Qualitative analysis of introductory biology students' recollections after a completing a CURE or non-CURE laboratory course indicates that CUREs Framework constructs are salient to students

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CONTEXT & RESEARCH QUESTION

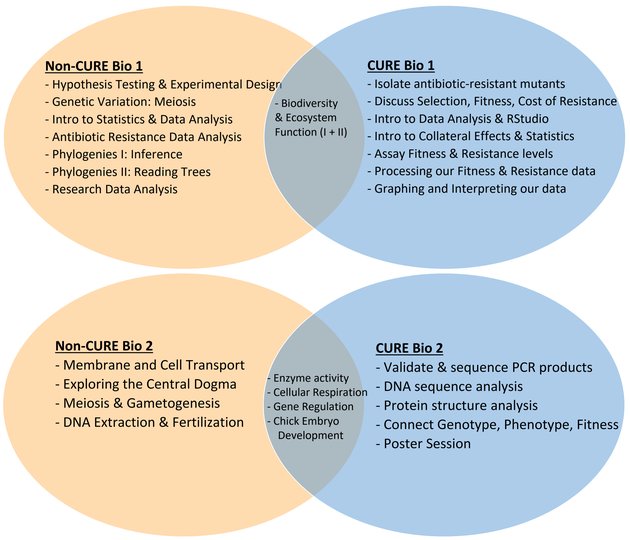
RESEARCH QUESTION: We investigated how participating in a CURE curriculum, or its traditional non-CURE counterpart, impacted students' perceptions of their introductory biology laboratory experience at the University of Washington (UW). Prior studies have defined key features of CUREs as: 1) use of scientific practices, 2) discovery and relevance, 3) collaboration, and 4) iteration {Auchincloss, 2014}. We analyzed students' post-course reflections to assess the extent to which CURE and non-CURE students consider these to be prominent features of their labs. Two primary goals of our study were to determine how our CURE curriculum influenced students' affect towards and understanding of scientific research, and to analyze how students' perceptions of their CURE or non-CURE laboratory experiences aligned with the field's established framework.

Figure 1 - Interview Participants: 40 volunteers were randomly selected from 4 introductory biology course-offerings spanning 3 quarters (Fall 2018, Winter 2019, and Spring 2019). All enrolled students were invited to participate in focus group interviews after completing the respective course(s). Sixteen focus groups interviews were conducted; data shown reflect 8 interviews analyzed thus far.

FALL 2018	WINTER 2019	SPRING 2019
Bio 1 Non-CURE ~1200 students enrolled **10 students interviewed** 4 students' data shown	**Bio 2 Non-CURE** ~550 students enrolled **9 students interviewed** 5 students' data shown **Bio 1 CURE** ~800 students enrolled **9 students interviewed** 4 students' data shown	**Bio 2 CURE** ~350 students enrolled **12 students interviewed** 6 students' data shown

Laboratory Modules in Non-CURE and CURE Bio1 & Bio2

Figure 2 – Venn Diagrams of Laboratory Modules: Laboratory modules included in the Non-CURE (orange shading) and CURE (blue shading) versions of Bio1 and Bio2, respectively, are shown. Overlapping modules were retained to meet key learning objectives not fulfilled in the CURE project, which focused on evolution of antibiotic resistance (CURE Bio1) and its molecular basis (CURE Bio2).



METHODS

RESEARCH DESIGN: We conducted focus group interviews with students who had recently completed either the CURE or non-CURE version of Part 1 or Part 2 of the introductory biology series at UW. All enrollees were invited to participate, and 40 volunteers were randomly selected (n = 16 groups; mean group-size: 2.5 students, range: 2-4 students). We employed a semi-structured interview protocol with 17 questions.

ANALYSES: Interviews were audio recorded, transcribed, and analyzed by a team of 6 qualitative data analysts using grounded theory to define emergent codes and themes. At least 2 coders analyzed each of the interview transcripts; all 6 analysts discussed their individually-generated codes to develop consensus codes. Tests of inter-rater reliability in applying consensus codes are in progress.

RESULTS

Here, we present preliminary qualitative analyses of students' responses to Question #3: ***"What did you do in labs for this course and why did you do it?",*** after participating in a CURE or Non-CURE series of laboratory modules (described in Figure 2).

