Lessons Learned from Interdisciplinary Teaching

Internet of Things (IoT) for Greenhouse Monitoring

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Dr. Nathan W. Eloe

- Education
  - Undergrad: Missouri S&T (2010)
    - B.S. Computer Science
    - B.S. Physics
    - Minors: Theater, Math
  - Ph.D. Computer Science, S&T 2015
    - VRCC-3D+: Qualitative Spatial and Temporal Reasoning in Three Dimensions
- Professional
  - 2015-Present Northwest Missouri State University
    - Assistant/Associate Professor
  - 2014-2015 Lumate
    - Senior Software Developer and Special Projects Lead
  - 2011-2014 Lumate, previously IDC Projects
    - Developer and Consultant

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Dr. Alexander W. Taylor

- Education
  - B.S. Geology, University of Arkansas 1989
  - Work towards M.S. in Geology and Electrical Engineering 1989-1993
  - Ph.D. Geology, LSU 1998
    - Effects of Military Off-road Trafficking on Desert Terrain
    - Integrated geological field mapping and remote sensing/GIS techniques
  - Ph.D. Soil Science, Mizzou 2018
    - Effects of Forest Harvest Methods on Soil Health
    - Integrated soil physics, chemistry and microbiology
- Professional
  - 2020-Present Northwest Missouri State University
    - Asst. Professor: Soil Science
  - 2019 USDA-ARS
    - Water Quality Lab Manager
  - 2018-2019 Truman State University
    - Asst. Professor: Soil Science, Geology, Remote Sensing
  - 2003-2013 U.S. Army National Ground Intelligence Center
    - AGI Scientist, Subject Matter Expert and All-Source Analyst
  - 1997-2002 Texaco EPTD Senior Geoscientist
    - Remote Sensing, Geomorphology and Structural Geology

Project Genesis

- In the Winter of 2020-2021, one of the Northwest Horticulture Greenhouses suffered an overnight heating failure leading to a total loss of all plants
- The greenhouses had current temperature and air humidity monitoring via an onsite LED interface dating back to the 1990’s.

Source: GoogleEarth 2023

https://memory-alpha.fandom.com/wiki/Project_Genesis?file=Project_Genesis.png

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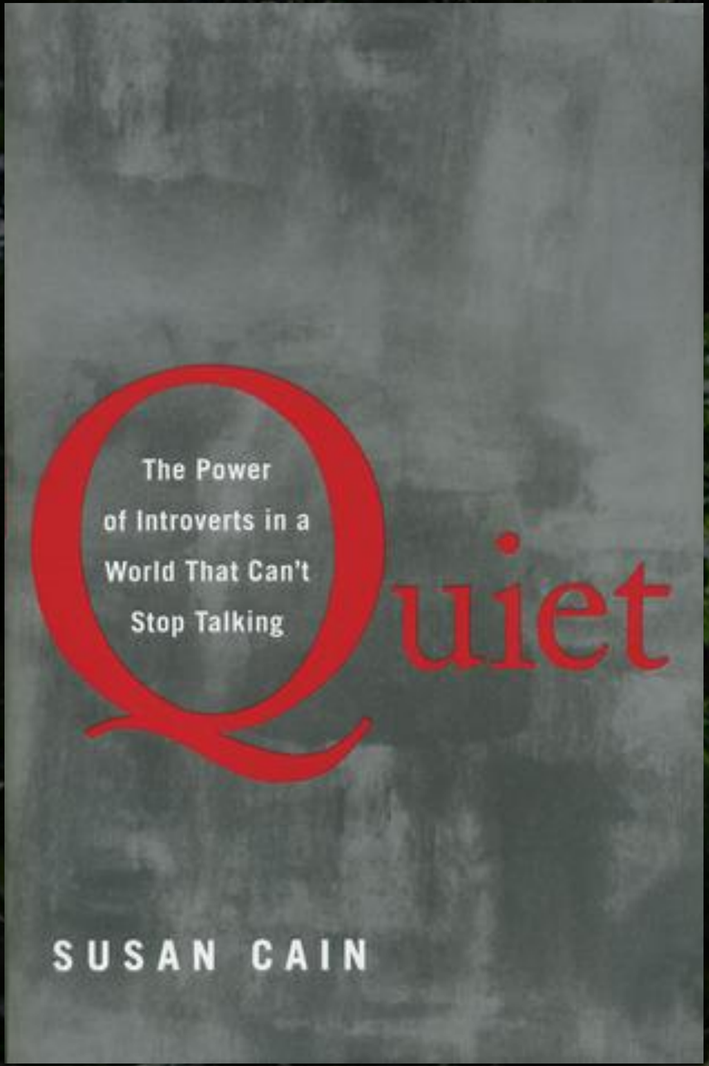
Friendship is Magic

