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Student Performance Enhancements via an Active, Integrated Engineering Physics Course

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Abstract

Incrementally, over the past five years, an engineering physics (mechanics) course has been completely restructured by combining the previously separate lecture, laboratory, and recitation components into a single, integrated learning environment. Moreover, many active learning components have been incorporated into the class. These include interactive laboratories, peer instruction, and use of electronic clickers. These changes have been made in phases over several years and each change was assessed using the Force Concept Inventory (FCI) assessment test, given on the first and last days of class. Results from the Force Concept Inventory test show that the overall gain in performance has tripled as a result of the combined effects of these changes. Additionally, course grades show that the overall pass rate for the course has increased by over ten percentage points. This paper describes the restructuring of the course to integrate the lecture, lab, and recitation components. It also covers how the traditional laboratories have been replaced with interactive laboratories and includes methodologies and best practices. The paper addresses the peer instruction method (also known as think-pair-share) including formation of concept questions and best practices. Five years worth of pre- and post-class assessment data are presented and show that significant performance gains were achieved as each of the elements (blended lecture and lab, interactive laboratories, and peer instruction) were incorporated. Lastly, the paper describes the current initiative to remove the remaining lecture component from the course, making the class completely active. This will be accomplished through the creation of videos covering the day's technical content that students must watch prior to class.

1.0 Introduction

The material covered in an engineering physics sequence includes vital foundational concepts used throughout a student's engineering education. Without a strong physics education, engineering students are often destined to struggle in future technical classes. Perhaps even more importantly, the engineering physics sequence provides an engineering student with numerous "soft" skills. These courses set the tone for future learning; they teach students problem solving skills, critical thinking, experimental inquiry, and the importance of developing a good work ethic. If done properly, these courses can teach students the importance of acquiring a conceptual understanding rather than rote memorization of how to plug into equations. When successful, these courses teach students how to digest a problem, sort out the relevant concepts, make assumptions, and reflect critically on their analyses. Conversely, if done poorly, students begin their engineering education unprepared, either in conceptual/technical knowledge, problem solving skills, or both.

Throughout its long history, physics has been taught in nearly the same manner – via lectures, often supplemented by a laboratory experience. Several decades ago physics educators recognized the need for change; students were not learning the concepts and/or were not engaged by the methods used in physics education.[1-4] Since then much progress has been made in physics education research. Efforts have led to new methods that reduce or remove lecture in favor of active learning methods,[5,6] focus on learning conceptual knowledge[7] and enhance the experimental/laboratory component.[8] Application of a standardized physics assessment test[9] by numerous physics educators has shown that these methods provide substantial gains over the traditional lecture format. Details of these methods, their assessment, and the evolution of physics education research have been documented in several books on physics education strategies.[5,10,11]

Despite these advances, many physics instructors continue to use the traditional lecture/lab format or have only incorporated a few select techniques. This paper describes the author's experience over the past six years as a traditional lecture-based physics course has undergone a phased transformation to a completely active learning experience. These phases included: blending the separate lecture, laboratory and recitation elements into a combined experience; development of interactive laboratories; introduction of electronic response systems (clickers); incorporation of peer instruction (a.k.a. think-pair-share); development of an active learning workbook; and, the removal of all remaining lecture elements in favor of pre-class videos (i.e. a flipped-classroom element). Each year, as new features were phased in, pre- and post-course assessments were conducted using the Force Concept Inventory (FCI) test.[9] This paper describes the evolution of the class, the methods that were used, and the results of the annual assessment tests. It also presents best practices/advice for each of the methods based on experience gained over the past six years.

2.0 Background

At the author's institution, as recently as 2008, the Engineering Physics I (Mechanics) course was taught in the traditional style, consisting of separate lecture, laboratory, and recitation components. Over the past six years the course has been completely transformed and the evolution in student learning has been assessed at each step along the way. This section describes both the original and new structure of the course. At the author's institution, a small liberal-arts based college with an engineering program, the engineering physics classes are taught by the engineering faculty. Over the past 7 years, the author (a mechanical engineering faculty member) has taught both sections of the engineering physics (mechanics) course each spring, including offerings with the original structure. This arrangement has provided the author with the flexibility to implement and monitor the various curricular changes described in the paper.

