Physics 140 Course Assessment

1. Project motivation and goals

Physics 160 suffers from a very high DFW rate of 40% ± 9% (Std. Dev.). Our new course offering, Physics 140, is intended to ease the transition into the Physics 160 series. In this class, students solidify their understanding of the mathematical foundations of physics, learn how to apply mathematical tools to physics problems, and develop effective problem-solving strategies. Physics 140 is a studio class in which students spend the majority of the class period working together in groups to solve problems. These problems' physics topics are 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 prerequisites 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 in a physics context. For most students, Physics 160 is their first college physics class, so we also believe that the jump in workload and sophistication from a high school science class is too high. (This is a particular concern for students coming New Mexico high schools.)

To better prepare students for Physics 160, we have tried several strategies and teaching pedagogies. The first attempt to reduce the DFW rate was implemented during the 2012/13 academic year as part of the STEM Gateway program. It involved reforming the one-hour Problems session associated with Physics 160. It was a worthy effort that helped some students substantially, but it did not completely solve the problem and had no significant effect on the DFW rate. We believe more needed to be done because a) we did not have the resources to require the Problems hour for all students – only a minority could attend (this remains true to the present day), b) the emphasis was on conceptual understanding rather than application of math skills and problem solving, and c) it did not address deficiencies before Physics 160 is attempted. (Nevertheless, some methods used there are well suited to Physics 140.)

The overall objective of Physics 140 is that by the end of the course the student will be mathematically and analytically prepared for the topics, abstraction, and pace of Physics 160. Based on conversations with UNM's faculty who have taught Physics 160 and by researching the issues raised in PER (Physics Education Research) literature, we developed four learning goals with various outcomes within each goal that we believed will lead to student success. Although we have come to the conclusion that some of these goals need modification (see section 4 of this report), they form the basis of our assessment of this course.

Our objective was to allow students enrolled in Physics 140 to meet our four goals by being able to do the following:

Student Learning Outcomes for Goal 1: Trigonometry Fluency

- (LO 1a) Compute the sine, cosine, and tangent for standard angles in all quadrants.
- (LO 1b) Determine and use the correct triangle in a figure to compute angles, lengths, and other magnitudes.
- (LO 1c) Sketch vectors, their components, and the vector sum.
- (LO 1d) Apply trigonometric concepts in finding the components and algebraic sums of vectors.

Student Learning Outcomes for Goal 2: Reasoning Skills

- (LO 2) Demonstrate hypo-deductive and proportional reasoning

Student Learning Outcomes for Goal 3: Conceptual Visualization

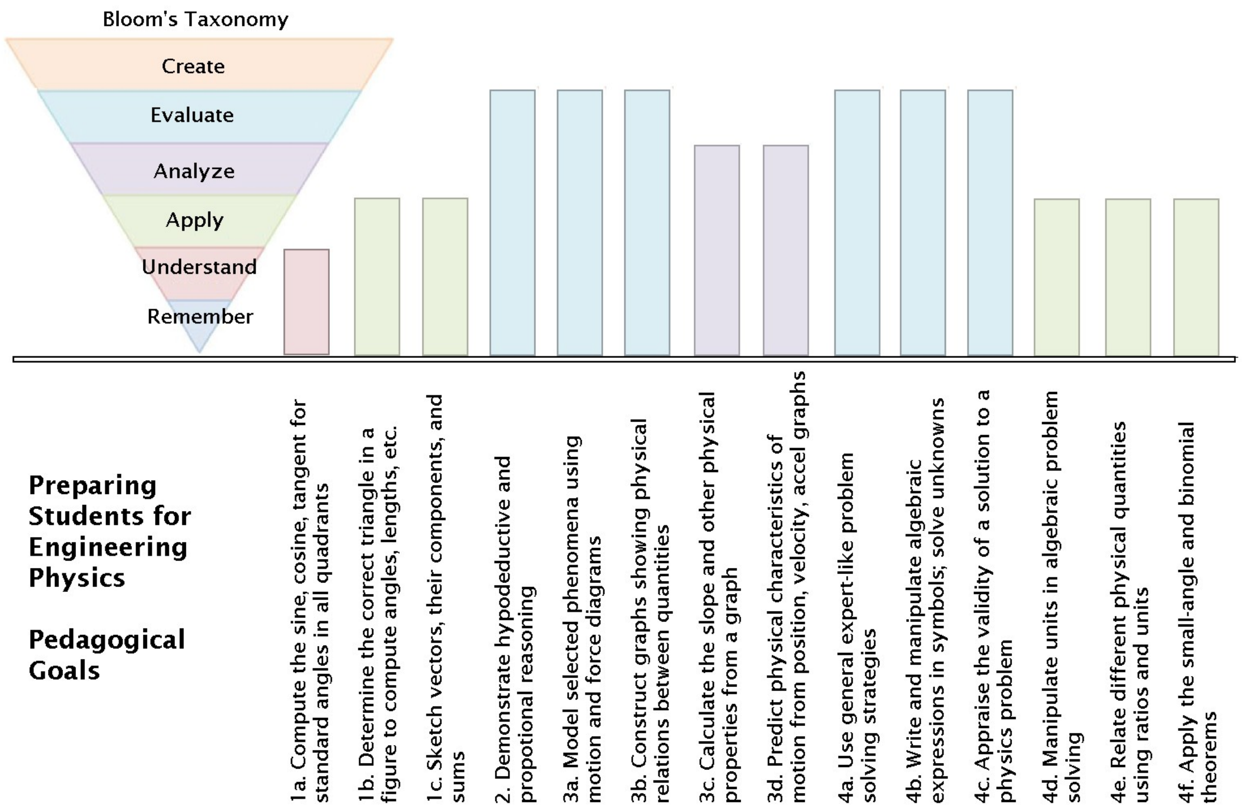
- (LO 3a) Model selected physical phenomena using visual tools such as motion diagrams and force diagrams.
- (LO 3b) Construct graphs showing relations between physical quantities.
- (LO 3c) Calculate the slope and other physical properties from a graph.
- (LO 3d) Predict physical characteristics of motion from position, velocity, and acceleration graphs.

