Request

1. Explain research frame of reference.
2. Discuss the direction of science research and the structures supporting it at universities.
3. Discuss the educational structure that supports the research.
4. Give examples of classes.
5. Update us on the technology (research & teaching - show cool animals & robots)
6. Ask for feedback.

Objective

What can SENCER and your approaches to education offer research (& teaching) universities?

What can research (& teaching) universities offer SENCER and your colleges and universities?
Perspective

Research
Large, Research University
Direct one Center and participate in 3 others
Direct and/or Participate in 4 Major Research Projects
(grants & contracts)
Projects include 9 universities & 3 companies
Projects involve 10 postdocs, 20 graduate, 20 undergraduate students

Teaching
Large, Research University
Two upper division undergraduate classes (one laboratory), one non-major undergraduate class, one graduate class and one graduate seminar per year

Our Challenge

The Scientist
August 19, 2003
Needs Improvement

Research universities lack creativity when it comes to training the next generation ...

By Harvey Black

Continuing Criticism

AMERICA’S SCIENCE TEST
The Tough Road to Better Science Teaching

Proponents of new methods encounter resistance, especially at research universities
Stick to Your Research

While college leaders talk about the importance of better teaching at their institutions, the academic departments controlling tenure decisions fear that an emphasis on teaching will lead them to fall behind peers at other institutions in the race for prestige, in which the winners are determined by their research productivity.

Our Challenge

THE CHRONICLE OF HIGHER EDUCATION
Government & Politics

From the issue dated August 3, 2007
Proponents of the new models have come up against particularly strong resistance at the nation’s research universities, which award most of the undergraduate degrees in science and engineering.

"In almost every discipline, I could point to a variety of really effective, wonderful sets of instructional materials and instructional practices, and say that if we could magically click our fingers and get everybody using them, there would be a huge improvement in undergraduate education that would happen instantaneously," says Myles G. Boylan, who directs a program on undergraduate education at the National Science Foundation that has provided much of the money to develop the teaching models. "But we’re nowhere near that.”
**Interdisciplinary Integration**

We are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline.  

—— Karl Popper

**Interdisciplinary Integration**

Interdisciplinary thinking is an integral feature of discovery because of four powerful “drivers”:
1. the inherent complexity of nature and society,
2. the desire to explore problems and questions that are not confined to a single discipline,
3. the power of generative technologies, and
4. the need to solve societal problems.

**Age of Integration**

Collaboration is Required for Transformative Research

Advantages of Diversity Comes with the Challenge of Communication

Transdisciplinary

Collective Discoveries Beyond Any Single Area

Interdisciplinary

Multidisciplinary

Disciplinary

**Interdisciplinary Vision**

Transforming Academia

Traditional

Emerging

<table>
<thead>
<tr>
<th>Department-based</th>
<th>Problem-based (Centers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campus-centric</td>
<td>Global Reach</td>
</tr>
<tr>
<td>Few Links to Industry</td>
<td>Robust Industry Partnership</td>
</tr>
<tr>
<td>Building-Block Courses</td>
<td>Integrative Curriculum</td>
</tr>
<tr>
<td>Research vs. Education</td>
<td>Integration of Research &amp; Education</td>
</tr>
</tbody>
</table>
### Interdisciplinary Approaches to Training

**Centers (Common Problem #1)**

<table>
<thead>
<tr>
<th>Area</th>
<th>Major</th>
<th>Dept.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A DEPT.</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B DEPT.</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C DEPT.</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D DEPT.</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>E DEPT.</td>
</tr>
</tbody>
</table>

**Centers (Common Problem #2)**

<table>
<thead>
<tr>
<th>Area</th>
<th>Major</th>
<th>Dept.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A DEPT.</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B DEPT.</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C DEPT.</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D DEPT.</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>E DEPT.</td>
</tr>
</tbody>
</table>

**Centers (Common Problem #3)**

<table>
<thead>
<tr>
<th>Area</th>
<th>Major</th>
<th>Dept.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A DEPT.</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>B DEPT.</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>C DEPT.</td>
</tr>
<tr>
<td>D</td>
<td>D</td>
<td>D DEPT.</td>
</tr>
<tr>
<td>E</td>
<td>E</td>
<td>E DEPT.</td>
</tr>
</tbody>
</table>

