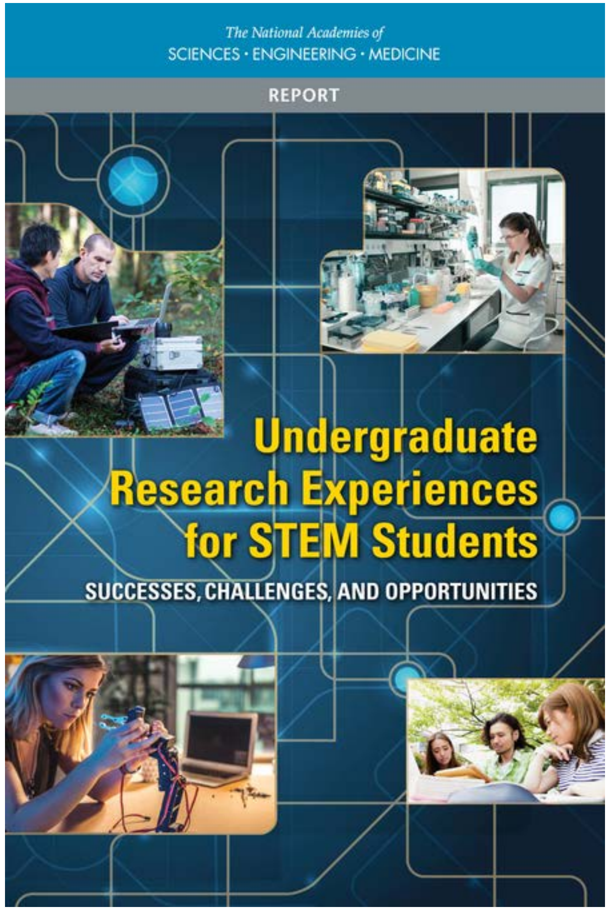
CUREs

Course-based Undergraduate Research Experiences

Why use CUREs?



2017- National Academies report examined the evidence on undergraduate research experiences (UREs) and **recommended 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**. UREs can be transformative to student outcomes.

Goals of CUREs:

- Engage students as active participants, not passive recipients, in undergraduate science courses.
- Ensure that undergraduate courses are active, outcome-oriented, inquiry driven, and relevant.
- Facilitate student learning within a cooperative context.
- Introduce research experiences as an integral component of science education for all students, regardless of their major.

Why use CUREs?

- SURE – and other surveys assessing undergraduate research impact show numerous learning gains and motivation for graduate school when students engage in research

    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, Winter2014

Challenges with incorporating traditional UR?

- Challenge: Independent undergraduate research experiences can be difficult to implement due to large enrollments and/or lack of infrastructure.

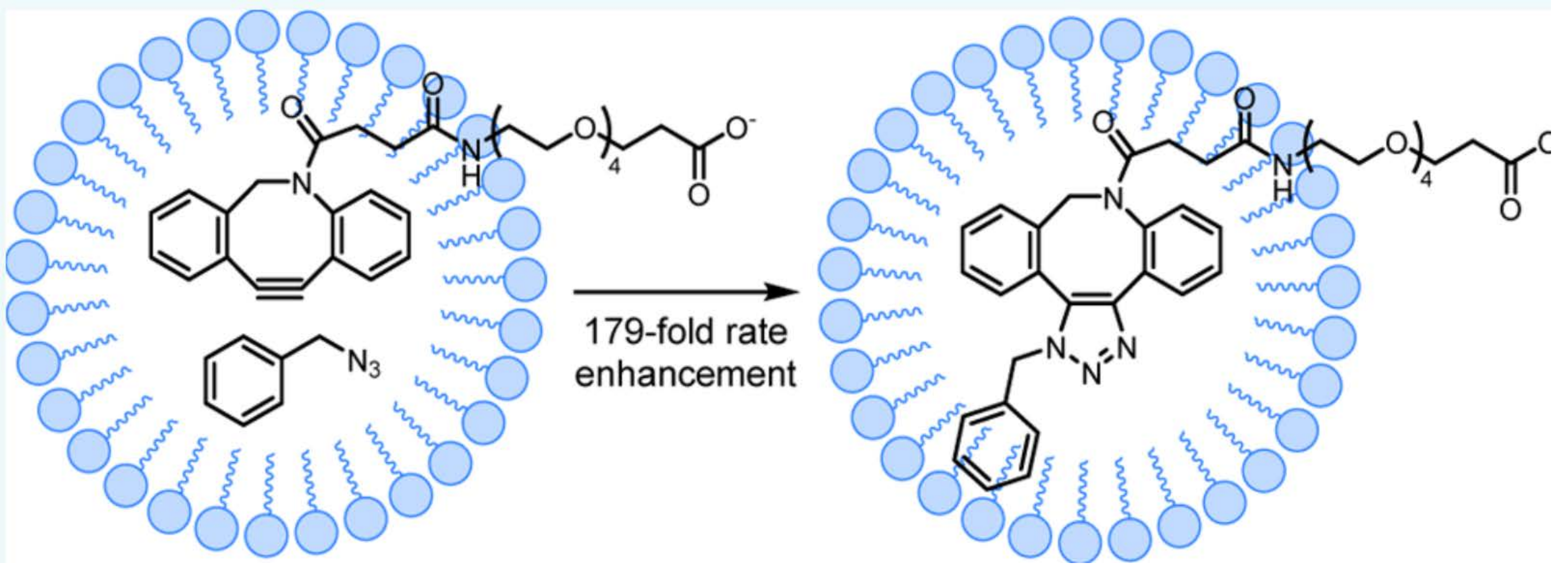
- Benefit: Undergraduate research is a very effective learning and training experience and is a recommended part of undergraduate training by ACS-CPT and Vision and Change (Biology) report.

