A Research Experience Based Measurement Laboratory Course

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Objective

• Provide undergraduate students with an alternative to experience of working in a research lab group (encouraged but not possible for all).

• Enhance practical skills with instrumentation, sensors, design, system characterization.

• Student enthusiasm and strong active engagement.

• Not too expensive (limited budget).

• Scalable (ideally).
Course Design

Foundational work (half of semester)
• Instrumentation, sensors, electronics, measurement techniques, system performance.
• Lecture (2h), homework, and lab(4h) strongly coupled.
• Lab: Rough guidelines of tasks, deviation and exploration not penalized.

Student project (half of semester)
• Students work on a project of their own design, trying to reach self-set milestones.
• Students test and characterize system in stages.
• Lecture switches into “on demand topic” discussions.
• Present to class (last week).
Semi-structured Lab Activities

- Electronic amplifiers (voltage, current, addition, subtraction, filter, integrator);
- Distance measurement (plate capacitor), curve fitting, noise/uncertainty.
- 1st order system (thermoresistor): Responsivity, dynamic system response).
- 2nd order systems (cantilever): Responsivity, dynamic system response).
- Feedback loops.
- Ultrasonic sensing.
Frequently Used Equipment

Digital/Analog I/O (NI/Digilent: $279) + software (free) = oscilloscope, function generator, voltmeter, logger, spectrum analyzer, network analyzer …

Translation/rotation stages, small optics mounting platforms, posts, etc.

3d printer on to-buy-list (a student owned one and let all in class use it)

Whatever we could find, borrow, scavenge ….
Student Projects

• Initial proposals 2-3 weeks before project start (motivation, description, planned course of action, parts requirements, project milestones).

• Instructors review and feedback.

• Order small parts as needed/within budget.

• A few doable backup projects were developed before course started.
Actual Projects Proposed

• Build an atomic force microscope (AFM).

• Build an optical spectrometer and measure fluorescence of a liquid (Spectrometer).

• Design a system which detects who in the room is speaking the loudest and from where (and then have a catapult shoot a marshmallow into the mouth of the loudest talker). (Audio)
Achieved Milestones - AFM

• Built laser-cantilever system with piezo-tubes for sample movement.
• Controlled and characterized 3d piezo-tube movement.
Achieved Milestones - Spectrometer

- Built a computer controlled spectrometer.
- Characterized resolution using neon lamp.
- Measured a fluorescence spectrum.
Achieved Milestones - Audio

- Built a detector structure with 5 digital microphones.
- Wrote algorithm to calculate origin of sound.
- Characterized system performance (cm accuracy at meter distances).
- Discovered measurable effects due to sound shadowing.
- (Described project in a paper and poster for a communications class.)
Student Reaction to Course

• **High level of motivation** (24/7 access to lab room, students found there late in evening & on weekend working on project. Students volunteered to bring some material/equipment from home to utilize in project.)

• **Strong cooperation** between all students.

• **High level of satisfaction** with course (students expressed that they learned a lot of practical skills in a short period of time).

• Some disappointment that fewer milestones were achieved than anticipated (welcome to reality!).
Challenges: Scalability

• Will we need too much stuff to maintain student project freedom/flexibility?

• Can we maintain lab access “after hours”?

• Can we attract a larger number of students?