### Approaches to Education

**Tunnel Approach**

- Specialized -ologist
  - "A" -ologist
- Funnel Approach
  - Synthetic -ologist
  - "B" -ologist
- "Interdisciplinary" Approach
  - "A, B, C" -ologist

**Interdisciplinary Approach**

- Specialized -ologist
  - "A" -ologist
  - "B" -ologist
- New Area D
- "Integrative" -ologist

---
**TRANSFORMATIVE EDUCATION MATRIX**

**UNIVERSAL DISCOVERY & IMPLEMENTATION**

- Practice, Collaboration, Communication
- INTERDISCIPLINARY CLASSES
- AREA A

**Depth**

**Fundamentals**

**UNDERGRADUATE RESEARCH**

**UNIVERSAL DISCOVERY**

**TEACHING LABORATORY**

**PERSONAL DISCOVERY**

**LECTURE CLASS**

**INTRODUCTORY CLASS**

**INTERDISCIPLINARY CLASSES**

**INTERDISCIPLINARY CLASSES**

**INTERDISCIPLINARY CLASSES**

**AREA A**

---

**NEW INTERDISCIPLINARY CENTER**

**CENTER FOR INTERDISCIPLINARY BIOLOGICAL-INSPIRATION EDUCATION & RESEARCH**

UC Berkeley

Director Robert Full

---

**BERKELEY NATURAL HISTORY MUSEUMS**

Tim White

Kevin Padian

Jim McGuire

---

**INTEGRATIVE BIOLOGY**

- Bioengineering
- Biomedical Engineering
- Integrative Biology
- Mechanical Engineering
- Electrical Engineering & Computer Science

- Shankar Sastry
- Jelena Malik
- Ron Fearing
- Stuart Russell
- David Forsyth
- Michael Jordan
- Kristopher Pister
- Luke Lee

---

**CENTER FOR INTERDISCIPLINARY BIOLOGICAL-INSPIRATION EDUCATION & RESEARCH**

UC Berkeley

Director Robert Full
**Time for Synergy**

Using Research-based Approaches

**Better Teaching**

Using An Interdisciplinary Approach to Teaching

**Better Research**

---

**Interdisciplinary Teaching Benefits**

1. Skilled undergraduate researchers
2. Higher quality graduate students and post-docs
3. Interdisciplinary research collaborations
4. Transfer novel concepts and devices to research
5. Industrial partnerships
6. Develop new fields
7. New funding sources

---

**UNIVERSAL DISCOVERY & IMPLEMENTATION**

**UNDERGRADUATE RESEARCH**

**UNIVERSAL DISCOVERY**

**TEACHING LABORATORY**

**PERSONAL DISCOVERY**

**RESEARCH-BASED LECTURE CLASS (SYMPOSIUM)**

**INTRODUCTORY CLASS - RESEARCH SECTION**

---

**TRANSFORMATIVE EDUCATION MATRIX**

---

**Scientific Meeting**

**Symposium**

The Power of Comparative Physiology: Evolution, Integration, and Application

90 Junior & Senior Bio Majors
**Original Research**

Research Articles

- William J. Kargo, Frank Nelson, and Lawrence C. Rome
  Jumping in frogs: assessing the design of the skeletal system by anatomically realistic modeling and forward dynamic simulation

- Jennifer C. Nauen and George V. Lauder
  Hydrodynamics of caudal fin locomotion by chub mackerel, *Scomber japonicus* (*Scombridae*)

- Tom McKean, Guolian Li, and Kong Wei
  Cardiac effects of hypoxia in the neotenous tiger salamander *Ambystoma tigrinum*

  High feeding costs limit dive time in the largest whales

- William K. Milsom, Stephen G. Reid, F. Tadeu Rantin, and Lena Sundin
  Extrabranchial chemoreceptors involved in respiratory reflexes in the neotropical fish *Colossoma macropomum* (*Colossomidae*)

- Stewart M. Holt and Stephen T. Kinsey
  Osmotic effects on arginine kinase function in living muscle of the blue crab *Callinectes sapidus*

- Peter Rombough
  Gills are needed for ionoregulation before they are needed for O2 uptake in developing zebrafish, *Danio rerio*

- Joshua J. C. Rosenthal and Francisco Bezanilla
  A comparison of propagated action potentials from tropical and temperate squid axons: different durations and conduction velocities correlate with ionic conductance levels

**Symposium Presentations**

**In-Class Presentations**

In-Class Presentations in the form of a scientific symposium.
Form Research Teams consisting of 2-4 individuals.
Two 20 min presentations per class period.
Ten minutes available for questions.

