Background:

In 2005, the American Association of Physics Teachers (AAPT) published a document titled “Guidelines for Self-Study and External Evaluation of Undergraduate Physics Programs.” This document provides a useful framework for us to think about our departmental assessment. The AAPT guidelines are arranged around 5 questions, and we will refer here to the first two as follows: 1) “What are the characteristics and goals of students in our undergraduate program?” and 2) “Does the department’s physics curriculum help students fulfill their goals”. With regard to question one, the physics department at SLU serves many audiences including the physics major, the 3+2 engineering student, pre-health career student, and the student interested in science distribution courses. In recent years, almost all of our physics majors have chosen to attend graduate school. The 3+2 engineering students want to take the courses that will allow them to transfer to an engineering school. Most of our pre-health career students are interested in taking an introductory physics course that is required for their post baccalaureate health education, and they want to be prepared to do well on the physics portion of the MCAT. The students interested in our science distribution courses have a primary goal of fulfilling a graduation requirement, but they also want to learn some science in a topic where they have some interest.

We turn our attention to question 2. Is our curriculum helping our students achieve their goals? First we look at our course offerings, and find that we are providing the classes necessary to fulfill the goals of each of these audiences. While our major curriculum is about as streamlined as it can be, our majors are getting in to graduate school. While they find graduate school challenging, they are also finding that they are well prepared. We offer each of the courses necessary for the 3+2 engineering students, and every year these students successfully transfer into engineering schools and do very well. We offer introductory physics courses for the pre-health career student. Students can take either the calculus based University Physics course or the algebra based College Physics course. Both courses fill the requirements for medical school, and they help prepare the students for the MCAT. In fact, one of the College Physics students from last year got a perfect score on the physics portion of the MCAT. We offer as many science distribution courses as we can after we staff the major courses and introductory physics courses. (We offer no major electives). These distribution courses total approximately 1/3 of our course offerings (as measured
by faculty FTE). Students can typically choose something that grabs their interest from Astronomy to Global Climate to Energy to History of Science.

Since our course offerings are fulfilling our student’s goals we have decided to look closer at our teaching methods. Are our teaching methods successful in accomplishing the goals of the individual courses? To begin to tackle this question, the Physics Department has chosen to focus on our introductory physics courses for our assessment project. University Physics and College Physics are both survey courses that present a variety of topics in physics including mechanics, wave phenomena, electricity and magnetism, and modern physics. University Physics relies on calculus where College Physics only uses algebra to explore these concepts. The students enrolled in University Physics include those who plan to major in Physics, do the 3+2 engineering program, or obtain the American Chemical Society accredited Chemistry Major. Most of the students who enroll in College Physics are students interested in a pre-health career or biological sciences. Because most of the College Physics students plan to take the MCAT, College Physics covers more topics than University Physics.

We decided to focus on these two courses for several reasons. University Physics is the foundation for the Physics Major, so it makes sense for us to start our assessment at the beginning. The combined enrollment for College and University Physics is typically around 90 students, so it is large enough for us to be able to compile reasonable statics. Finally, these courses are the focus of most of the physics education research, so there is lots of information available to us including assessment tools and innovative pedagogical strategies.

Since these courses cover a broad range of physics and use different mathematical techniques, we have decided to assess student’s conceptual understanding of only one area—Newton’s Laws. The instrument we are using is a multiple choice test called the Force Concept Inventory that is used extensively in Physics Education Research. This test has already been vetted by the Physics Education Community and is used routinely to assess the success of various physics pedagogies.

**Survey Methods:**

Our idea is to do a pre-test at the very beginning of the fall semester, and then do a post test after these concepts have been covered in class. We will compare the results of the pre-test and the post-test to find areas where student learning is weak. Then we will examine our courses to see how we could do a better job teaching those concepts. We are not comparing our students to those
at other schools. We are using the test to try to improve our teaching methods here by comparing pre and post test results.

We chose 30 of the questions in the Force Concept Inventory. We gave the pretest in lab during the first week of classes, and we gave the post-test in lab during the last week of classes. We gave the students 20 minutes to answer the questions at the beginning of the lab.

