



Enhancing Understanding of Multistep Projects Through Structured Concept Map Activities

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Abstract

Frontiers, Analysis, and Discovery in Biological Sciences is a first-year, research-based laboratory course. Throughout the semester, students work on a research project requiring them to make components of the experiment, such that each step builds off of a previous experiment. Students often have a hard time connecting the individual experiments with the overall goals of the project. To address this, we use a concept map activity to facilitate student discussions around individual steps of the project. The students work in groups to review the current experiment and connect it to previous experiments in addition to the overarching goal of the semester long project. Once a group has created their part of the map and added it to the board, they are tasked with explaining why they made their connections to the rest of the class. This presents an opportunity for the rest of the class to ask clarifying questions and for us to reinforce key concepts and connections.

Keywords: Concept map, group work, multiple interconnected steps, communication, review activity

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INTRODUCTION

A concept map is a way to organize ideas and visualize relationships between concepts (Novak 1981). It can be used to generate connections between different steps of a larger group assignment or project. This is especially useful in projects or assignments that contain multiple parts that are interconnected. This allows students to visually connect ideas and terms that relate to each other within individual parts and how they are related to the overall goal of the assignment or project. This strategy can be adapted to any class, project, or assignment that contains many related steps to achieve a goal (Novak et al. 2008).

In our course, 15-24 first year undergraduate students work on a semester long research-based laboratory project for three hours twice a week. They often struggle to maintain an understanding of how separate experiments, or individual steps of each experiment, contribute to the overall goals of the research project. We implemented this structured concept map activity to help students identify these connections and relate the individual experiments back to the semester long project goal. The students work in groups to review the current experiment and connect it to previous experiments in addition to the overarching goal of the research project. We keep the concept map on display in the laboratory during every class session

so students can review it at any time and add new connections throughout the semester. Often, students independently use the concept map to review experiments or identify areas of confusion; the physical presence of the concept map allows them to organize their thoughts, formulate questions, and seek answers in a low-risk environment. This also allows us to facilitate discussions to clarify confusion and help review material.

Preparing the Concept Map Activity

Preparation is key to the successful implementation of this concept map activity in class. We began with identifying the overarching topic or main goal of the project or assignment; for us, it was to mutate yeast using CRISPR. We next broke our overall research project into 3-5 main steps; for us this was “Isolate Plasmids with Ribosome Assembly Factor Targeting Sequences and Without, Generate CRISPR Mutations, and Characterize Mutations”. We then identified the most important events that contribute to each of the previously identified major steps; for us, this was how each individual experiment would contribute to the main steps of the project. Finally, we generated a list of terms that relate to each important event; for us, each experiment contained key words, definitions, or general knowledge pertaining to that specific experiment (see Appendix A, Examples 1 and 2). We then examined our list carefully to ensure that terms appearing in multiple experiments were not repeated, to encourage students to make connections between multiple events. For additional visual cues, we color-coded each step and list of terms so students could quickly identify which words are specific to each experiment.

Since we use this activity as review for our quizzes, we next identified areas (the individual experiments) that we wanted each quiz to focus on. This allowed us to break up the entire list of individual experiments into manageable pieces for each iteration of the activity in class. We then generated a handout for each group of experiments to help students work through the exercise (see Appendix A, Example 3). This preparation took 1-2 hours, easily achievable before or at the start of the semester.

Because our learning objectives for this activity include discussion and group work, we strategically opted to introduce the activity by modeling the creation of an example concept map ourselves for the students during class on a reasonably generic, multistep process with which most would be familiar: making cookies (See Figure 1). We used the previously described process to establish the concept map parts. During this modeling, we showcased group work and discussion through the implementation. Seeing their instructors work through the activity sets the expectations for how to create the concept map as well as the importance and added benefits of group work and discussion throughout the process.

