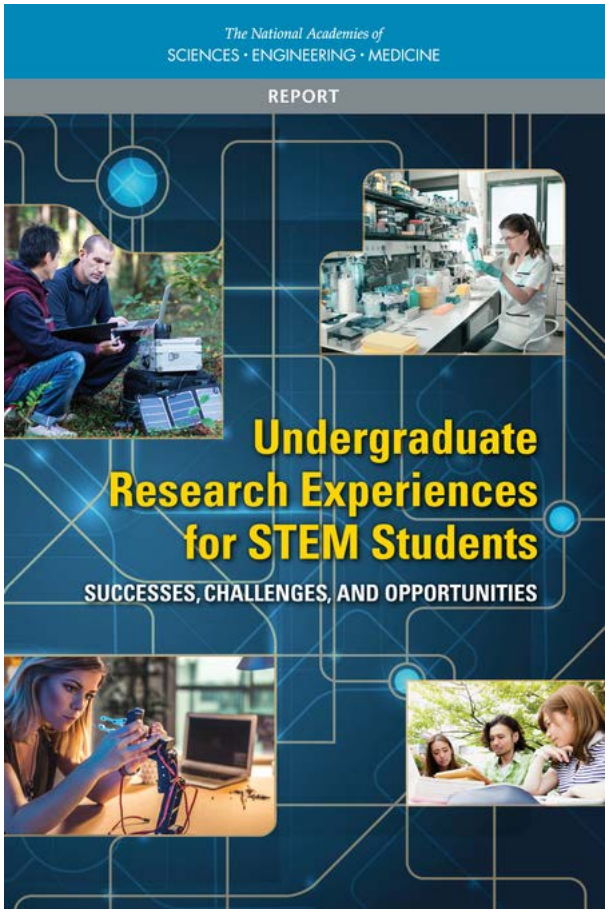
CUREs

Course-based Undergraduate Research Experiences



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:

- 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 CURE

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

- 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 report.

- Solution: CURE in the middle of undergraduate curricula.

Approaches to creating CUREs

1. Take existing courses and implement CURE in that context

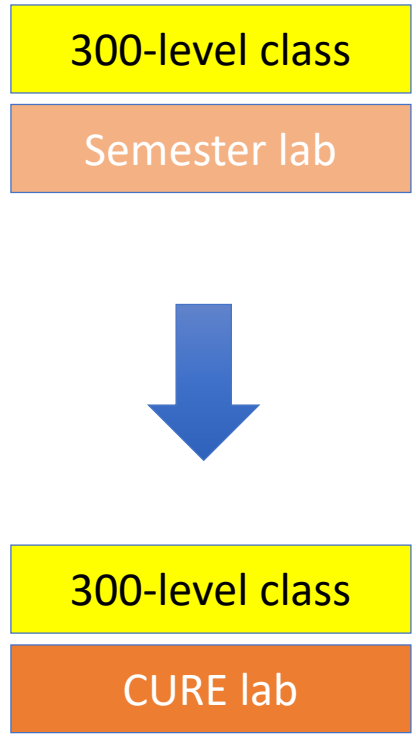
   - Labs attached to lecture classes
   - Independent lab classes
   - Large Lecture classes
   - Special topics classes

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

CURE example

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

- Outcome: comprehensive paper

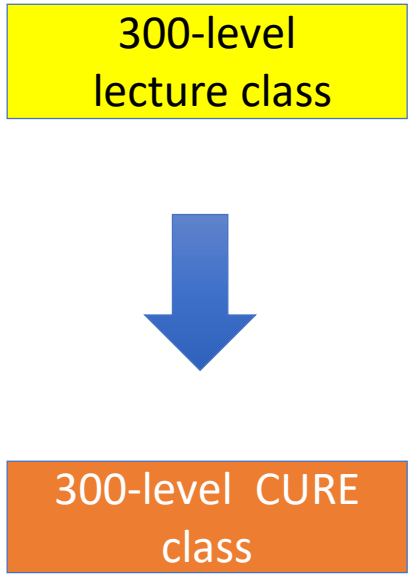


Anderton, G. I., Bangerter, A. S., Davis, T. C., Feng, Z., Furtak, A. J., Larsen, J. O., ... Heemstra, J. M. (2015). Accelerating Strain-Promoted Azide-Alkyne Cycloaddition Using Micellar Catalysis. *Bioconjugate Chemistry*, 26(8), 1687-1691.

