Revista ARACÊ
ISSN: 2358-2472

ACTIVE LEARNING AND DRAMATIZATION IN MICROBIOLOGY: AN INTERDISCIPLINARY APPROACH TO TEACHING BIOFILMS

APRENDIZAGEM ATIVA E DRAMATIZAÇÃO EM MICROBIOLOGIA: UMA ABORDAGEM INTERDISCIPLINAR NO ENSINO DE BIOFILMES

APRENDIZAJE ACTIVO Y DRAMATIZACIÓN EN MICROBIOLOGÍA: UN ENFOQUE INTERDISCIPLINARIO PARA LA ENSEÑANZA DE BIOPELÍCULAS

https://doi.org/10.56238/arev7n10-312

Submission date: 09/31/2025 **Publication Date:** 10/31/2025

Ercília Celso de Lima Souza[1], Késia Ramos Miranda[2], João Batista Monteiro da Costa[3], Edivânia Muniz de Souza Santos[4], Alexsandro Soares Sobrinho[5], Sheila Oliveira dos Anjos[6], Iago Gabriel de Oliveira Vieira[7], Aurizangela Oliveira de Sousa[8]

ABSTRACT

Microbial biofilms are clusters of cells embedded in a self-produced matrix of extracellular polymeric substances, which provide protection against adverse environmental agents, including antibiotics. Given the complexity of the subject, this experience report aimed to promote active learning among students, stimulate creativity, and enhance the understanding of a microbiological topic with a complex approach through an interdisciplinary activity. The methodology adopted was based on the active learning approach Mantle of the Expert (MOE), experienced by a graduate class in Environmental Sciences at the Federal University of Western Bahia. From the reading of a scientific article, the students created theatrical scripts addressing biofilm formation, architecture, resistance, and control, resulting in a theater performance divided into four acts. The outcomes included greater conceptual

[1] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: ercilia.souza@ufob.edu.br Orcid: https://orcid.org/0000-0001-5346-9150
Lattes: https://lattes.cnpq.br/5159012896037367002O
[2] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: kesia.m0807@ufob.edu.br Orcid: https://orcid.org/0009-0001-1282-132X
Lattes: https://lattes.cnpq.br/9078274451363678
[3] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: kesia.m0807@ufob.edu.br Orcid: https://orcid.org/0009-0001-1282-132X
Lattes: https://lattes.cnpq.br/9078274451363678
[4] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: edivania.santos@ufv.br Orcid: https://orcid.org/0009-0004-2951-0247
Lattes: https://lattes.cnpq.br/6202055267910553
[5] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: alexsandro.sobrinho@ufob.edu.br Orcid: https://orcid.org/0009-0009-5917-9555
Lattes: http://lattes.cnpq.br/5342785849381340
[6] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: sheila.a0752@ufob.edu.br Orcid: https://orcid.org/0009-0007-2304-3184
Lattes: http://lattes.cnpq.br/0399121926288615
[7] Master's student in Environmental Sciences. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: iago.vieira@ufob.edu.br Orcid: https://orcid.org/0000-0003-2608-2473
Lattes: http://lattes.cnpq.br/9293331968405479
[8] Dr. in Genetics and Molecular Biology. Universidade Federal do Oeste da Bahia (UFOB).
E-mail: aurizangela.sousa@ufob.edu.br Orcid: https://orcid.org/0000-0001-9669-7890
Lattes: http://lattes.cnpq.br/9568436688304062

Revista ARACÊ
ISSN: 2358-2472

understanding and facilitation of the teaching of the topic, in addition to fostering teamwork, communication, and creativity. Therefore, dramatization proved to be effective in the teaching-learning process of a complex subject, and the script developed can be applied in future practices on the same content and in integrated teaching-research-extension actions.

Keywords: Microbial Biofilms. Active Learning. Dramatization. Interdisciplinary Teaching. Creativity. Graduate Education.

RESUMO

Os biofilmes microbianos são aglomerados de células incorporadas em uma matriz autoproduzida de substâncias poliméricas extracelulares, que conferem proteção contra agentes ambientais adversos, incluindo antibióticos. Diante da complexidade do tema, este relato de experiência teve como objetivo promover a aprendizagem ativa entre os estudantes, estimular a criatividade e favorecer a compreensão de um tema microbiológico com uma abordagem complexa por meio de uma atividade interdisciplinar. A metodologia adotada baseou-se na abordagem ativa Mantle Of The Expert (MOE), vivenciada por uma turma de pós-graduação em Ciências Ambientais da Universidade Federal do Oeste da Bahia. A partir da leitura de um artigo científico, os discentes criaram roteiros teatrais abordando formação, arquitetura, resistência e controle dos biofilmes, resultando em uma apresentação de teatro dividida em quatro atos. Como resultados obteve-se a maior compreensão conceitual e facilitação do ensino da temática, além de proporcionar o desenvolvimento do trabalho em equipe, exercício da comunicação e da criatividade. Portanto, a dramatização se mostrou eficaz no ensino-aprendizagem de um conteúdo complexo, podendo o roteiro elaborado ser utilizado em práticas futuras de mesmo conteúdo e ações integradas de ensino-pesquisa-extensão.

