3.17

Where gains were calculated using:

$$g = \frac{(postscore\ \% - prescore\ \%)}{(100 - prescore\ \%)}$$

When viewed collectively, the gain presented in Table VI for all students (0.25 ± 0.04) is just slightly higher than the gains reported for "traditional" courses in a national study conducted by Hake[31]. Hake's original study consisted of 62 introductory physics courses (N = 6542), where 14 "traditional" courses (N = 2084) achieved an average gain of 0.23 ± 0.04, while 48 "interactive engagement (IE)" courses (N = 4458) achieved an average gain of 0.48 ± 0.14. When the results are viewed by gender, however, we see some rather unexpected differences in average gains. We found that the overall gains for females (0.13 ± 0.07) were significantly lower than those for their male counterparts (0.34 ± 0.04). At the national level other studies in physics education have indicated similar results in terms of gender and performance on the FCI. While our female students have slightly higher course grades and overall GPAs than our male students, they score much lower on the FCI. If course grade and GPA can be used as an indicator of academic performance, we would naturally expect the FCI scores for our female students to be higher than for our male students. Our data suggest exactly the opposite! We are interested in taking a more critical look at the other FCI data we have collected in our other introductory classes and expect to provide a summary of this data in in a future iteration to see if the results we've obtained pertaining to gender hold true across all of our introductory-level courses.

The above discussion above is illustrative of the type of discussion we provide in our annual assessment reports. We present the results of our data collection, and try to interpret those results in terms of how our students are learning and make connections to data at the national level (if available).

In the following section, we present an example of how we've conducted assessments within some of our upper level courses. We will provide an illustration of some of the assessment strategies we've been using in our Modern Physics course (Physics 331) over the past couple of years. Within our overall course rotation, we offer our Modern Physics course every fall term.

V. Assessment Example: Upper-Level Course

Our Modern Physics course is considered a gateway course for our majors. In addition, this course is also taken by students working towards a minor in physics or applied physics. Because this course commonly has a mixture of both majors and minors, we were particularly interested in learning how the current course curriculum was being "digested" by each group of students.

In fall 2010 we administered the Quantum Physics Conceptual Survey[21] (QPCS) in our Modern Physics course. In addition to this multiple choice assessment, a series of exam questions on a specific topic covered in the QPCS (i.e. the photoelectric effect), was given to the students on both the midterm and final exam.

The unique population of our Modern Physics course (majors, minors, and applied physics minors) allowed for us to calculate the gains for the various groups to see if any trends could be inferred. The results obtained are illustrated in Tables VII – IX (below).

TABLE VII.
Gains for Class

	QPCS	Photoelectric Effect Question
Gain	0.15	0.50
Error in Gain	0.37	0.54

Where gains were again calculated using:

$$g = \frac{(postscore\,\% - prescore\,\%)}{(100 - prescore\,\%)}$$

Given the sample size we also derive the error in the gain. However with the small sample size the fluctuations are not necessarily Gaussian, therefore it is impossible to determine whether the results are statistically significant.

TABLE VIII.
Average Normalized Gains for Majors and Minors

	QPCS	Photoelectric Effect Question
Major gain	0.31	0.55
Error in Gain	0.47	0.48
Non-major gain	0.11	0.47
Error in gain	0.35	0.58

TABLE IX.
Average Normalized Gains for Majors and Minors

	QPCS subset	Photoelectric Effect Question
Total Gain	0.30	0.50
Major gain	0.53	0.55
Non-major gain	0.17	0.47

The authors of the QPCS report an average normalized gain of 0.23 for first year students and 0.32 for second year students at the University of Sydney in Sydney, Australia[21]. Gains for our majors are certainly comparable with gains by our non-majors much lower. These results indicate that while our majors showed a large gain on both the written midterm/final exam questions as well as on a subset of QPCS questions pertaining to the photoelectric effect, our gains by our non-majors provide us with mixed result.

