CUREs

Course-based Undergraduate Research Experiences

What CURE
Course-based Undergraduate Research Experience

- Five characteristic features
  - Scientific practices
  - Discovery
  - Relevance
  - Collaboration
  - Iteration

Corwin Auchincloss L, Assessment of course-based undergraduate research experiences: a meeting report. CBE Life Sci Educ. 2014;13:29–40.

Why CURE
Course-based Undergraduate Research Experience

- **2017-New Report Examines the Impact of Undergraduate Research Experiences for STEM Students-**
  - **A new report from the National Academies of Sciences, Engineering, and Medicine examines the evidence on undergraduate research experiences (UREs) and recommends more well-designed research to gain a deeper understanding of how these experiences affect different students and to examine the aspects of UREs that are most beneficial.**
- **Vision and Change Report 2009 – Undergraduate Biology education-AAAS and NSF**
- Engage students as active participants, not passive recipients, in all undergraduate biology courses.
- **Ensure that undergraduate biology courses are active, outcome oriented, inquiry driven, and relevant.**
- Facilitate student learning within a cooperative context.
- **Introduce research experiences as an integral component of biology education for all students, regardless of their major.**

CURE
Course-based Undergraduate Research Experience

- **SURE – and other surveys assessing UG research impact show numerous learning gains and motivation for graduate school**
  - Undergraduate Research as a High-Impact Student Experience -David Lopatto, professor of psychology, Grinnell College –2010 –AAC&U.

- **Course-Based Undergraduate Research Experiences Can Make Scientific Research More Inclusive**

- **Gita Bangera and Sara E. Brownell**
- CBE—Life Sciences Education Vol. 13, 602–606, Winter 2014

CURE
Course-based Undergraduate Research Experience

- Independent undergraduate research experiences can be difficult to implement for large enrollments and/or lack of infrastructure

- Undergraduate research is a very effective learning and training experience and is a recommended part of undergraduate training by ACS-CPT and Vision and Change report

Approaches to CUREs

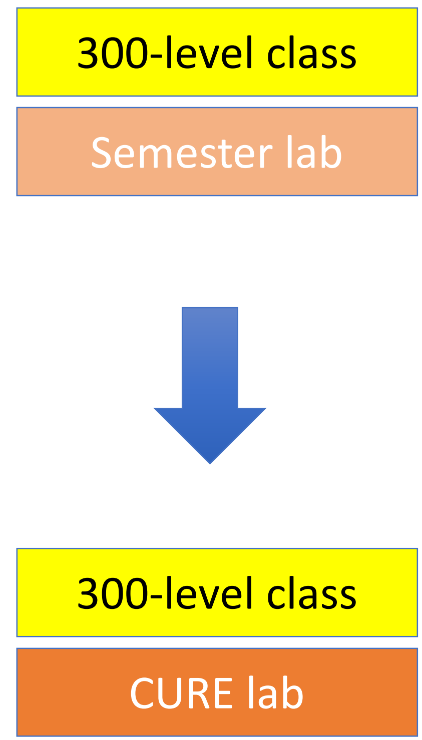
1. Take existing courses and implement CURE in that context

    - Labs attached to lecture classes
    - Independent lab classes
    - Large Lecture classes
    - Special topics classes

2. Re-arrange curricular structure to fundamentally seed UR via designed CURE courses

CURE examples

- **Utah advanced organic lab** (J. Heemstra): varying conditions for azide-alkyne cycloaddition reactions
- Outcome: comprehensive paper



Anderton, G. I., Bangerter, A. S., Davis, T. C., Feng, Z., Furtak, A. J., Larsen, J. O., ... Heemstra, J. M. (2015). Accelerating Strain-Promoted Azide-Alkyne Cycloaddition Using Micellar Catalysis. *Bioconjugate Chemistry*, 26(8), 1687-1691.

CURE examples

- **Chemical Biology, Northeastern**
- Week 1: pipetting and sterile technique

- WT vs knockout strain of *E. coli*
  - Students choose agents to test in zone of inhibition assays
  - Knockout strains with genes of unknown function
    - *yeaB*, NUDIX hydrolase
    - *ybfE*, metal metabolism?

