

# Microbial Model Construction Activity for Introducing Students to Microbiome and Metagenomic Fields

Robert J. Rabelo-Fernandez<sup>a</sup> and Carlos Rios-Velazquez<sup>b</sup>

<sup>a</sup>Biology Department, University of Puerto Rico Rio Piedras Campus, San Juan, Puerto Rico, USA

<sup>b</sup>Biology Department, University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico, USA

**KEYWORDS** microbiome, educational activity, metagenomics, emerging science, STEAM activity

## INTRODUCTION

Model construction is a learning process by which students enhance their perceptions of the system being depicted. The impact of models on biology learning is to help students visualize, recognize, and memorize concepts; moreover, they facilitate learning by addressing student misconceptions (1). Teaching an emerging field through the use of model construction in a biology class is an ideal approach for engaging students in fundamental questions that scientists pursue and encourage them to answer their own queries (2).

Within the emerging sciences to date, the study of microbiomes is one of several that have drawn scientific attention worldwide. Microbiome is defined as the collective of microbes and their genomic elements in a particular environment (3). The proposed educational activity aims to expose the student to emerging sciences, as in the study of microbiomes, using techniques such as metagenomics. The topics to be discussed are not part of the secondary school curriculum science class, representing a strategy to incorporate novel subjects in the academic teaching and learning process. The construction of a host-microbe model and its oral presentation allow students (i) to use and develop creative-artistic skills, (ii) to represent a cognitive model of what they have learned about the associations, and (iii) to develop oral communication skills (4). The hands-on activity allows students to learn about host-microbe interaction and the implications of those in biotechnology and ecosystems

dynamics. In that way, students will demonstrate the knowledge acquired and develop effective communication, teamwork, and creativity skills based on the postulates of science, technology, engineering, arts, and mathematics (STEAM), an approach that focuses on problem-solving (5).

## PROCEDURE

A group of high school students who had basic knowledge in biology was selected to employ this educational tool. To access knowledge acquisition, the students completed a pre/posttest (see Appendix 1). This test consisted of 14 closed questions and a sort exercise. On day one, the students had 15 min to complete the pretest. The presenter then offered a 45-min talk on microbiomes, entitled *Microbiomes: Knowing Our Microorganisms, Beyond Cultivable* (see Appendix 2), followed by 15 min of a question/answer section. The importance of microbiomes and their implications were explained, accompanied by examples where known specialized microbiome relations, including the host, its environment, and food aspects, were established. After the talk, the students were divided into teams no larger than four members. Each team had 45 min to discuss and select an organism with its microbiome of interest for the project. The students then developed a scale model of one microorganism that is part of the selected microbiome. Students had 2 weeks from the date on which the talk was offered to develop an oral presentation and to construct a scale model of the chosen microorganism, using any materials of their choice. On day two, each team showed their cell model and gave an oral presentation to the class. The oral presentation consisted of a 10-min talk and 5 min for questions. After the presentations, the students had 15 min to complete the posttest, followed by 30 min of project feedback from the professor to the teams. Total educational activity comprises 4 h total (2 h/day for 2 days). Using a rubric, all models were evaluated based on creativity, originality, if they described the proposed microorganism, if the concept discussed could be recognized in the model, and if the materials used were pertinent and effective in representing the microorganism. The five

---

**Citation** Rabelo-Fernandez RJ, Rios-Velazquez C. 2021. Microbial model construction activity for introducing students to microbiome and metagenomic fields. *J Microbiol Biol Educ* 22: e00107-21. <https://doi.org/10.1128/jmbe.00107-21>.

Address correspondence to Biology Department, University of Puerto Rico Rio Piedras Campus, San Juan, Puerto Rico, USA. E-mail: robert.rabelo@upr.edu.

Received: 20 September 2020, Accepted: 16 April 2021, Published: 30 June 2021

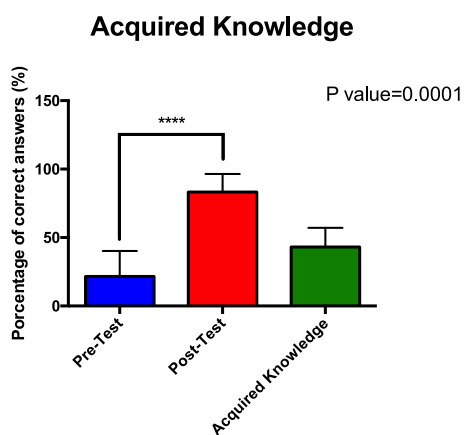


FIG 1. Student acquired knowledge based in the pre- and posttest. The figure shows the knowledge acquired by the students after participating in the educational activity titled *Microbiomes: Exploring Our Microbes Beyond the Cultivable*. The data suggest an increase of 43% ( $N = 35$ ). Difference between pretest and posttest is statistically significant.  $P = 0.0001$ .

criteria were scored in a scale from one (poor) to five (excellent; see Appendix 3).