Student Learning Outcomes for Goal 4: Problem Solving

- (LO 4a) Use general expert-like problem solving strategies to solve problems from various areas of physics and chemistry.
- (LO 4b) Manipulate algebraic expressions in symbols to solve for unknowns.
- (LO 4c) Appraise the validity of a potential solution to a physics problem.
- (LO 4d) Manipulate units in algebraic problem solving.
- (LO 4e) Relate different physical quantities using ratios and units.
- (LO 4f) Apply the small-angle and binomial approximations, where appropriate, in simplifying expressions.

(For ease of reference later, we have labeled all of the component learning outcomes by LO ##. These will be used extensively in sections 3 and 4, so it is suggested that the reader have this table available.)

As a final note, we have included a placement of our various learning outcomes within the context of Bloom's taxonomy, which is shown in the figure below. This helped us evaluate the legitimacy of our original goals and outcomes, as well as, aided in our development of the improved outcomes for Physics 140's subsequent offerings (see sections 3 and 4).



2. Project summary

The main theme of our approach to Physics 140 is that no one learns to apply mathematical concepts by passively watching others. Students were required to actively engage in the learning process during lecture time while preliminary contact with the topics discussed were made by the students before class.

The key elements of Physics 140 are enumerated below. Together, they are intended to engage students in the process of learning the background math and physics material, while allowing the introduction of new and unfamiliar topics.

1. From the class's learning goals and outcomes, a set of physics and physical-science topics were identified.

2. A textbook, *Preparing for General Physics: Math Skill Drills, and Other Useful Help, Calculus Version*, by Arnold Pickar, was chosen. From it, the pre-class material was identified.

3. Based on the textbook material, reading quizzes were created. These reading quizzes always contained a "muddy point" question where students listed any concepts about which they were still unsure. This allowed the instructor to briefly touch on those subjects at the start of class in order to make sure the students were maximally prepared for that day's worksheet.

4. Worksheets were created by the development team. These worksheets were designed to encourage active learning amongst students, facilitated by the instructor and one GA. (It also became clear that the possible instructors and GA's would need to be trained in the methods and good practices of active learning.)

5. During the semester, students would create their own mock exam questions before every test and then give these to fellow students to try out and critique.

In addition to this, we created a set of goals to track our success in the broader aim of creating greater student success in Physics 160 and beyond, as well as, reducing or hopefully eliminating Physics 160 from UNM's "killer course list". These goals 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.

In order to verify which of these goals are being met, we plan on tracking students who participated in the pilot offering of Physics 140 to see the comparison of their performance relative to comparable students who immediately jumped into the Physics 160 series. Although this data isn't yet available due to the recent offering of Physics 140, we hope to carry out this analysis as soon as possible, as this could potentially lead to changes in future offerings of Physics 140.

