Combined research & teaching labs: Engineering criteria and building system integration
Agenda

1 Combined research and teaching
   Discovery-based learning
   What is it? Why is it important?

2 Discovery-based learning STEM facilities
   Teaching & research labs area allocation
   Multi & interdisciplinary labs
   Support & collaboration requirements
   Program organization

3 Discovery-based Engineering Systems Design
   Robust/Flexible systems
   Energy efficient
   Utility requirements
Research + teaching = discovery-based learning

What is it?
Method of inquiry-based instruction
Learners discover facts and relationships for themselves.

Related Terms
Problem based learning
Challenge based learning
Active learning
Hands-on learning
Enhanced learning
Research + teaching = discovery-based learning

Why is it important?

200%

“...students learned twice as much based on test results as the students in the traditional section...”

1 Research + teaching = discovery-based learning

Why is it important?

- Increase learning
- Improve test scores
- Increase engagement
- Attract & retain students
- Increase student satisfaction
Research + teaching = discovery-based learning

Why is it important?

68%

of survey respondents indicate increased interest in STEM career as a result of undergraduate research opportunities

Science VOL 316 4/27/07 Benefits of Undergraduate Research Experiences - Susan H. Russell, Mary P. Hancock, James McCullough
Research + teaching = discovery-based learning

Why is it important?

College Enrollment (Age 18-24)
US Dept. of Education


+52%  +10%
2 STEM discovery-based learning facility attributes

- More research lab area
- Slightly larger teaching labs
- More support area
- More collaboration area
More research lab area
Slightly larger teaching labs
More support area
More collaboration area
Interdisciplinary
McMaster University

Single lab for multiple disciplines
Problem based learning
McMaster University
Multiple labs each capable of supporting multiple disciplines
Problem based learning
NSF/Person

Inter-Disc. Teaching Lab

- Office
- Support
- Lab

Harvard University
Facility Program Flexibility

**MATERIALS CHARACTERIZATION TESTING**

**POLYMER CHEMISTRY TESTING**

**TISSUE CULTURE TESTING**

**MOLECULAR BIOLOGY RESULTS**
Frugal Innovation Lab

Core Competencies

Rugged
- Cisco and Netfood’s Emergency Net Relief Kit

Lightweight
- Mobile phone

Human Centric
- Jomy Can for National’s Safe Water Program

“Last-mile” Distribution
- Solar lanterns, roof top solar product distribution

Simple
- Tata Chemical’s rice husk water filter

Adaptable
- Avokade, voice messaging board for education

Affordable
- Japi foot prosthesis

Green
- We Care Solar suitcases to easily light healthcare facilities

Local
- Husk Power Systems: rice husk gasification

Santa Clara University
Lab-on-a-chip – Arsenic Detection in Water
By Sonny Gandhi, Zuhayr Elahi, John Seubert, Ben Demarse, and Jessica VanderGiesen

Problem and Motivation

- Arsenic is a naturally occurring contaminant in water, toxicity makes it difficult for certain geographic locations such as South Asia to find drinkable water.
- Arsenic is hard and expensive to detect in water and millions of individuals are affected each year by Arsenic contaminated water.
- Delivering an accurate, on-site analysis of contamination levels is the critical first step in effectively creating arsenic contaminated groundwater.

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<thead>
<tr>
<th>WDI Criteria</th>
<th>Existing Techniques</th>
<th>Our Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advantages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>x</td>
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<td>Sensitivity</td>
<td>x</td>
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This chart shows the weaknesses of existing solutions and how there is a need for a product like this.

Project Description

- The Bioengineering side involves two main components, the disposable plastic sensor and the miniaturized electrochemical analyzer. The sensor is a disposable test strip with reagent, where cyclic voltammetry and amperometric detection is used to detect arsenic in the test strip. After the detection, the sensors will be dropped into the reagent, producing a current peak for each soluble analyte through the range of the potential scans.
- The electrical engineers connect the probe and control it. An Arduino Uno was used as the microcontroller board. The electrical device sends a range of voltages between the reference and the working electrodes. After it sends the voltages, the microcontroller captures the peak, these values are then stored in an array and sent to the phone.

The Next Steps

- The App will implement a database that stores local rad results and the location data at the time of analysis. This allows a user to have a record of when and where they took a sample so they do not have to remember certain bodies of water. Additionally, a web service will be implemented to allow users to share data over the internet.
- Arduino will be replaced with a tower-powered microcontroller Arduino was used mainly as a proof of concept due to its ease of use.

It is the hope we can get a few devices completed so they can be tested in the field in the summer of 2013 by traveling students.

Our Solution

- Combine three engineering disciplines (Bioengineering, electrical engineering, and computer engineering) to create a working solution.
- Develop a probe that can detect levels of arsenic that can interface with an Arduino device to use the processing power to analyze results.

The App

- An Android device is connected to the Arduino Board via an On-The-Go (OTG) USB cable and data is sent between the two via a serial connection. This also allows the Android to pull data from GPS units.
- Android was chosen because Android is a powerful smart phone OS that will and is becoming more prominent in developing markets.
- Once the data is received, it is analyzed via the Arduino programming library. This allows the data to be graphed and any useful information extracted from it.
- Another screen shows a simple Green (Drinkable) or Red (Un-drinkable) result based on the analysis for simplicity.
Discovery-based learning

STEM Facilities

95%

“...survey respondents note hands-on experience throughout curriculum is important ...”

