Smartphones in Labs Don’t Have to Be “Black Boxes”
Colleen Countryman, North Carolina State University

go.ncsu.edu/mytech
Introductory Mechanics Labs at NC State

• 2,000+ students per year
• Calculus-based first-semester University Physics course
• Primarily composed of engineering majors
• Lab sections are led by Graduate Teaching Assistants in Physics
• Lecture sizes are 50-330 students
• Lab sizes capped at 24 students
• Assignments collected through WebAssign
Institutional Problem / Challenge

no existing knowledge

existing knowledge
## MyTech Curriculum

<table>
<thead>
<tr>
<th>iPhone’s Axes</th>
<th>Free Fall</th>
<th>Motion with a Fan</th>
<th>Impulse and Momentum</th>
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<td><img src="image1.png" alt="iPhone Axes" /></td>
<td><img src="image2.png" alt="Free Fall" /></td>
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- **iPhone’s Axes**: Diagram showing the x and y axes.
- **Free Fall**: Diagram with a simple pendulum.
- **Motion with a Fan**: Diagram with a fan and a ball.
- **Impulse and Momentum**: Diagram with a spring and a block.
- **Physical Pendulum**: Diagram of a physical pendulum.
- **Rotation**: Diagram showing angular motion.

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**Graphs**

- **a vs t**
- **a vs t with oscillations**
- **a vs t with impulse**
- **a vs t with oscillations and impulse**
- **ω vs t**
**Study Design**

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| • AndroSensor and SensorLog apps used  
• minimally-adapted full lab curriculum  
• focus on technical and instructional challenges | • adapted 3 labs  
• focus on app-specific feedback | • Complete adaptation of lab curriculum |
## Study Design

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- AndroSensor and SensorLog apps used
- Minimally-adapted full lab curriculum
- Focus on technical and instructional challenges

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- Adapted 3 labs
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- Complete adaptation of lab curriculum

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<td>Complete Test</td>
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Pedagogical Outcomes of Using Smartphones

Using pre-existing apps:

- no significant difference in kinematics skills
- promising attitudinal results
- students are more capable of making “Real World connections” in the lab setting


Possible Causes of Improved Real-World Connections:

- Students are able to use their physics equipment in their daily lives.
- Students consider the forces experienced by the phone.
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Challenge: What does the accelerometer really measure?


So why does my phone say that it’s accelerating when it’s not moving at all?
Einstein’s Equivalence Principle
The phone feels “weightless” during free fall!
The accelerometer reads the “force” on the spring!

In free fall, the spring scale and weight experience “weightlessness!”
How the Accelerometer Actually Works

“How a smartphone tells up from down” [EngineerGuy]. https://www.youtube.com/watch?v=KZVgKu6v808
How the Accelerometer Actually Works

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How the Accelerometer Actually Works

\[ C_1 - C_2 = 0 \]

\[ C_3 - C_4 > 0 \]
The Accelerometer Acts Like a Mass on a Spring!

“Demonstration of a simple accelerometer.” http://imgur.com/yTxA9S
## Addressing Instructional Challenges with App Design

### Challenge
Students had little understanding of the data collection mechanism.

### Solutions
- Visualization of the spring model
- Help article explaining the spring model
The Importance of Understanding the New “Black Box”

A Relevant Mode of Inquiry in Physics Labs: “Subjecting a piece of equipment to close examination in context, figuring out how it works and how it might be used (rather than simply being told how it works and what it is supposed to do).”

- Arnold B. Arons
former president of AAPT

Concerns regarding “black boxes”

Regarding instruments used in teaching labs: “their inner workings are often hidden and thus poorly understood by their users...digital electronics and computational technologies have accelerated this trend, filling science laboratories and classrooms with ever more opaque black boxes.”¹

“The non-transparent smartphones, iPads, and similar technology don’t promote curiosity, at least not in the ways and to the extent that more transparent tools have.”²

How does the accelerometer work?
Using Pre-MyTech App

“The phone has a gyroscope which allows data to be taken in 3D. Using Bluetooth and wireless signals the phone is also able to measure speed (velocity) and acceleration based on location.”