3. Assessment: Present any and all data obtained as part of the originally stated or modified assessment plan that are related to students' (a) learning, (b) success, and/or (c) attitudes

(a) In this first implementation of Physics 140, we made sure to collect several different sources of data to help estimate the extent to which the class addressed each of our original learning outcomes. This data helped determine the students' progress in each learning outcome and gave a sense of the coverage that was allotted to each outcome during the class. This process was important not only for properly fine tuning the amount of time devoted to different learning outcomes, but also for evaluating the original list of outcomes to determine if modifications were needed. This latter process is inevitable in any new class, as the initial choice of learning outcomes, though reasonable at the time, is necessarily made with limited knowledge of how they will actually play out in the classroom.

The primary data sets used to arrive at an estimate of the students' progress in the original learning goals include a diagnostic test that was given on both the first and last days of class, as well as, the results of a comprehensive final exam. For the first, we present students' performance on each of the learning goals before and after progressing through Physics 140, which allows us to determine their increase in each skill. For the final-exam data, though, we don't have an initial data set to compare to. We have, therefore, tabulated the average performance of students on each learning outcome and compared it to the average score of the entire exam. This allows us to pinpoint with which learning outcomes the students had the most difficulty. This, in turn, lets us make recommendations about which topics should be covered more thoroughly and which should be covered less thoroughly in future offerings of Physics 140.

After this, we present an estimate of the coverage given to each learning outcome throughout the class, as determined by the number of questions pertinent to each outcome on each of the four non-cumulative exams. This helps paint a picture of which learning outcomes were given more coverage during the trial run of Physics 140, and which ended up being dropped in favor of more relevant outcomes. Again, this will help us revise our list of learning outcomes.

We give a summarized version of the data we used to arrive at our conclusions below. Additionally, the raw data sets consisting of the exams, final exam scores, and diagnostic scores can be found here:

https://docs.google.com/spreadsheets/d/1cou-CA34ildFqbGomzA0BP1DzgQPuuO5muvQ3tSPDEo/edit?usp=sharing .

Diagnostic Test: Students were given a diagnostic test at the beginning and end of the course to determine how their facility with skills related to the course learning outcomes changed over the semester. (A copy of the diagnostic can be found here: https://drive.google.com/file/d/0B2Ymgt04PCi2c19DdUJlaGFZSHc/edit?usp=sharing .)
After grading these tests, we grouped together the scores for all questions pertaining to each learning outcome and calculated the normalized gain for each. The results of this process are displayed in the table below.

Learning Outcome	**1a**	**1b**	**1c**	**1d**	**2**	**3a**	**3b**	**3c**	**3d**	**4a**	**4b**	**4c**	**4d**	**4e**	**4f**
Pre Average		0.4		0.4	0.45	0.1			0.09		0.46	0.4			
Post Average		0.6		0.6	0.45	0.1			0.09		0.62	0.6			
Normalized Gain		0.33		0.33	0.00	0.00			0.01		0.29	0.33			
# of Questions on Diagnostic		1		2	2	1			2		9	1			

All of the question scores have been normalized on a 0 to 1 scale for ease of comparison. The pre and post averages refer to the test results at the beginning and end of the course, while the normalized gain is calculated as the ratio of the improvement students made in a given learning objective to the greatest possible such improvement that could have been made. Finally, we give the number of questions on the diagnostic that were deemed relevant to each learning outcome, and were consequently used to compute the normalized gain.

For the learning outcomes in the diagnostic that were given adequate in-class coverage, the above shows significant progress made in each. This is very encouraging, and suggests that our initial offering of Physics 140 generally succeeded in accomplishing the goals we had set forth for it.

While the results above don't show a *decrease* in any outcome, learning outcomes 2, 3a, and 3d show essentially no increase in student mastery during the course. For outcomes 3a and 3d, this can be attributed to a lack of coverage in class, for which we suggest a remedy in section 4 of this report. It is harder to assign a direct cause for the stagnation in learning outcome 2, but we do mention that the learning outcome as it is currently written is quite vague. Consequently, it will be rewritten in a manner that permits a closer connection to the actual coverage of course topics in section 4.