Palavras-chave: Biofilmes Microbianos. Aprendizagem Ativa. Dramatização. Ensino Interdisciplinar. Criatividade. Pós-Graduação.

RESUMEN

Los biofilms microbianos son conglomerados de células incorporadas en una matriz autoproducida de sustancias poliméricas extracelulares, que confieren protección contra agentes ambientales adversos, incluidos los antibióticos. Ante la complejidad del tema, este relato de experiencia tuvo como objetivo promover el aprendizaje activo entre los estudiantes, estimular la creatividad y favorecer la comprensión de un tema microbiológico con un enfoque complejo mediante una actividad interdisciplinaria. La metodología adoptada se basó en el enfoque activo Mantle of the Expert (MOE), vivenciado por una cohorte de posgrado en Ciencias Ambientales de la Universidad Federal del Oeste de Bahía. A partir de la lectura de un artículo científico, los estudiantes crearon guiones teatrales que abordaron la formación, la arquitectura, la resistencia y el control de los biofilms, lo que resultó en una presentación teatral dividida en cuatro actos. Como resultados se obtuvo una mayor comprensión conceptual y la facilitación de la enseñanza de la temática, además de promover el trabajo en equipo, el ejercicio de la comunicación y la creatividad. Por lo tanto, la dramatización se mostró eficaz en el proceso de enseñanza-aprendizaje de un contenido complejo, pudiendo el guion elaborado ser utilizado en futuras prácticas del mismo contenido y en acciones integradas de enseñanza-investigación-extensión.

Palabras clave: Biofilms Microbianos. Aprendizaje Activo. Dramatización. Enseñanza Interdisciplinaria. Creatividad. Posgrado.

Revista ARACÊ
ISSN: 2358-2472

1 INTRODUCTION

Microbial biofilms are aggregates of cells embedded within a self-produced matrix of extracellular polymeric substances (EPS). These structures confer resistance to extreme environments by providing protection against factors such as ultraviolet radiation, high temperatures, pH fluctuations, high salinity, pressure, nutrient scarcity, and antibiotics, among others. The EPS are composed of polysaccharides, proteins, lipids, and nucleic acids (extracellular RNA and DNA), forming a highly hydrated polar mixture that contributes to the overall organization and three-dimensional structure of a biofilm (Yin et al., 2019).

This bacterial survival strategy has a significant economic impact on various industries, as bacterial adhesion can cause corrosion in equipment and pipelines, clog channels, and contaminate food (Reysenbach; Cady, 2001; Karatan; Watnick, 2009; Simões; Simões; Vieira, 2010; Srey, Jahid; Ha, 2013). In healthcare settings, biofilms not only cause but also worsen certain diseases and infections, posing a significant control challenge due to their complex structure and the physiology of their formation process (Damaceno; Farias, 2016). Pathogenic biofilms inherently enable the microorganisms within them to evade the host's immune defenses and resist antimicrobial agents (Mah; O'Toole, 2001). Biofilms can also act as a reservoir of pathogenic bacteria, which can then disperse to colonize new tissues (Fleming; Rumbaugh, 2018).

According to Cavassin (2008), theater is a fundamental form of learning; it enables us to confront life's challenges and the changes required to overcome them. When brought into the classroom, theatrical practice can be a tool to transform an educational model that still relies on rote memorization. It shifts the focus toward an approach that truly connects with the student, empowering them to reflect on and form a position on the everyday and scientific issues relevant to their society (Freitas; Gonçalves, 2018).

Although they belong to distinct fields, each with its own unique characteristics, Science and Art seek to explain, represent, and interpret reality, respectively. Despite their differences, the scientific and artistic fields also share similarities, particularly in their shared goal of unveiling and revealing the world (Santos; Rigolin, 2011). In this context, dramaturgy emerges as a valuable pedagogical tool, as it fosters learning by integrating emotion, expression, and knowledge. By enhancing the educational process, it also helps students grasp complex scientific concepts—such as those related to the microbial world and biofilm formation—through creative, affective, and interactive approaches. To this end, this

Revista ARACÊ
ISSN: 2358-2472

experience report aimed to promote active learning and creativity among students, facilitating their understanding of a complex microbiological topic through an interdisciplinary activity.

2 METHODOLOGY

The methodology for this study was based on the Mantle of the Expert (MOE), an active learning approach centered on dramatization. In this method, teachers and students collaborate to create fictional scenarios designed to build knowledge around specific subject matter (Souza; Luz; Rufca, n.d.). Boshi's (2021) study demonstrates the effectiveness of the MOE methodology for engaging students in the learning process by allowing them to participate in decision-making, thereby fostering their autonomy and creativity, while also facilitating interdisciplinary curriculum development across diverse areas.

Within this context, during a classroom study of an article for the Environmental Microbiology course (a curricular component of the Graduate Program in Environmental Sciences at the Federal University of Western Bahia), the use of the MOE methodology was proposed to help structure the activity.

The article titled “Microbial biofilm: formation, architecture, antibiotic resistance, and control strategies” (Rather et al., 2021) served as the source material for a theatrical script. For the activity, participants were divided into four groups, each delving into one of the subtopics from the title: biofilm formation, biofilm architecture, antibiotic resistance, and biofilm control strategies.

