STEM Gateway Course Reform Team project information for STEM Gateway website.

Course Name: Pending (new course)

Course prefix and number: PHYC 140

Course-reform team members:

Mark Morgan-Tracy, Lecturer III (Team Leader)
Jeff Saul, Lecturer III
Jim Thomas, Associate Professor
Mary Odom, Instructor (CNM)
Jacob Miller, Graduate Assistant

Background to Course Reform Effort:

Physics 160 suffers from a very high DFW rate of 40% ± 9% (Std. Dev.). We believe that we can address key reasons for this failure rate with the creation of Physics 140, which is meant to ease the transition into the Physics 160 series. In this class, students will solidify their understanding of the mathematical foundations of physics, and learn how to apply mathematical tools to physics problems, and effective problem solving strategies. We plan to make this a Studio class[i], during most of which students will work together in groups to solve problems, with a minimum of lecturing. The physics topics will be appropriately chosen from many areas, not just from those covered in Physics 160, with the additional goal of inspiring students to succeed by exposing them to engaging applications of their knowledge.

Although trigonometry and pre-calculus are pre-requisites for Physics 160, we find that many students do not have a solid knowledge of these areas of math and are unable to apply these tools to physics contexts. Second, we believe that, since for most students Physics 160 is their first college physics class, the jump in workload and sophistication from a high school science class is too high, and this is a particular concern for the case of New Mexico high schools. We therefore plan to ensure better preparation for Physics 160 by creating several pathways into it.

We will raise entrance standards for Physics 160 by requiring either higher grades in trigonometry and pre-calculus, high ACT scores or AP Physics scores, or passing Calculus I with a high grade. Currently Institutional Analytics is studying which of many factors correlate with success in Physics 160 to help decide how best to change the prerequisites. (Institutional Analytics are also assessing how the revised prerequisites will dictate the number of students who should take 140, to help us understand enrollment numbers and impact on teaching load.) Students who do not satisfy one of these requirements will be offered an alternative path into Physics 160 by taking and passing Physics 140. Before the new prerequisites for Physics 160 go into effect, we will advise our own majors whom we judge are not prepared for it to take 140, and ensure that advisors in Engineering and Earth and Planetary Sciences recommend Physics 140 for less well prepared students.

An attempt to reduce the DFW rate is being implemented this academic year as part of the STEM Gateway program[ii], involving reform of the one-hour Problems session associated with Physics 160. This is a worthy effort that is helping some students substantially, but it will not completely solve the problem and it has had no significant effect on the DFW rate. We believe more must be done because a) we do not have the resources to require the Problems hour for all students – only a minority can attend, b) the emphasis is on conceptual understanding rather than application of math skills and problem solving, and c) it cannot address deficiencies before Physics 160 is attempted. Nevertheless, some methods used there are well suited to the proposed Physics 140.

Goals and Student Learning Outcomes:

The overall objective of Physics 140 is that the student will be mathematically and analytically prepared for the topics, abstraction, and pace of Physics 160. Based on conversations with the faculty teaching Physics 160 on what students need to be successful as well as issues raised in the PER literature[iii], we have identified four goals, and outcomes within each goal. By the end of the course, the student should have met these goals by being able to do the following:

Student Learning Outcomes for Goal 1: Trigonometry Fluency

- Compute the sine, cosine, and tangent for standard angles in all quadrants.
- Determine and use the correct triangle in a figure to compute angles, lengths, and other magnitudes.
- Sketch vectors, their components, and the vector sum.
- Apply trigonometric concepts in finding the components and algebraic sums of vectors.

Student Learning Outcomes for Goal 2: Reasoning Skills

- Demonstrate hypo-deductive and proportional reasoning

Student Learning Outcomes for Goal 3: Conceptual Visualization

- Model selected physical phenomena using visual tools such as motion diagrams and force diagrams.
- Construct graphs showing relations between physical quantities.
- Calculate the slope and other physical properties from a graph.
- Predict physical characteristics of motion from position, velocity, and acceleration graphs.

Student Learning Outcomes for Goal 4: Problem Solving

- Use general expert-like problem solving strategies to solve problems from various areas of physics and chemistry.
- Manipulate algebraic expressions in symbols to solve for unknowns.
- Appraise the validity of a potential solution to a physics problem.
- Manipulate units in algebraic problem solving.
- Relate different physical quantities using ratios and units.
- Apply the small-angle and binomial approximations, where appropriate, in simplifying expressions.

This student learning outcomes address the following core competencies:

UNM/HED Area III Competencies in Physical and Natural Science: 2, 3, 4, & 5.
UNM/HED Area II Competencies in Mathematics: 1, 2, 3, & 4

Course-reform plan (a description of the elements of the reformed course: specific curricular changes and/or pedagogical changes that will be designed and implemented with an explanation of how each change will address the perceived reasons for past low student achievement**)**

The main theme of this proposal is that no one learns to apply mathematical concepts by passively watching others. Students will be required to actively engage in the learning process during lecture time while preliminary contact with the topics discussed will be made by the students before class. After class, students will work on assignments designed to help them practice, consolidate, synthesize and integrate the outcomes into their 'big picture'.