CURE example

- **Haverford "Topics in Bio-organic Chemistry"** 7 week class (L. Charkoudian)

- Outcome: published paper and bioinformatic repository entries



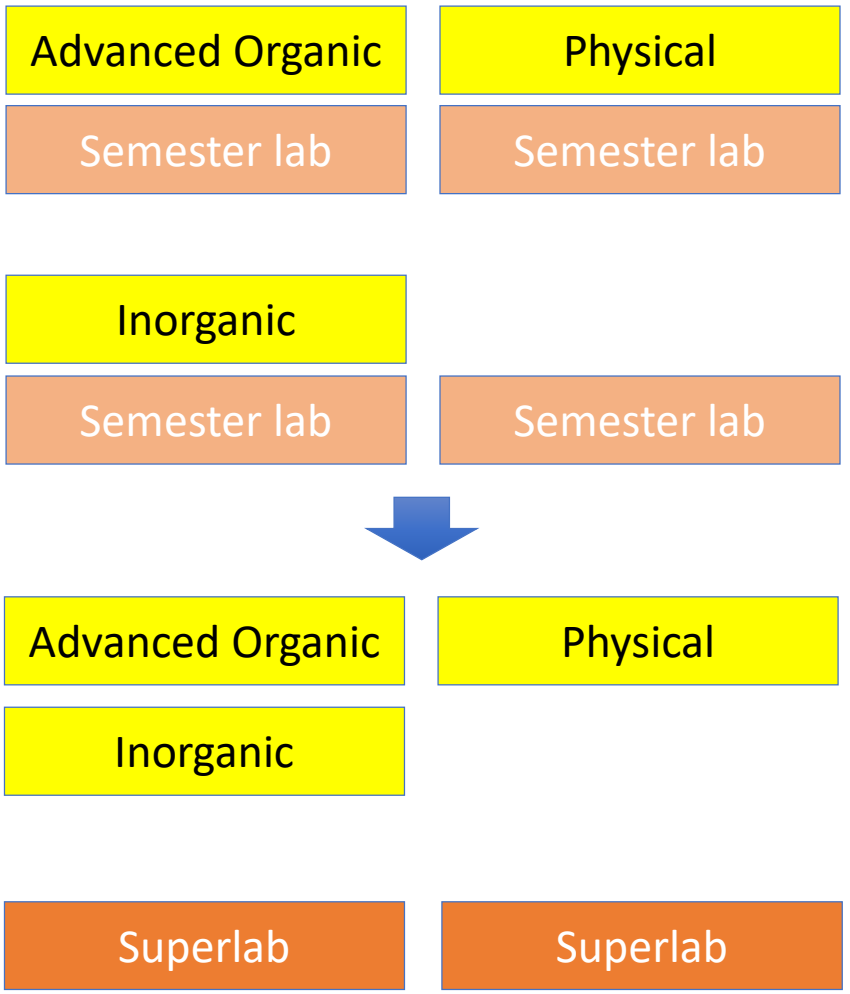
Fuga Li, Y.,Tsai, K., Harvey, C., Ary, B., Berlew, E., Boehman, B., Findley, D., Friant, A., Gardner, C., Gould, M., Ha, J.H., Lilley, B., McKinstry, E., Nawal, S., Parry, R., Rothchild, K., Silbert, S., Tentilucci, M., Thurston, A., Wai, R., Yoon, Y., Medema, M. H., Hillenmeyer, M. E., and Charkoudian,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

CURE example

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



Biochemistry CURE lab - JMU

- Biophysical Chemistry Major has two labs:
  - Fall: Purify protein and characterize kinetics
  - Spring: Structurally Characterize protein and perform student-designed experiments

Teaching Protein Purification and Characterization Techniques -A Student-Initiated, Project-Oriented Biochemistry Laboratory Course **-1250** Journal of ChemicalEducation Vol.85 No.9 - September2008

- Laboratory is constantly evolving with number of students – 6 (1998) – 30+ (2018)
- Goals of the Course: Chemistry 366 is designed to provide students with experience utilizing modern biochemical techniques to purify and characterize proteins. Students will be expected to use the primary literature to identify, plan, and execute a protein purification plan. This laboratory is designed to enhance problem-solving abilities while learning basic biochemical techniques. Experimental design plans, a laboratory final, laboratory reports and participation contribute to the the student's final grade.

