ASIAN PEOPLE JOURNAL 2023, VOL 6(2), 109-118
e-ISSN: 2600-8971
http://dx.doi.org/10.37231/apj.2023.6.2.548
https://journal.unisza.edu.my/apj

ASIAN PEOPLE JOURNAL
Multidiciplinary Social Science Journal
APJ

IMPACT OF MICROBIAL ART ON ADVANCING STUDENTS' CULTURING PROFICIENCY IN MICROBIOLOGY EDUCATION

Suraya Sulaiman[1*], Wan Nordini Hasnor Wan Ismail[1], Mohd Izani Othman[1], Mohd Nadzri Mohd Najib[1]

[1]Faculty of Pharmacy, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Bertam, 13200 Kepala Batas, Malaysia

Corresponding Author Email: suraya.sulaiman@uitm.edu.my

Received: 18 September 2023 • Accepted: 27 October 2023 • Published: 31 October 2023

Abstract

Microbial art, an emerging trend in microbiology education, integrates artistic activities to enhance critical thinking and deepen comprehension of intricate scientific concepts. This study examines the effect of microbial art activity on students' understanding and competency of microbiological culturing methods. A qualitative content analysis was employed to evaluate the comprehension of 108 students who participated in the microbial activity, which encompassed the assessment of both their visual creations and written reports. The relationship between students' understanding of bacterial culturing techniques and the quality of their artworks was assessed using descriptive statistics and Pearson's correlation coefficient. The quality of the artwork was classified as poor, moderate, and good, reflecting students' cultivation skills, with 53% at a moderate level, 30% good, and only 17% having poor artwork quality. According to the analysis of the students' written reports, it was found that 71% of the students exhibited a strong understanding of the activity, while 29% showed an average level of understanding. However, there was no correlation found between students' understanding and the quality of their artwork. This study demonstrates that incorporating microbial art into science education can improve student cultivation techniques by providing an engaging and creative way to practice microbiology skills.

Keywords*: Artworks; Culturing technique; Enhance; Microbial art; Microbiology education*

Cite as: Sulaiman, S., Wan Ismail, W. N. H., Othman, M. I., Mohd Najib, M. N. (2023). Impact of Microbial Art on Advancing Students' Culturing Proficiency in Microbiology Education. *Asian People Journal*, *6*(2), 109-118.

INTRODUCTION

Microbiology is a branch of science education that focuses on studying tiny organisms that are frequently only visible under a microscope. Understanding microbiology requires more than just memorization of the subject matter. Educators nowadays try everything they can to entice students to take an interest in their studies and to improve student learning outcomes, such as participation, interest, engagement and motivation. Most conventional tertiary higher education health science courses necessitate laboratory sessions, which is essential in providing hands-on experience and abilities which are otherwise unachievable through lectures and passive reading solely (Brockman *et al.*, 2020). Active learning entails teaching strategies that provide students with meaningful, active, and experiential roles in the learning process (Bonwell & Eison, 1991). Learners can exchange personal information and assimilate new ideas from instructors into their pre-existing knowledge, associate new concepts with old ones, and adjust their past thinking depending on gained knowledge in active learning classes. As a result, active learning is frequently supplemented by collaborative learning practises, in which instructors establish a classroom environment in which students can participate in common tasks, interact with one another, and share their knowledge (Kibble *et al.*, 2016; Najdanovic-Visak, 2017). Students learn best and can apply new knowledge when they participate actively in a course and when pedagogies actively facilitate meaningful ways for students to engage in the acquisition, processing, and application of new course content (Bull *et al*., 2020).