- Solution: CURE in the middle of undergraduate curricula.

http://visionandchange.org/finalreport/

CURE Examples – University of Utah

- **Utah advanced organic laboratory, 300-level** (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., Scroggin, T. L.; Heemstra, J. M. Accelerating Strain-Promoted Azide-Alkyne Cycloaddition Using Micellar Catalysis. *Bioconjugate Chemistry* **2015**, *26(8)*, 1687-1691.



CURE Examples – UNC Asheville

Freshman Fall	Freshman Spring	Sophomore Fall	Sophomore Spring
General Chemistry	Foundations Organic	Organic Chemistry II	Foundations Analytical
General Chem. Lab	Foundations Inorganic	Organic Chem. Lab	Physics II (with lab)
Calculus I	Quantitative Chem. Lab	Physics I (with lab)	Humanities II
Foundations of Writing	Calculus II	Free Elective	Free Elective
First Year Colloquium	Humanities I	Free Elective	
15 CREDIT HOURS	16 CREDIT HOURS	15 CREDIT HOURS	15 CREDIT HOURS
Junior Fall	**Junior Spring**	**Senior Fall**	**Senior Spring**
Foundations Physical	Chemical Research I	Chemical Research II	Chemical Research III
Foundations Biochem.	Project Lab	Upper-Level Chem.	Upper-Level Chem.
Chem. Research Methods	Upper-Level Chem.	ARTS	Humanities IV/Capstone
Project Lab	Humanities III	Diversity Intensive	Free Elective
Second Language	Free Elective	Free Elective	Free Elective
Social Science			
16 CREDIT HOURS	14 CREDIT HOURS	14 CREDIT HOURS	15 CREDIT HOURS

- Revamped Curriculum in 2016
- Curriculum based on 5 foundations of chemistry (organic, inorganic, analytical, biochemistry, and physical chemistry)
- All teaching laboratories in chemistry are research based (CUREs)
- All BS majors required to complete a minimum of 4 semesters of undergraduate research

CURE Examples – UNC Asheville

CHEM 145 – Quantitative Chemistry Laboratory

Prior to 1999:

- Originally a second semester freshman laboratory with "cookbook" experiments
- **Students assessed on accuracy of outcome**
- Service course for Chemistry, Biology, and Environmental Studies

Since 2000:

- Redesigned to be a semester long CURE on Phytoremediation of Metals
    - Students write a proposal and then get revisions until "funded"
    - Setup experiments early in the semester and then learn techniques while plants grow
    - Use atomic absorption spectrometry to quantify accumulation
    - **Students assessed on hypothesis and interpretation of results**

Debra L. Van Engelen, Steven W. Suljak, J. Patrick Hall and Bert E. Holmes. *J. Chem. Educ.*, **2007**, *84* (1), p 128.

Sally A. Wasileski, PhD.