The script's content was based on a core article, supplemented by literature from the field of microbiology dealing with biofilms and the microorganisms that interact with them. This culminated in a theatrical experience—a scientific-artistic performance on the topic—staged during a later class, in which every student from the Environmental Microbiology course participated.

The groups focusing on the themes of “formation, architecture, and antibiotic resistance” presented in a narrative theater format, using a third-person narrator.

3 RESULTS AND DISCUSSION

3.1 IMPACT OF DRAMATIZATION ON TEACHING MICROBIOLOGY

Applying the proposed methodology in the classroom had a positive impact on the graduate students' learning. The students reported high levels of active participation and enthusiasm, which resulted in a better assimilation of the scientific concepts from the article

Revista ARACÊ
ISSN: 2358-2472

used as the basis for the theatrical piece. The activity fostered teamwork, as well as creative and accessible scientific communication. The process of adapting academic language for the stage required students to engage in a deep, critical reading of the content, thereby aiding their own teaching and learning process.

This activity helps illustrate the value of active learning methodologies in higher education. According to Paulo Freire, knowledge should emerge from dialogue and the problematization of reality, allowing students to develop their own understanding through interaction with the subject matter, rather than simply storing content (Freire, 1996).

According to Zabala, teaching becomes special when it involves autonomy, dialogue, and critical reflection, a process that promotes the integration of prior and new knowledge. The use of dramatization, by fostering interaction among students, creates a student-centered context that can stimulate the construction of knowledge (Zabala, 1998).

3.2 RELATIONSHIP WITH THE ENVIRONMENT

The environmental impacts of biofilms can be seen in examples such as the contamination of water bodies, biocorrosion, and sewage treatment. When water bodies in reservoirs become contaminated, biofilms form in supply and distribution networks. These water bodies then act as reservoirs for pathogenic microorganisms such as Pseudomonas aeruginosa and enteric viruses. Many of these communities, which adhere to protective surfaces, can resist disinfection processes for days. Consequently, these pathogenic microorganisms pose a risk to public health, primarily through drinking water (Wingender; Flemming, 2011).

Biocorrosion in metal occurs in both aquatic and terrestrial environments. This process involves the formation of a biofilm by microorganisms that interact with metals such as lead, chromium, tin, iron, and nickel, thereby accelerating their corrosion. This phenomenon damages structures like ships, bridges, and tanks, and also results in the release of heavy metals into the environment (Mendes, 2015). However, in the context of wastewater treatment, biofilms serve a beneficial purpose. They are used as biological filters, as they have proven to be a viable alternative to conventional sludge treatments. The application of biofilms is not limited to sludge treatment; they are also used to control other environmental problems, such as contamination by heavy metals or excess nutrients in the soil (Singh; Naik, 2020).

Revista ARACÊ
ISSN: 2358-2472

Within the sciences, studying biofilm formation is relevant, as students can then understand the complexity of microorganisms. Furthermore, an interdisciplinary approach allows the study of microbiology, engineering, ecology, and other fields to be incorporated into environmental science courses at both the undergraduate and graduate levels. Although this topic may not be extensively covered in academic curricula, it is possible to devise activities—whether theoretical or experimental—that address biofilms. These activities should be simple, efficient, and dynamic, enabling students to apply this knowledge and these approaches in their professional training in environmental fields (Simões *et al*., 2021).

On the other hand, biofilms can have both negative and positive impacts depending on their application. For instance, as mentioned previously, they can harbor pathogenic or non-pathogenic microorganisms that may be resistant to disinfection. Yet, they can also serve as biological filters in applications vital to public and environmental health. Therefore, it is crucial to encourage the study of biofilms at all educational levels. This approach should apply concepts from ecology, microbiology, and engineering to bridge the gap between theory and daily practice, all with the goal of promoting environmental education.

3.3 SCRIPT IN FOUR ACTS

3.3.1 Act one

In a highly controlled, sterile hospital environment, brimming with technology and safety protocols, a central venous catheter is inserted into a patient following a routine surgery. The equipment was sterile, as protocol dictates.

However, while everything seemed calm to the naked eye, a microscopic process was beginning in silence...

(Staphy 1 swims into view through bodily fluids. She is excited, but cautious.)

Staphy 1: Wow, look at this place! Such a clean, cool tube! I finally found a surface where I can stop swimming aimlessly…

Narrator - Staphy now encounters other bacteria of her own species. Previously free-living, they must now transition to their sessile form to create a biofilm. This event is influenced by external conditions such as temperature, pH, gravitational forces, fluid dynamics (in this case, blood flow), the nature of the surface, quorum sensing, secondary messengers, and other signaling molecules.

Staphy 2: Hey, psst! Did you end up here too? Welcome to the club, sister!

Staphy 1: Hi! I'm Staphy 1. How long have you been here?

Revista ARACÊ
ISSN: 2358-2472

Staphy 2: I'm Staphy 2! I just latched on using my atlE protein. It's like an anchor that helps me stick to this plastic catheter wall. It's still just an initial adhesion, so one wrong move and *poof*, we're back to swimming.

Staphy 1: Ah, so that's it! I was wondering how to stay put. I'll activate my atlE too… whoa, there we go, that feels much more secure!