In general, as can be seen from the last row of the above table, the questions on the diagnostic clearly weren't evenly distributed with respect to their measured learning outcomes. Indeed, the number of questions addressing learning outcome 4b were equal to the number addressing all other outcomes combined. While this particular focus gives us confidence that students really did make progress in this learning outcome, it is imperative that we be able to evaluate the other learning outcomes in future offerings of the course.

In the diagnostic, some questions ended up testing tangential material that wasn't immediately relevant to any learning outcomes, while many learning outcomes (those with blank columns) didn't receive any questions at all. Consequently, the diagnostic must be rewritten with a stronger emphasis on assessing students' mastery of the learning outcomes, which will be discussed later.

Final Exam: Other data we have available are the students' outcomes on the class's cumulative final exam. While this doesn't permit a pre and post comparison of scores, it does assess the relative student performance on each topic. This is given in the table below.

Learning Outcome	1a	1b	1c	1d	2	3a	3b	3c	3d	4a	4b	4c	4d	4e	4f
Average		0.85	0.79		0.84	0.85	0.84	0.82	0.85		0.86	0.86	0.92	0.93	
# of Questions on Final		2	2		4	6	3	2	4		4	1	1	3	

The color above indicates whether the score (normalized on a scale of 0 to 1) was above, below, or at the median score of 0.85. We see students performing most strongly on questions related to problem solving (LO 4), which is consistent with the data from the diagnostic test. This is encouraging, as the development of students' problem solving skills was one of the chief motivators for developing Physics 140.

While the number of questions assessing each learning outcome is much more evenly balanced here than in the diagnostic test, it is harder to directly use this data for diagnostic purposes. We therefore refrain from any further interpretation.

Exams: Finally, we present an estimate of the time allotted to coverage of each learning outcome throughout the first iteration of Physics 140. This is measured by the number of questions on the course exams that assess each learning outcome.

Learning Outcome	1a	1b	1c	1d	2	3a	3b	3c	3d	4a	4b	4c	4d	4e	4f
Exam 1						1					1		1	3	
Exam 2					1		1	2	1		3	1	1	1	
Exam 3		6	2	1	2									1	
Exam 4					3	1			4	1	3	1			
Final		2	2		4	6	3	2	4		4	1	1	3	
Total		**8**	**4**	**1**	**10**	**8**	**4**	**4**	**9**	**1**	**11**	**3**	**3**	**8**	

Of course, each of the four exams were intended to only test a subset of the learning outcomes. The final exam was cumulative and was based on the earlier exams. It was intended to reinforce the same outcomes as the earlier exams. The final row gives an estimate of the amount of time students spent developing their competency in each learning outcome.

This data can be used to see how well each learning outcome was addressed in class. This is useful for two reasons: First, if a learning outcome is deemed crucial and was given insufficient coverage throughout the course, this should be evident. This was the case, for example, of learning outcome 1d, which is an essential skill for students wishing to take Physics 160. Second, if a great amount of progress was made on any particular learning outcome, as measured by earlier data, we can see to what extent this was due to frequent coverage in class. From this, we can make sure to provide similar coverage in the next iteration of the class. Such a phenomenon is evident in the gains in learning outcome 4, which is likely largely due to its significant coverage in nearly every course exam. Finally, the lack of any questions on outcomes 1a and 4f (so called “widowed” outcomes) indicates that these topics were found to be unimportant or irrelevant when the class was taught.

Conclusions: Our general conclusions from these assessments are as follows:

i) Students showed a strong improvement, as measured both by diagnostic test gains and final exam scores, in learning outcomes related to problem solving strategies (LO 4). This is very encouraging, as strengthening students’ ability to creatively apply mathematical techniques to open-ended problems was a major *raison d’etre* for Physics 140.

ii) Although showing strong improvement in certain aspects of trigonometric fluency (LO 1), our data indicates mixed results for that learning outcome as a whole, with insufficient progress made in students’ ability to manipulate vectors.

iii) Due to time constraints, very little class time was spent working with motion diagrams and ideas related to finding the slope of a graph. This is reflected in the fact that the collected data shows little improvement in several learning outcomes related to conceptual visualization (LO's 3c and 3d).

iv) The list of learning outcomes, as well as the diagnostic test used to assess them, need to be revised. The change of learning outcomes will be addressed in section 4, but the inadequacy of the diagnostic test for uniformly assessing the current set of learning goals is clearly seen from the last row of the first table. Also, the presence of widowed outcomes 1a and 4f on the last table encourages their removal from the list of class outcomes.