The non-majors showed a moderately large gain on the written midterm/final question, but that increase did not translate into same magnitude of gain on the subset of QPCS questions on the photoelectric effect. These results perhaps indicate to us that our non-majors are able to grasp many of the concepts taught at this level, but they face a gap when they are being assessed with more traditional assessment techniques as compared to our majors. The disparity we observed between the majors and non-majors warrants further study and suggests the need for more course development. This result can be viewed within the context of the bimodal distribution we often see in our 300-level classes and it provides further support for our decision to change the requirements for our minors this year so that they too are required to complete the Physics 110/210 (calculus-based) sequence or equivalently, a first-semester calculus course.

Again note that the above discussion represents the way in which we report what we've learned from our assessment and how we plan to make use of our results to improve student learning. We continue on with our example, presenting data and discussion based on our fall 2011 assessment efforts for Modern Physics.

For the fall 2011 Modern Physics course, we again administered the QPCS as a pre- and post-test as was done in fall 2010. Tables X - XII show the results from the QPCS, broken down the same way as was done in fall 2010. Table X provides gains on the entire QPCS for the class as a whole. Table XI shows results for the entire QPCS broken down into major and non-major groups. Table XII shows the results on the QPCS for the three questions that relate to the photoelectric effect.

TABLE X.
Gains for Entire Class

	QPCS
Gain	0.26
Error in Gain	0.28

TABLE XI.
Average Normalized Gains for Majors and Minors

	QPCS
Major gain	0.28
Error in Gain	0.22
Non-major gain	0.25
Error in gain	0.31

TABLE XII.
Average Normalized Gains For Majors and Minors

	PE QPCS subset
Total Gain	0.44
Major gain	0.43
Non-major gain	0.44

Note that the gains look very different from the fall 2010 class in that there is not a clear distinction in the performance between the majors and minors in the class. The gains for the QPCS questions that focus on the photoelectric effect are larger than on the entire QPCS. Since we've begun a formal assessment of Learning Outcome A (Measure 7 - Direct) we've been able to focus on what aspects of the photoelectric effect that really caused difficulty for our students. We've addressed these aspects in class by adding an additional writing activity on the photoelectric effect. What we've thus far been able to see is that student understanding of the photoelectric effect (which is so important as students move on to other upper-level courses) has improved. These results are in direct support of Learning Outcome A.

What we've found quite interesting is that for this particular topic, the difference in performance between our majors and minors seems to have narrowed. Perhaps the additional attention devoted to determining where student learning difficulties are has made a more significant impact on learning where our minors are concerned. We will continue to use these results to help us improve student understanding of this important concept in physics in direct connection to our Learning Outcome A.

In the section that follows we offer a brief look at how we put all of our assessment information together into an annual report. In addition, we will offer a short summary of the electronic data collection system that is used on our campus.

VI. The Mechanism of Assessment Reports

Since 2011, our institution has been using an on-line system of data collection called TracDat[33]. Using TracDat individual departments and units can organize, manage, and report on student assessment efforts. TracDat is configured specifically to facilitate assessment reporting and program improvement. Using TracDat departments and teaching units are able to:

- Update, change or archive student learning outcomes on-line, at any time;
- Document assessment plans, including any supporting documentation (such as rubrics, survey instruments, or evaluation notes);
- Tie assessment results to actions taken by the department;
- Develop and print reports at any time;
- Have a centralized location for the department to see feedback that has been given by the Learning Outcomes and Assessment Team; and
- Submit the annual report electronically (p.2)

.
Using TracDat has allowed us to keep all of the information we collect in a single place. Typically the data is collected by the faculty members who happen to be teaching a particular course (or courses) that we are focusing our assessments on for a given academic year. Sometimes our efforts call for a team of faculty to review the data we've collected, and other times a single faculty member will put together a set of data for their course. The data collection and interpretation often depend on the nature of the assessment that we're doing. If we are giving a standardized assessment, then there is no need for a team of faculty to review the data. If, on the other hand we are trying to assess student learning in an upper-level physics course, we might have a small subset of our faculty who are tasked with reviewing a collection of students' written work. In that case, we create a set of rubrics that are used as a measure of student learning. The data itself is typically entered into the TracDat system by our Assessment Committee Chair. One of the downsides of our assessment efforts in the past was trying to catalog all of the data and other information we had collected into some type of compact and user-friendly format. In the next section we provide additional details on how we put our assessment plan into action.