“Magic?”
How does the accelerometer work?

Using MyTech App

“There’s essentially 3 sensors corresponding to a vertical, and 2 horizontal axis's. These sensors measure force. Pretend there’s a ball inside of a box. When you move the box, the ball applies a force … to determine in which direction and how fast this box is moving.”
The visualization (spring model) helped me understand how the smartphone accelerometer works.
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<th><strong>Advanced Level</strong></th>
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<td>Students should be exposed to a range of standard laboratory measurements. They should learn to make measurements using standard equipment and accurately record their measurements and observations. Students should understand the limitations of their measuring devices and how to choose the appropriate equipment to use for particular measurements. Students should be able to use computers to acquire data and should develop other practical laboratory skills throughout the undergraduate experience. Students should gain experience in safely using specialized tools, materials, and devices when building and running experiments.</td>
<td><strong>Measuring devices and apparatus</strong>&lt;br&gt;Students should be able to use measuring devices and apparatus to make measurements consistent with the content covered in class. During the course of an introductory lab, students should, minimally, be able to measure time, distance, mass, temperature, potential difference, and current.</td>
<td><strong>Recommendations</strong>&lt;br&gt;Students should be able to understand the measuring devices and apparatus and make measurements appropriate to the content of the course. In Optics Lab, students should make relevant optics measurements (e.g., beam quality and characterization) and construct optical systems (e.g., interferometers, quantum optics/single photon experiments)</td>
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<td><strong>Examples</strong>&lt;br&gt;Students should be able to understand the limitations and associated uncertainties of measuring devices and choose an appropriate device for making the measurement. When making a length measurement, students choose an appropriate device (e.g., ruler, caliper, or micrometer).</td>
<td><strong>Examples</strong>&lt;br&gt;Students should be able to use and understand the limitations of measuring devices and sensors. Students could determine the optimal device for light collection based on wavelength of light: InGaAs photodiode, Silicon photodiode, PMT, NaI crystal, etc.</td>
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<td><strong>Students should make measurements, including uncertainties, with various analog and digital devices.</strong></td>
<td><strong>Students can look up the uncertainty of a multimeter reading on a particular setting in the manual or online specifications.</strong></td>
<td><strong>Students should make several different types of common laboratory measurements.</strong>&lt;br&gt;These could include: 1) Counting measurement (e.g., photons or particles) 2) Small signal measurement (e.g., using lock-in amplifiers or interferometry) 3) Resonance measurement (e.g.,</td>
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Additional outcomes using our app:
- students’ understanding of data collection mechanism and accelerometer improved
- Improved performance on acceleration problems

The following represents an acceleration graph for an object during a 5 s time interval.

Which one of the following graphs of velocity versus time would best represent the object’s motion during the same time interval?

Performance on Acceleration Question of TUG-K

Traditional Curriculum
Performance on Acceleration Question of TUG-K

- Traditional Curriculum
- SensorLog App + MyTech Curriculum
- MyTech App + MyTech Curriculum
We can’t neglect the curriculum!

“Although a well designed measurement tool can help, it certainly is not enough to ensure that science learning takes place...

In addition, the teacher using such materials must encourage, or at least not actively discourage, an inquiry-based approach to science learning.”

Welcome & Team Introduction

Dr. Colleen Countryman
Physics Ed Researcher

Yan Shen
Instructional Designer

David Tredwell
Developer

Dr. Michael Paesler
Physics Professor

Sam McCuen
Project Coordinator

Laurie Gyalog
Project Coordinator

Chrissie Van Hoever
Visual Designer

Kelly Fish
Visual Designer
Questions?

Download the app: go.ncsu.edu/mytech

Download a lab exercise: go.ncsu.edu/mytechlab

Download the pre-print paper: go.ncsu.edu/accelerometerunderstanding

colleen_countryman@ncsu.edu
What accelerometer value ($a_y$) do you expect?

Phone rests on a table in the “landscape” position
What accelerometer value ($a_y$) do you expect?

Phone moves forward on a cart at a constant velocity.
What accelerometer value ($a_y$) do you expect?

Phone accelerates forward on a cart with a fan at a constant acceleration.
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