Proposed Elements of Reformed Course:

1. A set of physics and physical science topics (to be developed) to apply the identified mathematical concepts, problem-solving strategy, and reasoning skills.
2. Developing the pre-lecture material both in terms of type (Kahn-Academy videos or similar, applets, reading assignments, quizzes, muddy-point questions) and delivery method. (We are also exploring whether there is an appropriate text for this class. It may be unique enough that there is not one; however, we believe that with materials drawn from other classes and new materials created for this course, the lack of a text would not compromise the course goals.)
3. Group problem solving (using worksheets we will create or adapt, and sometimes using cooperative group learning strategies[iv]), facilitated by the instructor, GA, and PLFs, at a ratio of one facilitator for 20-25 students.
4. Determining the type and delivery method for the post-class assignments. (Mastering Physics or similar as well as paper post-homework assignments.)
5. Training possible instructors and peer-learning facilitators (PLF's) in the methods and good practices of active learning.

Learning Achievement Gains/Assessment:

Our plan for reforming Physics 160 General Physics 1 by raising the level of the prerequisites and creating of Physics 140 to help bring students who do not meet the prerequisites to this level has two sets of goals. The first set of goals are specific to what students in Physics 140 need to learn in order to be successful in Physics 160, and were described above.

Since the ultimate goal of Physics 140 and the changes in the Physics 160 course prerequisites is greater student success in Physics 160 and beyond as well are reducing or hopefully eliminating Physics 160 from the UNM "killer course list", the 2nd set of goals address retention, and are as follows:

A. Improving the DFW rate and increasing the grade distribution for Physics 160.
B. Increase learning gains in Physics 160
C. Improve retention in later classes that build on concepts and topics covered in Physics 160. That is as more students pass Physics 160 with a C or better, the fraction of students passing should be as least as good as the current average in classes that build on topics covered in Physics 160.

D. Improve retention through the Physics 160-161 sequence of underrepresented minorities in STEM fields. We hope to see improvements for underrepresented minorities at least as good as the average for all students.
E. Determine which elements of this reform including the Physics 140 Physics prep class lead to significant learning gains and improving student success in Physics 160.

To measure learning gains in the first set of project goals (Goals 1-4), learning gains in Physics 140 we will use the following outcomes:

- A pre/post test will be created, validated, and administered to students in Physics 140 to look at student achievement for Goals 1, 2, and 3. Successful student achievement will show significant learning gain in comparing the pre and post results. Questions will both be drawn from existing assessments such as the Thornton and Sokoloff *Force and Motion Conceptual Evaluation* (FMCE)[v] and the Lawson Test of Scientific Reasoning.[vi] As is standard practice with Pre/Post assessments in Physics, we will use the normalized gain as our figure of merit for comparison. Validation will include correlating student scores in Physics 160 with their score in the class.
- Embedded exam questions in Physics 140 will be used to measure student-learning gains for Goals 3 and 4. Although Goal 3 will also be looked at with a pre/post assessment, it will also be useful to see how students use physics diagrams and graphs in the context of solving problems. For Goal 4, samples of individual and group solutions will be examined over the course of the semester to determine learning gains with regards to general problem solving and the use of an expert problem-solving strategy. The exam solutions will be evaluated on three criteria: correctness, completeness of reasoning, and students' ability to use the strategy taught in the class. A successful project outcome would show statistically significant improvement in the first two and success for over 50% of students for the latter.

To measure the effects of the proposed changes on increased student success, improved retention of students in STEM programs, and reducing the DFW rate, we propose the following outcome measurements for the retention goals (A-D):

- To address retention Goal A, we will ultimately look at the DFW rate and the average student GPA for enhanced-prerequisite Physics 160 classes and compare with pre-reform Physics 160 classes. For the Spring 2014 pilot of Physics 140, the grade distribution of students in Physics 160 (at UNM and CNM) in the 2015 academic year who also took Physics 140 will be compared with 160 grade distributions from previous years as well as that of students who took Physics 160 without 140 that year. A successful project outcome would show statistically significant improvement in average GPA and reduction in the average DFW rate in all reform sections of Physics 160 with a student population that includes at least 20% of students completing Physics 140 previously.