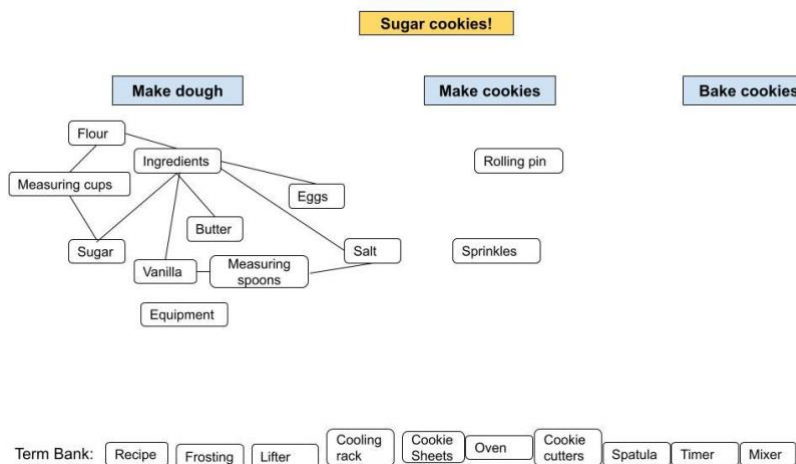


Figure 1. Introductory Generic Concept Map Made with Google Draw. Example of concept map generated by instructors used to introduce the concept mapping activity to students in the Spring 2021 semester using baking cookies as an example of a multistep project.

Implementing the Concept Map Activity in the Classroom

Introduction of the concept map activity involves two steps, an instructor example followed by student-led sections. Before having students concept map for the first time, instructors modeled the entire concept map process using the generic example of a multistep project: making cookies (See Figure 1). We began with the first main goal completed and present on

the map (make dough) and explained the connections we made, similar to how we would expect them to present their maps. Using the second main goal (make cookies), we modeled how to identify connections, discuss them as a group, and add them to the board. We highlighted making connections to the terms already present on the board. We used the third main goal (bake cookies) to show that the different portions build off of and expand from each other and that connections should be made throughout each step of the project. Additionally, we use it as a discussion point to show that each person can identify connections and organize information differently and that there is no right or wrong answer when generating a concept map; each instructor discussed how they would make the connections to emphasize this point.

We ran this activity multiple times throughout the semester and started it during the class period prior to our in-class quizzes. Each time, students are grouped into teams of 3-4 and are maintained throughout the semester. Each team is provided with terms for a specific experiment with each group responsible for concept mapping the terms for a different technique that would be covered in the upcoming quiz. The entire class is provided with a handout that includes each experiment that is being mapped as well as the list of terms and questions regarding the individual experimental goal and how that experiment relates to the overall project. Each student group uses the handout as a guide and drafts a concept map of the terms for their assigned experiment and then reviews their map with an instructor or TA for feedback. Once approved, students are invited to create their map on the board using provided materials and encouraged to make connections to other maps and terms already present on the board as well as add additional notes or context with the provided notecards (see Figure 2). This part of the activity is typically conducted during the last 45-60 minutes of class time the day prior to the scheduled quiz.