Staphy 2: But listen, the golden rule is: the more of us here, the stronger we get. We start to talk using quorum sensing.

Staphy 1: Quorum what?

Staphy 2: Quorum sensing! It's like… "chemical chatter". We release signaling molecules that float around. When there are only a few of us, the signals are too faint. But as more sisters arrive, the signal's concentration builds up.

Staphy 1: So… it's like we're all saying: "We've got a crowd! Time to work together!"?

Narrator - Once this anchor is established, production of the matrix begins—a mixture of polysaccharides, adhesive proteins, extracellular DNA, lipids, and water that can make up 90% of the biofilm's mass. This complex, functional framework, known as the EPS, is a protective structure that provides mechanical resistance, hinders the penetration of antibiotics, and impedes the action of immune cells.

Staphy 2: Exactly! When the signal hits a critical level, we activate specific genes. That changes everything. We stop floating, lock down tight, and start producing the EPS—that slimy stuff that becomes the biofilm!

Staphy 1: And that protects us, right? From antibiotics, the immune system, all of it.

Staphy 2: You got it! And there's more: inside the biofilm, some of us become persister cells—kind of dormant, just waiting for the perfect moment to strike.

Staphy 1: Wow… so the secret is communication and unity. A lone bacterium is weak, but together, we're an invincible community!

Staphy 2: Welcome to the team, Staphy 1. Now let's build this biofilm in style... and maybe conquer a few other body parts!

(They both laugh mischievously as their bond strengthens and the quorum sensing signal begins to echo throughout the catheter.)

Narrator - But community life also demands renewal. An accumulation of toxins, a scarcity of resources, or an environmental trigger can initiate the dispersion phase. Some bacteria activate genes that express lytic enzymes, degrading part of the EPS matrix and

Revista ARACÊ
ISSN: 2358-2472

liberating planktonic cells. These cells, now free-living once more, are capable of starting new colonies. This is what happened to Staphy 2. Meanwhile, Staphy 1 proudly tends to the EPS matrix. Staphy 2 is restless, eyeing the bloodstream flowing just beyond the biofilm's edge.

Staphy 2: I'm done with this place! This colony is too small for me. We've got the matrix, stable layers, persister cells… It's time to expand! I'm going to colonize the heart, the joints, maybe even the heart valves!

Staphy 1: *WHAT?!* You want to abandon our sacred biofilm? Our safe haven, built with our own EPS and c-di-GMP? You're acting like Donald Trump, thinking you're in charge of everything and can just build your own bacterial empire!

Staphy 2: *Oh, please!* This whole setup is compromised! This catheter is on the host's radar, the immune system is getting suspicious, and antibiotics are on the way… I'm getting out BEFORE they wipe us out. This place has become a comfort zone! I am Staphy 2, a visionary leader, ready to seed new biofilms out there!

Staphy 1: You'll be a sitting duck out there! No matrix, no quorum, no EPS... The immune cells will eat you alive, you megalomaniac!

Staphy 2: Wrong! I already have an evasion strategy, an escape plan. I'll go dormant, practically invisible. And when I get where I'm going, bam! New biofilm. I'm not an opportunist for nothing, darling. I'm a bacterium with vision!

Staphy 1: And I'm Staphy 1, a loyalist to this matrix! This is where we survive, where we communicate through quorum sensing, where we activate our genes with honor! We don't need to go around invading everything like some conquering empire!

Staphy 2: You're too attached to that catheter. It won't last forever. I'm thinking about the future of bacterial-kind!

Staphy 1: You only think about power! This is a biofilm, not a dictatorship!

Staphy 2: Fine. You stay here polishing the EPS while I go make history in the bloodstream! The new age of systemic infection is dawning… and Staphy 2 will be its pioneer!

(Staphy 2 detaches with a piece of the matrix and is swept away by the bloodstream. Staphy 1 watches, shedding a microscopic tear from her flagellum.)

Staphy 1 (sighs): Once my sister… now a systemic threat.

Narrator - What began with a single, invisible cell finding others had transformed into a complex, resilient, and resistant community. Biofilms remain a critical challenge in hospital-

Revista ARACÊ
ISSN: 2358-2472

acquired infections; combating them requires prevention, strict protocols, and constant scientific innovation.

3.3.2 Act two

Characters:

Staphy - A veteran bacterium from a previous lung infection, determined to establish a new biofilm.

Quoro - The quorum sensing specialist, coordinating all inter-bacterial communication.

Geni - The genetic regulator, activating the right genes in response to Quoro's signals.

Scene 1 - Landing on the Heart Valve

(Environment: blood turbulence, sound of heartbeat. A damaged heart valve appears in the background).

Staphy (latching onto the valve):

- This is the perfect spot! A damaged heart valve... Exposed fibrin, low immune surveillance... Our new colony starts right here!

Geni (scanning the surroundings):

- Confirmed. Conditions are ideal for initial adhesion: exposed matrix proteins and low oxygenation.

- I'm already activating the primary genetic regulators, like sarA and icaR, to promote adhesin production and trigger the ica operon.

Quoro (visor flashing with signals):

- Listen up! We need to start communicating to coordinate the build. Our numbers are still low, but I'm already releasing the first autoinducers.