- An additional assessment for retention Goal A is to separately assess the effects of the higher prerequisites. To do so, we make use of the fact the new prerequisites will not be introduced until AY 2015. Once the higher prerequisites are introduced, we will compare 160 grade distributions between students who took 140 and those who did not but satisfied the higher prerequisites. A statistically significant improvement over the current classes at UNM and CNM would indicate that stricter prerequisites are essential.
- To address retention Goal B, a post assessment will be developed, validated, and administered at the end of Physics 160, possibly as part of the final exam, to determine if students have achieved the core course competency skills currently required of Physics 160 students. Successful achievement of this outcome would be student scores on this assessment in reformed Physics 160 classes be as least as good as that of students in previous Physics 160 classes. Although we would hope to see a significant improvement, we recognize that since the number of students successfully completing Physics 160 should increase, including many who were unsuccessful in the past, even having students perform as least as well would result in improved retention in STEM fields where Physics 160 is required. That would tell us that the increased passing rate is not being achieved at the cost of diluted standards.
- To address retention Goal C of at least maintaining the passing rate of classes that build on Physics 160, we will examine the DFW rate of Physics 161 (General Physics 2), Physics 303 (Analytical Mechanics), Civil Engineering 202 (Engineering Statics), and Mechanical Engineering 306 (Dynamics) and compare the results before and after elements of this reform project are put into place. If we are successful and the DFW rate does not increase as more students pass through the filter of Physics 160, the gains in retention in Physics 160 will be maintained in follow-up classes in Engineering and Physics, which in turn should eventually result in the granting of more STEM degrees at UNM.
- To measure achievement of retention Goal D, demographic analysis will be used to separate results of all measures of the previous learning and retention goals by gender and ethnicity to determine if we are successful in producing results for underrepresented minorities in STEM as least as good as on average. This will help us make sure we are serving our minority population better and not leaving them behind.
- To address retention Goal E, we will first find a set of reforms that is effective for achieving the above outcomes for learning and retention. We will then experiment or encourage other adopters to do so to see which elements are essential. For example, the delayed start of the more rigorous prerequisites will allow us to determine whether they are an essential part of this reform if their implementation helps us achieve statistically significant improvement beyond the creation of Physics 140.

Timeline: (An outline of when different course-reform elements and assessments will be implemented during the next year, including the roles of each team member in each implementation step)

Summer 2013

- Determination of Topics. (All)
- Writing of worksheets for first half of semester. (Morgan-Tracy, Thomas, Miller, Odom)
- Revision of first set of worksheets. (All)
- Development of assessment tools. (Saul and Miller)

Fall 2013

- Writing of worksheets for the rest of the semester (Morgan-Tracy, Thomas, Miller, Odom)
- Revision of worksheets. (All)
- Training of Instructors and PLF's (Saul)
- Validation of assessment tools in current Physics 160 courses. (Saul and Miller)

Winter break 2013

- Final revision on beginning material. (All)
- Determine post-lecture homework for first couple of assignments. (Morgan-Tracy)

Spring 2014

- Physics 140 Piloted. (Morgan-Tracy)
- Determining of homework assignments. (Morgan-Tracy)
- Weekly meetings to discuss all aspects of course. (All, including PLF's)
- Gathering of assessment data on current Physics 140 students. (Miller)

Summer 2014

- Gathering of assessment data. (Miller)
- Analysis of assessment data (Saul and Miller)
- Prepare final report for the project. (All)

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[1] For example, see R. Beichner, J. Saul, D. Abbott, J. Morse, D. Deardorff, R. Allain, S. Bonham, M. Dancy, and J. Risley, "Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project," in E. F. Redish and P. J. Cooney (Eds.), *PER-Based Reform in University Physics* (American Association of Physics Teachers, College Park MD, 2006); J.M. Wilson, "The CUPLE physics studio," *Phys. Teach*. **32** (10), 518-523 (1994); and P. Laws, "Calculus-based physics without lectures," *Phys. Today* **44** **(**12), 24-31 (December, 1991).

[2] STEM Gateway 2012 Reforming Physics 160 project. See http://unmstemgateway.blogspot.com/p/course-reform.html

[3] See for example, V. Coletta and J. Philips, "Developing thinking and problem-solving skills in introductory mechanics, " in Physics Education Research Conference 2010 Proceedings, vol. 1289, 13-16 (2010); D.P. Maloney, "Research of problem solving: physics," in

Handbook of Research on Science Teaching and Learning, edited by D.L. Gabel (Macmillan Publishing Company, New York, 1994), 327-354; A.H. Schoenfeld, "Learning to think mathematically: problem solving, metacognition, and sense-making in mathematics," in *Handbook of Research in Mathematics Teaching and Learning*, edited by D. A. Grouws (Macmillan Publishing, New York, 1992), 334-370; and A. Arons, "Student patterns of thinking and reasoning," *Phys. Teach.* in three parts: **21**, 576-581 (1983); **22**, 21-26 (1984); **22**, 88-93 (1984).

[4] See for example: P. Heller, R. Keith, and S. Anderson, "Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving," *Am. J. Phys*. **60** (7), 627-636 (1992); and P. Heller and M. Hollabaugh, "Teaching problem solving through cooperative grouping. Part 2: Designing problems and structuring groups," *Am. J. Phys*. **60** (7), 637-644 (1992); and K. Cummings, J. Marx, R. Thornton, and D. Kuhl, "Evaluating innovation in studio physics," *Phys. Ed. Res., Am. J. Phys. Suppl*. **67** (7), S38-S44 July 1999.

[5] R.K. Thornton and D.R. Sokoloff, "Assessing student learning of Newton's laws: The Force and Motion Concept Evaluation and the evaluation of active learning laboratory and lecture," *Am. J. Phys*. **66** (4), 338-351 (1998).

[6] A. E. Lawson, "The development and validation of a classroom test of formal reasoning," *JRST*., **15** (1), 11-24 (1978).