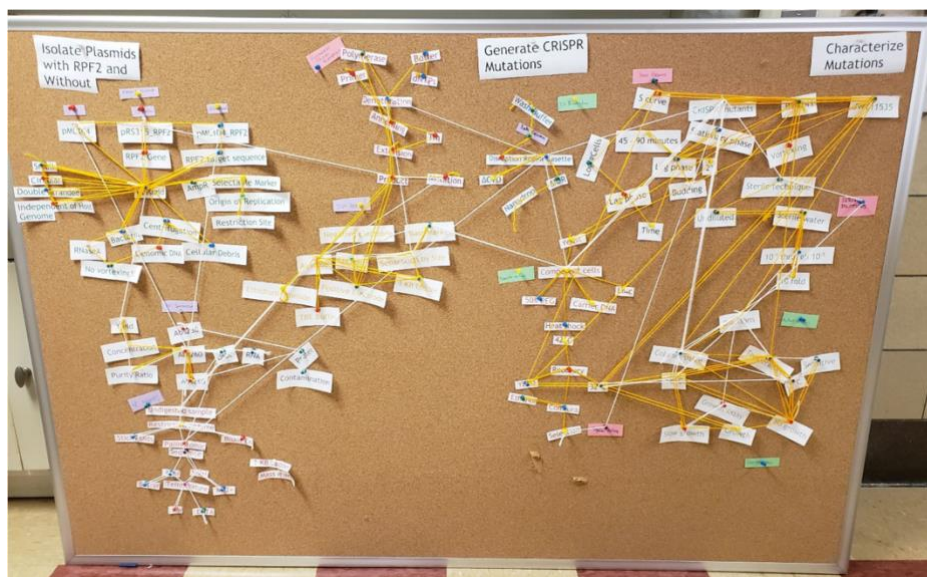


Figure 2. Specific Concept Map Made with Craft Supplies. Example of concept map generated by in person teams of students in Fall 2022. Total 15 students enrolled. Connections were implemented using yarn and terms added using push pins onto a 60-inch X 48-inch cork board. Additional details are added as needed using note cards. Instructors provided all materials.

The first 45-60 minutes of the next class is allotted for the groups to present their map to the rest of the class, focusing on why they made their connections within their assigned topic and how their specific experiment connects to the overall project. Students can use their handout as a reference during the presentation, answering the questions provided and discussing the connections they identified. After each presentation, instructors summarize the student-led presentation highlighting connections between terms and major topics and encouraging the class to determine if there are connections missing from the board, especially to other topics and experiments. During this time, we incorporate purposeful pauses to allow students time to synthesize information, identify points of confusion, and come up with questions. Immediately following this review session, students are provided with 10-15 minutes of additional time to review the material and ask any remaining questions to instructors and TAs one-on-one prior to taking their quiz.

Due to the COVID-19 pandemic, we have implemented this concept map activity in various modalities. Remote laboratory instruction and return to a hybrid classroom environment necessitated a pivot in implementation from the craft supply

model. We opted to use Google Draw to simulate the concept map activity in a completely online format (See Figure 3). Preparation remained the same, however we needed a way to facilitate the group discussion. Therefore, we used a combination of Google Draw (for each concept map) and Zoom (our university’s provided online collaborative meeting program). Students were put into their groups in a breakout room to work together to generate their map. This format allowed us to put groups together that included both in person and remote students and therefore had the added benefit of facilitating connections between first years who may or may not be present on campus. Each group was provided with their own Google Draw slide, which only contained the list of terms they were responsible for generating a concept map for and were tasked with making the connections. Each student in the group could move and edit the pieces of the concept map at the same time. After the group discussion, the instructors added the individual group concept maps to a separate overall semester concept map (which only the instructors had the ability to edit). This way students could view the overall concept map at any time, while working on their own portion. After each individual group presentation and discussion was completed, we focused the students’ attention on the overall concept map and tasked them with identifying connections between experiments. Since they could not edit the overall map, the instructors added the connections discussed by the students.