or how two of the more introverted professors on campus came together to develop this course



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Getting the Ball Rolling

- Unusual needs for the course and funding issues
  - Research of viable development boards and sensors
  - Initial Funding Request was rejected
  - Consideration of self-funding
  - Dr. Rod Barr to the rescue!

7x ESP32 Development Boards	https://www.mouser.com/ProductDetail/DFRobot/DFR0654-F?qs=DRkmTr78QARtpUKAs1lqkg%3D%3D	$56.91
6x Soil Moisture Sensor (analog)	https://www.mouser.com/ProductDetail/DFRobot/SEN0308?qs=W%2FMpXkg%252BdQ6OxAIir4dgLw%3D%3D	$89.40
6x Soil Temperature Sensor (digital)	https://www.mouser.com/ProductDetail/DFRobot/KIT0021?qs=lqAf%2FiVYw9gxyZsxJBRMfA%3D%3D	$48.00
6x IO Shield	https://www.mouser.com/ProductDetail/DFRobot/DFR0762?qs=7D1LtPJG0i1NKYlbZ6uNgA%3D%3D	$34.30
6x air temp/humidity (I2C)	https://www.mouser.com/ProductDetail/DFRobot/SEN0546?qs=Jm2GQyTW%2FbiSGx3%252BkXPsbg%3D%3D	$41.40
6x ambient light sensor	https://www.mouser.com/ProductDetail/DFRobot/DFR0026?qs=Zcin8yvlhnNtXxmrk6BPpQ%3D%3D	$15.60
7x Battery	https://www.adafruit.com/product/2011	$87.50
		$373.11

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Why Is This Interesting?

- Interdisciplinary and PBL exist!
  - Interdisciplinary programs
  - Knacktive
  - Client Project based classes
- Key differences
  - Product is more than a repackaging of previously taught material
    - Even though it's really not
  - The course was going to need to be flexible to hit relevant IoT topics
    - If the mesh networking day didn't work, there was going to be a VERY fast redesign of the next two weeks
  - Everything was outside their normal comfort zone
  - It felt different
    - To faculty AND students
  - Field trips are fun! (even if they're just across campus)

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CSIS 44-440 Internet of Things – Course Design

- Start with the “Things”
  - Basic safety (personal and equipment)
  - Basic circuits, schematics
  - Digital and Analog input and output
  - Coding in good ol’ C++
- Move to the “‘Internet’”
  - Talking to the Internet
  - Communication Protocols (not all on the internet)
  - Security basics
  - Mesh networking vs. point-to-point/star
  - IFTTT
- Primarily hands on assignments/projects and demos, very few theoretical quizzes/worksheets/assignments
  - Exceptions: basic electricity (Ohm’s Law), circuit diagrams, reading device data sheets

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Final Project Rollout

- When (at 8 weeks into the semester)
- How – a special class section held at the Horticulture complex
  - Alex discussed what a greenhouse is and why are they important
  - Introduced several exemplars (an example follows)
  - Followed up with a tour of Greenhouses 1-6 led by Crop Production Technician Josh Wiederholt

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Sample of Introductory Talk

(Why Greenhouses are Critical)