**Survey Results**

Since the two courses use different texts and different methods, we may find that one course has a more successful method of teaching a particular concept than the other. At this time, however, we don’t see any explicit connection to a particular method in a particular course. The College Physics students had a pretest score of 39% (52 students) and a post-test score of 54% (54 students). The University Physics students had a pretest score of 58% (33 students) and a post-test score of 74% (32 students). It was interesting for us to note that the University Physics students start with more knowledge/understanding about Newton’s Laws than the college physics students finish the semester with. Both classes improved with college physics students gaining 14 percentage points and university physics students gaining 16 percentage points. These overall statistics are merely scratching the surface of what we can learn from this inventory. There are more details in the appendix.

**Final Conclusions**

A common misunderstanding that runs through most of the questions where the students did poorly is the relationship between force and acceleration. In College Physics we gave a retest problem on this concept during the 2009-10 year because we recognized in class that the students were struggling with the concept. We have made several adjustments for the 2010-11 academic year. In College Physics, we built in more time for this concept, and we split the material a bit differently for emphasis. In 2009-10 we did not cover apparent weight problems in College Physics, and we added this to the 2010-11 syllabus. Apparent weight deals with the normal force, and the problem the students did poorly on was the tension force, however, the concept of force and acceleration is the same. Adding in the apparent weight section gives the students yet another opportunity to see this concept. In University Physics our adjustments have been more modest as a result of sabbatical leaves and personnel changes. However,
we have made some modifications to our elevator lab, and it will be interesting to see if the students perform any better on those questions this fall.

In a parallel development, we have often noted that students’ lab grades in these two courses do not accurately reflect their conceptual understanding of the material, and the lab grades are unreasonably high. Instead, these grades have typically been a measure of the students’ ability to follow directions and write a lab report. In an effort to emphasize the mastery of concepts more, we will carry out a trial project in University Physics in the spring semester, taking two approaches to what we perceive to be a problem. First, we will ask more specific conceptual questions of students in their lab reports to encourage more thoughtful reflection on the fundamental physical principles involved. Second, the weekly quizzes in class will all have one question testing mastery of the concept from the previous week’s lab. The scores on these questions will be tabulated separately and averaged into the students’ lab grades at the end of the semester. In this way, we will be able to better assess the success of laboratory at teaching some of the concepts mentioned earlier in this report, as well as other concepts that have typically been problematic for introductory students.

During the summer of 2011 we plan to examine two years of data to see what changes we can make to the courses or lab experiments to improve the student learning. We are also looking at test options for the spring semester that include questions on circuits and optics.

References
Hake, H. Richard. “Interactive-Engagement vs. Traditional Methods: A Six-
Appendix

We determined which of the questions from the Force Concept Inventory that seemed particularly problematic for the students. These questions fall into two categories. First there are the responses where on average everyone is scoring low. Second there are the responses where students score worse on the post-test than they did on the pretest.

With regard to overall low scores, for the College Physics (Phys 103) inventory, we took particular note of the responses where the students scored 33.3% and under. This occurred on questions 17, 23, 25, 26, and 30. For the University Physics (Phys 151) inventory we took particular note of the responses where the students scored 50% and under. This occurred on questions 17, 21, 22, 25, and 26. The table below summarizes this information.

<table>
<thead>
<tr>
<th>Question</th>
<th>Phys 103 %right</th>
<th>Phys 151 %right</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Tension force on an elevator moving up at a constant velocity is related to gravity in what way?</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>21 A rocket drifts from point (a) to (b) then it turns on the engines on constant thrust perpendicular to drift, from (b) to (c) then the engine is off. What does the path look like from (b) to (c)?</td>
<td>44.4</td>
<td>43.8</td>
</tr>
<tr>
<td>22 What is the Rocket speed during b)⇒c) and after?</td>
<td>48.1</td>
<td>37.5</td>
</tr>
<tr>
<td>23 Path after rocket turns of engine</td>
<td>33.3</td>
<td>62.5</td>
</tr>
<tr>
<td>25 Woman exerts constant horizontal force on box that moves at a constant horizontal speed.</td>
<td>24.1</td>
<td>37.5</td>
</tr>
<tr>
<td>26 The woman in Q25 doubles her force.</td>
<td>9.3</td>
<td>28.1</td>
</tr>
<tr>
<td>30 Forces on a tennis ball are hit, air resistance and gravity. After contact with the racket, which forces act?</td>
<td>27.8</td>
<td>71.9</td>
</tr>
</tbody>
</table>
The poor performance on question 17 is more surprising for University Physics than College Physics because the University Physics students do a lab exercise that is very similar to the question. In the lab exercise, students ride in an elevator and measure the normal force on themselves using a scale. What the students should note is that the tension force is equal to the gravitational force when moving at a constant velocity. For those students who got it wrong, I might have expected them to say that the Tension force is greater than gravity since the elevator is moving upward. However, almost every student who got this problem wrong said that the tension force was LESS than the gravitational force. While we might have expected the University Physics students to do better given their lab exercise, the College Physics student’s performance on this question is much worse than the University Physics student’s.