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

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

It's all about problem selection . . .

- 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

What is the most widely accessed article in the Journal of Organic Chemistry?

It’s all about problem selection . . .

Most Read Articles

Most Read articles are updated on a monthly basis and available as 1 month and 12 month lists. Below is a Top 5 excerpt from the 1 month list.

NMR Chemical Shifts of Common Laboratory Solvents as Trace Impurities

Hugo E. Gottlieb Vadim Kotlyar Abraham Nudelman

Publication Date (Web): October 17, 1997 (Note)
DOI: 10.1021/jo971176v

	$CDCl_3$	$(CD_3)_2CO$	$(CD_3)_2SO$
solvent residual peak	7.26	2.05	2.50
H_2O	1.56	2.84	3.33
acetic acid	2.10	1.96	1.91
acetone	2.17	2.09	2.09
acetonitrile	2.10	2.05	2.07
benzene	7.36	7.36	7.37
chloroform	7.26	8.02	8.32
cyclohexane	1.43	1.43	1.40

Figure 1 of 2

Abstract

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PDF w/ Links[81K]
Full Text HTML

Add to ACS ChemWorx

It's all about problem selection . . .

Table 1. ^{1}H NMR Data

	proton	mult	$CDCl_3$	$(CD_3)_2CO$	$(CD_3)_2SO$	C_6D_6	CD_3CN	CD_3OD	D_2O
solvent residual peak			7.26	2.05	2.50	7.16	1.94	3.31	4.79
H_2O		s	1.56	2.84[a]	3.33[a]	0.40	2.13	4.87	
acetic acid	CH_3	s	2.10	1.96	1.91	1.55	1.96	1.99	2.08
acetone	CH_3	s	2.17	2.09	2.09	1.55	2.08	2.15	2.22
acetonitrile	CH_3	s	2.10	2.05	2.07	1.55	1.96	2.03	2.06
benzene	CH	s	7.36	7.36	7.37	7.15	7.37	7.33	
tert-butyl alcohol	CH_3	s	1.28	1.18	1.11	1.05	1.16	1.40	1.24
	OH[c]	s			4.19	1.55	2.18		
tert-butyl methyl ether	CCH_3	s	1.19	1.13	1.11	1.07	1.14	1.15	1.21
	OCH_3	s	3.22	3.13	3.08	3.04	3.13	3.20	3.22
BHT[b]	ArH	s	6.98	6.96	6.87	7.05	6.97	6.92	
	OH[c]	s	5.01		6.65	4.79	5.20		
	$ArCH_3$	s	2.27	2.22	2.18	2.24	2.22	2.21	
	$ArC(CH_3)_3$	s	1.43	1.41	1.36	1.38	1.39	1.40	
chloroform	CH	s	7.26	8.02	8.32	6.15	7.58	7.90	
cyclohexane	CH_2	s	1.43	1.43	1.40	1.40	1.44	1.45	
1,2-dichloroethane	CH_2	s	3.73	3.87	3.90	2.90	3.81	3.78	
dichloromethane	CH_2	s	5.30	5.63	5.76	4.27	5.44	5.49	
diethyl ether	CH_3	t, 7	1.21	1.11	1.09	1.11	1.12	1.18	1.17
	CH_2	q, 7	3.48	3.41	3.38	3.26	3.42	3.49	3.56
diglyme	CH_2	m	3.65	3.56	3.51	3.46	3.53	3.61	3.67