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Phalaenopsis Orchids in the Wild

i.e., Indonesia

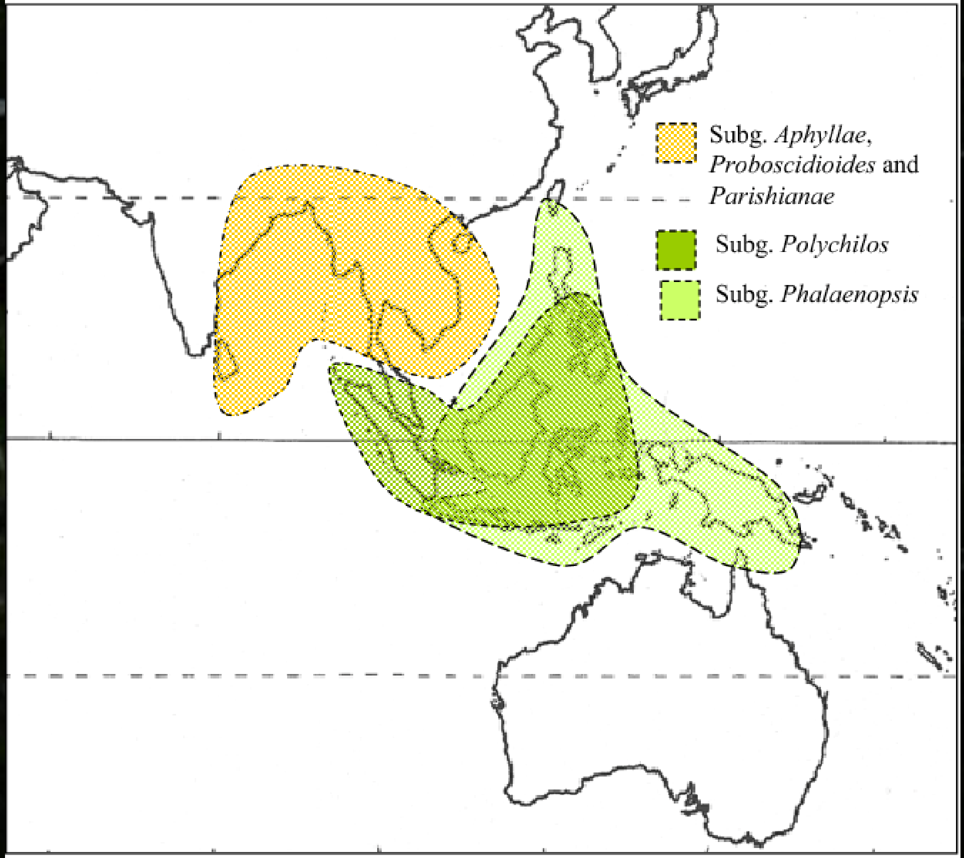

Fig. 1 The distribution pattern of different subgenera of *Phalaenopsis*.

A https://earlswoodgsy.com/gardening/phalaenopsis-orchids/

Tsai, C., & Chou, C.H. (2007). Molecular Phylogenetics of Phalaenopsis Taxa: An Updated Review.

Phalaenopsis Orchids

- Lighting
  - Indirect Sunlight during the summer
  - A brief period of direct bright light during the winter to help trigger blooming
- Temperature (Consistent and Warm)
  - 19–30°C (66–86°F) during the day and 16–19°C (61–66°F) at night.
  - Temperatures < 16 C (60 F) cannot be tolerated
  - Originated in SE Asia (Indonesia and Philippines have the highest diversity of species)
- Soil Water Content
  - Must be consistently damp, but not saturated.
  - Cannot tolerate dry conditions
  - Added water needs to be tepid (and non-alkaline)
- Other Requirements
  - Cannot tolerate drafty conditions due to temperature fluctuations – they are epiphytic (grow on trees)
  - They flourish in 20–35°C and 70% relative humidity
    - STR Isomegathermic and SMR Udic (Soils are Perudic)
  - pH 5 to 6 Moderately to Strongly acidic
    - Note: there are lithophytic varieties which prefer alkaline conditions