(b) Student Success:

Seventeen students enrolled in the pilot offering of Physics 140. All seventeen of those students passed the class. Given physics 160's high fail rate, this is extremely encouraging to the design team. The distribution of the final grades is shown below.

			Total
A+: 0	**A: 7**	**A-: 2**	**9**
B+: 3	**B: 1**	**B-: 2**	**6**
C+: 1	**C: 1**	**C-:0**	**2**

The instructor of the course feels confident that, with the exception of the two C-grade students, the remaining students have a good chance of succeeding when they take physics. Of the two students earning C grades, one of them earned that grade mostly due to lack of attendance and class participation. The instructor believes that this lack of discipline will follow that student into future courses and that their future performance is not a good measure of Physics 140's success.

(c) Student Attitude:

When the in-class diagnostic was given the second time, students were also asked to answer two questions on their attitudes about the class. The first question asked for topics that the student felt the class had done a good job of teaching them, while the second asked for topics with which the student still felt unprepared.

The most common response on the first question, with six students mentioning it, was the trigonometry section. In particular, the students felt that the class had fully prepared them to determine which trigonometric function to use in solving problems. Other responses to the first attitudinal question included the algebraic manipulation of equations and the solving of word problems.

Probably due to the lack of student anonymity, the second question elicited fewer responses from the students. (In order to match students' pre and post test scores, and to give them extra credit for doing the diagnostic, it was necessary to have the students' names on the papers.) Four students stated that they were still uncertain on exponentials and logarithms. Other responses included topics that were not covered, especially derivatives and integrals, as well as, a general lack of confidence in applying "any of it".

In addition to the in-class diagnostic, UNM's IDEA forms were administered to the students. This survey is given in all classes at the University of New Mexico. It gathers students' opinions on teaching effectiveness and their agreement on statements about the class's excellence. Unlike the in-class diagnostic, the IDEA form is submitted anonymously. The summary of the results, that students found the class to be of similar to higher excellence compared to other classes at UNM, are shown in the figure.

Your Converted Average When Compared to All Classes in the IDEA Database

Comparison Category	A. Progress on Relevant Objectives		Overall Ratings: B. Excellent Teacher		Overall Ratings: C. Excellent Course		Overall Ratings: D. Average of B & C		Summary Evaluation (Average of A & D)	
	Raw	Adj.	Raw	Adj.	Raw	Adj.	Raw	Adj.	Raw	Adj.
Much Higher Highest 10% (63 or higher)										
Higher Next 20% (56–62)	59	56			57		56		58	
Similar Middle 40% (45–55)			55	53		54		54		55
Lower Next 20% (38–44)										
Much Lower Lowest 10% (37 or lower)										

Your Converted Average When Compared to Your:[2]

Discipline (IDEA Data)	60	58	57	55	60	56	59	56	60	57
Institution	53	54	51	52	51	53	51	53	52	54

IDEA Discipline used for comparison:
Physics

4. Improvement

While we are quite happy with the learning progress students made throughout Physics 140, there are still many class details that can be improved. In this section, we outline what changes we feel should be made in the course before it is offered in fall 2014. These changes can mostly be grouped as follows:

a) Some crucial topics, such as introductory calculus skills, that were intended to be covered at the end of the semester, were omitted due to time constraints. Additionally, some topics that were given coverage were, in retrospect, not allotted sufficient time for students to develop any sort of mastery. We will fix both of these issues by decreasing the number of exams, each of which occupied roughly a week of class time (on account of a pre-exam review session), and by entirely removing significant figures from the course curriculum. Together, these should be sufficient to ensure the proper coverage of all essential subjects during the semester.

b) The vector-related learning outcomes, 1c and 1d are currently not addressed in the course textbook; therefore, significant class time was used for a basic introduction to these topics. We intend to remedy this by giving students supplementary reading material that allows for greater pre-class exposure to the topic. This way class time can be devoted to covering more interesting applications of vector-related concepts.

c) The set of learning outcomes as it currently stands has several outcomes which we found to have little relevance to the essential course goals. Furthermore, there are several outcomes currently doing “double duty”, by encompassing several disjoint skill sets. We have thus revised the learning outcomes accordingly, such that they now form an operationally useful document which can be used more easily to assess the success of future iterations of Physics 140.

d) Our diagnostic test, while still useful for assessing the progress of students’ comprehension, is currently very unevenly distributed relative to the collection of course topics. Consequently, it will be rewritten with a uniform coverage of our revised learning outcomes in mind, such that the next class iteration can benefit from a more fine-grained estimate of students’ learning.