	CH_2	m	3.57	3.47	3.38	3.34	3.45	3.58	3.61
	OCH_3	s	3.39	3.28	3.24	3.11	3.29	3.35	3.37
1,2-dimethoxyethane	CH_3	s	3.40	3.28	3.24	3.12	3.28	3.35	3.37
	CH_2	s	3.55	3.46	3.43	3.33	3.45	3.52	3.60
dimethylacetamide	CH_3CO	s	2.09	1.97	1.96	1.60	1.97	2.07	2.08
	NCH_3	s	3.02	3.00	2.94	2.57	2.96	3.31	3.06
	NCH_3	s	2.94	2.83	2.78	2.05	2.83	2.92	2.90
dimethylformamide	CH	s	8.02	7.96	7.95	7.63	7.92	7.97	7.92
	CH_3	s	2.96	2.94	2.89	2.36	2.89	2.99	3.01
	CH_3	s	2.88	2.78	2.73	1.86	2.77	2.86	2.85
dimethyl sulfoxide	CH_3	s	2.62	2.52	2.54	1.68	2.50	2.65	2.71
dioxane	CH_2	s	3.71	3.59	3.57	3.35	3.60	3.66	3.75
ethanol	CH_3	t, 7	1.25	1.12	1.06	0.96	1.12	1.19	1.17
	CH_2	q, 7[d]	3.72	3.57	3.44	3.34	3.54	3.60	3.65
	OH	s[c,d]	1.32	3.39	4.63		2.47		
ethyl acetate	CH_3CO	s	2.05	1.97	1.99	1.65	1.97	2.01	2.07
	CH_2CH_3	q, 7	4.12	4.05	4.03	3.89	4.06	4.09	4.14
	CH_2CH_3	t, 7	1.26	1.20	1.17	0.92	1.20	1.24	1.24
ethyl methyl ketone	CH_3CO	s	2.14	2.07	2.07	1.58	2.06	2.12	2.19
	CH_2CH_3	q, 7	2.46	2.45	2.43	1.81	2.43	2.50	3.18
	CH_2CH_3	t, 7	1.06	0.96	0.91	0.85	0.96	1.01	1.26
ethylene glycol	CH	s[e]	3.76	3.28	3.34	3.41	3.51	3.59	3.65
"grease"[f]	CH_3	m	0.86	0.87		0.92	0.86	0.88	
	CH_2	br s	1.26	1.29		1.36	1.27	1.29	
n-hexane	CH_3	t	0.88	0.88	0.86	0.89	0.89	0.90	
	CH_2	m	1.26	1.28	1.25	1.24	1.28	1.29	
HMPA[g]	CH_3	d, 9.5	2.65	2.59	2.53	2.40	2.57	2.64	2.61
methanol	CH_3	s[h]	3.49	3.31	3.16	3.07	3.28	3.34	3.34
	OH	s[c,h]	1.09	3.12	4.01		2.16		
nitromethane	CH_3	s	4.33	4.43	4.42	2.94	4.31	4.34	4.40
n-pentane	CH_3	t, 7	0.88	0.88	0.86	0.87	0.89	0.90	
	CH_2	m	1.27	1.27	1.27	1.23	1.29	1.29	
2-propanol	CH_3	d, 6	1.22	1.10	1.04	0.95	1.09	1.50	1.17
	CH	sep, 6	4.04	3.90	3.78	3.67	3.87	3.92	4.02
pyridine	CH(2)	m	8.62	8.58	8.58	8.53	8.57	8.53	8.52
	CH(3)	m	7.29	7.35	7.39	6.66	7.33	7.44	7.45
	CH(4)	m	7.68	7.76	7.79	6.98	7.73	7.85	7.87
silicone grease[i]	CH_3	s	0.07	0.13		0.29	0.08	0.10	
tetrahydrofuran	CH_2	m	1.85	1.79	1.76	1.40	1.80	1.87	1.88
	CH_2O	m	3.76	3.63	3.60	3.57	3.64	3.71	3.74
toluene	CH_3	s	2.36	2.32	2.30	2.11	2.33	2.32	
	CH(*o*/*p*)	m	7.17	7.1−7.2	7.18	7.02	7.1−7.3	7.16	
	CH(*m*)	m	7.25	7.1−7.2	7.25	7.13	7.1−7.3	7.16	
triethylamine	CH_3	t,7	1.03	0.96	0.93	0.96	0.96	1.05	0.99
	CH_2	q, 7	2.53	2.45	2.43	2.40	2.45	2.58	2.57