An effective strategy to enhance engagement with scientific content involves merging the rigor of science with the creativity of art (Colucci-Gray *et al*., 2017). The arts are one of the five sectors that STEAM (Science, Technology, Engineering, the Arts and Mathematics) education emphasises. Students are empowered through STEAM to be curious learners who seek creative solutions to topics they can't merely search online, allowing them to build the soft and hard skills required for success in college and in their professions. By incorporating creative art activities into science lessons, educators can help students develop their attention to detail, skills and creativity while also enhancing their enjoyment and motivation. Incorporating visual art into science lessons can be done in multiple ways to help students improve their critical thinking skills and understand complex scientific topics. Art-based activities demand students to convey the relationship between the visual or physical object and the scientific idea being taught. These activities not only benefit the students, but it also has the potential to educate the viewers. For instance, a study conducted by Sangweme *et al*. (2020) involving a microbial art exhibition showed that visitors to the exhibition had a better understanding of microbiological terms and concepts, and reported an increase in knowledge about microorganisms compared to those who did not attend. Their study suggests that artistic representations of microorganisms can effectively educate both academic and non-academic audiences.

In more recent years, both artists and scientists have created similar plates for the Agar Art Contest. Agar art has gained significant attention due to its online visibility and support from established organizations like the American Society for Microbiology (ASM), which conducts an annual agar art competition. According to de Ondarza (2019), it is possible to design an inquiry-based learning module for small-group and active learning experiences that explores and understands the roles of microorganism pigments. These cross-disciplinary learning opportunities can involve physics, chemistry, biology, and even art. Examples showcasing the utilization of agar art in educational contexts include the bacterial calligraphy by undergraduate research students (Ng, 2012), the incorporation of DNA and gene expression activities for students ranging from grades 8 to 12 (Wu *et al*., 2018)), the integration of a course-based undergraduate research experience (CURE) specifically centred around gene expression in an introductory microbiology class (Adkins-Jablonsky *et al*., 2021) and combining the creativity of agar art with the fundamental principles of inducible promoters (Jefferies *et al*., 2022) .

In order to address students' problems with the lack of understanding and interest in microbiology among Diploma of Pharmacy students, an initiative has been taken to implement agar art activity in a microbiology laboratory practice. The agar art activity provides hands-on experiences for the students in which they use cells from various bacteria to draw on the agar plates to produce agar art. The goal of the activity is to enhance students' understanding in microbiological laboratory techniques. Considering the lack of documentation related to the use and effectiveness of agar art in teaching microbiology, there is a need to conduct a study to assess students' understanding of the activity.

METHODOLOGY

Study Design

The agar art activity was conducted in collaboration with students enrolled in the Microbiology course during their third year of Diploma in Pharmacy. The activity consists of two parts: students' agar art and students' written reports. For the first part, each student received one nutrient agar and one MacConkey agar plate as their canvas in the microbial art activity, along with five different species of bacteria (*Escherichia coli*; ATCC25922, *Staphylococcus aureus*; ATCC25923, *Pseudomonas aeruginosa*; ATCC10145, *Serratia marcescens*; ATCC13880 and *Micrococcus luteus*; ATCC10240) that generate different colours represented the paint. Students must use these bacteria to produce agar art by employing cells from various bacteria species to draw on the agar plates.

Students must apply the knowledge they have acquired from their microbiology lesson (including the bacteria they are using, the morphological traits of bacteria that grow on both agar plates and aseptic techniques, as well as culturing methods) into this activity to successfully colonise the agar plates using any combination of techniques and bacteria. For the second part, students need to submit a report based on their understandings of bacterial culturing technique used in completing their artworks.

Data Collection

Students' understanding of bacterial culturing techniques were evaluated based on students' artworks (agar arts submitted by students) and students' written report (open-ended questions answered by students) as shown in Table 1. Students' artworks were assessed based on students' ability to use different microorganisms on each agar plate (1, 2 or ⩾3 microorganisms) and the quality of culturing skills used in completing their artwork; categorised as 1) poor = poor streaking skills (unable to identified/ recognised what the artworks were about), 2) moderate = able to use basic streaking technique (observed by simple artwork) and 3) good = able to create/ streak difficult artwork as shown in Figure 1. Meanwhile, students' written report consists of 4 questions regarding the microorganisms (3 questions) and the technique used in their agar art activity (1 question).

The total score is 8; 6 until 8 marks of correct responses (⩾75%) is considered as good, 3 until 5 marks (>25 -74%) of correct responses is considered as moderate and 0 until 2 marks of correct responses (⩽25%) is considered as poor understanding of the activity.