We now discuss each of these changes in more detail, with an explanation of the necessity of each change.

The authors had high hopes for Physics 140 during the initial design phases of this project, and consequently included a rather wide selection of topics in the syllabus for the initial course offering. We have found that a decent coverage of all of these topics is very difficult in light of the real time constraints involved in teaching such a class. However, after looking through our various outcome-related data (section 3) and reflecting on the process of teaching the course, we have come to a few compromises and changes that we feel will ensure proper coverage of the essential course topics.

First, we intend to eliminate any discussion of significant figures from the course syllabus. While an understanding of this topic is certainly necessary for anyone wishing to pursue a career in science or engineering, we feel that Physics 140 is not the right place to deliver this. In our pilot offering, significant figures was the first topic covered by students, and we found it very much at odds with later topics. In particular, the initial coverage of the subject gave many students the impression that they should be concerned with significant figures in *all* calculations, even those of a purely theoretical nature. This led to several students feeling like they had to unlearn what they knew about significant figures after its initial coverage, leading to frustration during later topics. We feel that this difficulty in properly teaching significant figures ultimately comes from the very nature of Physics 140 which, while applications-oriented, doesn't involve a substantial amount of real-world data collection. Thus, while students should be expected to learn this subject in some class, a laboratory course with significant real-world experimentation would be a better place for it.

In addition to the time savings coming from removing significant figures, we also feel one exam can be removed from the course curriculum. Due to the Tuesday-Thursday schedule of the class, and the fact that an entire class was devoted to review before each exam, each exam ended up occupying an entire week. While these exams are important in encouraging students to review their previous learning, we feel that losing four out of sixteen weeks is unacceptable. Also, the instructor feels that the addition of a topic or two to each individual exam would leave students enough time to finish their tests in a single class period.

With the removal of significant figures and one exam, we free two weeks of class time that can then be used for more important topics. In the first offering of Physics 140, the coverage of motion diagrams, motion graphs, and their interrelations (which involves basic calculus concepts) was virtually nonexistent. With two additional weeks of class time, we can ensure that these topics are explored in sufficient depth and that students will feel able to apply calculus concepts, such as slopes and areas, in the context of future physics classes.

The coverage of vector concepts was also not as extensive as we had hoped. This was largely on account of the textbook which, while otherwise being a very good fit for the class, did not contain any vector-related materials. While we encouraged students to consult one of several given resources on the subject before coming to class, the lack of a mandatory reading quiz meant that most students had no pre-class exposure to the subject. The instructor noticed that this somewhat hampered students' understanding of vectors, which is traditionally a difficult subject for students in any introductory physics course. As a result, more class time was spent on introducing basic definitions to students that on building proficiencies.

To remedy this problem, we intend to develop a set of reading material for students that is in line with the textbook's style. This material will be required reading before class, as are all other textbook reading assignments, and will be assessed by a dedicated reading quiz. This way students will have been forced to resolve some of the standard initial questions before coming into class. The instructor found this model to work very well with the other subjects introduced in

Physics 140, and the clear contrast with students struggling throughout the vector unit is strong evidence that it should be consistently applied.

In hindsight, the set of learning outcomes, which has formed much of the foundation for this assessment of Physics 140, were developed without much thought of their ultimate diagnostic role. As the previous section's assessment showed, some of the learning outcomes constitute relatively unimportant skills, while others lump together several distinct major proficiencies. We have, therefore, made several changes to the original list of goals and outcomes. We list these changes in bullet point below, with learning outcome abbreviated throughout