[a] In these solvents the intermolecular rate of exchange is slow enough that a peak due to HDO is usually also observed; it appears at 2.81 and 3.30 ppm in acetone and DMSO, respectively. In the former solvent, it is often seen as a 1:1:1 triplet, with $^2J_{HD} = 1$ Hz. [b] 2,6-Dimethyl-4-*tert*-butylphenol. [c] The signals from exchangeable protons were not always identified. [d] In some cases (see note *a*), the coupling interaction between the CH_2 and the OH protons may be observed ($J = 5$ Hz). [e] In CD_3CN, the OH proton was seen as a multiplet at δ 2.69, and extra coupling was also apparent on the methylene peak. [f] Long-chain, linear aliphatic hydrocarbons. Their solubility in DMSO was too low to give visible peaks. [g] Hexamethylphosphoramide. [h] In some cases (see notes *a*, *d*), the coupling interaction between the CH_3 and the OH protons may be observed ($J = 5.5$ Hz). [i] Poly(dimethylsiloxane). Its solubility in DMSO was too low to give visible peaks.

Table 2. ^{13}C NMR Data[a]

		$CDCl_3$	$(CD_3)_2CO$	$(CD_3)_2SO$	C_6D_6	CD_3CN	CD_3OD	D_2O
solvent signals		77.16 ± 0.06	29.84 ± 0.01 206.26 ± 0.13	39.52 ± 0.06	128.06 ± 0.02	1.32 ± 0.02 118.26 ± 0.02	49.00±0.01	
acetic acid	CO	175.99	172.31	171.93	175.82	173.21	175.11	177.21
	CH_3	20.81	20.51	20.95	20.37	20.73	20.56	21.03
acetone	CO	207.07	205.87	206.31	204.43	207.43	209.67	215.94
	CH_3	30.92	30.60	30.56	30.14	30.91	30.67	30.89
acetonitrile	CN	116.43	117.60	117.91	116.02	118.26	118.06	119.68
	CH_3	1.89	1.12	1.03	0.20	1.79	0.85	1.47
benzene	CH	128.37	129.15	128.30	128.62	129.32	129.34	
tert-butyl alcohol	C	69.15	68.13	66.88	68.19	68.74	69.40	70.36
	CH_3	31.25	30.72	30.38	30.47	30.68	30.91	30.29
tert-butyl methyl ether	OCH_3	49.45	49.35	48.70	49.19	49.52	49.66	49.37
	C	72.87	72.81	72.04	72.40	73.17	74.32	75.62
	CCH_3	26.99	27.24	26.79	27.09	27.28	27.22	26.60
BHT	C(1)	151.55	152.51	151.47	152.05	152.42	152.85	
	C(2)	135.87	138.19	139.12	136.08	138.13	139.09	
	CH(3)	125.55	129.05	127.97	128.52	129.61	129.49	
	C(4)	128.27	126.03	124.85	125.83	126.38	126.11	
	CH_3Ar	21.20	21.31	20.97	21.40	21.23	21.38	
	CH_3C	30.33	31.61	31.25	31.34	31.50	31.15	
	C	34.25	35.00	34.33	34.35	35.05	35.36	
chloroform	CH	77.36	79.19	79.16	77.79	79.17	79.44	
cyclohexane	CH_2	26.94	27.51	26.33	27.23	27.63	27.96	
1,2-dichloroethane	CH_2	43.50	45.25	45.02	43.59	45.54	45.11	
dichloromethane	CH_2	53.52	54.95	54.84	53.46	55.32	54.78	
diethyl ether	CH_3	15.20	15.78	15.12	15.46	15.63	15.46	14.77
	CH_2	65.91	66.12	62.05	65.94	66.32	66.88	66.42
diglyme	CH_3	59.01	58.77	57.98	58.66	58.90	59.06	58.67
	CH_2	70.51	71.03	69.54	70.87	70.99	71.33	70.05
	CH_2	71.90	72.63	71.25	72.35	72.63	72.92	71.63