2.1 Original Structure

Under both the original and new structures, the Engineering Physics I class is a five-credit course. Prior to the spring 2009 offering, the class was taught as a three-credit lecture (meeting three hours per week), a one-credit laboratory (meeting three hours per week), and a one-credit recitation (meeting one and a half hours per week). In total, the students were occupied for seven and a half hours per week with "in-class" work.

In the spring of 2008, which was the last offering using the old structure, there were three sections of the lecture, taught by a faculty member (the author), and five sections of the laboratory, taught by a laboratory instructor. All of the recitation components were also taught by the author. In 2008, the lecture and recitation sections each operated with approximately 27 students (80 total students) while the laboratory sections had approximately 16 students each.

2.2 Problems with the Old Structure

Having taught the course in the traditional structure for thee offerings, the author found that for each offering the typical failure rate (where a failure is defined as a grade of D, F, or a withdrawal), was 50% or higher. These poor results led to critical reflections on the course and, through anecdotal investigation, a number of problems were noted. In its original structure it was observed that: the students retained little from the lecture; the lecture and laboratory components were disjointed and did not compliment one another; and, the laboratories themselves, while occupying a significant amount of the students' time, were not effectively reinforcing the material.

During one of the offerings with the old structure, the author instructed one of the laboratory sections which provided an excellent opportunity to investigate the contributions (or lack thereof) the laboratories made to the learning process. Those observations led to several important observations on the laboratory component:

- During the lab the students suffered from "cookbook syndrome". It seemed that they were preoccupied with the rote following of instructions rather than intellectual thought. Students would not pause prior to an experiment to predict what might happen nor would they reflect on their results. It was not uncommon to see students collect nonsensical results, write them down, and move on without sensing that something was wrong.
- The setup and tear down of the lab equipment took up a significant amount of time and the students got little or nothing out of it.
- Since the labs were self-paced and each group was allowed to leave when finished, the students took on a race mentality were it seemed they were more interested in getting done (and getting out of lab) rather than taking their time and learning from the lab.
- Despite using a fairly popular laboratory textbook, the labs were disjointed and were often out of phase with the lecture material. The labs were further disjointed due to using a separate laboratory instructor who was not "in tune" with what was discussed each day in class.
- The laboratory equipment was expensive and took up a significant amount of storage space.

2.3 New Structure

Given the problems noted with the original structure, and the desire to improve student comprehension and performance, the author set out to reformulate the physics class. The originally separate lecture, recitation, and lab components were abandoned in favor of a blended class that incorporates all of those elements.

The new course structure was designed to meet three times per week, with each meeting being two and a half hours long. This gave the same amount of instructional time per week as the original structure (7.5 hours); as such, it remained a five-credit-hour course. The course continues to serve a total student population of between 80 and 90 students each spring. However, the operation of the course was changed substantially, including the classroom facilities and the role of the instructors, both of which are described in the next section.

2.4 Classroom & Instruction Changes

As part of the switch to the new structure, a special classroom was built for physics instruction. One of the goals of the restructured course was to incorporate active learning and stimulate student interactions. The existing lecture room was not conducive to those goals, so a dedicated physics classroom was established. The new classroom was configured with a series of workbenches designed to foster group interactions. Students sit in groups of 3 at lab tables. The tables are configured such that any group of students can interact with several other groups, if needed. The capacity of the classroom was also increased by 50% so that in the new structure 45 students can be accommodated (compared to 30 in the original structure.) It should be noted that there is no need for special tables and any environment that can be made conducive to discussions with small groups of neighboring students will work. Additionally, provided the necessary physics lab equipment exists, the only cost expenditure required for the classroom changes was for the purchase of the electronic clicker system, which was just over a thousand dollars. Even this expense can be avoided by simply giving each student a pack of 5 different-colored index cards lettered A through E which they can raise in response to a concept question. (This method was used for one semester before switching to electronic response units.)