https://en.wikipedia.org/wiki/Phalaenopsis

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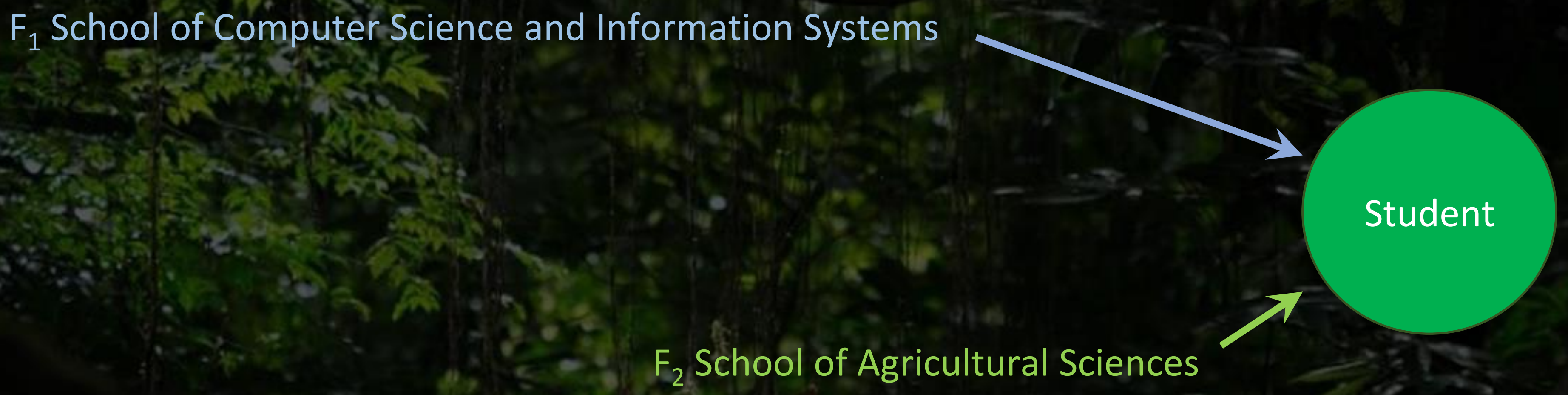
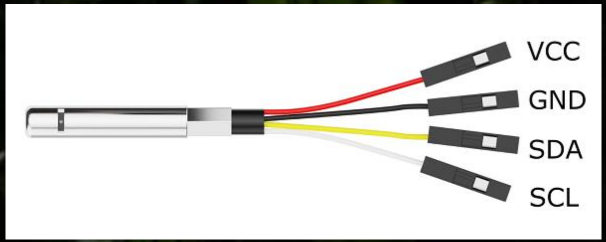
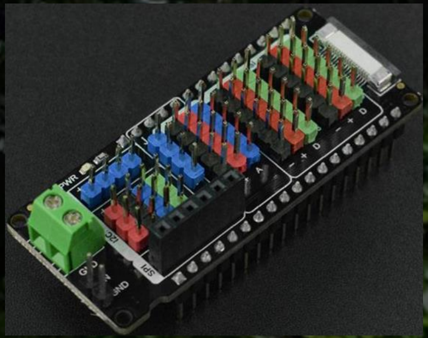
Resultant