Table 1: Data Collection and Evaluation Characteristics

	Characteristics	Evaluation
Artwork	1. Number of bacteria species used on an agar plate 2. Quality of artwork	- 1 – used only 1 species of bacteria - 2 – used 2 species of bacteria - >2 – used more than 2 species of bacteria - Poor - poor streaking skills (unable to identified/ recognized what the artworks were about) - Moderate - able to use basic streaking technique (observed by simple artwork design) - Good - able to create/ streak difficult artwork design.
Written report	4 open ended question (Total = 8 marks).	- Poor - 0 until 2 marks of correct responses (≤25%) - Moderate - 3 until 5 marks (>25 -74%) of correct responses - Good - 6 until 8 marks of correct responses (≥75%)

(a) (b) (c)

Figure 1: Examples of students' agar artwork according to level of culturing skill (a) Poor (b) Moderate (c) Good.

Data Analysis

The data obtained were analysed qualitatively and presented in descriptive form. Mean and standard deviation (SD) were presented for numerical data, while frequency and percentage were presented for the categorical data. The Statistical Package for Social Sciences (SPSS) version 26 was used for extracting the data from the excel file and performing the analysis. A Pearson's correlation coefficient was applied to examine whether there is a relationship between students' understanding and the quality of students' artworks (students' culturing skills).

RESULTS AND DISCUSSION

A total of 108 students participated in the activity and 216 plates of agar artworks were collected from this activity (108 of nutrient agar and 108 of MacConkey agar plates). Out of 216 agar plates, 45% (n=98) were colonised with only 1 bacterial species, 41% (n=88) with 2 bacteria and only 14% (n=30) with more than 2 bacteria (Figure 2a). Most of the students (44%, n=47) choose to use 2 bacteria, 35% used 1 bacteria species and 21% use more than 2 species of bacteria on nutrient agar plates (Figure 2b). Meanwhile for MacConkey agar, most of the students (56%, n=60) choose to use 1 bacteria species, 38% (n=41) used 2 bacteria and only 6% (n=7) use more than 2 species of bacteria. This may be due to the students' lack of experience with inoculating multiple bacterial species on an agar plate. As a result, they were hesitant to mix several microorganisms on a single agar plate.

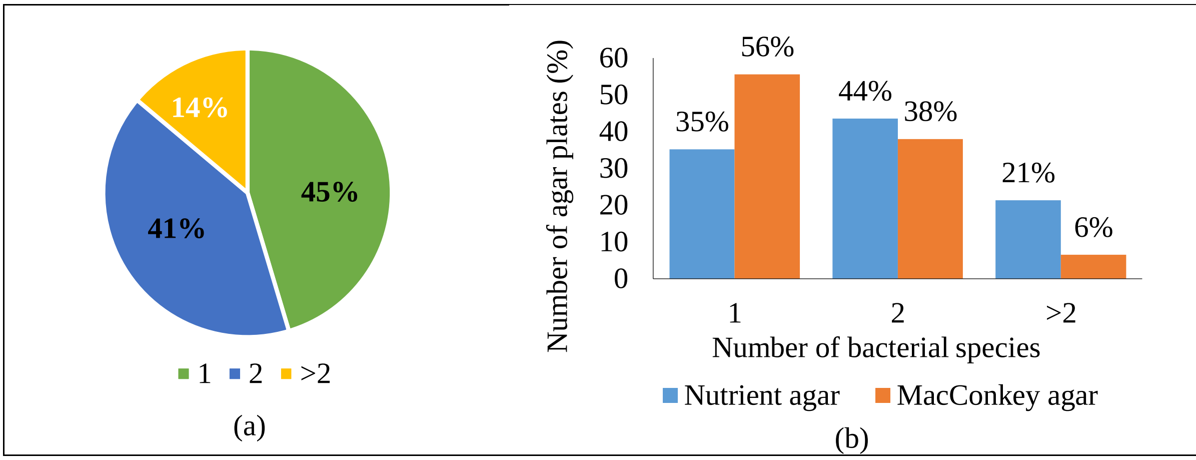

Figure 2: Number of bacterial species used on agar plates. (a) The average number of plates (%) colonised with one, two or more bacterial species (b) Number of plates (%) colonised with one, two or more bacterial species on different agar plates.