1,2-dimethoxyethane	CH_3	59.08	58.45	58.01	58.68	58.89	59.06	58.67
	CH_2	71.84	72.47	17.07	72.21	72.47	72.72	71.49
dimethylacetamide	CH_3	21.53	21.51	21.29	21.16	21.76	21.32	21.09
	CO	171.07	170.61	169.54	169.95	171.31	173.32	174.57
	NCH_3	35.28	34.89	37.38	34.67	35.17	35.50	35.03
	NCH_3	38.13	37.92	34.42	37.03	38.26	38.43	38.76
dimethylformamide	CH	162.62	162.79	162.29	162.13	163.31	164.73	165.53
	CH_3	36.50	36.15	35.73	35.25	36.57	36.89	37.54
	CH_3	31.45	31.03	30.73	30.72	31.32	31.61	32.03
dimethyl sulfoxide	CH_3	40.76	41.23	40.45	40.03	41.31	40.45	39.39
dioxane	CH_2	67.14	67.60	66.36	67.16	67.72	68.11	67.19
ethanol	CH_3	18.41	18.89	18.51	18.72	18.80	18.40	17.47
	CH_2	58.28	57.72	56.07	57.86	57.96	58.26	58.05
ethyl acetate	CH_3CO	21.04	20.83	20.68	20.56	21.16	20.88	21.15
	CO	171.36	170.96	170.31	170.44	171.68	172.89	175.26
	CH_2	60.49	60.56	59.74	60.21	60.98	61.50	62.32
	CH_3	14.19	14.50	14.40	14.19	14.54	14.49	13.92
ethyl methyl ketone	CH_3CO	29.49	29.30	29.26	28.56	29.60	29.39	29.49
	CO	209.56	208.30	208.72	206.55	209.88	212.16	218.43
	CH_2CH_3	36.89	36.75	35.83	36.36	37.09	37.34	37.27
	CH_2CH_3	7.86	8.03	7.61	7.91	8.14	8.09	7.87
ethylene glycol	CH_2	63.79	64.26	62.76	64.34	64.22	64.30	63.17
"grease"	CH_2	29.76	30.73	29.20	30.21	30.86	31.29	
n-hexane	CH_3	14.14	14.34	13.88	14.32	14.43	14.45	
	$CH_2(2)$	22.70	23.28	22.05	23.04	23.40	23.68	
	$CH_2(3)$	31.64	32.30	30.95	31.96	32.36	32.73	
HMPA[b]	CH_3	36.87	37.04	36.42	36.88	37.10	37.00	36.46
methanol	CH_3	50.41	49.77	48.59	49.97	49.90	49.86	49.50[c]
nitromethane	CH_3	62.50	63.21	63.28	61.16	63.66	63.08	63.22
n-pentane	CH_3	14.08	14.29	13.28	14.25	14.37	14.39	
	$CH_2(2)$	22.38	22.98	21.70	22.72	23.08	23.38	
	$CH_2(3)$	34.16	34.83	33.48	34.45	34.89	35.30	
2-propanol	CH_3	25.14	25.67	25.43	25.18	25.55	25.27	24.38
	CH	64.50	63.85	64.92	64.23	64.30	64.71	64.88
pyridine	CH(2)	149.90	150.67	149.58	150.27	150.76	150.07	149.18
	CH(3)	123.75	124.57	123.84	123.58	127.76	125.53	125.12
	CH(4)	135.96	136.56	136.05	135.28	136.89	138.35	138.27
silicone grease	CH_3	1.04	1.40		1.38		2.10	
tetrahydrofuran	CH_2	25.62	26.15	25.14	25.72	26.27	26.48	25.67
	CH_2O	67.97	68.07	67.03	67.80	68.33	68.83	68.68
toluene	CH_3	21.46	21.46	20.99	21.10	21.50	21.50	
	C(*i*)	137.89	138.48	137.35	137.91	138.90	138.85	
	CH(*o*)	129.07	129.76	128.88	129.33	129.94	129.91	
	CH(*m*)	128.26	129.03	128.18	128.56	129.23	129.20	
	CH(*p*)	125.33	126.12	125.29	125.68	126.28	126.29	
triethylamine	CH_3	11.61	12.49	11.74	12.35	12.38	11.09	9.07
	CH_2	46.25	47.07	45.74	46.77	47.10	46.96	47.19

Our experience

- Failure on many levels
  - Failure training!!!
- Overhead/time/planning
- Unpredictable resource use

- Publication: when and how? And with what level of class involvement?