Because of the active nature of the new course structure, there is a need for considerable interaction between the students and instructor. To facilitate those interactions, each two and a half our class is staffed by two instructors. One instructor functions as the lead and the other acts as a "floater". When the students are engaged in active learning, which is a majority of the time, both instructors float among the class and interact with the students. In addition to helping the students during the active learning experiences, the lead instructor orchestrates the course, controls the pace of the class and leads discussions. Without the need for separate laboratory sections, the laboratory instructor, who functioned independently in the old structure, now joins the lead instructor in the classroom and serves the role of the floating instructor. In terms of contact hours with the students, the staffing requirements for the new structure are exactly the same as they were in the old structure.

To incorporate active learning within the classroom, several innovations developed through physics education research were incorporated. Those methods include peer instruction, interactive labs, use of electronic clickers, and, for the upcoming Spring 2014 semester, the use of online lecture videos to remove the last vestiges of lecture from the classroom. Each of these methods are described in the next section.

3.0 Methods and Metrics

3.1 Integrated Class

As noted in the previous section, the main structural change was to blend the original lecture, laboratory, and recitation components into an integrated experience. However, that was just the beginning. The goal was then to fill the new structure with active learning methods proven effective through research in physics education. An additional goal was to structure the course as a series of packets, each no more than 15 minutes in length since research shows the average student attention span is at most 15 minutes.[12] In the new structure, during any given class period the goal is to use a host of active learning methods, regularly moving back and forth between the methods. The remainder of this section describes the methods that have been used thus far.

3.2 Peer Instruction

Complete details on the Peer Instruction method can be found in Mazur's book[7] and only a brief outline is presented here. In the peer instruction process, students are presented with a multiple-choice question that address a conceptual topic. (Many refer to these as "concept questions" or "think-pair-share" questions.) After presenting the students with the question, they are given a brief period to think about it and respond using their electronic clickers. The students initially respond individually and this process normally takes between 30 seconds and two minutes. After submitting their own responses, the students are allowed to discuss the question with their group mates, and if they like, with other groups and/or one of the instructors. After the group discussions, the students answer the same question again. Having listened in on the student discussions and viewed the responses submitted via the clickers, the lead instructor then discusses the question and tries to clear up any misconceptions.

3.3 Interactive Labs

The goal of the interactive laboratories is to eliminate the problems with traditional laboratories noted in section 2.2. In an interactive laboratory, the instructor controls a single, pre-configured laboratory setup at the front of the room. This eliminates the unproductive time required when students setup and tear down the equipment themselves. It also allows the instructor to control the pace of the experiment and to help guide the students through the experimental process by requiring them to evaluate, predict, and reflect. In a typical interactive laboratory experience the instructor first reviews the experimental setup with the students to make sure they understand the experiment, what data is being collected, and how. Next, students are given a short period to think about the experiment and ask questions. Then each student makes a self-prediction for the outcome which can take various forms such as:

- Creating a drawing: Example: "Draw the proper free-body diagram that would apply for this experiment."

- Predicting the shape of a graph. Example: "A cart is released from rest at the top of the ramp. Predict the position, velocity and acceleration graphs as a function of time."
- A deductive conclusion. Example: "If the spring is compressed twice as much as the previous experiment, how much farther will the cart travel up the ramp?"
- An analysis. Example: "In the experiment that was just done, what must the spring constant have been?"

In many cases the electronic clickers can be used for the predictions. For example, as an alternative to asking the student's to construct a predictive graph, one can ask "Which of these graphs would must likely represent the cart's velocity versus time?"