Figure 3 shows examples of agar artwork created by students on nutrient agar and MacConkey agar. As shown in Figure 3a, the student chooses to create an artwork of a maple leaf on a nutrient agar plate using a strain of *Escherichia coli* (*E. coli*) and *Serratia marcescens* (*S. marcescens*). Each bacteria have different nutritional needs and can produce different colours. The student has successfully combined two different types of bacteria with different colours to differentiate the structure of the leaf. This demonstrate students' understanding of bacterial pigment production, which can be assessed by observing the pigment production on nutrient agar at different incubation temperatures. Serratia, for example, only generates pigment below 35°C and is unpigmented above that temperature. Meanwhile in Figure 3b, the student only uses one strain of bacteria (*E. coli*) to create an artwork of butterfly on MacConkey agar. Since there are only 3 choices of Gram-negative bacteria that can grow on MacConkey agar, students won't have many choices of pigmented bacteria to use. Moreover, these 3 Gram-negative bacteria will only produce either pink pigment or colourless colony on MacConkey agar.

Figure 3: Examples of students' agar artwork. (a) Two different bacteria species with different colours drawn on nutrient agar (b) Only one bacteria species drawn on MacConkey agar (2021).

The quality of the students' artwork was further classified as poor, moderate and good, which reflected their cultivation skill. Based on Figure 4a, out of 216 agar plates, 53% (n=115) were at a moderate level, 30% (n=65) were good and only 17% (n=36) had poor artwork quality. The quality of students' artwork was also assessed according to the type of agar used (Figure 4b), which yielded a similar result: 51-56% moderate skill, 31%-33% good quality, and 14-19% poor quality for both nutrient agar and MacConkey agar. Fisher's exact test was used to examine whether the type of agar medium used showed significant difference on the quality of students' artwork. Based on the Fisher's exact test statistic, with the value of 1.228 and p value of 0.544, it was found that there was no statistically significant difference on the quality of students' artwork between these two agars. The Pearson Chi-Square test statistic (1.230) similarly does not reach significance ($p<0.05$). Therefore, it can be concluded that there is no association between agar medium and students' culturing skill.

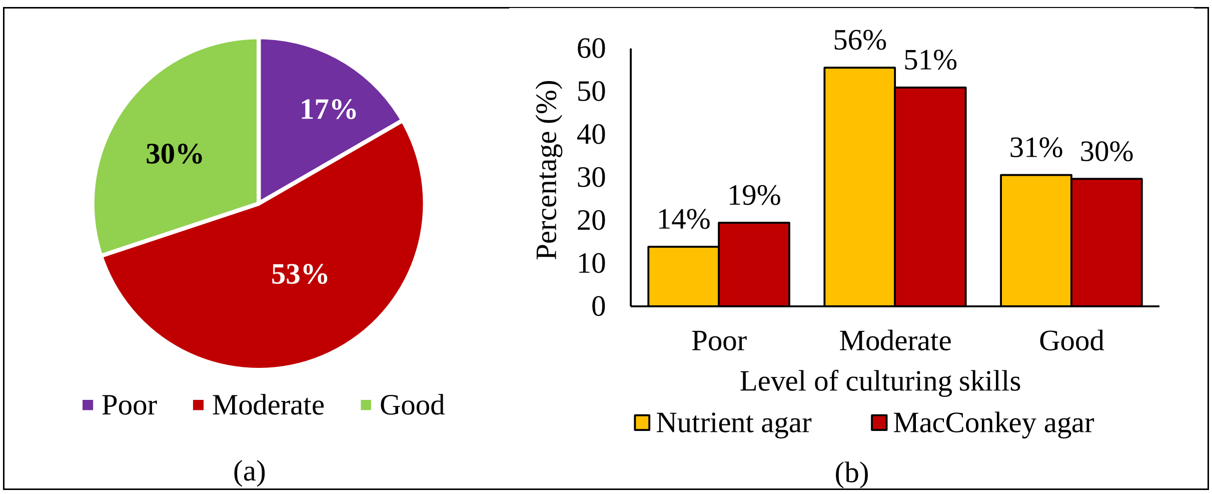

Figure 4: Quality of students' artwork (%) (a) Overall percentage (total of 216 plates) (b) Quality of artwork according to agar plates.