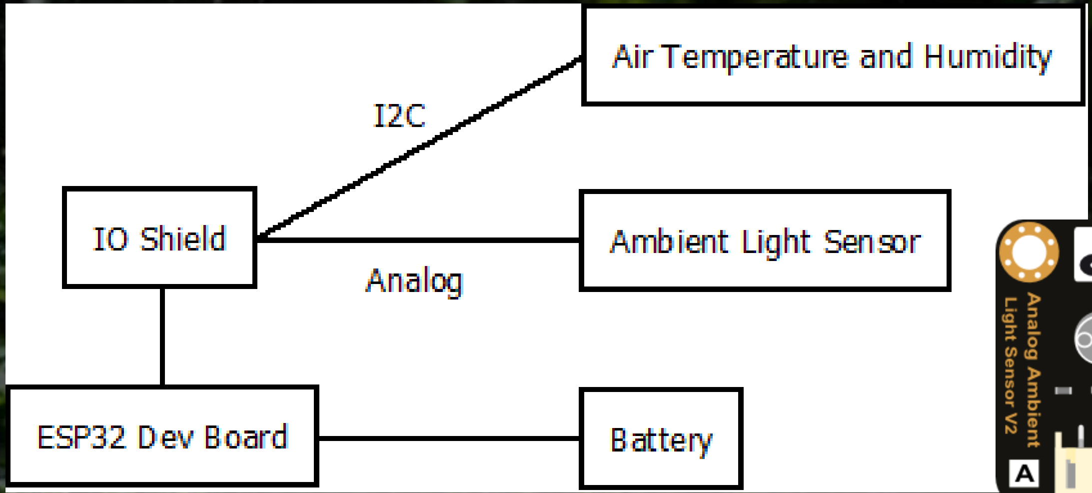
- *a force, velocity, or other vector quantity which is equivalent to the combined effect of two or more component vectors acting at the same point.*

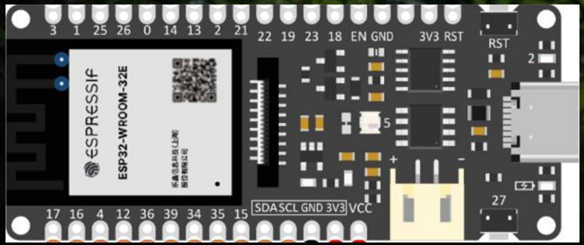


Sensor Array





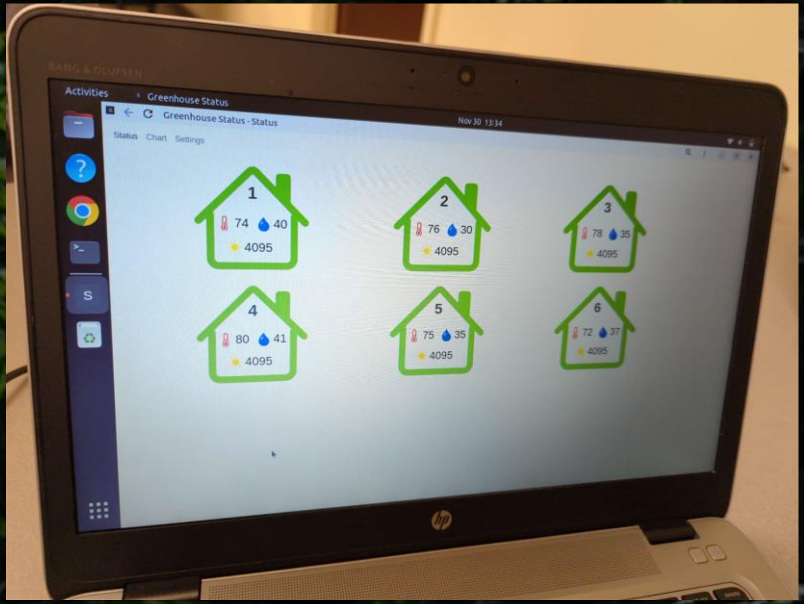




All electronics images: product pages from https://wiki.dfrobot.com

Network and Web Interface

- Mesh network using Espressif's ESP-NOW protocol through PainlessMesh
- Sensors send measurements to base station (repurposed laptop)
- Base station displays results, alerts when abnormal conditions are detected