- Sneak in fundamental skills

CURE examples

- Bioinformatics lab, Chemical Biology, Northeastern
- Added in 2015 after discussion with Sir Richard Roberts (COMBREX)

- Each lab section gets a “known” characterized protein
- Students find similar, uncharacterized proteins and analyze for likely function
- Work-study student tabulates results

- Longer-term goal: project lab to characterize annotated genes

CURE examples

- Site-directed mutagenesis lab, Chem. Biol., Northeastern

Multi-week lab, with critical timing issues:

Molecular modeling: predict important residues, design mutants to test predictions

↓

Construct variants using site-directed mutagenesis, confirm by DNA sequencing

↓

Proteins are related to (non-critical!) research of TA

Purify protein variants

TA purifies protein variants, ideally a purification in which several variants can be done in parallel

↓

Assay wild-type and variants to determine effects of mutation

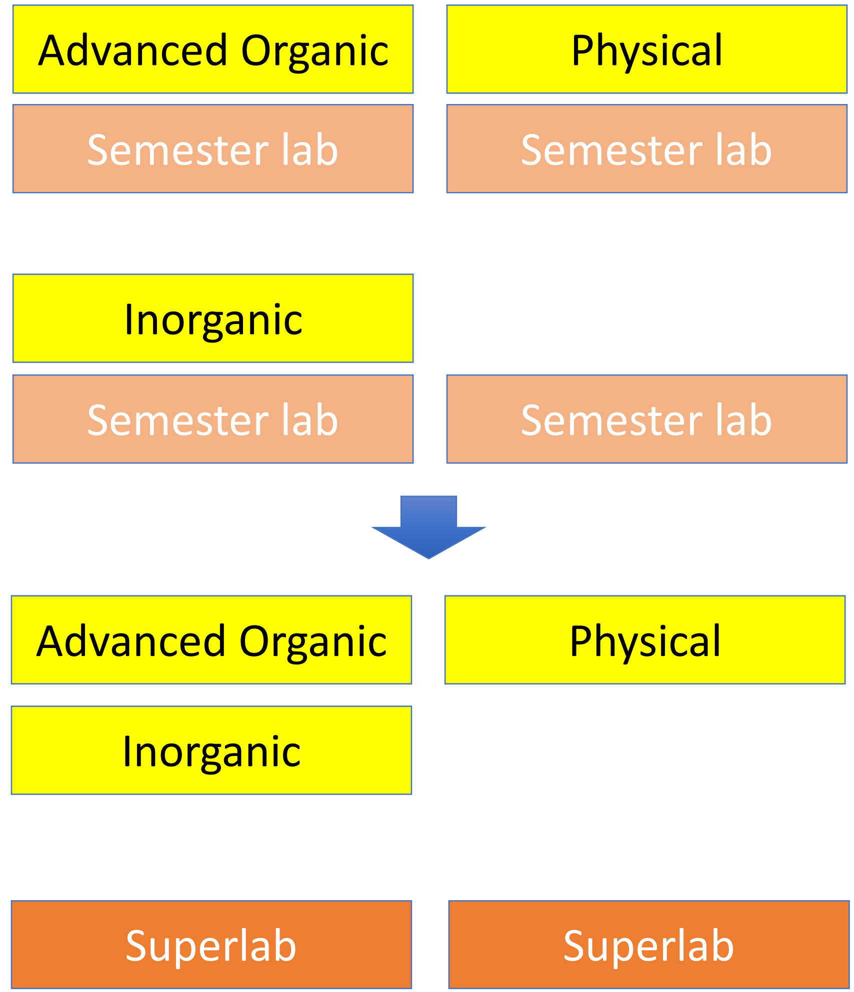
CURE examples

- Site-directed mutagenesis lab, Northeastern
- Started with easy system: Alkaline phosphatase
  - Residues remote from active site
  - Simple purification
  - Activity assay is a standard biochem lab experiment, colorimetric assay
- Single-stranded DNA binding protein
  - Residues predicted to mediate protein-protein interaction from Molecular Modeling class project
  - “Simple” purification, many variants in parallel
- DNA polymerase, cancer-associated SNPs
- Outcomes: CURE survey, other end-of-semester attitude surveys
    - Lopatto 2008 *Science*
  - Gains in student confidence in their ability to write about results
  - That writing about science is helpful for understanding science
  - Large gain in their confidence in using computer modeling