VII. Assessment Plan into Action: How It Works

Prior to 2011, each department was required to submit a Word document that was to catalog the assessment efforts for a given year. The university provided a set of templates from which a department was to build and frame their own plan. Completing the templates and preparing a formal written assessment report was a very time-intensive task. Needless to say, the intense time commitment required to complete and submit a report was not seen as a productive use of time by many. In fact, the act of preparing a report often became a bigger issue than the actual interpretation of what the data collected meant in terms of what students were actually learning. What we found in our own department was that the task of writing the assessment report was distracting us from our primary goal. That is, the assessment of student learning!

For approximately 10 years, we have been collecting assessment data and preparing annual reports. Because, as a department, we understood the value of assessment, we diligently put together our annual reports. The way we chose to go about doing so was a bit different from what many other departments were doing. Our initial thoughts when we started collecting assessment data on a regular basis was that if we were going to have to put a significant amount of faculty time into this effort, we wanted to get a little bit more out of it for ourselves. Hence, we have used our assessment reports to tell a story. The story pertains to how we have grown as a department, updated and modified our curriculum, added new tenure lines to our program, etc. Using the TracDat system to capture our data and catalog our assessments has proved invaluable for us. All of our assessment material is now in one place. And, we've found that the new system has helped us to substantially decrease the time we're spending writing reports so we have more time to focus on the actual assessment of what our students our learning.

VIIII. Making Changes and Improvements Based on Assessment Results

Assessment is an ongoing process. An annual assessment report can represent a subset of this process. In response to our own assessment results, we have worked to make changes to our overall program. In the present work, we focused on one lower-level General Education course for non-majors (Physics 100) as well as one upper-level course (Physics 331). For these two courses, the assessment data collected and corresponding results show us that our students do show significant gains characteristic of those reported at the national level. Because we have an unusual population of students in our Modern Physics course, we find these results quite informative. We plan to continue collecting similar data for future courses and as we do, we can make better comparisons between and across terms.

Regardless of what subgroup of faculty is working with our assessment plan, we now have all of our data and assessment tools and instruments together in one place. We are no longer "starting from scratch" each time we put together a report. This fact alone has helped us to shift our focus from the onerous task of report writing to one that focuses on how the courses our students are taking are helping to prepare them for the future.

We have found that for assessment to be truly valuable, we need to have regular discussions at the department level regarding our findings as we prepare our assessment reports for a given period. We've also found that these discussions help us to make changes to our overall program as well. Assessment is on the agenda for just about all of our regular department meetings. Our ongoing discussion helps to ensure that all of our faculty members play a key role in creating a plan to assess both *what* and *how* our students are learning.

IX. Summary and Conclusions

In this paper we've provided an update on our assessment efforts from 2007 forward. We've also provided a look at the assessment models and tools that we've developed as a result of these efforts. Using two of our classes as examples, we've illustrated the *how* and the *why* behind our chosen assessments and how we've been able to use those assessments to make modifications to our curriculum as needed. We hope that the examples we've provided will serve as a catalyst for others to make changes and/or enhancements to their own assessment plans.

Assessment should not be perceived as a threatening exercise. Assessment is not about assessing the performance of individual faculty or anything even close to that. Instead, programmatic assessment should be about uncovering what our students are actually learning while the learning is taking place. Based on assessment results, changes can be made to the curriculum to ensure that the learning outcomes of the program are being achieved.

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