Scene 2 – Growth and Communication

(The bacteria begin to multiply, and small colonies form on the valve.)

Staphy (observing the expansion):

- We're growing fast. But how do we know when to act as a group?

Quoro (proudly):

- Quorum sensing, my dear. As our population grows, so do the chemical signals. When we reach a critical concentration... that's the signal: time to change our collective behavior.

Geni (activating genes on a holographic interface):

Revista ARACÊ
ISSN: 2358-2472

Signal detected! Activating the agr system, our primary quorum regulator. Issuing genetic commands for:

• Extracellular matrix production (icaA, icaD)

• Inhibition of motility

• Formation of persister cells (relA, spoT)

• Toxin production (hla, psm) to block local defenses

Staphy (curiously):

- But how do you turn a simple chemical signal into a molecular weapon?

Geni (excitedly):

- I access the DNA and copy the necessary gene into a molecule called messenger RNA. That RNA travels to the ribosomes, which read the message and build the proteins using amino acids. It's like writing a recipe and delivering it straight to the cell's kitchen!"

Quoro (proudly):

- And it's all based on chemical communication... it's our secret language!

Scene 3 – Mature Biofilm and Total Coordination

(The biofilm structure solidifies on the valve. Visible layers, structured channels, protected inner zones.)

Geni:

- Our matrix is perfectly structured. Thanks to agr, sarA, sigB, and other regulators, we can coordinate multiple behaviors. We've created low-oxygen zones in the core and have active cells on the periphery.

Staphy:

- What if the immune system decides to fight back?

Quoro (calmly)

- We've already activated our immune evasion and antibiotic resistance genes, controlled by mgrA and norA. We're ready. Our quorum sensing keeps everything under control.

Geni:

- And it doesn't stop there: I'm activating the dispersal module with regulators like spo0A. A group is preparing to leave if the environment becomes hostile. They'll spread our genes to new territories!

Staphy:

Revista ARACÊ
ISSN: 2358-2472

- Incredible. We used to be just survivors... now we're an advanced bacterial civilization—and it all started with the right signal, at the right time.

Final Scene - Narrator or Caption

Quorum sensing is the key to bacterial collective intelligence.

It regulates the formation, maturation, resilience, and dispersal of biofilms in critical locations such as heart valves.

Interrupting this process may be the most effective strategy for preventing persistent and fatal infections.

Explanation of Genetic Regulators:

- What is the agr system and what is its function?

It is a quorum sensing-activated regulatory system. It coordinates the collective behavior of bacteria by activating toxin, dispersal, and biofilm genes. It acts as a "population-level decision-making hub."

- What is the role of the sarA regulator in biofilm formation?

It activates adhesion genes and the *icaADBC* operon, stimulating the production of the extracellular matrix (EPS). It works in synergy with *agr*.

- What is the function of the icaA / icaD genes?

They encode enzymes responsible for producing intercellular polysaccharide (PIA), an essential component of the biofilm matrix.

- What do the relA / spoT genes do?

They regulate the stress response and the formation of persister cells. They produce (p)ppGpp, a signaling molecule that induces dormancy and resistance.

- What is the function of the global regulator mgrA?

It activates antibiotic resistance genes (e.g., *norA*) and represses adhesion genes. It plays a role in dispersal and immune evasion.

- How does the sigB regulator function under stress?

It is an alternative sigma factor that activates protective and resistance genes in response to stressors such as heat, pH, or defensins.

- What is the function of the norA gene?

It encodes an efflux pump that expels antibiotics from the cell, contributing to bacterial resistance.

- What is the role of the spo0A regulator in the biofilm?

Revista ARACÊ
ISSN: 2358-2472

It controls bacterial dispersal from hostile environments, allowing cells to escape the biofilm and colonize new sites.

3.3.3 Act three

Scene 1 - THE ANTIBIOTIC'S ARRIVAL

(The NARRATOR emerges downstage.)

Narrator:

(In a solemn and mysterious tone)

In a microscopic world, deep inside a venous catheter...

an antibiotic arrives, its mission: to eliminate the threat.

But he is about to discover that this enemy will not be so easily defeated.

ANTIBIOTIC enters with a confident expression, striding purposefully across the stage. Heroic music swells in the background.

Antibiotic: At last! I've found you, biofilm bacteria! Brace yourselves! I am here to eradicate you, once and for all!

(A spotlight snaps onto BACTERIA, revealed beneath a layer of biofilm scenery.)

Bacteria:

Another antibiotic? Let me save you the trouble. This is a biofilm, not some run-of-the-mill colony.

Do you really think you're going to penetrate this matrix of extracellular polymeric substance—our EPS?

EPS? That's just a little slime! Destroying you is what I was made for! (scoffing)

Scene 2 — THE BIOFILM'S DEFENSE

(A figure appears, wrapped in shimmering fabric. It is the EPS.)

EPS (Extracellular Polymeric Substance Matrix): That's where you're wrong! (makes a grand entrance). I am the EPS, the Extracellular Polymeric Substance Matrix, built by the democratic quorum sensing of the entire community! And do you know what my job is? To stop you from getting to the bacteria. With my components, I can neutralize you and protect my friends.