Figure 3 –Tree of qualitative codes applied to analyze Non-CURE and CURE students' responses to Question #3: Emergent codes were generated by 6 qualitative data analysts (raters) who read and memo-ed transcripts, and discussed the meaning of participants' statements to arrive at consensus codes, shown below-left. The raters were blind to whether participants were in a Non-CURE or CURE course.

- Parent-level codes are denoted with teal-blue bars; child-codes with pink, and sub-child-codes with orange. Parent-level codes were "CURE", What ("WH"), and Why ("WY").
- Child-codes under "CURE" include alignment with undergraduate major and/or career objective (MjrCarr), Interpersonal Skills (IntrPersSkll), doing research (Doing), real-world applications (RlWrld), Contributing to a professional research-lab's research (ContrReal Rsch), and obtaining unknown/open-ended results (UnkwnOpenRes).
- Child-codes under "What" (WH) mainly refer to topics of specific lab modules (Figure 2), with the exception of activities, such as Discussion (Disc), experience with lab-work and techniques (ExpLab), reading studies (RdStdy), mini-lectures by the teaching assistant (TAMinLec), teamwork on dry-erase boards (Whiteboard), and worksheets (WrkSht); and one experimental outcome: RNA polymerase change due to selection of resistance-conferring mutation(s) (RNAPoly).
- Child-codes under "Why" (WY) range in focus from providing direct support for lecture objectives [e.g., learn Mitosis/Meiosis (Me/Mit), familiarize with lecture content (FamLectCont)], to transferrable skills, science process skills, and broader relevance of the labs' objectives.

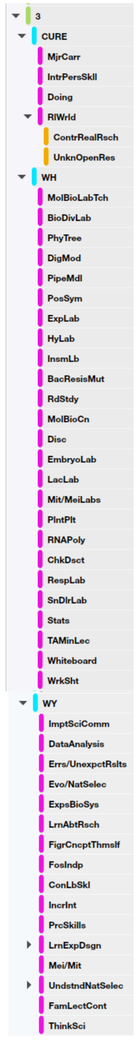


Figure 4 – Code co-occurrence plots for participants who completed a Non-CURE or CURE series of lab modules: Codes that 2 independent raters assigned to describe statements made by participants who completed a Non-CURE (Panel A) or CURE (Panel B) series of lab modules are shown, below-right. The code-tree (described in Figure 3) appears in the left-most 2 columns, and student-aliases for the participants in each treatment-group are noted at the top of each column. The frequency with which codes were assigned is color-coded in a heat-map: low, intermediate and high frequencies are indicated with blue, green, and red shading, respectively; absence of color indicates no code was assigned. Totals are reported in the bottom-most row (per participant), and the right-most column* (per code). [* The latter totals include co-occurrence with all other codes in the table, although only a subset of columns – the student's aliases – are shown].