Following the self-predictions, the students then discuss with one another what the expected outcome of the experiment should be and submit a revised prediction. The experiment is then conducted and the results are discussed. Typically the entire process takes five minutes or less from start to finish. These experiments can then be delivered to the students throughout the class period in a just-in-time manner to most effectively link the experiments to the concepts and theories. It is also useful to note that the interactive laboratories are effectively just concept questions (described in section 3.2 on peer instruction) with the addition of an experimental apparatus.

A secondary benefit of the interactive laboratories is that they significantly reduce costs and storage requirements by eliminating the need to have many duplicate setups. Additional material on interactive labs can be found in the book by Sokoloff and Thornton.[8]

It is important to note that the interactive laboratories are not simply demonstrations that the students passively observe. During a typical interactive laboratory the students: provide input on the experiment, the equipment used and its setup; do pre-analysis to develop the supporting theory; provide input on how to collect and process the data; perform analysis of the results; discuss sources of error; and suggest potential improvements.

3.4 Electronic Clickers

To facilitate rapid feedback from the students during class, electronic response units ("clickers") have been incorporated into the new course structure. The electronic response units are used in conjunction with the pre-class reading quiz, with all of the peer instruction questions, and with many of the interactive laboratory experiences. The data collected from these units have proven extremely valuable for assessing student comprehension, for identifying where additional discussion is needed, and for pacing the class.

3.5 Implementation

All of the above methods have been incorporated into a class workbook developed by the author. [13] The students complete the workbook throughout the course of the semester as opposed to taking lecture notes. The workbook serves as the framework for presentation of the material through the active learning methods described in the previous sections.

A typical two and a half hour classroom session proceeds as follows. The class begins with a short reading quiz (4 to 5 questions) to make sure the students have done the pre-reading assignment. The reading quiz is administered using the electronic clickers and takes approximately two minutes. Next, a portion of the day's conceptual material is reviewed via a short lecture/discussion. This process normally takes less than fifteen minutes. A series of peer instruction questions are then presented to further develop the concept, assess comprehension, and correct misconceptions. Finally, a short interactive laboratory is conducted. The process then repeats itself during the remainder of the class until all of the day's reading material has been addressed.

Of course there are many variants to this model. For example, sometimes it is better to introduce the material through an experiment, proceed through some concept questions, frame the theory, and then return to more interactive labs and concept questions. While the order varies, the main goal is to intersperse periods of lecture, discussion, peer instruction, interactive laboratories, and group problem solving in short packets lasting no more than 15 minutes.

It should be noted that there is no standard formula for every class. In many class periods there is no new theory presented. Also, the interactive laboratories and peer instruction are often intertwined and not presented as distinctly separate activities.

3.6 Flipped Classroom Videos

To date, considerable effort has been made to minimize the amount of time spent lecturing and to break any lecture time that is required into small packets distributed throughout the class period. For the upcoming offering of the class (spring 2014), the next phase in the redevelopment of the physics course will be to remove the remaining lecture components and incorporate them into video training modules which the students must watch prior to class. As part of these training modules, the students will be required to complete portions of their active learning workbook before class. (This will be checked during the first several minutes of class and will replace the need for the reading quiz). Removing of the last vestiges of lecture will free up more class time for additional concept questions, interactive laboratories, and group problem sessions. It is hoped that this will further improve student performance. As with the other methods which have been incorporated, the impact of this change will be assessed via pre- and post-course administration of the Force Concept Inventory test.