CURE Examples – UNC Asheville

Weeks	Laboratory Work	Research Project Components
1-3: Building Laboratory Skills	• Laboratory check-in • Activity on using volumetric glassware • Quantitative analysis of an unknown solution (Experiment 1)	• Background literature research • Experiment design • Proposal submission and approval
4: Research Experiment Setup	• Soil contamination and planting, set up controls and experimental variable	
5-8: Learn Techniques of Metal Extraction and Analysis	• Total metal extraction by acid digestion and soluble metal extraction (Experiment 2) • Analysis of total and soluble Fe content in soil by atomic absorption spectrometry (Experiment 3)	• Plants grow in experimental conditions for 6 weeks • Draft introduction (Week 7)
9-14: Group Project Work	• Harvest plants • Use techniques learned in Experiments 1, 2 & 3 to answer research questions via independent laboratory work • Laboratory check-out	• Draft experimental methods (Week 10) • Draft results and discussion on Experiment 3 (Week 12)
16: Final Report and Presentation		• Final project report • Oral presentation

Sally A. Wasileski, PhD.

CURE Examples – UNC Asheville

CHEM 312 – Interdisciplinary Chemistry Project Laboratory

- 6 hour research based laboratory taken during the junior year (one per semester)
- Replace traditional upper level subdiscipline specific laboratories (physical (I/II), analytical, biochemistry, inorganic)
- Developed to
  - Increase interdisciplinary problem solving skills (each integrate at least two subdisciplines of chemistry)
  - Improve the transition between teaching laboratory and independent research

Major implementation issue is faculty "buy in" due to increased work load and lack of administrative support.

Fix: Co-teach laboratories and pilot new research projects

CURE Examples – UNC Asheville

W 1-2

- *Proposal Writing and Research*
  - *Goals:* To promote a productive work environment between students and to write a well researched proposal for their individual projects.

W 3

- *Proposal Review and Revision:*
  - *Goals:* To increase oral presentation skills related to drug discovery research and to increase critical thinking skills relating to their own proposed work and the proposed work of other student teams.

W 4-6

- *Computational Modeling and Docking*
  - *Goals:* To successfully dock the designed analogs into the protein and to analyze and interpret the computational data collected from each experiment.

W 7-11

- *Analog Synthesis*
  - *Goals:* To build upon skills learned during the sophomore organic chemistry laboratory relating to reaction set up (specifically air and moisture sensitive reaction set up), extraction and purification techniques, and spectroscopic identification of complex organic molecules.

W 12-13

- *Analog SAR analysis*
  - *Goals:* To learn biochemical and molecular biology techniques related to drug discovery.

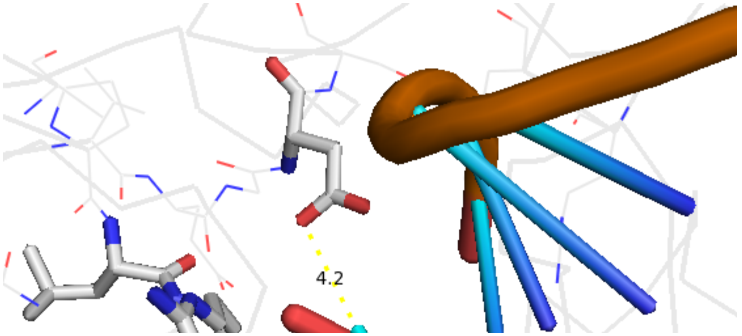
W 14

- *Presentation of results*
  - *Goals:* To learn to critically interpret data from multiple experiments compared to literature and to present their findings to discipline specific and lay audiences.

