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Abstract

Frontiers, Analysis, and Discovery in Biological Sciences (FADS) 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.

Activity Design

- A concept map is a way to organize ideas and visualize relationships between concepts
- Selected three major steps in our overall research project
- Divided up experiments based on which of the major steps they contributed to
- Identified key terms for each experiment
- Color coded experiments to quickly identify the related terms
- Instructors introduced concept maps, why they are useful, and demonstrated for a non-laboratory related project (ex: baking cookies)
- Assigned groups of 3-4 students to concept map terms for each experiment
- Each group generated a concept map for a different experiment and added it to the board under the correct major step
- Ensured students had plenty of time to create concept map and class discussion review

Lessons Learned

- Instructors modeling concept mapping helped empower students to generate their own
- Students worked well in groups, enhancing teamwork and communication skills by reviewing with an instructor or TA prior to presenting to the class
- After students presented their part, class discussion helped identify new connections
- Displaying the concept map in the classroom at all times allowed students to review as needed
- Handout facilitated note taking and participation

Digital Concept Map Example

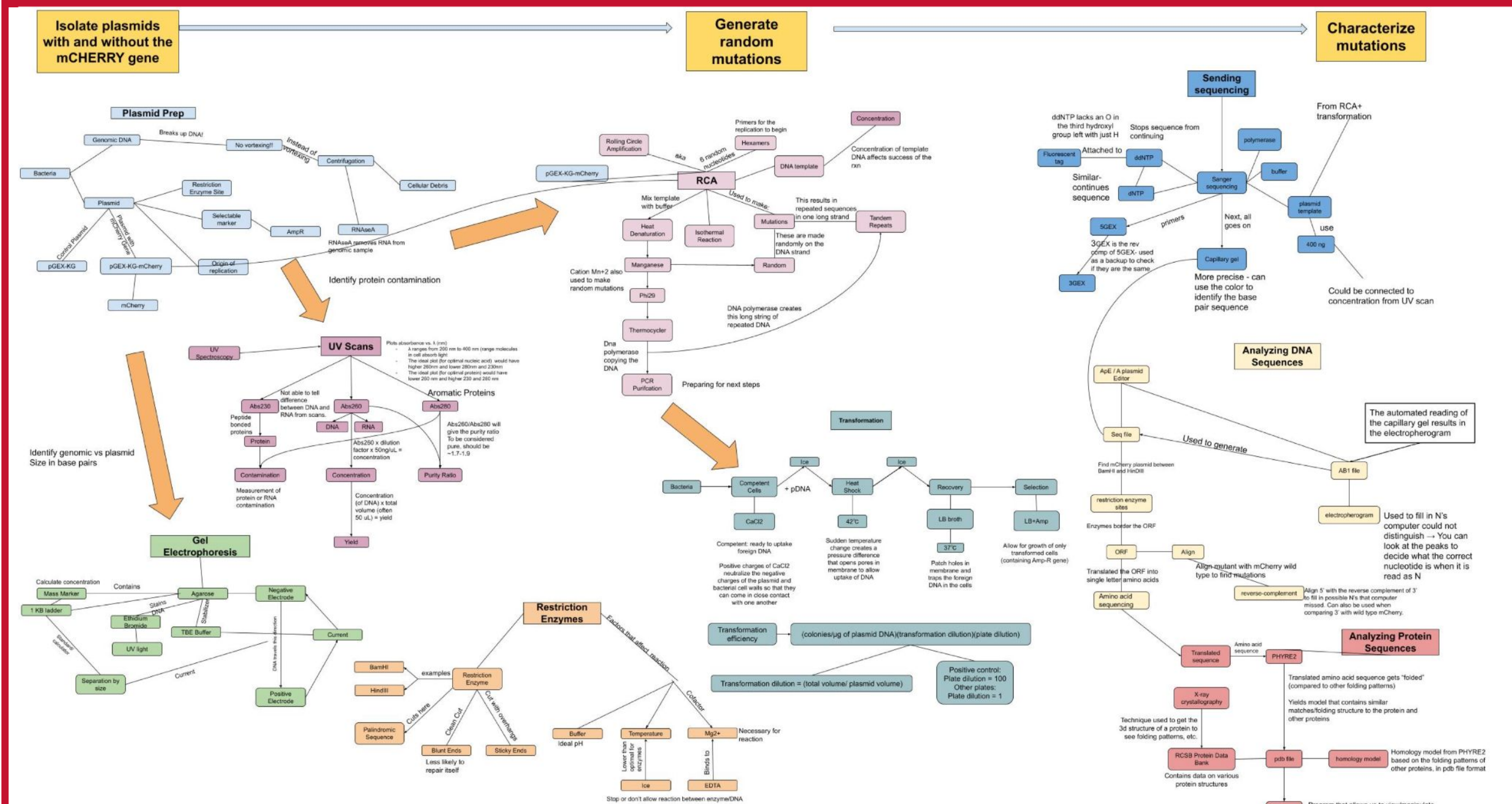


Figure 1. Concept Map Made Using Google Draw. Example of concept map generated by FADS in person and remote teams of students in Fall 2020. Total 13 students enrolled - 7 in person and 6 remote. Individual maps were created using Google Draw with students in breakout rooms via Zoom. The concept maps were then transferred to a file containing all maps.

During Class Approach

Part 1: Student Led Portion

- Students split into teams of 3-4 and provided with terms to include for their specific experiment
- Each group focuses on a different technique
- Draft concept map on scratch paper and review with instructor or TA
- Students create map on board using provided craft supplies
- Students present their map to the class focusing on why they made connections and how it connects to the overall project

Part 2: Instructor Led Portion

- Encourage student discussion
- Review the connections between terms and the major topics
- Ask all students to determine if there are connections not already present on the board, especially to other topics and experiments
- Review the important details of experiments by walking through the connections and summarizing student led portion
- Incorporate purposeful pauses to allow students to synthesize information and identify points of confusion