A) Non-CURE

CODES	Sub-codes	Student 11	Student 12	Student 13	Student 14	Student 15	Student 16	Student 17	Student 18	Student 19	
CURE		0	0	0	0	0	0	0	0	0	0
	MjrCarr	0	0	0	0	0	0	0	0	0	0
	IntrPersSkll	0	0	0	0	0	0	0	0	0	0
	Doing	0	0	0	0	0	0	0	0	0	0
	RlWrld	0	0	0	0	0	0	0	0	0	0
WH		3	3	0	2	6	6	1	1	2	106
	MolBioLabTch	0	0	0	0	0	0	0	0	1	5
	BioDivLab	0	0	0	0	2	1	0	0	0	12
	PhyTree	0	0	0	0	1	0	0	0	0	4
	DigMod	0	0	0	0	0	0	0	0	0	0
	PipeMdl	0	0	0	1	1	0	0	0	0	10
	PosSym	0	0	0	0	0	0	0	0	0	0
	ExpLab	0	0	0	0	0	0	0	0	0	0
	HyLab	0	0	0	0	0	0	0	0	0	0
	InsmLb	1	0	0	0	0	2	0	0	0	18
	BacResisMut	0	0	0	0	0	0	0	0	0	0
	RdStdy	0	0	0	0	0	0	0	0	0	0
	MolBioCn	0	0	0	0	0	0	0	0	0	0
	Disc	0	0	0	0	0	0	0	1	0	6
	EmbryoLab	0	0	0	0	0	2	1	0	1	18
	LacLab	0	0	0	0	0	0	0	0	0	0
	Mit/MeiLab	0	0	0	0	1	0	0	1	0	17
	PlntPlt	0	0	0	1	0	0	0	0	0	3
	RNAPoly	0	0	0	0	0	0	0	0	0	0
	ChkDsct	1	0	0	0	0	0	0	0	0	4
	RespLab	0	0	0	0	0	0	0	0	0	0
	SnDlrLab	1	0	0	0	0	0	0	0	0	4
	Stats	0	0	0	0	2	2	0	0	1	22
	TAMinLec	2	3	0	0	1	0	0	0	0	27
	Whiteboar	0	1	0	0	0	1	0	0	0	10
	WrkSht	0	0	1	1	1	3	0	0	0	20
WY		2	2	1	2	3	1	1	1	1	77
	ImptSciCo	0	0	0	0	0	0	0	0	0	0
	DataAnalys	0	0	0	0	0	0	0	0	1	6
	Errs/Unexpc	0	0	0	0	0	0	0	0	0	0
	Evo/NatSel	0	0	0	0	1	0	0	0	0	5
	ExpsBioSys	0	0	0	0	0	0	0	0	0	0
	LrnAbtRsch	0	0	1	1	0	0	0	0	0	9
	FigrCncptT	1	0	0	0	0	0	0	0	0	5
	FosIndp	0	0	0	0	0	0	0	0	0	0
	ConLbSkl	0	0	0	0	0	0	0	0	0	0
	IncrInt	0	0	1	0	0	0	0	0	0	2
	PrcSkills	0	0	0	0	0	0	0	0	0	0
	LrnExpDsgn	0	0	1	2	1	3	1	0	1	44
	Mei/Mit	0	0	0	0	0	1	0	0	0	10
	UndstndNa	0	0	0	0	0	0	0	0	0	0
	FamLectCo	1	2	1	2	0	1	2	1	1	50
	ThinkSci	0	0	2	0	0	1	0	0	0	19
Totals		17	15	12	17	30	33	15	6	13	

B) CURE

CODES	Sub-codes	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8	Student 9	Student 10	
CURE		1	0	3	4	1	2	1	1	3	4	119
	MjrCarr	0	0	0	0	0	0	0	0	3	2	35
	IntrPersSkl	0	0	0	0	0	0	0	0	0	0	0
	Doing	1	0	0	0	0	0	0	1	2	2	42
	RlWrld	0	0	0	1	0	0	1	0	2	2	47
WH		3	3	0	0	0	1	1	0	2	3	78
	MolBioLab	0	1	2	2	0	0	0	0	0	0	30
	BioDivLab	0	0	0	0	0	0	0	0	0	0	0
	PhyTree	0	0	0	0	0	0	0	0	0	0	0
	DigMod	0	0	0	0	0	0	0	0	0	0	0
	PipeMdl	0	0	0	0	0	0	0	0	0	0	0
	PosSym	0	0	1	0	0	1	0	0	0	0	3
	ExpLab	0	0	1	1	0	0	0	0	0	0	4
	HyLab	0	0	0	0	0	0	0	0	0	0	0
	InsmLb	0	0	0	0	0	0	0	0	0	0	0
	BacResisMu	6	5	1	4	0	1	1	0	2	3	130
	RdStdy	0	0	0	0	0	0	0	0	0	0	0
	MolBioCn	0	0	0	0	1	0	0	0	0	0	3
	Disc	0	0	0	0	0	0	0	0	0	0	0
	EmbryoLab	0	0	0	0	0	0	0	0	0	0	0
	LacLab	0	0	0	0	0	0	0	0	0	0	0
	Mit/MeiLab	0	0	0	0	0	0	0	0	0	0	0
	PlntPlt	0	0	0	0	0	0	0	0	0	0	0
	RNAPoly	0	0	0	2	0	0	1	0	0	0	21
	ChkDsct	0	0	0	0	0	0	0	0	0	0	0
	RespLab	0	0	0	0	0	0	1	0	0	0	8
	SnDlrLab	0	0	0	0	0	0	0	0	0	0	0
	Stats	0	0	1	0	0	0	0	0	0	0	11
	TAMinLec	0	0	1	1	0	0	0	0	0	0	15
	Whiteboar	0	0	0	0	0	0	0	0	0	0	0
	WrkSht	1	0	0	0	0	0	0	0	0	0	8
WY		2	2	1	0	1	0	1	0	3	3	82
	ImptSciCo	0	0	1	0	0	0	0	0	0	0	4
	DataAnalys	1	0	2	1	0	0	0	0	0	0	31
	Errs/Unexpc	0	0	2	1	0	0	0	0	0	1	33
	Evo/NatSel	1	0	0	0	1	0	0	0	0	0	10
	ExpsBioSys	2	3	0	0	0	0	0	0	0	1	32
	LrnAbtRsch	2	2	1	0	0	0	1	0	1	3	86
	FigrCncptT	0	0	0	0	0	0	0	0	0	0	0
	FosIndp	1	0	0	0	0	0	0	0	0	0	6
	ConLbSkl	0	1	0	0	0	0	0	0	1	1	19
	IncrInt	0	0	0	0	0	0	0	0	0	1	3
	PrcSkills	0	1	1	0	0	0	0	0	1	1	30
	LrnExpDsgn	2	1	0	0	0	0	0	0	1	1	30
	Mei/Mit	0	0	0	0	0	0	0	0	0	0	0
	UndstndNa	3	3	0	0	0	0	0	1	1	1	59
	FamLectCo	0	0	2	3	1	0	1	0	0	0	40
	ThinkSci	2	2	0	0	0	0	0	0	0	0	14
Totals		32	24	25	25	6	6	10	2	28	35	