Antibiotic: But I was made to attack bacterial cells! (confused, but insistent)

Bacteria: Only the planktonic cells… and maybe a few of us on the surface of the biofilm, at best! You can barely scratch the surface, antibiotic! We block you with

Revista ARACÊ
ISSN: 2358-2472

exopolysaccharides, proteins, and eDNA. And what's more... we have modifying enzymes in here! (laughing sarcastically)

The MODIFYING ENZYME appears with an air of superiority.

Modifying Enzyme: Well, well, look who's here! The antibiotic decided to pay us a visit! I already know you're here to try and beat us. But it's no use. Because I'm smarter than you. Before you can even act, I'll modify you into a non-toxic form right here inside the EPS. You want to know how? By breaking your essential chemical bonds or by blocking your binding to specific targets. I'm like an antidote to your poison.

Scene 3 — STRATEGIC RESISTANCE

The antibiotic shows its frustration.

Bacteria: And don't even think about attacking the center of the biofilm. Down there, there's a lack of oxygen, nutrients, and energy.

That slows everything down: metabolism, cell division… even your effect. You depend on active cells to function, but here… everything is in slow motion. Our inactivity is our greatest defense. (serious, formal tone)

Antibiotic: Fine... But what if I find a cell off-guard?! (irritated, trying to resist)

Bacteria: You'll run up against the persister cells!

A serious and imposing figure slowly appears: the PERSISTER CELL.

Persister Cell: I am a persister cell. I'm a specialized phenotype of bacterial cells that neither grow nor die, even in the presence of powerful antibiotics like you. The moment you're gone, I will multiply and rebuild the biofilm. What's more, I can form entirely new biofilms! (She enters, serious and resolute.)

Scene 4 - THE COUNTER-ATTACK

The Bacterium taunts the Antibiotic.

Bacterium: You really want to take me on? If I were you, I'd give up right now. And even if you do manage to get in, we have our... efflux pumps! Any little drop of you that makes it inside… (shoving gesture)… gets kicked right back out! They shove antibiotics out of our cells before you can do any damage. (sarcastically)

Antibiotic: This is a conspiracy! What about the immune system? It's going to destroy you! (glancing around, already looking defeated)

Bacterium: That's where you're wrong. We've taken care of that, too. The biofilm stops the white blood cells from swallowing us. We shut down phagocytosis, neutralize antibodies, interfere with the complement system…

Revista ARACÊ
ISSN: 2358-2472

Oh, and there's more! We share genes with each other. Horizontally! (laughs superiorly)

HORIZONTAL GENE TRANSFER enters, handing out small "packages" to the Bacterium.

Horizontal Gene Transfer: Hey everyone, I brought gifts! And what I'm offering here is only the good stuff! For you, I've got: acclimatization (which is great for you bacteria… you'll get way more resistant to this antibiotic thing). And for the whole microbial community, I guarantee: structural stability, integrity, and resilience. The antibiotic doesn't stand a chance here!

Scene 5 - THE ANTIBIOTIC'S DEFEAT

The lights dim. The Antibiotic cowers or backs away slowly.

Antibiotic: It's... it's a fortress... (defeated, confused)

Bacterium: No. It's a biofilm. A community. Organized, resilient... and invisible to its creators. Go back to your bottle. You've lost this battle. (stern and proud)

The lights fade to black. A single spotlight remains on the Narrator.

Narrator: The antibiotic retreats, overcome by the molecular ingenuity of a highly organized system. (in a concluding tone)

3.3.4 Act four

Microbial Interview: The Power of *Bacillus*

Jimmy Neuron: After the silent battle inside the catheter, where *Staphylococcus epidermidis* and its allies built a nearly impenetrable biofilm, the situation seemed hopeless. But it is in the most critical moments that the agents of change emerge. Now, a new phase begins, and it will be broadcast live from the heart of the infection on the best interview show there is: THE MICROCAST. Hello, MicroCast listeners, the podcast where the smallest lives tell the biggest stories! I'm Jimmy Neuron, your favorite electrical messenger, always ready to transmit the hottest signals straight from the brain of the action. Here, where every impulse counts, no synapse is left disconnected, and nothing escapes my radar—not even what happens in the depths of biofilms. Today, we have a guest: *Staphylococcus epidermidis*, master of biofilms. Staph, it's a pleasure to have you.

Staphylococcus epidermidis (vain): Thank you, Jimmy. I'm here to show that we're not villains, we're just... adapted.

Bacillus storms the interview and takes a seat.

Revista ARACÊ
ISSN: 2358-2472

Jimmy Neuron (turning): Whoa! And who are you?

Bacillus subtilis (enters with a dominant posture, a firm, confident voice): You can call me *Bacillus subtilis*. I represent resistance... but the kind that protects. I'm not here for small talk. (Glares at Staph) You think you're going to turn this catheter into your kingdom of slime? Forget it.

Staphylococcus epidermidis (nervous, trying to maintain her composure): E-excuse me? You weren't even invited…

Bacillus subtilis (interrupts, pacing around the studio): An invitation? Humans call on me all the time—in probiotics, in smart coatings, even in regenerative agriculture. I am the answer science has been looking for.

Staphylococcus epidermidis (suspiciously): You came to challenge me?

