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# SHARE: The Mobile BME Lab - Using Smartphones to Teach Core Biomedical Engineering Principles

**Dr. Douglas Yung, Syracuse University**

Doug Yung is a Teaching Professor and Director of the Undergraduate Program in Biomedical Engineering at Syracuse University. His teaching and scholarship focus on experiential learning, engineering design education, and ethics in emerging technologies. He has developed and implemented several innovative, hands-on assessment models that integrate computation, teamwork, and professional competencies into early engineering courses. Dr. Yung's recent work explores collaborative and competency-based assessment in first-year engineering, embedding Kolb's experiential learning cycle and learner engagement frameworks into design-focused exams and lab experiences.

Beyond the classroom, Dr. Yung is active in K–12 STEM outreach, diversity and inclusion initiatives, and faculty development for evidence-based pedagogy. He serves as an ASEE Campus Representative, a Meredith Professorship Faculty Fellow, and a member of multiple university and national committees dedicated to advancing engineering education. His work reflects a commitment to cultivating curiosity, creativity, and reflective practice in the next generation of engineers.

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## Motivation and Instructional Challenge

First-year biomedical engineering courses are often delivered in standard classrooms with limited access to laboratory instrumentation, leaving core measurement concepts such as sensing, noise, and interpretation abstract until later coursework.

Smartphones contain sensors that operate on the same principles as many biomedical instruments, yet prior classroom uses often emphasize feasibility or data collection rather than early development of engineering judgment. This paper presents the Mobile BME Lab, a set of classroom-ready, smartphone-enabled modules for gateway BME courses. The contribution is an intentionally scaffolded workflow that foregrounds noisy data, measurement limits, and evidence-based interpretation in non-laboratory settings, enabling first- and second-year students to collect real data and justify claims while explicitly acknowledging uncertainty.

The modules were developed through iterative pilots in introductory biomedical engineering courses and outreach settings. Early implementations revealed that students could collect data but struggled to justify measurement validity, leading to refinement of the scaffolded workflow emphasizing artifact identification, uncertainty, and evidence-based interpretation.

## Learning Objectives

After completing one or more modules, students will be able to:

- Collect smartphone sensor time-series data and distinguish signal features from noise.
- Apply core measurement concepts including sampling, filtering, calibration, and uncertainty.
- Support claims using plots, simple metrics, and stated limitations.
- Explain how low-cost laboratory experiences can broaden access while maintaining rigor.

## Implementation

The Mobile BME Lab is implemented as a modular sequence within an introductory biomedical engineering course or outreach program. Each module is designed to fit within a single class period and requires only a smartphone and simple materials such as tape, cardboard, gels, or translucent phantoms. Constraining modules to a single session reduces logistical barriers while preserving authentic data collection and interpretation.

All modules follow a common workflow, shown in Figure 1, that guides students from setup and measurement framing through data collection, analysis, and concise reporting using smartphones as laboratory instruments. A representative module vignette is illustrated in Figure 2, which highlights the photoplethysmography activity and demonstrates how artifact introduction and guided analysis support the development of engineering judgment during signal interpretation. The primary audience is first- and second-year undergraduate biomedical engineering students, with demonstrated adaptability to high-school and outreach contexts. No programming background is required; optional spreadsheet or Python analysis may be incorporated to extend analytical depth.

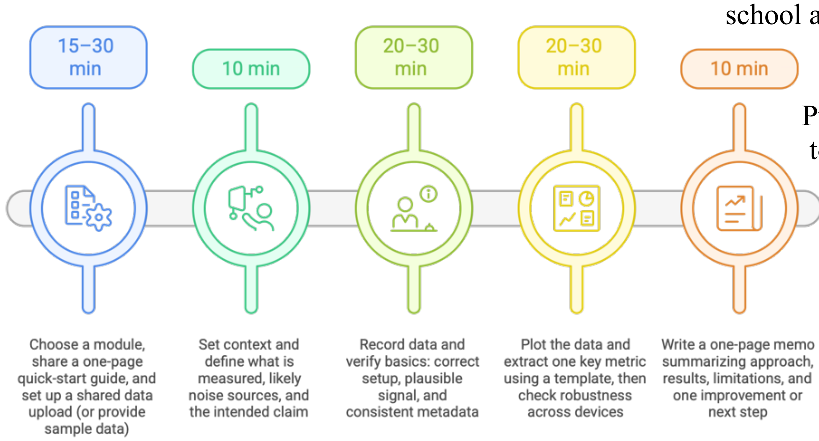


*Figure 1 Workflow using smartphones as lab instruments, leveraging built-in sensors and free apps (e.g., Phyphox).*