Students' understanding on the culturing technique, bacteria and growth medium were also assessed based on students' written report. In this activity, students' understanding was assessed based on their discussion on the choice of bacteria used on different medium, bacterial pigment produced and the different technique used upon completing their artworks. Based on Figure 5, 71% (n=77) were good and 29% (n=21) were at an average level of understanding of the agar art activity. Students shows good understanding in discussing the type of bacteria and pigment produced on different nutrient agar with the averaged value of M = 4.40 (Min = 3.00, Max = 6.00, SD = 0.74). Students also shows good understanding of the culturing technique used in the activity with the averaged value of M = 1.53 (Min = 0.00, Max = 2.00, SD = 0.59). Pearson's correlation coefficient was applied to examine whether there is a relationship between students' understanding and the quality of students' artworks (students' culturing skills). The Pearson correlation coefficient shows a low degree of correlation, $r = 0.108$ with p-value of 0.264. Since the p-value is larger than 0.05, we can conclude that students' understanding does not correlate with the quality of students' artworks.

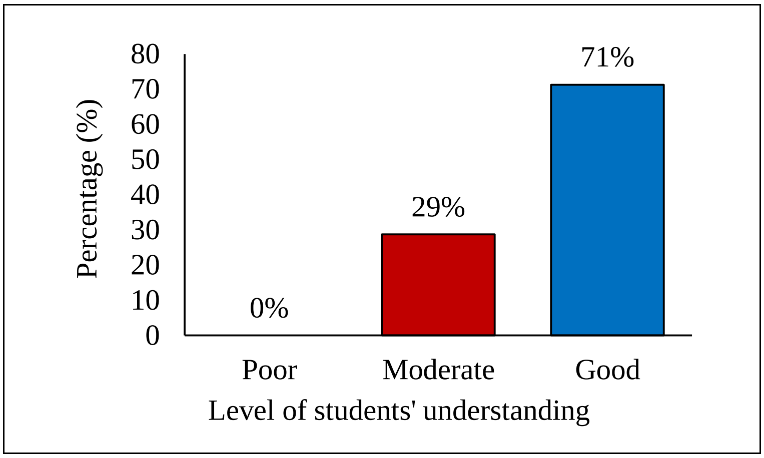

Figure 5: Level of students' understanding (%).

To create microbial art, students must learn how to aseptically inoculate the agar medium with different bacterial strains, and then carefully manipulate the bacterial growth to create specific designs. These steps require students to practice proper sterile technique and improve their overall microbiological skills. For instance, students need to make sure that their agar plates are sterilized to avoid contamination and also learn how to properly handle bacterial cultures to prevent cross-contamination between different strains. In addition, students need to understand the growth patterns of different bacterial strains and how to manipulate their growth to create specific designs. By learning how to manipulate bacterial growth, students can gain a better understanding of how bacteria interact with each other and their environment. Based on Adkin-Jablonsky *et al*. (2020) observation of an activity using agar art in the classroom, it was found that visual art can be a valuable addition to course-based undergraduate research, and science educators should think about adding artistic innovation into their teaching practises.