A) Non-CURE

B) CURE

Figure 5 – Word-cloud of codes applied to statements from interview participants who completed a Non-CURE or CURE series of lab modules: Word-clouds visualizations of codes that 2 independent raters assigned to describe statements made by participants who completed a Non-CURE (Panel A) or CURE (Panel B) series of lab modules are shown above. These word-clouds provide an alternative view of the code-frequency data depicted in Figure 4.

RESULTS SUMMARY

INTERPRETATIONS: Our preliminary analyses of students' responses to "What did you do in your labs and why?" in 8 transcripts indicate that CURE students mention parameters not found in non-CURE students' discourse. For example, whereas non-CURE students emphasized content-delivery methods, mastery of discrete skills, and reinforcement of lecture concepts; CURE students cited encountering unexpected results (opportunities for iteration) and learning about professional research by conducting their own research (scientific practices), which addressed questions that could help inform public health measures and clinical practices (discovery and relevance).

CONTRIBUTION: In this study, we found that students' salient reflections on their introductory biology laboratory experience align with outcomes predicted by the CUREs framework to a greater extent if they participated in a CURE than if they participated in a non-CURE laboratory experience. Therefore, our data suggests that students recognize the benefits of CUREs, and that students' perceptions of those benefits are consistent with CURE experts' views. Thus, our findings may help encourage faculty to implement CURE curricula by reinforcing – in the words of students – that the outcomes merit investing extra effort in leading CUREs.

FUTURE DIRECTIONS

Next steps for this project include:

1. Analyze 8 additional interview transcripts (21 participants.)
2. Complete qualitative analysis for other interview questions within the 16 transcripts, such as:
   - "What did you think about how science is done before taking this course's labs? If your understanding has changed in any way, how did it change?"
   - "Did you encounter any unexpected results? If so, what was that like?"
3. Troubleshoot R source-code to:
   - calculate Cohen's kappa (for inter-rater reliability),
   - perform statistical analyses of significance, and
   - graph percentage of interviewees in Non-CURE and CURE lab series who made a statement that elicited each code.
4. Seeking collaborators:
   - To analyze Spring '21 Scientist Spotlights data, &/or R code.