Questions 21, 22 and 23 are all about a rocket that is drifting horizontally and then it turns on its engines so that it has a constant force in the vertical direction. This question is exploring concepts that were taught in the context of projectile motion, only now they are applied to a slightly different situation. The idea is to see if the students really understood those concepts. Question 21 asks about the path that the rocket takes when it is experiencing this constant force. There was no predominant wrong answer chosen by the College Physics Students perhaps indicating an even deeper lack of understanding. The wrong answer the University Physics students chose most often was a straight line path rather than a curved accelerating path. Question 22 asked about the rocket’s speed while it is experiencing a constant force. The rocket’s speed is continuously increasing; the wrong answer most chosen by both classes was that the speed was constant. The University Physics class actually did slightly worse on the post-test than the pre-test on this question but only by two students. Question 23 asks what the rocket’s path will look like when the engine is turned off. Here, the wrong answers were not consistent.

Questions 25 and 26 were problematic for both classes. The scenario is that a woman is exerting a constant horizontal force on a box. In question 25, the box moves at a constant speed, and the students are asked about the force the woman exerts. The correct answer is that the force must have the same magnitude as the forces that resist the motion of the box. The most common answer chosen by the students is that the total force must be greater than the force that resists the box. Question 26 asks what happens if the woman doubles her force. The correct answer is that the box should move with a continuously
increasing speed. The most common answer is that the speed is constant but twice what it was in the first scenario.

Question 30 is about a tennis ball that experiences three forces, (1) due to gravity, (2) being hit by a racket and (3) air resistance. The question asks which of these forces are “acting on the tennis ball after it has left contact with the racquet and before it touches the ground”. The correct answer is that only gravity and air resistance are forces acting on the ball after it has left contact with the racket. Here the most popular answer is that all three forces are acting. The University Physics students did not have much difficulty with this question, but the College Physics students did very poorly.

There are a few questions where there is a significant reduction in the score from the pre-test to the post-test.

<table>
<thead>
<tr>
<th>Question</th>
<th>College Physics</th>
<th>Pretest%</th>
<th>Post test%</th>
<th>%delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Woman exerts constant horizontal force on box that moves at a constant horizontal speed. What happens when she stops pushing</td>
<td>65.4</td>
<td>50</td>
<td>-15.4</td>
</tr>
<tr>
<td>10</td>
<td>What is the speed of a puck along a frictionless path after receiving a kick?</td>
<td>87.9</td>
<td>78.1</td>
<td>-9.8</td>
</tr>
<tr>
<td>22</td>
<td>a rocket drifts from point (a) to (b) then it turns on the engines on constant thrust perpendicular to drift, from (b) to (c) then the engine is engine off. What does the path look like from (b) to (c)</td>
<td>42.4</td>
<td>37.5</td>
<td>-4.9</td>
</tr>
</tbody>
</table>

Question 27 is a continuation of the scenario where the woman is pushing the chair. In this question, she stops pushing the chair and the students are asked what happens. The correct answer is that the chair immediately starts slowing to a stop. Here the most popular wrong answers were two. Students chose that the box immediately came to a stop OR that it continued moving at a constant speed for a while and then slows to a stop.
Question 22 has already been explained above. In question 10 the students are asked what happens to the speed of a hockey puck after it has been hit if it travels along a frictionless path. The correct answer is that it continues at a constant speed. The most popular wrong answers had the puck speed changing. They either thought it continuously decreased or increased for awhile and then decreased.