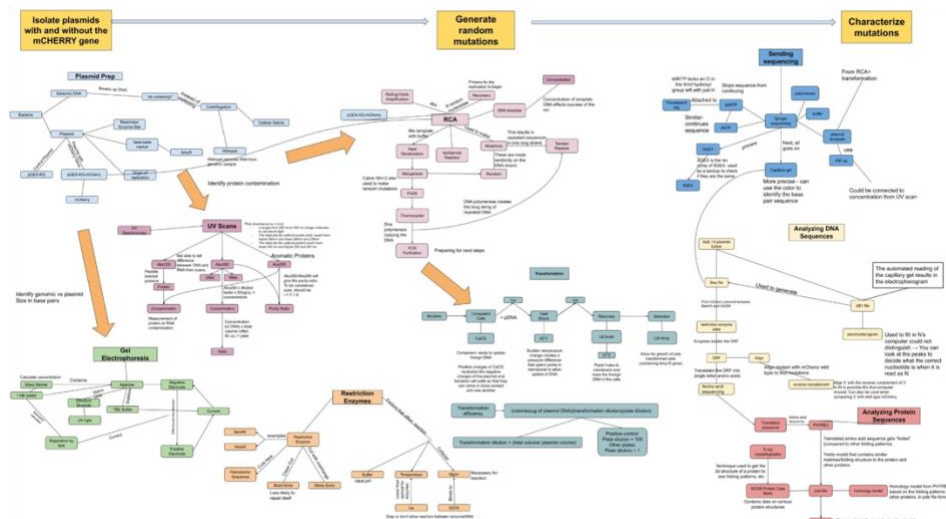


Figure 3. Specific Concept Map Made with Google Draw. Example of concept map generated by in person and remote teams of students in Fall 2020. Total 13 students enrolled - 7 in person and 6 remote. Individual maps were created using Google Draw with students in breakout rooms via Zoom. The concept maps were then transferred to a file containing all maps.

STUDENT OUTLINE

Objectives

Make connections between individual steps and long-term goals
 Identify relationships between multistep procedures
 Review material through student collaboration and class discussion

Instructions provided to group of students generating concept map:

1. Using the terms provided, draft a concept map on scratch paper. Identify connections between terms and determine a way to organize the information. Consider connections you can make to other terms in concept maps already present on the board. Remember, there is no right or wrong way to generate a concept map!
2. Review your proposed concept map with an instructor and/or TA for feedback.
3. Once approved, add your concept map to the board with the materials provided. Add connections from your map to other terms already on the board. You can also add notes about how information is connected or why it organized in a certain way using the provided notecards.
4. Use the provided handout to take notes about your connections and connections other groups made. Everyone is responsible for understanding the entire project, not just your part of the concept map. Be sure to answer the questions in the handout to put the experiments into context. You can use these notes as a reference to help you present your map to the rest of the class.
5. For the group presentation, you will discuss the entire section in the handout for your map, including the questions. Be prepared to explain the connections you made within your concept map and to other terms already present on the board to the rest of the class. Everyone in your group should participate in the presentation.
6. Be sure to ask questions!

Example of handout provided to all students in the course:

Quiz 3 Review

Topic	Task	Response
PCR	<u>Answer the following question.</u> What is the goal of this experiment in general?	
	<u>Answer the following question.</u> How did this experiment help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Nucleotides (dNTPs) Polymerase Denaturation Annealing Extension Primer Melting Temperature (T _m) Product Template Buffer Mutation	

MATERIALS

- Materials needed for any format of concept map.
 - Approach to project list in instructor version. It should contain the overarching topic, the 3-5 major steps that lead to the overarching topic, the most important events that contribute to the major step, and list of terms that relate to the most important events. One for instructor(s) only.
 - Student handout. One handout per student.
- Materials needed for in person concept map activity
 - Approach to project list in concept map form. This is the same as the instructor version but printed out in different colors and broken out for each topic. The overarching topic and major steps are placed on the board in a singular color. Most important events and list of terms are printed in different colors (one for each important event) large enough to be visible on the board by the students. One per group.
 - Large (60-inch X 48-inch) corkboard. One per class. Multiple sources available – Example from Amazon: \$269.90. <https://www.amazon.com/VIZ-PRO-Notice-Inches-Silver-Aluminium/dp/B07GPMNN4B?th=1>
 - Yarn. One to three skeins as necessary.
 - Scissors. One to three pairs as necessary.
 - Notecards. Ten to twenty as necessary.
 - Permanent Marker. One to three as necessary.
 - Pushpins. Fifty to one hundred as necessary.
- Materials needed for online concept map activity
 - A computer with Internet access.
 - Access to Google Draw or similar online collaborative drawing tool.
 - Individual group concept maps. Using the approach to project list, individual group maps with just the words listed should be generated. Each different most important event should be listed in a different color. Editing access should be granted to students. One per group.
 - Group concept map. There should be an additional Overall Class concept map, where each individual group maps are added to for the entire class to view. This is only edited by the instructors. One per class.
 - Zoom Client or other online collaborative technology, which allows small group, collaborative, discussion.