Physical Concept Map Example

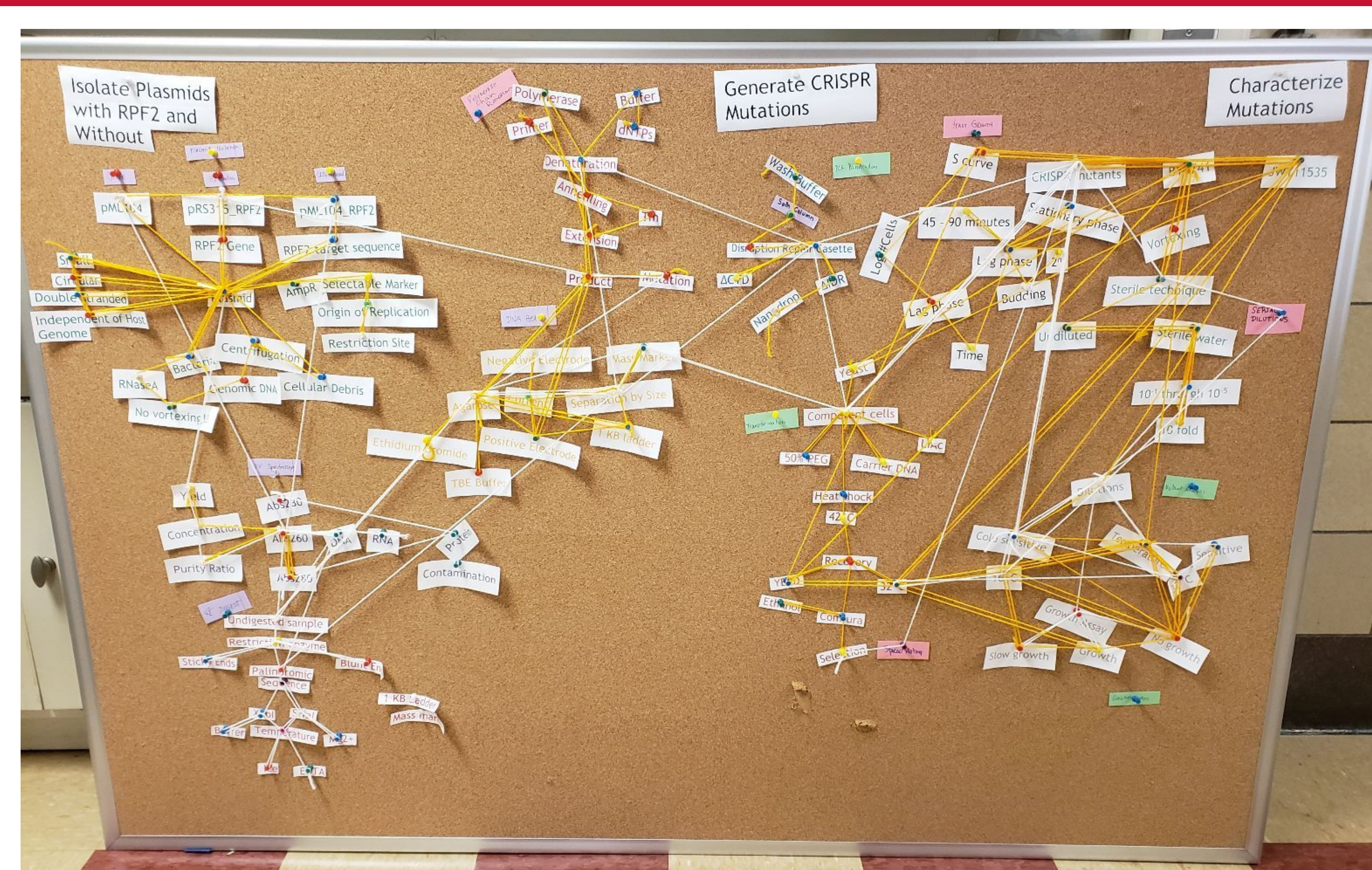


Figure 2. Concept Map Made Using Craft Supplies.
Example of concept map generated by FADS in person teams of students in Fall 2022. Total 15 students enrolled. Connections were implemented using yarn and terms added using push pins onto a 60 inch X 48 inch cork board. Additional details are added as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

Class Handout Example

Topic	Task	Response
PCR	Answer the following question. What is the goal of the experiment in general?	
	Answer the following question. 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	

Figure 3. Concept Map Student Handout. Example of class handout provided to FADS students during concept map review in Spring 2023. Space to take notes, add context, and draw connections enhance student participation.

Applying to Different Projects

- Identify the **overarching topic** of project or paper
- Break into 3-5 major steps that lead to the **overarching topic**
- Select the *most important events* that contribute to the major step
 - Ex: people, places, events, experiments, dates in history
- Generate list of terms that relate to the *most important events*
 - Avoid using the same term multiple times to encourage connections between events
 - Color code each event to quickly identify which words are grouped together
- Give student teams time to concept map the *most important event* they are responsible for
- Encourage discussion and emphasize that there is not a single correct answer since many connections can usually be made
- Provide feedback on connections before students present to the rest of the class
- Permit students adequate time to put their map on the board and make connections to other parts
 - Use yarn to make many connections to many parts
 - Use notecards to leave comments or add more information as necessary
- Allow students to present their concept map and the logic for the connections without interruption
- Ask for all students to identify additional connections
- Discuss the major points of emphasis for review
- Handout is provided to all students with all the *most important events* and related **terms** so all students have a chance to take notes or make their own connections even if they are not in the group responsible for presenting that section
- Everyone is expected to participate in all portions of the concept map activity

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