## CONCLUSIONS

We have conducted this activity for two high school groups as part of their biology class. The educational activity described increases the general knowledge of the participants about emerging science topics, such as microbiomes and metagenomics. A 43% increase in general knowledge acquired was seen (Fig. 1). The pretest showed that 52% of the students could define the concept of metagenomics appropriately. However, there was a 30% increase after the activity was implemented. In contrast, on the topic of microbiomes, 37% of the students knew the definition of the subject before the activity was implemented. Still, this was the concept in which the participants appeared to have acquired the most knowledge, since a 49% increase was seen (Fig. 2). The data suggest that after the use of the educational tool, students were able to define the concept of metagenomics and microbiome more successfully.

During the presentations by students, all teams used Power Point as an audiovisual tool to present their work and explain the host-microbe interaction. The students used the model and the oral presentation to represent the microbe and describe the host-microbe interaction, respectively. The models showed great similarity with microscopic images of the species the students used as references. They included structures such as cell organelles and locomotion structures. The models prepared by the teams resembled *Allivibrio fisheri*, *Rhodobacter sphaeroides*, *Saccharomyces cerevisiae*, and mycorrhiza-associated species (see Appendix 4). In the case of the *Saccharomyces cerevisiae* model, the students built not only a representation of the yeast but also the environment it inhabits, the intestine of the host organism.

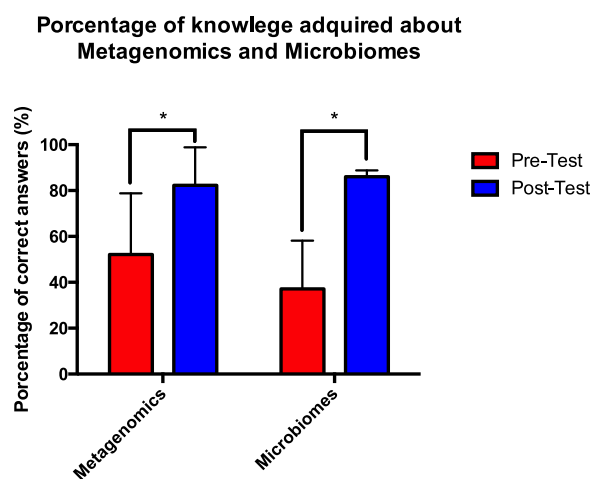


FIG 2. Student knowledge acquired about metagenomics and microbiomes topics based on the evaluation tool. The percentage of knowledge about the topics of metagenomics and microbiomes before and after the talk was obtained according to the data from the pre- and posttest ( $N = 35$ ). Questions 1 to 11 were used to assess the acquired knowledge in microbiomes; moreover, questions 12 to 14 tested the knowledge regarding metagenomics. The results suggest significant increases in knowledge after the talk on both topics, metagenomics and microbiomes, of 30% and 49%, respectively.  $P = 0.01$ .

The students also represented the phenomenon of bioluminescence in the *Allivibrio fisheri* model by using fluorescent paint (see Appendix 4). The most used materials by students were plastic foam, paint, and other craft supplies, such as chenille stems and acrylic paint. Activities like these promote interest in scientific issues relevant to disciplines such as microbiology and biology. Our activity allows students to conceptualize the host-microbe relation and how metagenomics help in the study of microbiomes.

## SUPPLEMENTAL MATERIAL

Supplemental material is available online only.

**SUPPLEMENTAL FILE 1**, DOCX file, 5.9 MB.

## ACKNOWLEDGMENTS

We thank Mary Padilla and Cristal Hernandez for their help in the educational activity implementation and manuscript editing.

## REFERENCES

1. Werner S, Förtsch C, Boone W, von Kotzebue L, Neuhaus BJ. 2019. Investigating how German biology teachers use three-dimensional physical models in classroom instruction: a video study. *Res Sci Educ* 49:437–463. <https://doi.org/10.1007/s11165-017-9624-4>.

2. Fuhrmann T, Schneider B, Blikstein P. 2018. Should students design or interact with models? Using the bifocal modelling framework to investigate model construction in high school science. *Int J Sci Educ* 40:867–893. <https://doi.org/10.1080/09500693.2018.1453175>.
3. Ho HE, Bunyavanich S. 2018. Role of the microbiome in food allergy. *Curr Allergy Asthma Rep* 18:27. <https://doi.org/10.1007/s11882-018-0780-z>.
4. Iwaniec D, Childers D, VanLehn K, Wiek A. 2014. Studying, teaching and applying sustainability visions using systems modeling. *Sustainability* 6:4452–4469. <https://doi.org/10.3390/su6074452>.
5. Quigley C, Herro D. 2016. “Finding the joy in the unknown”: implementation of STEAM teaching practices in middle school science and math classrooms. *J Sci Educ Technol* 25:410–426. <https://doi.org/10.1007/s10956-016-9602-z>.