NOTES FOR THE INSTRUCTOR

Throughout multiple semesters of using this activity, we encountered several challenges that led us to make changes to the structure of the concept map activity. One of the biggest challenges we identified was implementation. We have adjusted the time and structure of the activity to the version presented here. The time required for the activity varies depending on the complexity of the most important event, the number of most important events, and the modality. More complex events (for us experiments) take longer to concept map, as students generally have more questions and there are more terms to connect. The number of most important events you have students concept map during the same period can increase the time to make connections and add to the board. Additionally, we found that when concept mapping in person, it is helpful to provide students with other tasks they can work on during the activity. Since only one group can be working on the corkboard at a time and each group moves at different pace in constructing their map, this provides something for faster groups to do while the rest finish their task. However, in online format, multiple groups can be working at the same time so additional activities are not required resulting in the entire activity generally taking less time. The follow up discussion can also vary depending on the topic and review; generally, more complex topics and multiple most important events require more time to review. It is important to provide students adequate time to put their map on the board and make connections to other parts without feeling rushed.

We have also learned that more structure for the activity is necessary, especially in our first-year course. Instructions are provided during the introduction of the activity, as the instructors are presenting the generic example, and included on the handout. Feedback is given every time the concept map is conducted; we give students feedback on their maps and ask for student feedback on the concept map activity at least once every semester. In fact, the student handout was created as a result of this feedback; the students asked for more structure and a way to organize their thoughts. We use this handout as a way to help students review and put the experiments in context; they often know the purpose of the experiment but struggle to identify how it is related to the overall goal. The handout is a way to help them compare those differences. This handout allowed all students equal access to all portions of the map, a way to organize their thoughts, facilitated participation, and gave them a way to review content at any time during the semester; we also encourage anyone not presenting to take notes on their handout during presentations. Generating the template for the handout presented a challenge, because we wanted all students to use it to help them organize their thoughts but also keep a consistent structure so they could approach it a similar way each time the activity was conducted with different topics. We settled on the template below as a way to accomplish both tasks, allowing us to apply it to any activity we were concept mapping and to any project or assignment outside of our class.

We also found the best way to introduce this activity is to first model it using multiple instructors or instructor/TA groups; we learned that modeling the concept map process helped empower students to generate their own maps and identify the value in the activity. We illustrate that the work is collaborative and the activity is discussion and participation based. While we keep the assessment of this activity low-stakes and participation based, we are still meeting our learning objectives of improving group work, communication, and presentation skills. We also use this opportunity to emphasize that there is no one correct answer for concept mapping since many connections can usually be made.

The most valuable part of the activity is discussion, both after the group make their initial connections and after groups have added their portion to the overall board. It is critical to have students review their map with an instructor or TA prior to presenting to the class as it helps to clarify confusion and provides them with the confidence to present their work; it also sets the precedent that everyone is expected to participate in all portions of the concept map activity. We also learned to allow the students to present their concept map and the logic for the connections without interruption. We want them to feel empowered to discuss their experiment and their logic for connections without the instructors intervening, which they could interpret as an indication that they did the activity 'wrong'. After each group presents their portion, we ask the class to help identify new connections to the larger board; we purposefully design the activity such that common or related terms across all maps and duplicates are removed during the preparation of the activity to help encourage connections across the board. This emphasizes that experiments are interconnected and related. Following this discussion, the instructors then facilitate the review discussion, asking for questions, highlighting any areas that students may have missed, and reviewing information to correct any misconceptions or incorrect information presented.

One final thing to keep in mind is to leverage the power of the concept map. Refer to it as often as possible throughout the semester. We display the concept map in the classroom at all times to allow students to review as needed. We encourage the

TAs and the instructors to use it as a tool to answer questions for students. Just the physical presence of the board allows the students to remind themselves any time during the semester of what we have accomplished and where we are going. The students often use the board to focus their thoughts or ask questions as to how things are related; sometimes it is difficult for students to formulate their question but by being able to point at specific places on the board, we can help identify points of confusion and facilitate discussion.