In this study, the quality of the artwork was classified as poor, moderate, and good, reflecting students' cultivation skill, with 53% at a moderate level, 30% good, and only 17% with poor artwork quality. The classification of artwork quality in the study can be seen as a measure of students' ability to effectively apply their culturing techniques to create visually appealing and intricate designs on agar plates. This suggests that the ability to create high-quality microbial art requires a certain level of skill in selecting, growing, and manipulating different microorganisms, which in turn can improve students' ability to isolate and culture specific microbes. In other words, the act of creating microbial art can serve as a creative and engaging way for students to practice and refine their microbiology skills, which can ultimately enhance their overall understanding and mastery of culturing techniques. According to Adkins *et al*. (2018), incorporating visual art in practical settings such as laboratory courses can effectively engage and stimulate students, leading to significant impacts on scientific discovery. Their study revealed that undergraduate students who engaged in open-inquiry activities involving agar art during an introductory microbiology laboratory course showed increased confidence in their scientific abilities compared to a control group. Agar art is an excellent fit for teaching laboratories (Charkoudian *et al*. 2010) since it encourages microbiology students to practice essential microbiological skills like clonal isolation and aseptic technique while engaging them in creative and personalized artistic expression. It's important for participants to take into account the organisms they're utilising because different bacterial species require different nutrients to successfully colonise a plate. Jefferies *et al*. (2022) proposed that the agar art activity serves as a means to enhance students' comprehension of promoters, making it an effective introductory tool to facilitate discussions on recombinant DNA and fluorescence in biochemistry lecture and lab courses. His study shows that the agar art activity encourages student innovation and is particularly suitable for upper-level undergraduate students enrolled in biochemistry courses.

Students' understanding was also assessed based on their discussion of the choice of bacteria, bacterial pigment produced, and techniques used in completing their artwork. The results showed that 71% had good understanding and 29% had an average level of understanding of the activity. The artwork examples depicted on nutrient agar and MacConkey agar plates showed students' understanding of bacterial pigment production, which can be assessed by observing the pigment production at different incubation temperatures. Furthermore, this activity can foster critical thinking skills as students explore how to create different patterns and shapes using various bacterial strains and growth conditions.

Certain microorganisms, such as fungi, bacteria, archaea, algae, and protists, synthesize their own pigments, allowing them to generate a stunning palette of colours. These pigments can be synthesized through different pathways that depend on the genetics of the organism, and they can either be intracellular or diffuse in the surrounding media (Chatragadda & Dufossé's, 2021). Bacterial pigments are ideal for interdisciplinary activities as they are visually attractive and spark curiosity (de Ordanza, 2019). Sharma & Meyer (2022) state that biological pigmentation is an interesting feature of fungi with significance to scientists and artists alike, as it reflects the organism's metabolism and environment while providing natural colours. They suggest that such pigmentation could inspire empathy towards microorganisms, important for conserving microbial biodiversity. The colours and pigments generated in bacterial art are constantly changing, peaking at certain points and fading over time or when exposed to sunlight. This unique aspect of bacterial art creates an opportunity to bridge the gap between art and science, as well as the gap in knowledge between humans and microbes (Frankel *et al*., 2023).

In summary, engaging in activities involving microbial art offers numerous benefits, including enhanced understanding of microbiology, stimulation of creativity, interdisciplinary collaboration, and effective science education. It is an exciting and innovative way to explore the microbial world while unleashing artistic potential and fostering a deeper appreciation for the wonders of science.

CONCLUSION

This study proved that microbial art could enhance student culturing techniques by providing a creative and engaging way to practice microbiology skills. It involves using different types of bacterial cultures to create visually appealing and intricate designs on agar plates. This activity not only provides an opportunity for artistic expression but also has the potential to enhance students' culturing techniques.

Creating microbial art involves selecting, growing, and manipulating different microorganisms, which can improve students' ability to isolate and culture specific microbes. Additionally, the visual aspect of microbial art may motivate students to pay closer attention to the physical characteristics of the microorganisms they are working with, which can improve their observation and identification skills. Overall, agar art can enhance students' culturing techniques by providing a fun and creative way to practice basic microbiological skills and learn about bacterial growth patterns. By incorporating microbial art into microbiology education, students can develop a deeper understanding and appreciation of the microbial world while also improving their technical skills.