**Presenting Research Team**

Responsibilities of Presenting Research Team

1. Select a research paper and be able to defend why they selected that particular paper.
2. Get approval to present this paper from Professor.
3. Prepare a clear 20 min presentation of the research paper as if they were the researchers. Review their presentation with Professor.
4. Prepare to answer questions after their presentation.

**Elements of a Presentation**

**Advice on Presentations**

1. Define the state of the field. What is known and not known?
2. Defend the system or animal model selected for study.
3. What are the hypotheses being testing?
4. What methods were selected? Sufficient controls?
5. What was discovered? Do data provide a test for the hypotheses?
6. Articulate the conclusions. Do the conclusions match the data collected?
7. What is the next step in this area of research?
Attending Research Teams

Responsibilities of Teams “Attending Meeting” (not presenting)
1. Read the 2 research papers before each class.
2. Be prepared to write and hand-in one question from their group at the end of each presentation.
3. Be prepared to ask their best question publicly to the presenting group.

Real-time prediction of hand trajectory by ensembles of cortical neurons in primates

Human Brain Machine Interface will allow “thought” control of prosthetic limbs

Think Interdisciplinary - Engineering

Fictive Locomotion Induced by Octopamine in the Earthworm

Kenji Mizutani 1, Hiroto Ogawa 2, Junichi Saito 3 and Kotaro Oka 1,4,*
1 Center for Life Science and Technology, School of Fundamental Science and Technology, Keio University, Japan
2 Department of Biology, Saitama Medical School, Japan
3 Institute of Biomedical Engineering, Faculty of Science and Technology, Keio University, Japan and
4 Department of System Design Engineering, Faculty of Science and Technology, Keio University, Japan

Think Interdisciplinary - Mathematics of Oscillators
Work and Power Output in the Hind limb Muscles of Cuban Tree Frogs, Osteopilus septentrionalis during Jumping

Think Interdisciplinary - Computer Science

By Matthew M. Peplowski & Richard L. Marsh

Department of Biology, Northeastern University, 360 Huntington Avenue, Boston, MA 02115, USA

Behavioral recovery from spinal cord injury following delayed application of polyethylene glycol

Richard B. Borgen, Rui Shi and Debra Bohnert

Nicole George, Amina Sutherland-Stolting, Yumin Yeh

Group 20

Relevance to Cutting-Edge Research

Students adopt “We can do that” attitude

Purdue Research Offers Hope For Canine, Human Spinal Injuries

In 2005, researchers at Purdue University successfully treated a paralyzed dog with polyethylene glycol (PEG), a product used in other medical treatments. This breakthrough has led to new possibilities for spinal cord injury patients.

In the study, a dog paralysis dog between 2 and 5 years of age was treated with a PEG injection within 72 hours of injury. The dog was able to stand and walk again, demonstrating that it is possible to repair spinal cord injuries and improve the quality of life for paralyzed individuals.

The researchers, led by Dr. Anna Ahn, Harvard Post Doc Professor, have questioned the Nobel Prize Recipient - Muscle NOT just motors.

How Muscles Work

Questioned Nobel Prize Recipient - Muscle NOT just motors

Cal Undergraduate, Department Citation Winner, Dr. Anna Ahn, Harvard Post Doc, Harvey Mudd, Professor

Insect Leg

Extend Leg

Insect Leg

© iStockphoto.com/Alexander C. Durgesh and Nicole M. McDonald
**How Muscles Work**

Muscle are Multifunctional Materials

- **Artificial Muscles**

  Soft ElectroActive Polymers (EAP)
  Polymer film sandwiched between compliant electrodes and acts as a dielectric (insulator).