Template for Student Handout:

Topic	Task	Response
Insert most important event #1 here.	Answer the following question. Insert specific question about topic achieving the goal here.	
	Answer the following question. Insert big picture goal question here.	
	These are the words for the concept map. Make connections or take notes. Insert list of terms here.	
Insert most important event #2 here.	Answer the following question. Insert specific question about topic achieving the goal here.	
	Answer the following question. Insert big picture goal question here.	
	These are the words for the concept map. Make connections or take notes. Insert list of terms here.	
Insert most important event #3 here.	Answer the following question. Insert specific question about topic achieving the goal here.	
	Answer the following question. Insert big picture goal question here.	
	These are the words for the concept map. Make connections or take notes. Insert list of terms here.	

CITED REFERENCES

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About the Authors

Lynley Doonan has been an Instructor at Carnegie Mellon University in the Department of Biological Sciences since 2018, where she teaches laboratory courses for first year students as well as non-majors of all class years.

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APPENDIX A

Example 1. Approach to Project Instructor Document.

The document below was used in Fall 2022 and Spring 2023 semesters for concept mapping in our class. The instructor uses this for planning purposes for the entire semester. It is organized by the overarching topic (Use CRISPR to Mutate the Intrinsically Disordered Regions of Ribosome Assembly Factors), the 3 main steps (Anchor Goals), the most important events (Techniques), and the list of terms (Terms/Concept). Each grouping is color coded to indicate which terms go with which experiment.

FADS CRISPR IDR RAF 2022-2023 Concept mapping

Project Goal: Use CRISPR to Mutate the Intrinsically Disordered Regions of Ribosome Assembly Factors

Anchor goals

1. Isolate Plasmids with RAF Targeting Sequences and Without
2. Generate CRISPR Mutations
3. Characterize Mutations

Techniques

1. Plasmid Preps
2. Gel Electrophoresis
3. UV Scans
4. Restriction Enzyme Digests
5. Calculations
6. PCR
7. PCR Purification
8. Transformation
9. Serial Dilution
10. Spot Plate
11. Yeast Growth

Terms/Concepts

Plasmid Prep

1. Restriction Site
2. Selectable Marker
3. AmpR
4. Origin of Replication
5. NOP2 target sequence
6. NOP2 Gene
7. DRS1 target sequence
8. DRS1 Gene
9. pML104
10. pML104_NOP2
11. pML104_DRS1
12. pGP564_NOP2
13. pGP564_DRS1
14. Small
15. Circular
16. Double stranded
17. Independent of Host Genome
18. Plasmid
19. Genomic DNA
20. Cellular Debris

21. RNaseA
22. Centrifugation
23. No vortexing!!!
24. Bacteria

Gel Electrophoresis

1. Agarose
2. Positive Electrode
3. Negative Electrode
4. TBE Buffer
5. Ethidium Bromide
6. 1 KB ladder
7. Mass Marker
8. Separation by Size
9. Current
10. 10X DNA Dye

UV Scans

1. Abs230
2. Abs260
3. Abs280
4. Concentration

5. Yield
6. Purity Ratio
7. Contamination
8. Protein
9. RNA
10. DNA

Restriction Enzyme Digests

1. Restriction enzyme
2. Palindromic Sequence
3. Sticky Ends
4. Blunt Ends
5. XhoI
6. Swal
7. Buffer
8. Temperature
9. Mg²⁺
10. EDTA
11. Ice
12. Undigested sample

Calculations

1. Abs260/Abs280
2. 1 Abs260 = 50 ng/ μ L
3. Concentration * Elution volume
4. LogMW vs distance traveled
5. Base pairs
6. cm
7. Graph
8. ng

PCR

1. dNTPs
2. Polymerase
3. Denaturation
4. Annealing
5. Extension
6. Primer
7. T_m
8. Product
9. Template
10. Buffer
11. Mutation

PCR Purification

1. Input
2. DRS1 Δ NTD
3. NOP2 Δ NTD

4. Wash Buffer
5. Nanodrop
6. Disruption Repair Cassette

Transformation

1. Competent cells
2. Heat shock
3. Recovery
4. Selection
5. LiAc
6. 32°C
7. 42°C
8. Com-ura
9. Yeast
10. Ethanol
11. Carrier DNA
12. 50% PEG
13. YEPD