CURE examples

Haverford "Superlab"

- Biology junior year
- Chemistry junior year
- Biochemistry interdisc. Module (semester)



- Outcomes:
  - Training for senior independent research
  - Breadth of research experiences
  - Semi-regular publications with juniors

CURE examples

- **Computing and Data Science in Chemistry, University of Kentucky**

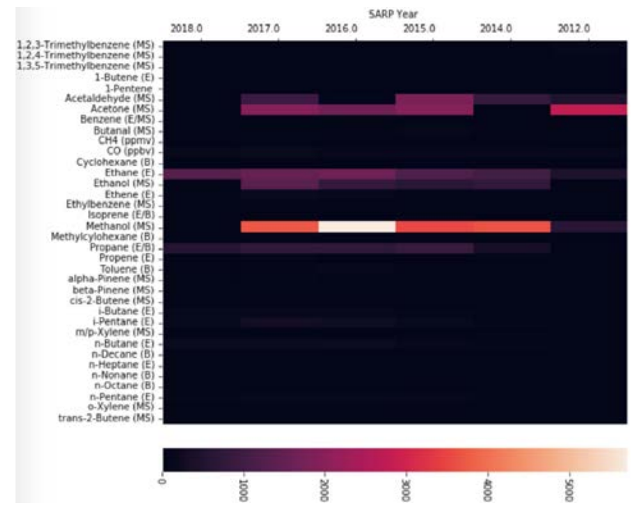
- When we think about "big data", chemists have critical roles to play in the generation of data, but often do not have the necessary computing (or mathematical) backgrounds to be key data analytics contributors.

- Growing evidence suggests that undergraduates do not develop information literacy (of which big data is a subset) without explicit instruction. This is a problem:
  - it is not uncommon for research instruments to now generate petabyte datasets
  - beyond the scientific or medical career pursuits commonly followed by chemistry undergraduates, there is a growing need across the economy for employees with the skills requisite to analyze and draw conclusions from big data

G.V. Shultz & Y. Li. *Journal of Chemical Education* **2016**, 93, 413.

CURE examples

- Discussed topic within the context of chemistry (science & engineering):
  - Introduction to big data, databases, and scientific computing
  - Python programming
  - Data processing, statistics, and advanced data visualization
  - Research
    - Student developed hypotheses & methods
    - Scientific writing
    - Refereeing (ACS Reviewer Lab)



- Opportunity for teacher-scholar training
  - Two graduate students assisted with the development of the course, including the modules used to train the students on python and data analysis

CURE examples

- A few comments from the students:

“Python is a great source that's becoming more widely used, so I was able to learn a skill that will transcend outside of my academics and will continue to grow throughout my career.”

“I was interested before (or else I wouldn't have signed up for this course); however, I now want to further my education in computational data analysis and pursue it as a part of my research project.”

(New skills or knowledge) *“Ability to work long term with a group and maintain pace working towards a goal.”*

“I'm amazed by the fact that how much can extra knowledge can be obtained by looking at a data set from a different perspective”

Philosophical differences

- Conventional courses:
  - Content
  - Skills
  - Exams

  - Individual assessment
    - Exams
    - Reports

  - Training for the next course

- CURE courses:
  - Context
  - Process [skills in context]
  - Reports, results, and self-evaluation
  - Group and individual assessment
    - Reports based on shared data

  - Training for real problems

Implementation challenges

- Fitting into prescribed curricular “holes”
  - Make new holes?
- Re-fitting of personnel into new roles
  - Lab instructors
  - TAs
  - Course instructors/Pis
  - Does not require extra personnel, just strong buy-in
- Follow-through and external presentation of results
  - Redeployment to research group personnel and/or continuing UGs

Everybody wins (?)