3.6 Force Concept Inventory (FCI) Assessment

In moving from the original structure to the new structure (which itself is a moving target), the various methods described above were incorporated in phases over a period of 6 years (including the planned changes for the upcoming offering). The FCI assessment test was administered each year (pre- and post-class) as the changes were incorporated. The FCI test consists of 30 multiple choice questions that examine conceptual knowledge of mechanics (i.e. there are no quantitative questions). According to Hake[14] who has studied application of the FCI test in over six thousand students, the best metric for presenting the results is the normalized gain given by

$$G = \left[\frac{(post\ class\ average) - (pre\ class\ average)}{100 - (pre\ class\ average)}\right] \quad (1)$$

The gain compares the overall improvement in the FCI test average to the maximum improvement possible. Based on his extensive data set, Hake found that courses with interactive engagement (IE) had larger gains than traditional (T) lecture-based classes. Hake also presented correlations for the gain based on the structure of the class:

Traditional lectures: $G_T = 0.23G_{max}$ (2)

Interactive Engagement: $G_{IE} = 0.48G_{max}$ (3)

In the above relations G_{max} represents the maximum gain possible (i.e. 100 – pre test score). Results for the IE courses had more scatter than the traditional, lecture-based courses since they depend on the extent to which the interactive methods were used. Hake found that the gains in the IE courses were bounded by

IE Range: $0.3G_{max} < G_{IE} < 0.7G_{max}$ (4)

The above results show that active learning methods improve performance on the FCI test. Also, the data give an upper limit on what has been attainable thus far.

In the subject study, the FCI test has been given each of the past 5 years as the changes noted previously were phased in. The results from those assessments are described in the following section.

4.0 Results

Table 1 gives the results from the FCI test over the past 5 years. The table gives the number of students enrolled, N, the pre- and post-class averages on the FCI test, the average FCI gain calculated using equation (1), and the pass rate for the course.

Table 1: FCI Assessment Results

	N	Pre	Post	G	Pass Rate	Phase**
2008	80	49	-	11.7*	52.5	0
2009	85	47	65	18	52.9	1
2010	71	49	78	29	63.4	2
2011	74	50	83	33	66.2	3
2012	86	51	83.5	32.5	65.1	4
2013	78	48.5	81.5	33	59.0	4

* Estimated based on equation (2)
**The Phase refers to the structure of the course, as delineated below:

- Phase 0 – the course was offered in the traditional lecture/lab format described in section 2.1
- Phase 1 – the first offering of the course with the lecture, laboratory, and recitation blended together, as described in section 2.3. A modest amount of active learning was introduced via a reduced suite of interactive laboratory demonstrations and classroom exercises.
- Phase 2 – The suite of interactive laboratories was expanded significantly and significant revisions were made to the activities. Overall, a substantial amount of active learning was added.
- Phase 3 – Peer instruction and electronic response units (clickers) were included. The first version of the active learning workbook[13] was introduced. The interactive laboratories where further revised, broken into smaller segments, and distributed more evenly throughout the course to better mesh them with the lecture content.
- Phase 4 - Modest revisions to the interactive laboratories, peer instruction questions, and the active learning workbook were implimented.

Data for 2008 represent the last time the course was offered in the original lecture/lab format described in section 2.1. It is important to note that the FCI test was not administered in 2008. The gain of 11.7 was estimated using equation (2), which Hake[14] has shown to be a good correlation for lecture-based classes. The pass rate for the course was 52.5% which was typical for offerings prior to 2008 (using the traditional lecture/lab format). In calculating the pass rate, grades of D, F or W (withdrawal) were considered failures.

The initial blending of the course and the introduction of a reduced set of interactive laboratories (Phase 1), boosted the gain to 18. This result falls within the bounds of other Interactive Engagement courses covered by equation (4), for which the range in gain would be 15.9 to 37.1. Given that only a limited amount of active learning was incorporated in this phase of the course's development, it makes sense that the gain would be closer to the lower limit.

Table 1 show that continued efforts to phase in more active learning have resulted in significant improvements to both the FCI gain, G, and the pass rate of the course. From equation (4), the upper limit on gain for students whose pre-test score was 50% is G_{max} = 35. The gains from the three most recent offerings of the course are all around 33 and are approaching the upper limit of the gains reported by Hake.[14] Additionally, over the last three years the pass rate for the course has averaged 63.4% compared to an average of 51% for the four year span from 2005-2008 using the traditional structure. This represents a growth in pass rate of over 10%.