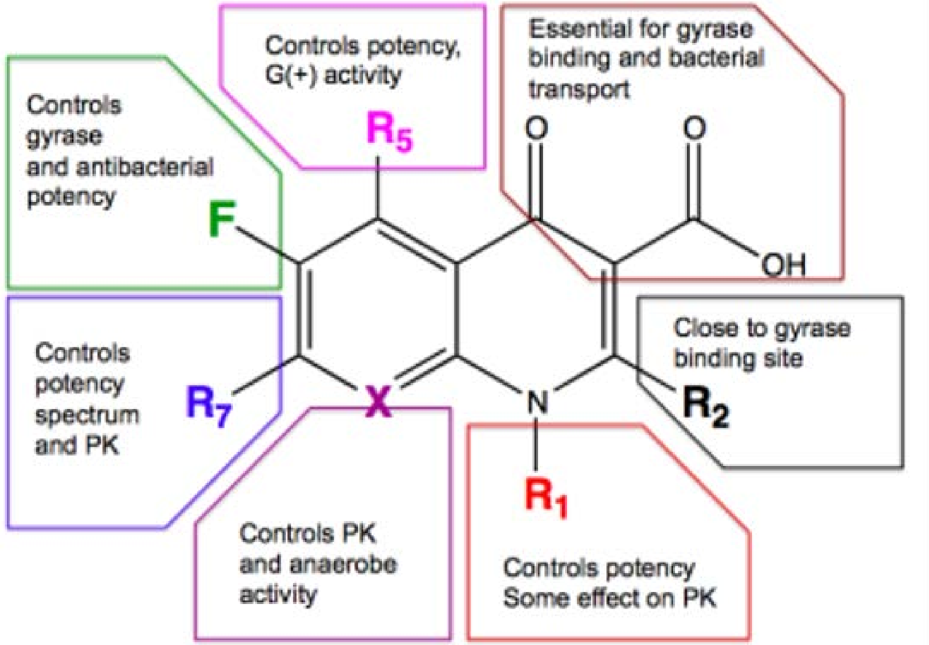
CURE Examples – UNC Asheville

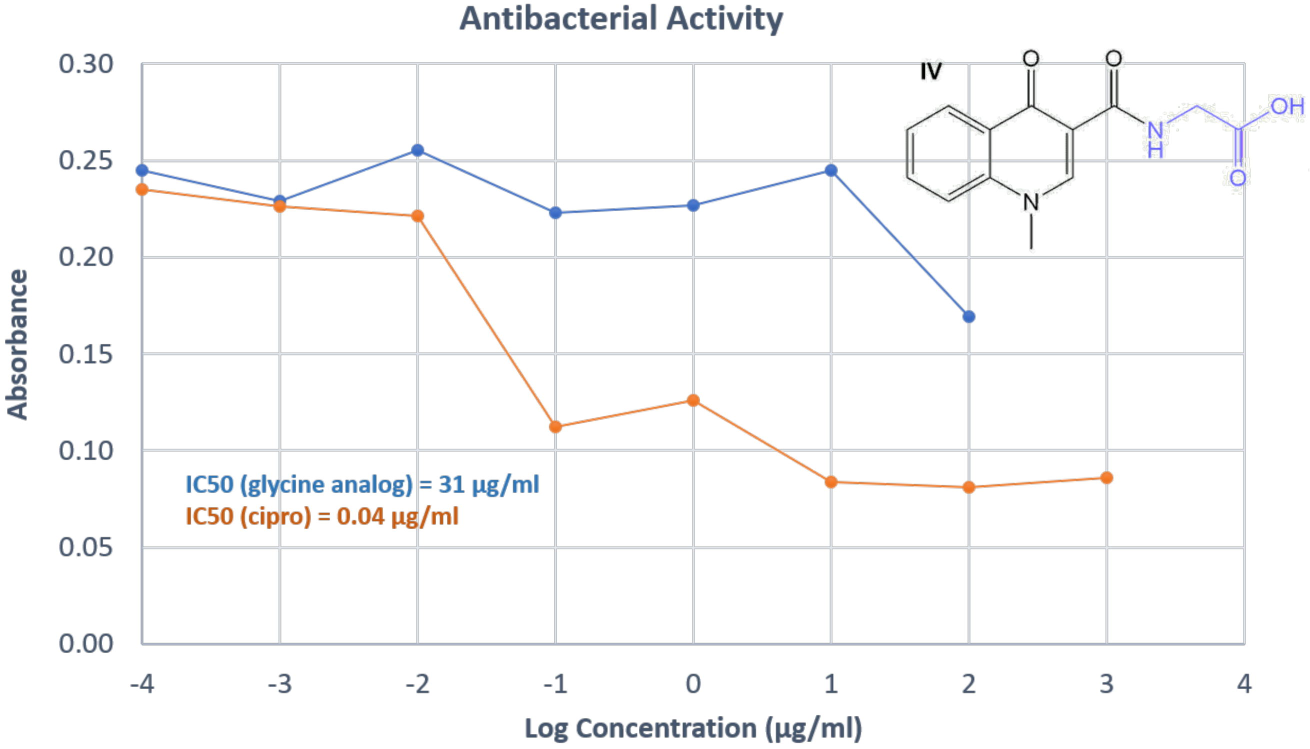
Drug Discovery Project Laboratory

- Synthesis and SAR Evaluation of Quinolone Class of Antibiotics
- Ciprofloxacin as a flagship in this class
- Mechanism of action: inhibition of D