*Table 1 Smartphone-enabled gateway biomedical engineering lab modules using built-in sensors to introduce core BME concepts through guided data collection, basic analysis, and brief interpretation for early-year students.*

| Lab Module | Smartphone sensor(s) | Tasks | Key idea(s) | Student output |
|---|---|---|---|---|
| **Physiology (PPG)** | Camera + flash | Record a 60-s fingertip PPG at rest, then repeat after 1 min of light activity. Do one motion-contaminated trial with intentional finger motion. | Optical sensing of blood volume changes; peak finding; motion artifacts | Raw vs smoothed PPG plot; heart-rate estimate; 3–5 sentence artifact explanation |
| **Biomechanics (walking)** | Accelerometer | Collect 30–60 s walking data (normal vs fast). Compare phone in pocket vs hand. | Periodic motion; simple filtering; cadence estimation | Acceleration plot; cadence estimate; short comparison of placements + limitations |
| **Biomedical optics (relative intensity)** | Camera | Photograph two to four colored samples (e.g., food dye dilutions or colored paper) under fixed lighting. Extract average brightness (or RGB mean) from a marked region. | Relative measurement; controls (lighting/distance); basic calibration thinking | Intensity metric vs sample condition; brief notes on controls and confounds |
| **Neuroscience (reaction time)** | Timer + audio/visual cue | Run a simple reaction-time test (visual vs audio) with 15–20 trials each. Compare results across teammates. | Human variability; distributions; experimental design basics | Histogram; mean/median; 3–5 sentence interpretation + confounds list |

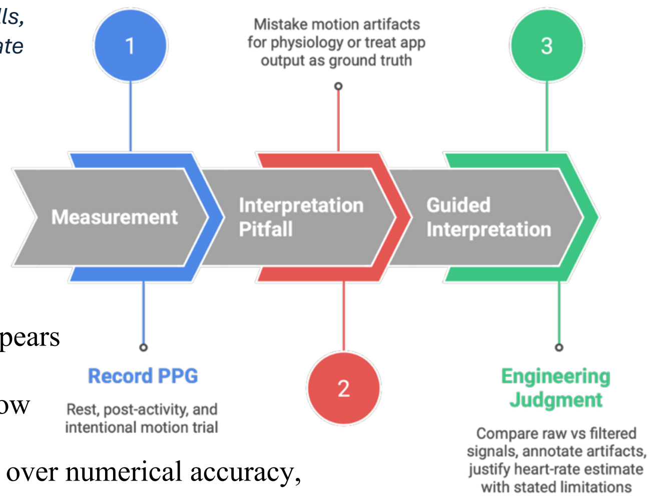


*Figure 2 PPG module vignette showing measurement, interpretation pitfalls, and scaffolded analysis guiding students toward evidence-based heart-rate estimation with explicit consideration of uncertainty.*

### Assessment

Formative assessment is emphasized, consistent with first-year instructional goals:

- Module memo rubric (four criteria, 0–2 scale): data quality, correct plot or metric, interpretation, and limitations or improvements.
- In-class signal sanity check: students annotate where noise appears and identify likely causes.
- Optional exit ticket: a short concept-transfer prompt (e.g., “How do transduction and calibration differ in your module?”).

Assessment prioritizes engineering judgment and sense-making over numerical accuracy, reinforcing early professional habits of interpretation.

### Situational Factors and Adaptation Guidance

**Device access and equity:** Smartphone access should not be assumed; pairing, loaner devices, or instructor-provided datasets can mitigate access and compatibility variability in BYOD environments.
**Privacy and consent:** For physiology modules, students may opt out without penalty, and no identifiable physiological data are collected. Alternative sample datasets are provided.
**Device variability:** Sampling rates, sensor permissions, and app behavior vary across devices; modules therefore emphasize robust features such as trends rather than absolute measurements.
**Classroom constraints:** Activities are designed for standard classrooms with minimal materials and can be delivered as rotating stations to accommodate large enrollments.

### Dissemination Package

To support adoption, the Mobile BME Lab is designed for plug-and-play reuse. Shared materials include one-page module guides, analysis templates, a brief memo rubric, sample datasets, and instructor notes on timing, accessibility, and common pitfalls.

*This work was reviewed by the institutional review board and determined to qualify for an educational practice research exemption, as it involves normal instructional activities conducted in established educational settings. Participation in classroom activities was voluntary, no identifiable physiological data were retained, and alternative datasets were provided to mitigate privacy concerns.*