Investigating genetic diversity through microbial species identification

Activity Name: The BAC-Trackers: tracking organismal diversity

Team:

Gabriel Mednick (team leader): UCSC Postdoctoral fellow, Chemistry

Tyler Dewitt: UCSC Graduate student, Molecular Cell & Developmental Biology

Arina Favilla: UCSC Graduate student, Ecology & Evolutionary Biology

Veronica Urabe: UCSC Graduate student, Molecular Cell & Developmental Biology

Audience: 20 undergraduate biology students, mostly rising sophomores

Venue: Biol 20L - Experimental Biology Lab summer course at UCSC (3 days of the 4-week course)

Activity Summary:

As part of the undergraduate biology curriculum, the Biol 20L course is intended to provide students with lab experience at the beginning of their undergraduate career in order to prepare them for higher-level lab courses. Early exposure to lab techniques, critical thinking, and analyses is critical for supporting students with diverse backgrounds and levels of experience and helping them enhance their self-efficacy and persist in STEM. Our inquiry-based lab activity focused on the theme of genetic diversity—understanding how the demands placed on an organism influence genetic diversity and how different genes function to allow adaptations for a specific niche. Genetic diversity underlies the vast diversity of life on our planet and provides the basis for evolution, which is one of the core concepts in biology, but a challenging one as it requires integrating knowledge of genetics and adaptation.

Our activity tasked students with identifying the species of an unknown sample of DNA from a suite of diverse microbial samples. Students worked together in pairs and were given a primer set to test against all unknown DNA samples from a suite of possible microbial organisms. Before the lab, they raised questions about how the microbial organisms differ and why those differences arose. These questions guided them as they used observation, molecular techniques (PCR and gel electrophoresis), and bioinformatics to gather multiple lines of evidence to distinguish species based on their unique characteristics and genetic make-up. Based on their findings, they made a claim about which gene from a particular species their given primer set was meant to target and explained the evidence that supports/refutes it. This practice of explaining results and/or solutions based on multiple lines of evidence mirrors authentic STEM practices of supporting scientific arguments with appropriate and sufficient evidence.

The culminating assessment task was a scientific poster presentation in which each group summarized their research from the lab activity. Before the final presentation, the students were given the opportunity to practice presenting in a mini-poster session in order to obtain feedback on how they formulated their claim and the evidence and rationale they intend to use for explaining their results. This low-stakes practice session was also intended to help students gain confidence in their presentation skills. In the final presentation, the students presented their claim as to which gene their primer set targeted, the function of the gene and its relevance to the species, and the multiple lines of evidence they used to develop their rationale. They also pointed out whether they had sufficient evidence to support their claim, identified any unexpected results and proposed appropriate causes, and suggested alternative experiments or lines of evidence that would further support their claim. The goal of presenting their findings with a poster was to provide them with an experience similar to a poster presentation at a conference and introduce them to the practice of designing good posters. The students were assessed on content and their proficiency of the STEM practice based on our rubrics.

In identifying their species based on a unique gene, the students demonstrated in their rationale that the gene under investigation provided a unique function to the species to allow it to survive in its usual environment or on the cultured plates they observed in the lab (dimension 2 of content rubric). All students demonstrated proficient understanding that certain genes are unique to a species; however, there was not sufficient evidence to determine if the students fully understood that many genes are also common among species (dimension 1 of content rubric). This is due to the fact that a positive control was not included as part of the evidence they gathered in the molecular techniques. The design of the activity should be modified to include a positive control, which would provoke discussion of similarity across some of the DNA samples.

Some students initially struggled in analyzing their results and developing a rationale for their claim because their results were unexpected and required in-depth understanding of the molecular techniques to provide plausible explanations (dimension 2 and 3 of practice rubric). Guidance from the facilitators while the learners proceeded with their investigations, especially when the students were using bioinformatics, was crucial in ensuring progress towards the content and practice goals of the activity. By the end of the activity, all students showed proficiency in the STEM practice, including stating a concise claim (dimension 1 of practice rubric) and identifying future directions (dimension 4 of practice rubric); however, some demonstrated a more refined rationale and sophisticated level of analysis, particularly of the unexpected results. Upon reflection of their performance, all students merited a maximum score on the rubric for each dimension, but in order to distinguish those that demonstrated a higher level of understanding and proficiency, the rubric would need to be modified with another level.