Interviews and surveys of students, faculty, and Advisory Board conducted during Visioning Phase

Santa Clara University
3

STEM Discovery Based Engineering Systems Design

Nazareth College
Lessons learned...
Computational Science – Concentrated Cooling Load

Lessons learned...
SEAS NanoFab Facility – Low Vibration and Specialized HVAC
Lessons learned...
Chemistry Teaching Labs may...

Marist College Chemistry Lab

...or may not have fume hoods

Lessons learned...

Nazareth College Science Building
Health Science – More Cadavers

Lessons learned...
Engineering – Welding & Other “Hands On” Activities

Lessons learned…..
MEP Infrastructure for STEM Discovery Based Teaching:

a “Scaled Down” version of the Infrastructure for a Major Research Facility

Rensselaer Polytechnic Institute - Center for Biotechnology and Interdisciplinary Studies

Nazareth College
Flexible & Energy Efficient Systems

What are the utilities and services that should be provided?

QUALITY and VARIETY not QUANTITY are the principal design criteria for utilities in the lab today.

- Water: Less non-potable more pure (RO vs. RODI)
- Chilled H₂O: More process water (some local some central)
- Steam: Less (except for sterilizers can be local)
- Gases: More N₂, CO₂, less natural gas (less central)
- Air: Clean Oil free
- Vacuum: Some local some central
- Electricity: Clean / grounded
- Exhaust: More localized
- Waste: Less need
Innovative & Energy Efficient

Mechanical Systems

What are the metrics that allow for long term, robust flexible utilities and services serving instruments and equipment?

HVAC Design Capacity Criteria for Various Space Types

- General Laboratories: 1 CFM/NSF (fume hood count dictates otherwise)
- Organic teaching lab; 150 CFM/LF of fume hood
- Biology (Gross Anatomy) Labs : 15 air Changes per hour
- General Classrooms: 1 CFM/NSF
Flexible & Energy Efficient Systems

Energy Efficiency: Reducing Energy Use

• Variable Air Volume (reduces, cooling, and fan energy)
• Aggressive controls (reduces heating and cooling energy)
• Low pressure drop (air distribution system) (reduces fan energy)
• Demand based air volume flow rate control (reduces heating, cooling, and fan energy)
• Chilled beams (reduces cooling and fan energy)
• Heat recovery (reduces heating and cooling energy)
Flexible & Energy Efficient Systems

Conventional teaching lab building HVAC concept

- Dedicated lab system - 100% outdoor air
- Dedicated Admin/
- Classroom/Lecture Hall system - 50% outdoor air
Flexible & Energy Efficient Systems

Single air system serves lab and non-lab functions

- Greater flexibility for modifications
- Reduced energy cost
- Higher quality environment
- Reduced first cost / less equipment
Flexible & Energy Efficient Systems

Conventional Lab Building HVAC Concept - Heat Recovery Applied to Lab Exhaust

- Heat Wheels
- Heat Pipe
- Glycol Run-around Loop
Flexible & Energy Efficient Systems

Create manifold serving lab and non-lab functions

• Provides higher degree of redundancy
Services & Utilities

Mechanical Services Capacity Design Criteria

Steam
- Primarily for autoclaves
  - 1000 PPH per autoclave
- Total 1000 – 2000 PPH per 10,000 NSF

Circulating Chilled Water
- 30 to 40 Tons per 100,000 GSF

Process Chilled Water
- Environmental rooms
  - 5 – 10 GPM per environmental room
- Lasers
  - 5 – 10 GPM per laser
- Total 20 – 25 GPM per 10,000 NSF
Services & Utilities

Plumbing Services Capacity Design Criteria

Lab compressed air
1 CFM per outlet at 40 PSIG
100 – 120 PSIG system pressure
Some prefer gaseous nitrogen in lieu of compressed air

Lab vacuum
0.5 CFM per outlet at 19 in. Hg (482 Torr)
Central system will address acoustic issues

Pure water
0.25 gallons per day per student station
25 GPD per glass washer
Consider circulating RO water with local polishers
Electrical Services Capacity Design Criteria

Normal power
- Receptacles: 5 – 15 Watts/NSF
- Lab equipment: 2 – 3 Watts/NSF

Emergency (Standby) power
- Receptacles: 0.0 Watts/NSF
- Lab equipment: 0.0 to 0.7 Watts/NSF
- Technology: 0.1 – 0.5 Watts/NSF
Tradeline Three

1. Combined research and teaching = Discovery-based learning
   - Increases learning
   - Improves test scores
   - Increase engagement to attract & retain students

2. Discovery-based learning STEM facilities
   - Multi and Interdisciplinary lab differences
   - Multidisciplinary adjacencies for improved results
   - Real-world problem based learning impacts

3. Innovative mechanical solutions
   - Discovery-based learning facilities ≈ multidisciplinary research facilities
Questions?