Student Engagement

- Student Evaluation Excerpts:
  - "I enjoyed seeing code come to life in this class and the project with ag was so much fun and a dip into the industry in terms of coding as a team"
  - "This class never failed to keep my interest and taught me amazing skills directly related to the topic"
  - "I think that this class has been the most interesting and the most real world application of a class"
  - "he [Eloe] let us (the students) take over towards the end with the ag project as if its was a real world problem. He of course would help with anything and show us new ideas but he left all of the decision making up to us the students."
- Faculty Observation
  - On in class work days, the groups were listening to each other. If someone spoke up about having a problem and someone else had already solved it, they would be running across the room to offer their expertise. It was a beautiful chaos
  - Very little hands on required from me; I spent time in class answering questions, doing some minor debugging, and designing the 3D printed enclosures

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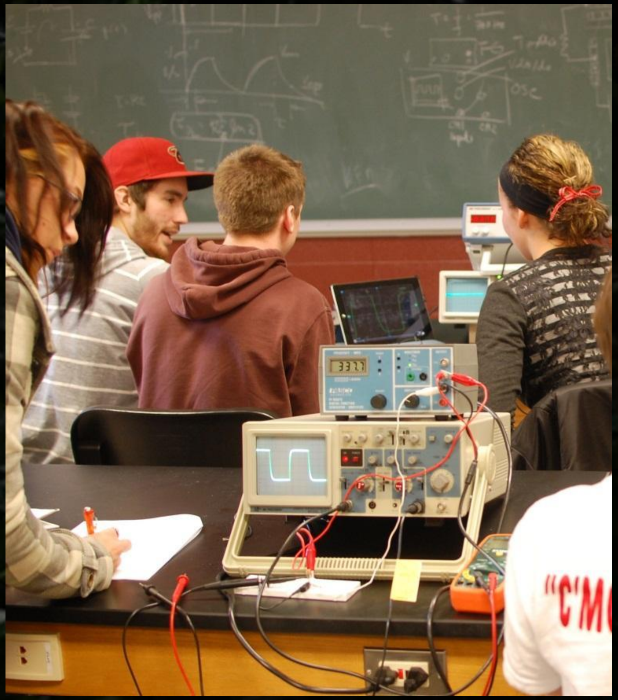
Our Lessons Learned

Source: University of Arkansas Department of Electrical Engineering

- What appeared to work
  - Explanation of the (monetary) importance of the application
  - A “non business” problem space with real world applications and consequences
- What we would do different
  - Greenhouse Talk earlier in the semester
    - Substantively changed student engagement
  - Scoping document soon thereafter (managing expectations)
  - Lean more heavily into hardware earlier in the semester
    - Many students first experience with hardware-software interface
    - Do we need a hardware-oriented course?
      - Circuits and Instrumentation Lab?



https://www.researchgate.net/figure/Physics-students-use-a-conventional-oscilloscope-in-the-foreground-while-another-group_fig5_262179821

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Lessons Learned: Anecdotal

- Some material didn't "click" without the motivating factor of the greenhouse project
  - Takeaway: Figure out how to interleave the motivation with the theory and practice; don't want students to lose sight of the end goal while working through the nitty gritty
    - Are you the kind of person who learns a game by wanting to know how to win first, or what the rules are first?
- Group sizes *slightly* too large
  - Unlike "normal" CS project, need more than your computer to make progress, so if you didn't have the hardware you were stuck
  - Some of this could be mitigated by better management of individual groups
  - Takeaway: more groups, more granular sensor platforms
    - Fish tanks, anyone?
- Sensor groups "finished" early
  - In reviewing their code after the course, found significant improvements that could be made
  - Takeaway: have sensor groups audit each other's code, perhaps offer incentives for smallest working implementation…

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Lessons Learned: Course Design

- Integrate project elements earlier in the semester
  - Example: have students or groups wrap functionality for various project sensors in a library and have them use the best in their resulting project
- Manage dual “new” topics better
  - Most students haven’t seen C++, though many had seen C
  - Few if any students had worked with hardware and circuits before
  - Was a neat “chicken and egg” problem
- Takeaway: learning is (more) fun when it is tactile!

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Show and Tell