- LO 1a is too low-level a skill to be eligible for inclusion as a learning outcome. Consequently, it will be subsumed under LO 1d.
- The new LO 1a will deal with circular geometry, which currently is only implicitly included under LO 1b. This topic is an important learning outcome in its own right, and deserves inclusion in the syllabus.
- LO 1b gets split into two learning outcomes, LO 1b and 1c. The former will deal with proper matching of trigonometric variables and functions to different right triangles ("Should I use sine or cosine here?"), while the latter will deal with actual application of trigonometry in the context of problem solving.
- LO 2 is at present very vague, with even the authors not always knowing when to apply it to a given activity. As such, it will be removed entirely, with the element about "proportional reasoning" moved into a separate learning outcome within section 4. In this context, the learning outcome will more effectively assess the ability of students to work with proportionalities or power law relations.
- LO 3a needs some rewording, with the emphasis placed less on specific visual representations, force diagrams in particular, than on the general process of using visual representations for problem solving.
- An additional learning outcome will be added to section 3 to address students' ability to understand the layout and general format of a graph. For instance, skills related to understanding the differences between the dependent and independent axes, which we assumed students would be familiar with before entering the course, often needed to be explicitly developed in class.
- The widowed learning outcomes 4a and 4f will be removed from the list entirely. The first is extremely vague and wasn't operationally useful for diagnosing students' understanding of course materials. The last, while representing an important skill, isn't used until higher-level physics classes, and thus is outside of the scope of Physics 140.

The new set of learning goals and outcomes that will be used for the second offering of this course will be that the students should be able to:

Student Learning Outcomes for Goal 1: Trigonometry Fluency

- (LO 1a) Compute the arclength and angles for circles using the radian unit.

- (LO 1b) Determine the proper trigonometric function to use given two sides of a right triangle.

- (LO 1c) Use trigonometric functions, the law of sines, and the law of cosines to compute angles, lengths, and other magnitudes.

- (LO 1d) Sketch vectors, their components, and the vector sum.

- (LO 1e) Apply trigonometric concepts in finding the components and algebraic sums of vectors.

Student Learning Outcomes for Goal 2: Conceptual Visualization

- (LO 2a) Determine the correct visual tool, such as a motion diagram or graph, to use in setting up a problem.

- (LO 2b) Read and interpret the information given in a graph.

- (LO 2c) Construct graphs showing relations between physical quantities.

- (LO 2d) Calculate the slope and other physical properties from a graph.

- (LO 2e) Predict physical characteristics of motion from position, velocity, and acceleration graphs.

Student Learning Outcomes for Goal 3: Problem Solving

- (LO 3a) Manipulate algebraic expressions in symbols to solve for unknowns.

- (LO 3b) Appraise the validity of a potential solution to a physics problem.

- (LO 3c) Manipulate units in algebraic problem solving.

- (LO 3d) Relate different physical quantities using ratios and units.

- (LO 3e) Use proportions, both linear and nonlinear, to calculate unknown physical quantities.

Although this set of learning outcomes will likely undergo further changes in future iterations of the course, at present we see them as a large improvement over the learning outcomes used in the trial run of Physics 140.

To complement this change in learning outcomes, the course diagnostic used to assess students' progress through the class will be changed before the next iteration of Physics 140. As we mentioned earlier, the diagnostic used was not an ideal assessment tool due to the content of the diagnostic being relatively mismatched with the set of learning outcomes. To remedy this, we plan on writing the next diagnostic with the explicit goal of achieving reliable, statistically significant information about students' mastery of the new set of learning outcomes. In order to achieve this goal, we will try to lay out the questions such that there is roughly an even spread in the number of questions pertaining to different learning outcomes. Concretely, this means there will be less of an emphasis on more arithmetic concepts, and more of an emphasis on algebra and trigonometry. This is as it should be, since these concepts are the ones that are actually discussed at the greatest length in class. This new diagnostic should be in place by the spring of 2015.

Finally, we intend to take at least some of the questions from the different exams that were given in the initial implementation of Physics 140. This will have the effect not only of making the diagnostic a more integrated part of the course, but also of giving the instructors more freedom to pick and choose questions that seem most relevant.

Hopefully, these changes taken together should allow the next iteration of Physics 140 to overcome some of the difficulties encountered in our first offering of the course, while still retaining the positive learning gains made by students.

5. Expansion: Outline your plan for continuation of the redesign project, which should include (a) an indication of the approximate number of sections of the course that will be taught using the redesign in fall 2014 and spring 2015 and (b) who the likely instructors will be and/or how those instructors will be recruited.

(a) The immediate future plans for offerings of Physics 140 are modest, as there is currently only demand for single section. Physics 140, being an entirely new course, is not well known; moreover, it does not count towards a student's degree and delays his or her graduation date. Through a vigorous recruitment campaign, we enlisted enough students for the pilot course, but, understandably, student resistance to the course remains high. It seems prudent, therefore, to keep the number of sections at a minimum until the class's reputation increases and its usefulness becomes known to students. (We, of course, will continue actively recruiting students. We will widely circulate the data from this report, as well as, any longitudinal studies of the pilot-class students as proof of the class's ability to improve student success.)