ACKNOWLEDGEMENT

We would like to express our gratitude to the university for their ethics approval, which allowed us to conduct this study. A special thanks and deepest appreciation to all the students for their time and efforts in participating the microbial art activity.

REFERENCES

Adkins, S. J., Rock, R. K., & Morris, J. J. (2018). Interdisciplinary STEM Education Reform: Dishing Out Art in A Microbiology Laboratory. *FEMS microbiology letters, 365*(1), fnx245.

Adkins-Jablonsky, S. J., Akscyn, R., Bennett, B. C., Roberts, Q., & Morris, J. J. (2020). Is Community Relevance Enough? Civic and Science Identity Impact of Microbiology CUREs Focused on Community Environmental Justice. *Frontiers in Microbiology*, *11*, 578520.

Adkins-Jablonsky, S. J., Arnold, E., Rock, R., Gray, R., & Morris, J. J. (2021). Agar Art: A CURE for the Microbiology Laboratory. *Journal of microbiology & biology education, 22*(2), e00121-21.

Bonwell, C. C., & Eison, J. A. (1991). Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports. ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC 20036-1183.

Brockman, R. M., Taylor, J. M., Segars, L. W., Selke, V., & Taylor, T. A. (2020). Student Perceptions of Online and In-Person Microbiology Laboratory Experiences in Undergraduate Medical Education. *Medical education online, 25*(1), 1710324. https://doi.org/10.1080/10872981.2019.1710324

Bull, H., Premkumar, K., & Acharibasam, J. W. (2020). Using an Innovative Intervention to Promote Active Learning in an Introductory Microbiology Course. *Canadian Journal for the Scholarship of Teaching and Learning, 11*(2), n2.

Charkoudian, L. K., Fitzgerald, J. T., Khosla, C., & Champlin, A. (2010). In living color: bacterial pigments as an untapped resource in the classroom and beyond. *PLoS biology, 8*(10), e1000510.

Chatragadda, R., & Dufossé, L. (2021). Ecological and biotechnological aspects of pigmented microbes: A way forward in development of food and pharmaceutical grade pigments. *Microorganisms*, *9*(3), 637.

Colucci-Gray, L., Trowsdale, J., Cooke, C. F., Davies, R., Burnard, P., & Gray, D. S. (2017). Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21st learning: how can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education?. British Educational Research Association.

de Ondarza, J. (2019). The Color of Survival: An Inquiry-Based Inter-Disciplinary Study of Bacterial Pigments. *Bioscene: Journal of College Biology Teaching*, *45*(3), 22-30.

Frankel, E., Temple, J., Dikener, E., & Berkmen, M. (2023). Bridging the gap with bacterial art. *FEMS Microbiology Letters*, fnad025.

Jefferies, L. R., Giordano, A. N., & Hicks, B. W. (2022). Agar Art as an Instructional Tool to Teach Inducible

Promoters via Fluorescent Protein Expression. *Journal of Chemical Education*, *99*(12), 4181-4185.

Kibble, J. D., Bellew, C., Asmar, A., & Barkley, L. (2016). Team-based Learning in Large Enrollment Classes. *Advances in physiology education*, *40*(4), 435-442.

Najdanovic-Visak, V. (2017). Team-based Learning for First Year Engineering Students. *Education for Chemical Engineers, 18,* 26-34.

Ng, W. (2012). Bacterial Calligraphy: A Memento for Undergraduate Research Students. *Journal of Microbiology & Biology Education*, *13*(2), 172-174.

Sangweme, D., Lampert, E., & Mcintosh, E. (2020). Microbe art can educate & correct misconceptions about microorganisms. *The American Biology Teacher, 82*(3), 162-169.

Sharma, S., & Meyer, V. (2022). The colors of life: an interdisciplinary artist-in-residence project to research fungal pigments as a gateway to empathy and understanding of microbial life. *Fungal Biology and Biotechnology*, *9*, 1-11.

Wu, R., Brinkema, C., Peterson, M., Waltzer, A., & Chowning, J. (2018). STEAM connections: Painting with bacteria. *The American Biology Teacher*, *80*(4), 305-307.