ACKNOWLEDGEMENTS

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hhmi Howard Hughes Medical Institute

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1) Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., Lawrie, G., McLinn, C. M., Pelaez, N., Rowland, S., Towns, M., Trautmann, N. M., Varma-Nelson, P., Weston, T. J., & Dolan, E. L. (2014). Assessment of course-based undergraduate research experiences: a meeting report. CBE life sciences education, 13(1), 29–40. https://doi.org/10.1187/cbe.14-01-0004

Comments during Zoom poster session from visitors:
Met Supriya, from SEB's group at ASU (PD hired for quanitative; gave me GREAT advice on when to try quant or stay 100% qualitative – Follow up via email

More notes on "June 2020" page of Ram Dass notebook, from: Supriya, and from Jon Herron

Chat:
2:43:06 From Becca Price (she/hers) : Joya - I've looked through your poster, and it's exciting and strong research! Sounds like your coding scheme is quite strong, and I like the plan to start lumping into bigger themes. Happy to talk in more detail later on. So nice to see you!
12:43:19 From Becca Price (she/hers) : I've got a ton of posters to visit today, so I'm going to move on.
13:00:30 From Bailey Rowe (she/her) : I'm going to run Joya. Your poster was great!! Super interested in how you do quantitative stuff going forward.
14:02:51 From Kelly McDonald : Nice work, Joya. I have to run to a Buddy meeting.
14:03:18 From Heather Fletcher : Thanks, Joya! :)

Q3: What did you do and why?

Why response without a what

- Evolution / Natural selection
- Thinking like a scientist
- Become familiar with lecture content

What response without a why.

- Reading Studies
- "Plant plot"
- Studying RNA polymerase change due to mutation
- Chicken dissection
- Respiration lab
- Statistics
- Sand dollar lab
- Embryo Lab
- Mitosis/Meiosis Labs
- TA Mini-Lectures
- Worksheets
- Discussion
- Lactose lab
- Whiteboard work

↓ What? ↓

- Making digital models and using the computer (R-studio)
- Drop-ins
- Doing instead of learning about how research is done
- Exposure/Experience with lab work and techniques
- Molecular Biology Lab Techniques: PCR and electrophoresis
- Molecular Bio Concepts: Glycolysis and pathways
- Insemination Lab
- Phylogenetic tree
- Poster symposium
- Biodiversity lab
- Bacterial resistance and mutation
- Hymenoptera lab
- Pipe cleaner models

↓ Why? ↓

- Learned interpersonal skills (collaboration)
- Data analysis
- Fostered independence
- Ties to major/own future career goals
- Practical and transferable skills (Personal)
- Confidence in lab skills
- Figure out difficult concepts for themselves
- Learning how research is actually done
- Exposure to biological systems
- Importance of science communication, sharing data
- To learn meiosis and mitosis
- Increased interest, Want to do further research experiences
- Applicable to own UG research experience
- Developing own conclusions, challenging paper results
- Learning experimental design/scientific research (hypothesis, predictions)
- Learning about margin of error and dealing with unexpected Results
- Understanding antibiotic resistance, fitness, competition, mutations, genotype/phenotype, protein structures
- Importance of issue of antibiotic resistance as a whole

CURE

- Real-world applications
- Contributing research to actual research (Kerr) lab
- Getting unknown/open-ended results

Q5: Lab/Lecture Connection

- Exams limited lab enjoyment
- Lab disconnected from exams
- Labs helpful to recall during exams
- Re: Exams
- Labs as progress check in understanding lecture content
- Lab as a smaller learning community than lecture
- Different kind of learning (hands-on, physical/visual activities)
- Required TA explanation to connect lab and lecture
- Lab reaffirmed lecture
- Timing Not Aligned
- Lab to apply concepts learned in lecture
- Lab disconnected from lecture
- Lab connected to lecture
- Lab providing supplementary info to lectures, dive in more deeply
- Introduce/learning new concepts in lab before discussing in lecture
- Lecture was so complete that it lessened the impact of lab