Concurrently, UNM's Physics and Astronomy Undergraduate Committee along with the Office of Institutional Analytics is investigating the possibility of a placement criteria for Physics 140. While the exact nature of this criteria is still unknown, we imagine using a cutoff prerequisite-course grade or minimum ACT (or some other similar placement exam) score to identify students for Physics 140. This investigation should be completed by the end of the fall 2014 semester, and if a clear criteria can be found which leads to increased Physics 140 enrollment, the number of sections offered would likewise be increased.

(b) Instructors:

Dr. Kent Morrison has been recruited for the fall section while Dr. Morgan-Tracy, who piloted the original class, will once again teach it in the spring. Dr. Morrison is fully invested in the inverted classroom approach that is central to this class and has been appraised of this report's results. He is eager to improve the course by enacting the recommended changes.

6. Sustaining: A plan for sustaining the curricular and pedagogical innovations of the redesign. This section should include (a) achievements and/or intentions for accessible curation and dissemination of redesigned instructional components, (b) plans for continued work by the team to assess outcomes and make adjustments for continuous improvement, and (c) plans for assuring successful, self-efficacious implementation of the redesigned course elements by instructors who were not part of the original team.

(a) During the development of course materials, we used a "course wiki" to share the worksheet drafts and finished worksheets. We now maintain a course webpage which contains finished worksheets and assignments from the text. This webpage will be an ongoing resource for future instructors.

(b) Plans for Continuous Improvement:

During the preparation of this assessment, we noted several areas in which the course may be improved. In addition to better aligning our pedagogical goals with what we feel the students most need, we also identified areas of weakness (specifically in vectors and in motion diagrams) and we have developed new worksheets covering this material. Additional time can be carved out by removing one classroom exam.

To enable continuous course improvement, the course webpages include areas with trial worksheets, finished worksheets, exams, and other course material. The fall 2014 instructor (Dr. Kent Morrison) has kindly agreed to post his observations on the efficacy of the various worksheets and on student engagement in a password protected part of this website. He has also expressed some interest in continuing to develop new materials and worksheets. Essentially, we view the course webpage as a library of worksheets developed not only by the original team, but supplemented by future instructors. The complete list of web-based materials we developed and used in this course is:

Tests from the class -
https://drive.google.com/folderview?id=0B1GZK2GRT3ULZFZpajY4dklWTWM&usp=sharing

Backup documents from the wiki -
https://drive.google.com/folderview?id=0B1GZK2GRT3ULY01iQVFUTFlqUDA&usp=sharing

All the worksheets that were used in class -
https://drive.google.com/folderview?id=0B2Ymgt04PCi2SEpFdUcwNDFMVkE&usp=sharing

The complete collection:
https://drive.google.com/folderview?id=0B1GZK2GRT3ULNUNCS0YwNjlPTE0&usp=sharing

(c) Plans for implementation:

As mentioned above, the instructor for the fall semester is Dr. Kent Morrison, who has a great deal of experience in teaching all three semesters of engineering physics. Dr. Morgan-Tracy will resume teaching this course in the spring.

This course was developed from scratch by the design team; it is not a redesign of an existing course; therefore, there will be little tendency for future instructors to “revert” to a pre-existing course format or approach. Rather, the course has been integrally designed to be taught in an “inverted” studio classroom. The textbook and course material itself are ill-suited to a conventional classroom, as there is very little explanatory or descriptive material; rather, almost all of the material is focused on *doing.* We were able to design the course in this way because we are drawing on mathematical tools the students have seen in their mathematics coursework. While they have seen the math, they have little experience at application to physics or “story” problems, and have not yet practiced integrating different mathematical concepts to arrive at solutions for real-world problems. These higher level skills are best acquired, we believe, through supervised practice. That will continue to be the essence and focus of this course, regardless of the instructor.

Finally, our perception of the need for such a course is based on our experiences (and experiences of other instructors) in freshman engineering physics, where we found a large fraction of students that struggled with integrating mathematical concepts. As UNM student tracking becomes more sophisticated, we hope to be able to identify students who may struggle, not merely with engineering physics, but with their entire engineering curriculum *before* they begin engineering physics. These students would then be ideal candidates to populate this novel course in the future.