Bacillus subtilis (looks directly at Jimmy): I didn't come for a duel, I came for a dialogue. I came to show that you can be fought in a way that's natural, safe... and sustainable.

Jimmy Neuron (trying to keep control of the show): Well, this just got interesting! Let's proceed with the interview with both of you, then. First, I want to understand your biochemical weapons. Bacillus, can you tell our audience how you manage to destabilize such complex biofilms?

Bacillus subtilis (clearly, as visual examples are projected): With compounds like surfactin and DNase. Surfactin acts like a smart soap: It dissolves the glue holding the biofilm together, punctures the bacteria's protective barriers, and teams up with friendly enzymes to clean everything up.

Jimmy Neuron: And DNase?

Bacillus subtilis: If the biofilm were a brick wall, DNA would be the cement. DNase? That's my cement-dissolving acid. It melts the bonds and takes the whole thing apart.

Staph (grumbles): Unfair…

Bacillus subtilis (ignoring her): And it works even in hostile environments like this catheter right here.

Jimmy Neuron: Very interesting, Bacillus, quite a performance. I see you're not too pleased, are you, Staph? But tell me, after everything you did—forming a biofilm, resisting antibiotics, tricking the immune system... and yet, the human survived. Was that a mistake, or do you actually not want to kill the host? What's your real endgame here?

Revista ARACÊ
ISSN: 2358-2472

Staphylococcus epidermidis (in a calculating tone): Don't be mistaken, Jimmy. I need the human alive. If they die, I lose my environment, my sustenance, my colony. It's not about kindness... it's survival. I adapt, but without the host, there's nowhere to anchor myself. We've formed a great biofilm in this body, and luckily for us, they're going to make it out alive. That's in our interest, too!

Jimmy Neuron: Before we wrap up, I wanted to hear from you both about an alternative that's been gaining traction: phytocompounds. Staph, have you ever encountered any?

Staphylococcus epidermidis (a bit uncomfortable): I've heard of them, unfortunately... Compounds like taxodione, from *Salvia austriaca*, prevent me from attaching to surfaces. It's like trying to build a house on sand.

Bacillus subtilis: And it doesn't stop there, Jimmy. Cinnamon oil affects adhesion genes, resveratrol disrupts bacterial communication, and curcumin, from turmeric, interferes with matrix formation. All of it coming from plants.

Staph (sighs): Even mangoes and lemons are against us…

Jimmy Neuron (looking at the guests, visibly impacted): Wow... So plants aren't just food, they're also powerful allies against infections as complex as biofilms?

Bacillus subtilis (affirmatively, looking at the camera): Exactly. Phytocompounds aren't just alternatives—they are valuable tools that nature provides. But to continue discovering and using these solutions, we need to protect the environment they come from. Forests, healthy soils, biodiversity.

Jimmy Neuron (concluding): Saving the patient was a victory. But understanding where the cure came from is even cooler, especially when we discover new ways to take down biofilms. Phytocompounds are true superheroes, and so are you, Bacillus, of course.

Bacillus subtilis: Thank you, Jimmy. Because preserving human life also depends on protecting the soil, the forests, and biodiversity. The future of health may be rooted in the earth.

Jimmy Neuron: Incredible... But tell me something, Bacillus: if you're so effective and full of natural solutions, why do we still see hospitals using antibiotics as the first line of defense?

Bacillus subtilis (sincerely): Good question, Jimmy. The answer involves three major challenges:

1. Producing solutions like me on a large scale is still expensive.

Revista ARACÊ
ISSN: 2358-2472

2. We need to ensure total safety—no side effects.

3. And, of course, some biofilms are too complex for a single solution.

Staph smirks, but quickly stops when she catches *Bacillus*'s eye.

Jimmy Neuron: Wow! It looks like we're gaining smarter weapons in this microscopic war!

Jimmy Neuron (more seriously, crossing his arms): But tell me, Bacillus... even with all that, why are there still so many infections caused by biofilms?

Bacillus subtilis: For three reasons, Jimmy:

1. Ignorance—many humans still use antibiotics that wipe me out along with the villains.

2. Laziness—they don't apply my spores to catheters like they should.

3. And Complexity—(glances at Staph) some biofilms are just... stubborn.

Staphylococcus epidermidis (thoughtfully, breaking the tone): Bacillus... if you're so efficient, why don't we work together?

Bacillus subtilis (surprised, but curious): Work together? What do you mean?

Staph (shrugs): Think about it: I know everything about sticking to surfaces, and you're the master of destroying biofilms. If we joined forces against bacteria like Pseudomonas or E. coli...

(Bacillus reflects. Jimmy leaps from his chair, animated.)

Jimmy Neuron (excited): That would be incredible! A microbial cooperation to keep medical devices clean and safe!

Bacillus subtilis (smiling for the first time): As long as you stop forming pathogenic biofilms, we have a deal.

Jimmy: Well, on that note, we'll wrap things up. (Speaking to the audience) "I want to thank our guests for being here, and remember what we learned today: preserving the environment is ensuring the future of medicine itself. Here on MicroCast, the smallest lives tell the biggest stories, and the battle against biofilms is just one chapter in this saga. On our next episode, we're going to dive even deeper—straight into the labyrinth of the human gut—to talk with an expert in symbiosis: the incredible *Bacteroides fragilis*. Get ready to discover how she helps balance our immune system and keep our gut health in check. Until then, connect your neurons and stay tuned!"