Known SAR





CURE Examples – UNC Asheville

Project Laboratories Developed

- Biochemistry/Organic Chemistry:
  - Synthesis, Computational Docking, and Biochemical Analysis of Quinolone Antibiotics
  - Biochemical Determinants of Proton Dumping in ATP Synthase
- Bioanalytical:
  - Detoxification by Glucuronosyltransferases
- Inorganic/Analytical:
  - Water Quality and Contamination
  - Part 1: Synthesis and characterization of $[Co(NH_3)_6]Cl_3$, $[Co(NH_3)_5Cl]Cl_2$ and $[Co(en)_3]Cl_3$ precursors; Part 2: Synthesis and characterization of Co and Co_3O_4 Nanoparticles from the previously synthesized precursors
  - Synthesis and evaluation of Schiff Bases and Silver Lutedienes
- Physical/Organic:
  - Disproportionation-Combination Rate Constant Ratios for Halocarbon Radicals

CURE Examples – Haverford

- **Haverford "Topics in Bio-organic Chemistry"**
  7 week class (L. Charkoudian)
- Outcome: published paper and bioinformatic repository entries

300-level lecture class → 300-level CURE class

Article – Nucleotide Pairs

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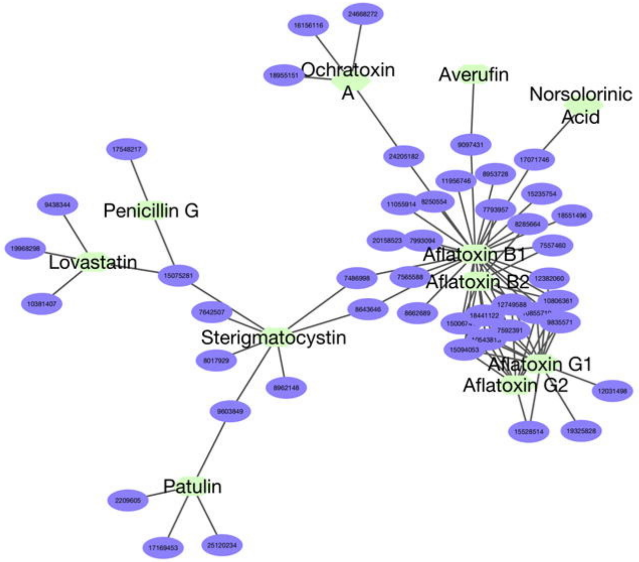
Natural Product – Article Network



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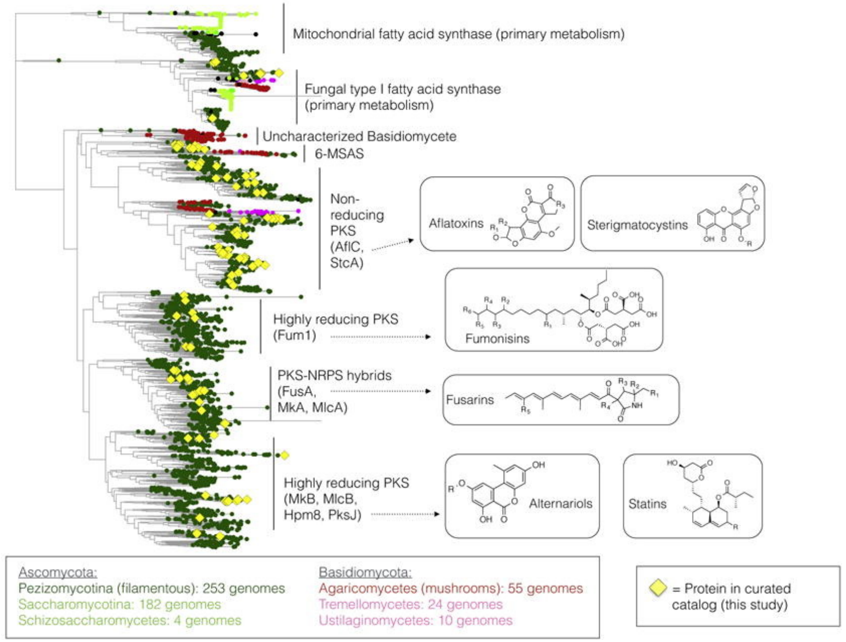
Chemical and Enzyme Sequence Diversity



