Engaging Physics Students to Go Beyond the Quantitative

Clemson University
“Deb Katz’s approach is to tie entire chapters around interesting and relevant case studies that will keep the students reading and wanting to know more. She has been able to do this without compromising on the delivery of core concepts the students need for their futures in science and engineering. In fact, I think the approach will help the students remember the core principles better.”

---

**Jason Brown**
Instructor, Clemson University

For many physics instructors, maintaining motivation and building engagement to better support students with various learning challenges can be difficult. Students often view physics as a series of unrelated facts, concepts, and equations that have little or no bearing on their everyday lives. This disconnect can often lead to disengagement and lack of motivation. Additional common student learning challenges include: difficulty connecting mathematical formalism and physics concepts, assembling diverse concepts, and overcoming common preconceptions (or misconceptions). Physics education research (PER) suggests that by addressing student preconceptions and focusing on conceptual learning, students will achieve a much deeper understanding. Students who connect physics to the real world and confront preconceptions will be better engaged and more equipped to build the necessary conceptual framework to achieve better learning outcomes.

To meet the needs of today’s learners, Cengage Learning is publishing a groundbreaking calculus-based physics program, *Physics for Scientists and Engineers: Foundations and Connections* by Debora Katz that will engage students in a modern, interactive way. By leveraging physics education research best practices and her extensive classroom experience, the author addresses the areas students struggle with the most. How Dr. Katz deals with these challenges—with case studies, detailed two column examples, and student dialogues — will assist students to go beyond the quantitative.

**Clemson University Study—An Introduction**

In spring 2014, Cengage Learning conducted a semester long class study of *Katz, Physics for Scientists and Engineers: Foundations and Connections* (Advance Edition) at Clemson University. Founded in 1889, Clemson University is a public research university located in Clemson, South Carolina. The current undergraduate enrollment is around 17,000, and the student/faculty ratio is 16:1. Over 800 introductory physics students were involved in the study. Students were required to take a pre-survey at the beginning of the semester to share their study habits, motivation, and interest in the subject matter before using the textbook. At the close of the term, students completed a post-survey to share how the text impacted their conceptual understanding. From this pool of 800 students, 588 students completed the pre-survey and 167 students completed the post-course survey.
AUTHOR’S CASE STUDY APPROACH MOTIVATES STUDENTS AND MAKES ABSTRACT CONCEPTS CONCRETE

Debora Katz’s case studies, many based on real-world experiences such as news items and historical events, draw readers into the story of physics and make concepts understandable. The case studies are introduced and revisited throughout the chapters in interactive concept exercises, examples, and end-of-chapter problems. This unique case study approach makes abstract physics concepts concrete and bridges the formal language and mathematics of physics with key concepts.

Students were asked to rank the author’s approach based on which features most supported their learning. The author’s case study approach was the most popular pedagogical device among students. Of the 132 students who responded to this ranking question, 31% agreed the author’s chapter case study approach was the most helpful to their studies (See Table 1).

TABLE 1: Students Rank Which Features Most Support Learning

<table>
<thead>
<tr>
<th>Feature</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Study #1</td>
<td>31%</td>
</tr>
<tr>
<td>Two-column Examples #1</td>
<td>26%</td>
</tr>
<tr>
<td>Interactive Concept Exercises #1</td>
<td>20%</td>
</tr>
<tr>
<td>Concept Maps #1</td>
<td>20%</td>
</tr>
</tbody>
</table>

“I think case studies are a good way to learn and remember the material because you can make a personal connection to it.” (Student, Clemson University)

“I really enjoyed the case studies and found them helpful in seeing the real world applications of physics.” (Erik, Clemson University)

“The case studies helped me to see why I was learning what I was learning. I liked the real-world connection.” (Becca, Clemson University)
TWO-COLUMN FORMAT FOR EXAMPLES AND DERIVATIONS HELPS STUDENTS CONNECT MATHEMATICAL FORMALISM AND PHYSICS CONCEPTS

Two-column examples and derivations use graphics to clearly frame the qualitative reasoning and quantitative steps behind a problem, helping students make connections between the concept being taught and the mathematical steps to follow. This two-column example format is also an equally important pedagogical component for students. From this same group of students, 25% ranked the two-column examples as the most helpful to their studies.

“The examples helped when completing homework because they display step-by-step solutions and usually include images/diagrams that allow the reader to visualize the problems.” (Student, Clemson University)

“I like having problems worked out step by step with explanations. It helps connect each step until the final answer is reached, giving meaning to the problem.” (Rebecca, Clemson University)

“Two column examples were the most helpful because you can see the problem side by side.” (Offik, Clemson University)

STUDENT DIALOGUES ADDRESS PRECONCEPTIONS

The author uses student preconceptions (or misconceptions) as building blocks toward proper understanding, showing students the connection between their notions and the true physical principles. Preconceptions are primarily addressed by dialogues between fictional students that allow readers to discover their preconceptions without a sense of failure. In terms of student preferences, this pedagogical feature was ranked below author’s case study approach and two-column example format; however, these mock conversations between students are popular among instructors who want to confront preconceptions in their own classroom—whether through a dialogue or in a workshop setting.
WHEN WAS THE TEXTBOOK MOST USEFUL?

Almost half the students who referred to the textbook indicated that they benefited the most when using it to complete homework assignments. A third of this group agreed the text was also helpful when preparing for exams.

“If you need help with working out problems and understanding homework, I would recommend this textbook.” (Student, Clemson University)

“It is a really good extension of the physics course. Honestly, it is worth the read. Not only does it go over the topics that are covered in class, it explains the topics in more in-depth manners. There are a lot of examples and real-world situations that show how integral physics is to our world.” (Student, Clemson University)

“It’s the perfect study aid.” (Student, Clemson University)

“A good way to help prepare for exams.” (Chris, Clemson University)

“This book helped me understand examples.” (Crystal, Clemson University)
Roughly 60% of the students surveyed who were well-prepared for lecture and referred to the textbook:

- Agreed using the textbook allowed them to better understand the course material and learn new concepts.
- Agreed the textbook helped them better prepare for exams.

“Easy to read, very helpful. It helps explain confusing material with examples.” (Student, Clemson University)

“It is a great way to learn the concepts of physics and how to solve some physics problems.” (Student, Clemson University)

**KATZ’S APPROACH RECEIVES HIGH MARKS FROM STUDENTS**

“I gave it an A because it mainly addressed everything a textbook should from review to case studies” (Student, Clemson University)

“For a science textbook it was extremely easy to read.” (Emily, Clemson University)

“I gave it this grade because I didn’t pay attention in class and that’s the grade I have in the class after using the textbook to prepare for exams.” (Chris, Clemson University)

“I like this textbook a lot and it helped me get a good grade in the class.” (Student, Clemson University)

“It was all around one of the better science textbooks I've had.” (Student, Clemson University)

“Great book. It helped me get a B in the course.” (Student, Clemson University)
FINAL THOUGHTS

These initial findings illustrate that an interactive case study approach can play a significant role in student engagement. Physics describes the world around us. Students can better build an appreciation for physics when using a textbook that contains problems that are drawn from the real world. Student engagement should only increase when online resources such as pre-lecture explorations (many linked to chapter case studies) and text-specific tutorials - are available upon publication.