---

**Success Story**

From UCB Biology Undergrad to Designing Artificial Muscle to Spin-off Company

Marcus Rosenthal
UC Berkeley’s Award for Innovation

Artificial Muscle Inc

---

**Octopus arm, Robo-snake or Endoscope?**
Artificial Muscles in Prostheses

Anthropomorphic arm by Blake Hannaford

Assisted Human Exoskeletons by Daniel Ferris

Bipedal Octopus Disguised as a Rolling Coconut


Beginning of Soft Robotics!


Transformative Education Matrix

Universal Discovery & Implementation

Undergraduate Research
Universal Discovery

Teaching Laboratory
Personal Discovery

Research-Based Lecture Class (Symposium)

Interest, Focus, Creativity, Vision

Interdisciplinary Research-Based (Project)
BioMotion

Developed a new course called BioMotion. Taught in parallel at Public Middle School and UC Berkeley

6th Grade Public Middle School Science Class

UC Berkeley Undergraduate Non-majors Class (120 students)

Course - BioMotion

Biological Motion
Biological Inspiration
Biomechatronic Design

Biomorphic Explorers Design

Challenge: Design the Next Robotic Explorer Based on Bio-Inspiration

NASA JPL

Biomotion

Prerequisites: Open to all students.


CD: R. McNeill Alexander. Animals on the Move CD.

Design Kit: Zoob construction kit. 125-piece kit.
Interdisciplinary Influence

- Animatronics
- Robotics
- Computer Animation
- Medicine
- Sports

Biological Inspiration

Original Discoveries

BioMotion

Science and Society

“The nation has no more money to waste on curiosity based research!”

Presidential Science Advisor

Roots - origins

Rules - how it works

Relevance -

humans
organisms
environment

Basic

Applied

From Bullock
Reasons for Research

**Roots - origins**

**Rules - how it works**

**Relevance -**
- humans
- organisms
- environment

---

Pogo Stick Model Fits All

SIX-Legged
Cockroach
Full and Tu, 1990

EIGHT-Legged
Crab
Blickhan and Full, 1987

TWO-Legged


---

Extraordinary Stability

Animals appear to be Self-Stabilizing using Springy Legs

Cockroach on Rough Terrain

Obstacles as great as 3 times hip height!

---

Interdisciplinary Teaming

VISUALIZATION (dynamic modeling)
Marc Raibert
Pixar

ANIMATION (inspiration)

Age of Interdisciplinary Science

BIOLOGY
Full
Success Story

Ed Chen
From BioMotion to PIXAR

Computer Animation

Disney/Pixar A Bug’s Life
Computer Animation

Disney/Pixar A Bug’s Life

Art Inspires Science

Pixar’s Question
Why model just “up and down” motion if insects move in the horizontal plane?

Interdisciplinary Teaming

MATHEMATICS
Holmes
Guckenheimer

ENGINEERING
Buehler
Koditschek
Rizzi
Cutkosky

BIOLOGY
Full

Novel Simple Model
Passive, mechanical self-stabilizing system with no brain

Animal
3 Legs Acting as One
Bouncing Side to Side

Schmitt & Holmes, 2000
**Tunable Legs**

**STANFORD UNIVERSITY**
Cham, Bailey and Cutkosky
**SPRAWL**

*Shape Deposition Manufacturing allows Tuning and Embedding*

G. Cham, E. Bailey, F. Full and M. Cutkosky, 2003

**Dynamic Hexapod**

**Biologically Inspired Bouncing Robot**

Martin Buehler
Boston Dynamics

Dan Koditschek
University of Pennsylvania

AI Rizzi
Boston Dynamics

**Clock**

**Springy Legs**

No sensing of environment!
Search & Rescue

Homeland Security
Defense
Natural Disasters
Surveillance
Privacy

Disabled or Super-human?

Oscar Pistorius finished second in the 400m, nearly qualifying for the World Championships. He runs 100m in 10.91 seconds (WR 9.77 seconds). He wants to race in the Beijing Olympics.