Revista ARACÊ
ISSN: 2358-2472

4 CONCLUSION

The student-led dramatization, employed here as a teaching method in higher education, proved to be a powerful tool for building and sharing knowledge. It made learning about "Bacterial Biofilms" accessible and simplified a complex subject. In essence, the dramatization was an effective learning tool, translating the scientific language of academic papers into a more engaging and understandable format. Furthermore, writing the play's script fostered the students' creativity and enhanced their ability to communicate scientific concepts. Our theatrical experience, designed to explain biofilms, was a success. It stimulated creativity, honed communication skills, and improved planning, organization, and teamwork – all crucial for professional development and social interaction. Ultimately, this activity demonstrated the potential of dramatization as a pedagogical tool, seamlessly integrating scientific knowledge with artistic expression. It serves as a valuable teaching method that future educators can utilize in their classrooms.

REFERENCES

Ather, M. A., Gupta, K., & Mandal, M. (2021). Microbial biofilm: Formation, architecture, antibiotic resistance, and control strategies. Brazilian Journal of Microbiology, 52, 1701–1718.

Boschi, R. L. (2019). Mantle of the Expert (MOE) e o uso das tecnologias digitais na escola - uma experiência inglesa. Scias: Educação, Comunicação e Tecnologia, 1(1), 24–38.

Cavassin, J. (2008). Perspectivas para o teatro na educação como conhecimento e prática pedagógica. Revista Científica – FAP, 3. http://periodicos.unespar.edu.br/index.php/revistacientifica/article/view/1624

Damaceno, N. B., & Farias, L. R. (2016). Relação existente entre biofilmes bacterianos, quorum sensing, infecções e resistência a antibióticos: Uma revisão bibliográfica. Revista Brasileira de Pesquisa em Ciências da Saúde, 3(1), 46–51. http://revistas.icesp.br/index.php/RBPeCS/article/view/23

Freire, P. (1996). Pedagogia da autonomia: Saberes necessários à prática educativa. Paz e Terra.

Freitas, N. M. da S., & Gonçalves, T. V. O. (2018). Práticas teatrais e o ensino de Ciências: O teatro jornal na abordagem da temática do lixo. Educar em Revista, 34(68), 199–216.

Fleming, D., & Rumbaugh, K. (2018). As consequências da dispersão do biofilme-sal no hospedeiro. Scientific Reports, 8, 1–7.

Revista ARACÊ
ISSN: 2358-2472

Karatan, E., & Watnick, P. (2009). Signals, regulatory networks, and materials that build and break bacterial biofilms. Microbiology and Molecular Biology Reviews, 73(2), 310–347.

Mendes, N. H. (2015). Desenvolvimento do biofilme bacteriano em superfícies de metais puros [Doctoral dissertation, Universidade de São Paulo].

Pawinger, J., & Flemming, H. C. (2011). Biofilms in drinking water and their role as reservoir for pathogens. International Journal of Hygiene and Environmental Health, 214(6), 417–423.

Rather, M. A., Gupta, K., & Mandal, M. (2021). Biofilme microbiano: Formação, arquitetura, resistência a antibióticos e estratégias de controle. Revista Brasileira de Microbiologia, 52(4), 1701–1718. https://doi.org/10.1007/s42770-021-00624-x

Reysenbach, A. L., & Cady, S. L. (2001). Microbiology of ancient and modern hydrothermal systems. Trends in Microbiology, 9(2), 79–86.

Santos, R. R. dos, & Rigolin, C. D. (2011). Diálogos entre ciência e arte sob o enfoque CTS: Proposta de uma agenda. In Anais do 4º Simpósio Nacional de Tecnologia e Sociedade. UTFPR. https://repositorio.utfpr.edu.br/jspui/handle/1/546

Simões, M., Simões, L. C., & Vieira, M. J. (2010). A review of current and emergent biofilm control strategies. LWT - Food Science and Technology, 43(4), 573–583.

Simões, M., et al. (2021). Desafios no ensino da ciência e tecnologia dos biofilmes.

Souza, B. C., Luz, P. F. da, & Rufca, R. L. (n.d.). Aprendizagem ativa pautada na dramatização: MoE (Mantle of the Expert) (pp. 635–639). Balneário Camboriú, SC, Brasil.

Singh, R., & Naik, M. (2020). Biofilm-mediated bioremediation: Current advances and future prospects. Journal of Environmental Management, 260, 110–120.

Srey, S., Jahid, I. K., & Ha, S. D. (2013). Biofilm formation in food industries: A food safety concern. Food Control, 31(2), 572–585.

Mah, T. F. C., & O'Toole, G. A. (2001). Mecanismos de resistência do biofilme aos agentes antimicrobianos. Trends in Microbiology, 9, 34–39.

Yin, W., Wang, Y., Liu, L., & He, J. (2019). Biofilms: The microbial 'protective clothing' in extreme environments. International Journal of Molecular Sciences, 20(14), Article 3423.

Zabala, A. (1998). A prática educativa: Como ensinar. Artmed.