These results show the switch to the new course structure and the implementation of active learning methods have proven to be very beneficial. Throughout the implementation process a significant amount of insight was gathered on the active learning methods used. The following section gives tips and advice based on the author's experiences restructuring the course.

5.0 Best Practices

5.1 Peer Instruction

For those looking to incorporate or improve the use of peer instruction, the book by Mazur[7] is a valuable resource. His book not only describes the method and discusses best practices but also includes numerous concept questions. Based on the author's experiences using the method, the following suggestions are offered (many of which line up with Mazur's suggestions):

- Invest a significant amount of time constructing the questions; they are critical. They should be made difficult enough to cause the students to think but not so difficult that a majority of the students cannot figure them out. Occasionally, I will incorporate a question where my goal is to get 90% or more correct; I refer to those as "Are they with me?" questions. However, for a majority of the questions I tend to shoot for correct response rates between 60 and 75% when the students first answer on their own. If the individual response rate is less than 50% correct, there are not enough students who understand the concept to have a productive discussion.
- Work hard at generating the incorrect answers for the questions. The incorrect answers should expose the common misconceptions so that one can identify what is keeping the students from understanding the problem. That knowledge can also be used to tailor the discussion to address those misconceptions.
- Limit the questions to a single concept. In introductory physics courses the students have enough trouble with one concept and bringing in multiple concepts is usually a recipe for low response rates. For more complex situations, it is best to break it down into a sequence of concept questions where each question builds upon the previous one.
- Listen to the students when they discuss their answers. This will help identify the misconceptions they are having, as their conversations are usually very

enlightening. Also, I often find students explaining things in a very elegant way and often have those students explain it to the class. I find that sometimes the best explanations come from those who are just learning the material as they see it differently than someone who is intimately familiar with it.

- Reflect on and revise the questions after each offering. The electronic clicker data makes it very easy to review the responses to every concept question. Questions which are too easy, too hard, or confusing/misworded should be revised. Also, as noted above, be sure to revise the incorrect answers as you learn more about the common misconceptions through listening to the student discussions.
- Include conceptual questions on exams. This will reinforce the importance of conceptual knowledge and will encourage students to take the conceptual questions in class seriously and to study them.
- Make the responses to the questions part of the course grade. This helps ensure that the students will take them seriously.
- Review the electronic student responses prior to the next class and be sure to revisit any concepts that were particularly troublesome.
- Get students vested in the answer. While this is last in the bullet list, it may be the most important. One of the roles the lead instructor can take is to pique student curiosity and even spark a friendly competitive spirit. It is very rewarding to hear students debate answers, wager who is correct, and be excited to learn the correct answer. If done properly, the peer instruction process can be a fun way to develop student interest.

5.2 Interactive Laboratories

As noted earlier, the goal with the interactive laboratories is to get the students engaged by guiding them through the important process of synthesizing, evaluating, predicting, and reflecting on a scenario. Strategies for making this method effective are given below, many of which are similar to those for the peer instruction method:

- Create an atmosphere of curiosity. As with the concept questions discussed in the previous section, it is important for the instructor to establish an inquisitive atmosphere.
- Setup and debug the experiments ahead of time; this avoids unproductive downtime.
- Focus the experiments on a single concept. For more involved scenarios, break it down into a train of experiments.
- Keep the experiments short. Nearly all of the interactive experiments I employ last less than a minute and many are just seconds in length.
- Collect data in real time and display live results. Experience shows that the students enjoy seeing the data as it is created. This works much better than doing the experiment first and then displaying the results afterward.
- Couple the interactive labs with the concept questions. I frequently use the labs to "reveal" the answer to a concept question.

- Use the labs to create interest for a discussion or a series of concept questions. In this instance, the experiment is used to pique curiosity for subsequent learning rather than to reveal a result. This works well for situations where students have common misconceptions.

5.3 Electronic Response Units

The clickers serve as an invaluable tool when implementing the active learning methods.