Use General Principle of BioMotion

Set Stiffness of Prostheses

Flex Foot-
Ossur
**Disabled or Super-human?**

**Designs for the Future**

Novel Bio-Inspired Materials can be used by Students to Design Truly Novel Robots Not Yet Taught in Engineering!

Use Toys, NOT Toy Designs

---

**Biomechatronic Design**

In Class Form BiolInspired Design Teams of 3-5 Students

Use Toys (Zoobs) with Biological Links to Design Explorers

**BioDesign**

Explorer MUST be Biologically Inspired Design

Ariel, First Legged Amphibious Robot - iRobot
Presentation and Defense

15 min Presentations of Biomorphic Explorers

As if the team is from a University or Company

Presentation and Defense

Snake-bot
Go where no other robot can!

The design of our explorer combines several major modes of locomotion borrowed from the snake and the gecko.

ANJAR 2005

Association of Novel Jointed and Automated Robotics

Amy  Naomi  Justin  Alex  Rachel
2CB: Contraction Climbing Biomorph

David Longiaru
Christina Morua
Tri Nguyen
Parissa Vassef

BioMotion Explorers Awards
Most Diverse Teams Do Best!

Success Story
Naomi Davidson
From UCB’s BioMotion to PhD at MIT

SUCCESS STORY

UNIVERSAL DISCOVERY & IMPLEMENTATION
Practice, Collaboration, Communication

UNDERGRADUATE RESEARCH
UNIVERSAL DISCOVERY

CIBER CENTER

INTERDISCIPLINARY TEACHING LAB

RESEARCH-BASED LECTURE CLASS (SYMPOSIUM)

INTRODUCTORY CLASS - RESEARCH SECTION

TRANSFORMATIVE EDUCATION MATRIX

BIOLOGY
### Interdisciplinary Laboratory

<table>
<thead>
<tr>
<th>FIRST ROTATION (4 wks)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature and tissue function</td>
<td>Anatomy &amp; histology</td>
<td>Diving physiology</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SECOND ROTATION (4 wks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity physiology</td>
<td>Hypoxia</td>
<td>Math Modeling &amp; Computer Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>THIRD ROTATION (3 wks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metabolic thermoregulation</td>
<td>Behavioral thermoregulation</td>
<td>Statistics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDEPENDENT PROJECTS (3 wks)</td>
<td>Original Research (Universal Discovery)</td>
<td></td>
</tr>
</tbody>
</table>

**Structured, but NOT “cookbook”**

### Research-Based Approach

1. Suggest search for one known solution.
2. Known solution does not completely explain data.
3. Encourage students to examine literature IN LAB and conduct simple experiment.

**Low Cost of Running?**

- Increase temperature and find it explains more of the data.

---

**Students Comments**

At the beginning of the course or project:
- My data are bad.
- My data are wrong.
- The lab or project doesn’t work. This class su…
- You told us that …

Later:
- [Smith 2005] said I should have found …
- Different scientists have found different results, so mine are O.K.
- My data are inconsistent with [Smith 2005] because …

By the end of the course:
- [Smith 2005] hypothesized X, but did not consider Y.
- I would design the experiment as follows because …
- The next area of investigation should be …

---

**Critical Thinking**

- Perry, 1970
- Nelson, 1989

**Perceiving uncertainty as real**

- Right or Wrong
- Rely on authority
- Just the facts
Critical Thinking

1. Ask questions: be willing to wonder
2. Define the problem
3. Examine the evidence
4. Analyze assumption and biases
5. Avoid emotional reasoning
6. Don’t over simplify
7. Consider other interpretations
8. Tolerate uncertainty

Wade and Travis
**Tools for Critical Thinking**

1. **Falsifiability** - prove false
2. **Logic** - sound arguments
3. **Comprehensiveness** - exhaustive
4. **Honesty** - no self-deception
5. **Replicability** - must repeat
6. **Sufficiency** - extraordinary claims demand extraordinary evidence

**Research-Based Approach**

1. Suggest search for one known solution.
2. Known solution does not completely explain data.
3. Encourage students to examine literature and conduct simple experiment.

**Low Cost of Running?**

- Low temperature
- Increase temperature and find it explains more of the data.