- Undergraduates
  - More dynamic and effective learning environment
- PI/faculty
  - Teaching credit for research
  - Mobilization of large numbers to research area
  - Opportunity to seed a new research area with preliminary data
  - Identify promising students for research group
- Lab personnel and TAs
  - Greater investment and engagement in program
  - Synergy with ongoing research
  - New professional development opportunities

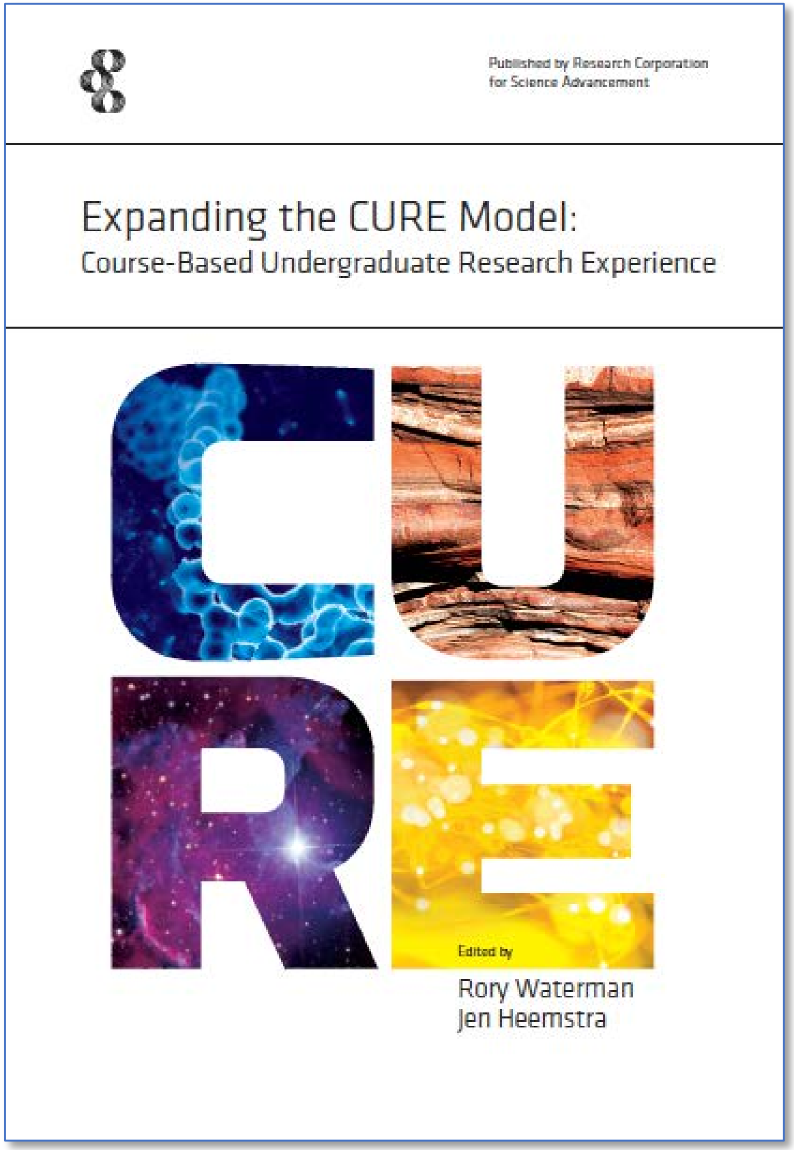
The keys are…

- Watch for opportunities
- Look for small to large curricular changes that can incorporate research into coursework
  - o Reading literature to design and develop experiments – grant proposals
  - o Adding design experiments into existing laboratories - characterization
  - o Incorporating larger scale research into lecture class or laboratories

- Pay attention to available questions that might scale differently than “normal” projects in your group
- Be creative
  - Within your curriculum
  - Within your own research

Key resources!

- CUREnet (for Biology)
  - https://curenet.cns.utexas.edu/
- CSC project on CUREs
- Adding Research to a Class Facebook Group



Discussion questions

1. Are there any pieces of your institution's curriculum, or in pre-established classes that you will likely teach, that appear amenable to a CURE approach?

1. Are there projects in your research area, or ancillary questions, whose solutions might scale with a "more semi-qualified bodies, better answers" approach?