Spot Plating

1. Cold sensitive
2. Temperature Sensitive
3. Growth Assay
4. Dilutions
5. 16°C
6. 37°C
7. Growth
8. No growth

9. Slow growth
10. 45-90 minutes
11. Budding

Serial Dilution

1. Vortex
2. 10-fold
3. Sterile water
4. Sterile technique
5. BY4741
6. CRISPR mutants
7. JWY11535
8. 10⁻¹ through 10⁻⁵
9. Undiluted
10. YEPD

Yeast Growth

1. Lag phase
2. Log phase
3. Stationary phase
4. 45 – 90 minutes
5. Budding
6. Time
7. Log # Cells
8. S curve
9. 2ⁿ

Example 2. Approach to Project in Concept Map Form Document.

The document below was used in Fall 2022 and Spring 2023 semesters for concept mapping in our class. This document is printed, and each individual term is cut out to be given to students to apply to the concept map in class. It is put in a font size large enough to be seen by the class (at least 48 pt, often 72). It is organized by the overarching topic (Use CRISPR to Mutate the Intrinsically Disordered Regions of Ribosome Assembly Factors), the 3 main steps (Anchor Goals), the most important events (Techniques), and the list of terms (Terms/Concept). Each grouping is color coded to indicate which terms go with which experiment.

Isolate Plasmids with RAF Targeting Sequences and Without

Generate CRISPR Mutations

Characterize Mutations

Restriction Site

Selectable Marker

AmpR

Origin of Replication

NOP2 target sequence

NOP2 Gene

DRS1 target sequence
DRS1 Gene
pML104
pML104_NOP2
pML104_DRS1
pGP564_NOP2
pGP564_DRS1
KanR
Plasmid
Genomic DNA
Cellular Debris
RNaseA
Centrifugation
No vortexing!!!
Bacteria
Small
Circular
Independent of Host Genome
Double stranded

Agarose
Positive Electrode
Negative Electrode
TBE Buffer
Ethidium Bromide
1 KB ladder
Mass Marker
Separation by Size
Current

10X DNA Dye

Abs230

Abs260

Abs280

Concentration

Yield

Purity Ratio

Contamination

Protein

RNA

DNA

Restriction enzyme

Palindromic Sequence

Sticky Ends

Blunt Ends

XhoI

Swal

Buffer

Temperature

Mg²⁺

EDTA

Ice

Undigested sample

Abs260/Abs280

1 Abs260 = 50 ng/μL

Concentration*elution volume

LogMW vs distance traveled Graph

Base pairs

cm

ng

dNTPs

Polymerase

Denaturation

Annealing

Extension

Primer

T_m

Product

Template

Buffer

Mutation

Input

DRS1ΔNTD

NOP2ΔNTD

Wash Buffer

Nanodrop

Disruption Repair Cassette

Competent cells

Heat shock

Recovery

Selection

LiAc

32°C

42°C

Com-ura

Yeast

Ethanol

Carrier DNA

50% PEG

YEPD

Cold sensitive

Temperature Sensitive

Growth Assay

Dilutions

16°C

37°C

Growth

No growth

Slow growth

45 – 90 minutes

Budding

Vortex

10-fold

Sterile water

Sterile technique

BY4741

CRISPR mutants

JWY11535

10⁻¹ through 10⁻⁵

Undiluted

YEPD

Lag phase

Log phase

Stationary phase

45 – 90 minutes

Budding

Time

Log # Cells

S curve

2ⁿ

Example 3. Student Handout

The document below was used in Fall 2022 and Spring 2023 semesters for concept mapping in our class. This document is printed out and handed to students. It is designed to help them identify the overall goal and the purpose of each experiment. They then take notes on how they put together their own group’s concept map and how other groups put together their concept maps. We use this activity for quiz review, which contains multiple experiments. Students retain this handout for reference.