**Independent Teaching Lab Project**

**Think Interdisciplinary**

**Could Physics Explain Mystery?**

- Amazing
- No-slip Toes?
How Does the Gecko Do It?

2 Billion Nano-sized split ends
Stick by van der Waals forces!

Amazing Feat!

Journal Nature

Adhesive force of a single-gecko foot-hair

Cal Undergraduate
Tonia Hsieh
Departmental Citation Winner
Graduate Student, Harvard

Biological Inspiration - Nanotech
First Self-cleaning, Dry Adhesive

100X
30,000X

Top 10 Nanotechnology Patent 2007

Natural Lizard Nanoarray
Polyurethane Nanoarray

Full UC Berkeley
Autumn Lewis & Clark
Ron Fearing UC Berkeley
**The Gecko Product Line?**

- Move wafers/computer chips
- Move optic fibers
- Robot inspection of Space Shuttle and satellites

Great ideas that stick. For about a year, images, words, sounds, movements, and behaviors were reproduced in the new Honda nano tape, Post-it® Notes, and 3M Scotch® Magic Tape. The miracles of science.

---

**Future Bio-Inspired Band-Aid?**

Also used in Microsurgery for Compliant Manipulation of:
- Blood vessels
- Nerves
- Muscle fibers

Rows of Actual Gecko Hairs from Molting Animal for Demonstration

From Autumn, Gassett and Schade.

---

**First Dynamic Legged Climbing Robot**

- Body & Legs
- Toes & Feet
- Claws
- Friction pad
- Setae

Nanostructure 200 nm

---

**RiSE Project**

Robots in Scansorial Environments

- Autumn
- Buehler
- Cutkosky
- Fearing
- Full
- Koditschek
- Rizzi

Involves:
- Lewis & Clark
- Boston Dynamics
- Stanford
- UC Berkeley
- UC Berkeley
- U Penn
- Boston Dynamics
**Challenge - Go Anywhere**

**Toe Peeling**

**Time Magazine - Top 10 Inventions 2006**

Cutkosky and Kim Stanford University

**TRANSFORMATIVE EDUCATION MATRIX**

**UNIVERSAL DISCOVERY & IMPLEMENTATION**

- **INTERDISCIPLINARY TEACHING LAB**
- **TEACHING LABORATORY**
- **PERSONAL DISCOVERY**
- **RESEARCH-BASED LECTURE CLASS (SYMPOSIUM)**
- **UNDERGRADUATE RESEARCH UNIVERSAL DISCOVERY**

**ENGINEERING**

- ** интерес, фокус, творчество, видения**

**PHYSICS**

**MATHEMATICS**

**BIOLOGY**

**COMPUTER SCIENCE**

**ART & DESIGN**
Physical Model as Hypothesis

Research & Educational Robot

Edubot

Hai Komisuglu, Joel Weingarten & Daniel Koditschek, Penn

New Freshman Engineering Curriculum

Integrates Programming with Engineering Science

Research-based Teaching Laboratories

Teams Use Cutting-edge Bio-Inspired Robots (Edubot & RHex)

Design & Build Novel Legs to Negotiate Obstacles

Implement Creative Control Algorithms (Dancing Project)

New Freshman Engineering Curriculum

Service Learning

Weingarten & Koditschek

Penn

Freshmen undergrads paired with local Philadelphia high school students

8-week program on Saturday mornings

Conduct three laboratory exercises (building a wall following mouse, a Lego robotics rover, and choreographing dance with robot)

Conclusions

1. Challenges in science, industry and society demand research-based skills while cooperating in diverse interdisciplinary teams.

2. Training to conduct transformative research requires a change in education. Courses that provide fundamentals & depth can integrate disciplines within the course. Centers can integrate disciplines with problem-based courses. Interdisciplinary teaching can lead to better research.

3. Using research-based teaching allows students to challenge the literature, develop critical thinking skills, realize the direct advantage of diverse teams, and experience the thrill of discovery on real problems.
**Objective**

What can SENCER and your approaches to education offer research (& teaching) universities?

What can research (& teaching) universities offer SENCER and your colleges and universities?