- They provide immediate feedback which helps to guide the pace of the class.
- They make grading easy. It is highly recommended that points be assigned for each clicker response to motivate students to take their answers seriously.
- They can be used to take attendance.
- Answering with the clickers and "unveiling" the results, when done properly, can be fun.

6.0 Student Feedback

While the results in section 4.0 show a marked improvement in conceptual knowledge based on the FCI test and a significant increase in the pass rate, it is also important to consider feedback from the students who have taken the course. Overall, the student reviews of the course in its new structure are better than those using the traditional lecture/lab format. Numerous positive comments have been collected each semester that support the integrated, active nature of the course. In the category of "What did you like most about the course?" the most prevalent comment is that the students feel the active course structure keeps them engaged and helps in learning the material. Conversely, there have not been any comments suggesting that the course revert back to being offered as a separate lecture and lab (which is how other lab science courses are still offered at the author's institution including those in chemistry and biology). Students also frequently comment that they like the peer instruction questions, the group discussions, and the use of the electronic response units (clickers).

The most prevalent negative comment is typically directed at the length of the class, which runs two hours and half hours three times per week. However, the frequency of this comment has dropped significantly in recent years, most likely as part of efforts to increase the amount of active learning while reducing the amount of lecture/discussion.

7.0 Summary & Future Directions

This paper describes the transformation of an engineering physics class from a traditional lecture and laboratory to a fully integrated classroom experience using a combination of active learning methods including peer instruction, interactive laboratories, and the use of electronic response systems. Continuous evaluation of the transformation was done using the FCI test. Assessments using this test show that the methods have been extremely successful. Pre- to post-class gains on the FCI test have increased substantially as a result of the changes and are now approaching three times those of a traditional lecture-based class. Changing the traditional class to the new structure required a substantial time investment. However, the rewards are significant; hopefully the results contained herein will motivate and guide others to make similar changes.

Future plans are in place to remove the remaining lecture portions of the class by moving them to pre-class video modules. The time freed up will be used to incorporate more active learning experiences. Results from those efforts will be available for the conference presentation.

References

1. Halloun, I.A., and Hestenes, D., "The initial knowledge state of college physics students," *Am. J. Phys.* **53**, 1056-1055, (1985).
2. Halloun, IA, & Hestenes, D., "Common-sense concepts about motion," *Am. J. Phys*. **53**, 1056-1065, (1985).
3. Tobias, S., *Revitalizing Undergraduate Science; Why Some Things Work and Most Don't*, Tucson, AZ: Research Corporation, (1992).
4. Tobias, S., *They're Not Dumb, They're Different: Stalking the Second Tier*, Tucson, AZ: Research Corporation, (1990).
5. Laws, P., "Calculus-based physics without lectures," Phys. Today **44**(12), 24-31, (1991)
6. Laws, P., *Workshop Physics*, J. Wiley, (2004)
7. Mazur, E., *Peer Instruction: A User's Manual*, Prentice Hall, (1997).
8. Sokoloff, D. & Thornton, R., *Interactive Lecture Demonstrations*, J. Wiley, (2004).
9. Hestenes, D., Wells, M., & Swackhamer, G., "Force Concept Inventory," Phys. Teach. **30**, 141-158 (1992)
10. Redish, E., *Teaching Physics with the Physics Suite*, J. Wiley, (2003).
11. Knight, R., *Five Easy Lessons: Strategies for Successful Physics Teaching*, Addison Wesley, (2004).
12. Wankat, P., *The Effective Efficient Professor: Teaching, Scholarship, and Service*, Allyn and Bacon, Boston, MA, (2002)
13. Garrison, T., *Exploratory Physics: An Active Approach to Learning Physics*, 2014 Version, currently self-published, (2014).
14. Hake, R., "A six thousand student study of mechanics test data for introductory physics courses," *Am. J. Phys*. **66**(1), 64-74, (1998).