Quiz 1 Concept Map Handout

Topic	Task	Response
Plasmid	<u>Answer the following question.</u> What is the goal of the experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Restriction Site Selectable Marker Ampicillin Resistance Kanamycin Resistance Origin of Replication NOP2 target sequence	

	NOP2 Gene DRS1 target sequence DRS1 gene pML104 pML104_NOP2 pML104_DRS1 pGP564_NOP2 pGP564_DRS1	
Plasmid Purification	<u>Answer the following question.</u> What is the goal of the experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Plasmid Genomic DNA Cellular Debris RNaseA Centrifugation No vortexing!!! Bacteria Small Circular Double stranded Independent of Host Genome	

Quiz 2 Concept Map Handout

Topic	Task	Response
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Agarose Gel Electrophoresis	<p><u>Answer the following question.</u> What is the goal of the experiment in general?</p>	
	<p><u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?</p>	
	<p><u>These are the words for the concept map. Make connections or take notes.</u> Agarose Positive Electrode Negative Electrode TBE Buffer Ethidium Bromide 1 KB ladder Mass Marker Separation by Size Current 10X DNA Dye</p>	
UV Scans	<p><u>Answer the following question.</u> What is the goal of the experiment in general?</p>	
	<p><u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?</p>	
	<p><u>These are the words for the concept map. Make connections or take notes.</u> Abs230 Abs260 Abs280</p>	

	<p>Concentration Yield Purity Ratio Contamination Protein RNA DNA</p>	
Restriction Enzyme Digests	<p><u>Answer the following question.</u> What is the goal of the experiment in general?</p>	
	<p><u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?</p>	
	<p><u>These are the words for the concept map. Make connections or take notes.</u> Restriction enzyme Palindromic Sequence Sticky Ends Blunt Ends XhoI SmaI Buffer Temperature Mg²⁺ EDTA Ice Undigested sample</p>	
Calculations	<p><u>Answer the following question.</u> What is the goal of the experiment in general?</p>	
	<p><u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?</p>	
	<p><u>These are the words for the concept map. Make connections or take notes.</u> Abs₂₆₀/Abs₂₈₀ 1 Abs₂₆₀ = 50 ng/μL Concentration * Elution volume LogMW vs distance traveled Base pairs cm</p>	

	Graphing	
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Quiz 3 Concept Map Handout

Topic	Task	Response
PCR	<u>Answer the following question.</u> What is the goal of the experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Nucleotides (dNTPs) Polymerase Denaturation Annealing Extension Primer Melting Temperature (T _m) Product Template Buffer Mutation	
PCR Purification	<u>Answer the following question.</u> What is the goal of the experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Input DRS1ΔNTD NOP2ΔNTD Wash Buffer Nanodrop Disruption Repair Cassette (DRC)	
Transformation	<u>Answer the following question.</u> What is the goal of the	

	experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Competent cells Heat shock Recovery Selection Lithium Acetate (LiAc) 32°C 42°C Complete media lacking uracil (Com-ura) Yeast Ethanol Carrier DNA 50% PEG YEPD	

Quiz 4 Concept Map Handout

Topic	Task	Response
Spot Plating	<u>Answer the following question.</u> What is the goal of the experiment in general?	
	<u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?	
	<u>These are the words for the concept map. Make connections or take notes.</u> Cold sensitive	

	<p>Temperature Sensitive Growth Assay Dilutions 16°C 37°C Growth No growth Slow growth 45-90 Minutes Budding</p>	
<p>Serial Dilution</p>	<p><u>Answer the following question.</u> What is the goal of the experiment in general?</p>	
	<p><u>Answer the following question.</u> How did this help you achieve your goal of CRISPRing yeast in our lab?</p>	
	<p><u>These are the words for the concept map. Make connections or take notes.</u> Vortex 10- fold Sterile water Sterile technique BY4741 CRISPR mutants JWY11535 10⁻¹ through 10⁻⁵ Undiluted YEPD</p>	

Mission, Review Process & Disclaimer

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