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

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

Your turn!

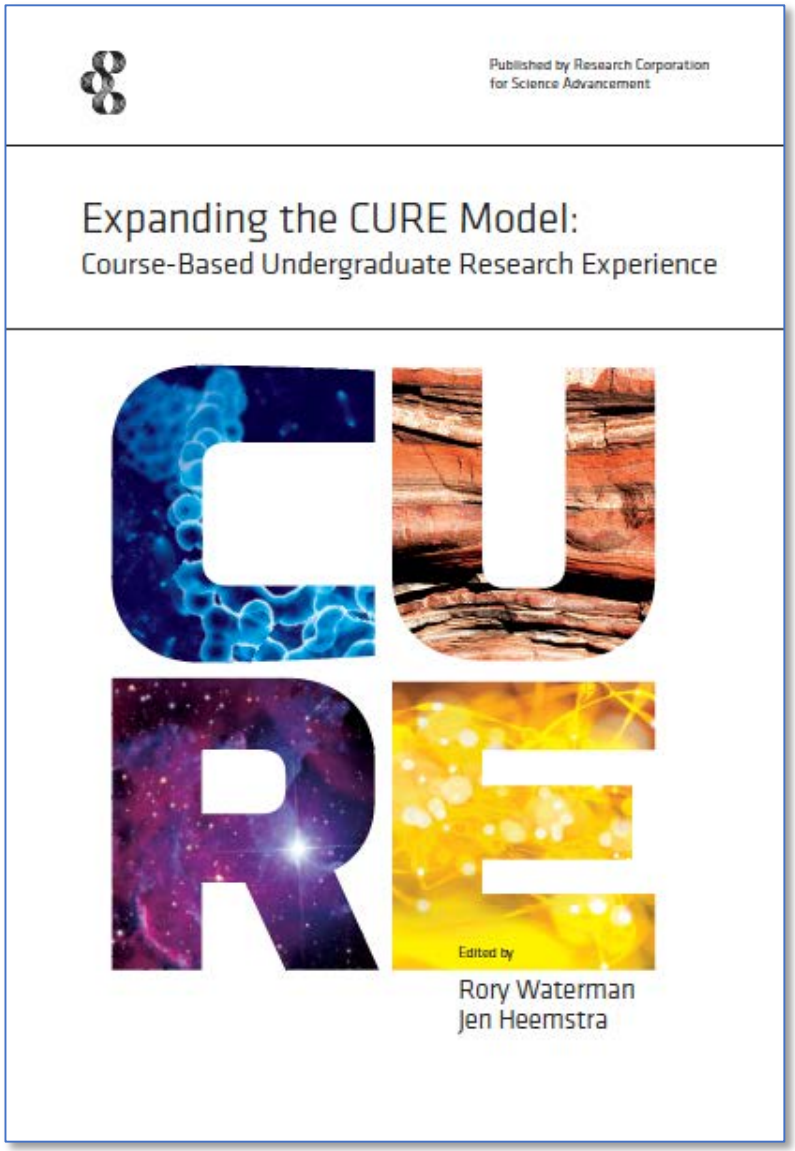
- Where is there a space in your curriculum that you could integrate a CURE?
- What project ideas would you want to explore?
- What support do you need from your department to do this?

Some keys for CUREs

- 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

Key resources!

- CUREnet (started for Biology: now for all!)
  - https://serc.carleton.edu/curenet/index.html
- CSC project on CUREs
  - CURE Institute (July 2019, …)
- "Adding Research to a Class" Facebook Group
- CURE Survey



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?