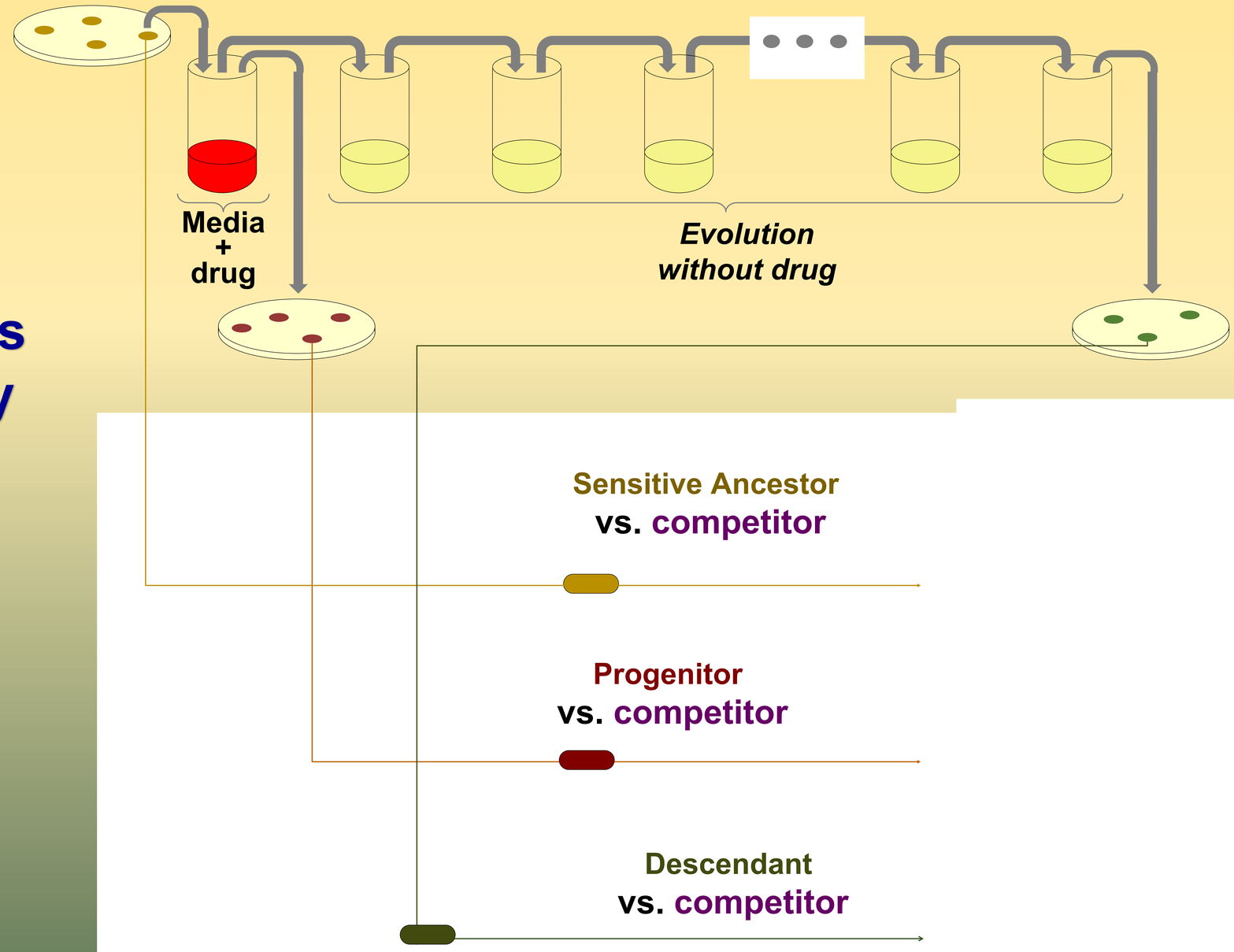
- Graphs and charts
- Learning style not possible in lecture.
- Visualization
- Q&A with TA
- Lab introducing concepts before lecture
- Repetition of concepts
- Explaining helped understanding (Discussion with classmates)
- Hands-on learning (Practical application)
- Reinforcement of concepts via application
- B/c of TA explanation than activity itself
- Access to learning resources
- Helpful
- Sense of ownership of own research
- Actually helping people with research in this lab
- Aimed at learning instead of completing assignments.

- Graded on material not taught
- Overemphasis on correct answers
- Emphasizing that there are no right answers
- Stressful
- Unnecessary/ Useless, Waste of Time
- Spent too long on/ Could spend less time on
- Confusing
- Boring
- Redundant
- Dislike
- Unhelpful
- Frustrating
- Liked it
- Purposeful (Motivational)
- Less Stressful
- Engaging
- Enjoyed it

- No
- Yes

Q4: Do you feel that lab supported your understanding?

BIOL 1: Experimental evolution & fitness competition assay



BIOL 2:
Molecular basis for fitness differences