Fuga Li, Y.,Tsai, K., Harvey, C., Ary, B., Berlew, E., Boehman, B., Findley, D., Friant, A., Gardner, C., Gould, M., Ha, J.H., Lilley, B., McKinstry, E., Nawal, S., Parry, R., Rothchild, K., Silbert, S., Tentilucci, M., Thurston, A., Wai, R., Yoon, Y., Medema, M. H., Hillenmeyer, M. E., and Charkoudian, L. K. "Complete Curation and Analysis of Literature Describing the Biosynthesis of Fungal Natural Products." *Fungal Genet. & Biol.*, **2016**, 89, 18-28.

Philosophical Differences of CUREs

- 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

Benefits of CUREs

- Undergraduates
  - More dynamic and effective learning environment
  - Improved critical thinking skills
  - Opportunity to engage in ongoing research projects with faculty
- 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

Approach to CURE development

1. Modify existing courses or individual assignments.
    - Best place to start

2. Rearrange curricular structure to fundamentally seed undergraduate research via designed CURE courses.
    - Once your department and institution has “bought in”

Choosing Projects for CUREs

- Factors:
  - Available instrumentation/expertise
  - Need for individual experiments/contributions that are closely related but intellectually individualized
  - Timing
  - Clear stakeholders
- Planning variables
  - Individual vs group data sets
  - Availability of materials or starting point from another course or research project

Choosing Projects for CUREs

Systematic study of a previously reported technology

- takes advantage of large number of students
- each student has their own defined piece of the project
- troubleshooting is more straightforward
- all students carrying out similar experiments – easier for TAs and instructor to help – also promotes peer-to-peer learning

Useful to scientific community, but typically not possible in traditional research lab due to funding constraints

Where to start

Questions to ask when you are starting a CURE

1. What do you want to accomplish?
2. **Who is this for?**
3. What will the students actually do?
4. What do you need?
5. **Do you have the time?**
6. What are the safety hazards?

Expanding the CURE Model: Course-based Undergraduate Research Experience. Rory Waterman and Jen Heemstra, 2018, Research Corporation for Science Advancement. https://rescorp.org/gdresources/publications/Expanding-the-CURE-Model.pdf

Where to start

Initial stages

1. Select research objectives and develop learning objectives from these.
2. Identify the course (new or converted) that will be used.
3. Select problem(s) to be investigated and techniques to be employed.
4. Plan the scope and scale of the course.
5. **Acclimate students. Research means failure, so students need to know that success in the course is not attached to success in their project.**
6. **Iterate. Like all changes to your teaching, adding a research component will be most successful after some trial and error.**

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Where to start

Administrative work

1. **Solicit buy-in from appropriate administrator** (e.g., department chair).
2. Identify needs, if any, beyond a conventional course and make the ask.
3. Assemble the necessary resources for the course (space, TAs, instrument time, etc.).
4. Assemble the necessary personnel (trained TAs, stockroom, faculty, etc.).
5. Devise any non-learning metrics of success.

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Where to start

Educational work

1. Using your objectives, design the course details (activities, assessment, etc.).
2. Develop an explicit plan to instruct students on research as an activity.
3. Include features that ensure the work is research (iteration, discovery, risk assessment, etc.).
4. Test the plan with a smaller group of students to ensure they are engaged in the targeted activities.

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Where to start

Execution

1. Be flexible in running the course; let the learning outcomes drive the curriculum.
2. **Solicit feedback from students and/or faculty.**
3. Evaluate against your learning objectives and any metrics of success.
4. **Be prepared to make choices between research progress and student learning with attention to both.**
5. Iterate the course and run again.

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CURE 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 between CURE semesters

Tips!

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

- Pay attention to available questions that might scale differently than "normal" projects in your research or your colleagues' research
  - Be creative
    - Within your curriculum
    - Within your own research

Tips!

1. Get help!
    - Colleagues
    - CUREnet (https://curenet.cns.utexas.edu)
    - CIRTL (https://www.cirtl.net)
    - "Adding Research to a Class" Facebook Group
    - Cottrell Scholars Project on CUREs (RCSA)
2. Plan...and then plan some more.
3. Start small.
4. Be cognizant of time and timing.
5. Acclimate students.
6. Iterate.

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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?

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