RURAL STUDENTS' EMPOWERMENT: FOSTERING SCIENTIFIC CURIOSITY THROUGH MICROBIOLOGY

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Abstract

Rural communities worldwide face unique challenges, with limited access to quality education initiatives and significant disparities in accessing science. In places such as Armamar, a village located in the interior of northern Portugal, unique socio-economic and geographical factors create barriers to providing equitable educational opportunities, hindering the principles of quality education and equal opportunities for all. In response, GOMA (Gomes Teixeira Science Academy) was established in Armamar's public school cluster in 2022 through collaboration with Armamar's Municipality and the University of Porto.

This study presents GOMA's program, 'The Invisible Life of Bacteria', over the academic years 21/22 and 22/23, tailoring 60 fourth-grade students (9-10 years old) of Armamar primary school. Feedback from students and schoolteachers was analysed. Through engaging storytelling, hands-on activities and direct scientist interactions, the program enhances students' comprehension of microbiology, fosters a lasting curiosity for science, challenges stereotypes and promotes inclusivity in science, addressing educational and opportunity gaps in rural areas. For instance, (i) a significant majority of students exhibited an improved understanding of microbiology concepts and all confirmed the acquisition of significant new knowledge, underlining the workshop's effectiveness; (ii) around 80% of students experienced their first interaction with a scientist, and in response, 100% expressed enthusiastic emotions, highlighting a solid connection to this aspect of the workshop; (iii) when asked about their overall impression of the workshop, 91% of the students described it as "spectacular" and 7.4% found it "fun." Schoolteachers unanimously reported positive changes in student's attitudes toward science, recognizing the program's pivotal role in promoting inclusivity in science education.

The significance of the study extends beyond the inspiration of rural students. Education inequalities and limited access to science in rural areas persist worldwide, making it critical for academia and society to address these issues. We propose a promising model for bridging these gaps by empowering underprivileged communities, fostering inclusivity and promoting microbiology literacy. This study also provides insights for future research and contributes to the ongoing discussion on improving access to science in underserved communities. Through innovative strategies and a commitment to inclusivity and microbiology literacy, we envision a future where every student, regardless of background, has equal opportunities to explore and embrace science.

Keywords: Rural Education, Microbiology literacy, Empowerment, Inclusivity, Counterstereotypical.

1 INTRODUCTION

In order to achieve the United Nations' 2030 Agenda for Sustainable Development, a comprehensive approach is essential. Education is a key component of the Sustainable Development Goals (SDGs) and is critical to the solution of global challenges [1]. The importance of education, particularly in the STEAM disciplines (science, technology, engineering, arts and mathematics), is undeniable. However, realising its full potential faces unique barriers in rural areas.

Despite ongoing efforts, disparities in education persist in rural areas, which cover around 75% of the territory of the European Union [2]. This restricts youngsters' access to effective education and prevents them from reaching their full potential [3,4].

Promoting a scientifically literate society is paramount for facilitating well-informed decision-making on individual and public policy levels. However, a significant challenge arises from the gap between academic research, schooling and society, which has led to declining student interest in STEAM disciplines [5,6]. This disconnect has become even more pronounced by the rise of scientific scepticism and the prevalence of conspiracy theories, emphasizing the pressing need to bridge these gaps [7].

To tackle these challenges, initiatives worldwide have shown significant potential in bolster scientific literacy routed in interdisciplinary STEAM education [8-12]. In Portugal, the "Cientista regressa à escola" program, pioneered by Native Scientists, has successfully facilitated the engagement between scientists and young students [13], highlighting the importance of STEAM disciplines in fostering students' sense of competence, belonging and representation, while promoting integrated learning based on principles of equity, diversity and inclusion [14].

Microbiology has been emerging as a vital component of STEAM education, serving as an interesting bridge to link the realms of science and society. Its role is crucial in nurturing an understanding the significance of microorganisms, particularly in the light of persistent misconceptions about their impact on health or in the environment [15,16]. The COVID-19 pandemic highlighted this challenge. Therefore, it is important to increase the awareness of microbiology in society, including key stakeholders such as schools.

The GOMA (Gomes Teixeira Science Academy), which was established in 2022 to improve scientific literacy in rural areas of Portugal, with a particular focus on Armamar [17], has been dedicated to increasing the awareness of microbiology.

This research investigates the impact of 'The Invisible Life of Bacteria' program on fourth-grade students in the context of Armamar. By integrating STEAM domains with microbiology, this study aims to improve scientific literacy in microbiology and enhance essential 21st-century skills, fostering inclusivity and advancing science education in underprivileged communities.

The specific objectives of the study are as follows:

- Dispel misconceptions: Evaluate the program's effectiveness in dispelling microorganisms-related misconceptions.
- Foster curiosity and understanding: Assess the program's impact on stimulating curiosity and establishing a foundational understanding of microbiology among students.
- Bridge science and everyday life: Examine the program's ability to facilitate a dynamic exchange between scientific concepts and students' daily experiences, thereby promoting active engagement and awareness of science's societal relevance.
- Promote science equity: Investigate how the program enhances science identity, counters stereotypes, fosters inclusivity, and empowers students in underprivileged communities to embrace science within their unique sociocultural backgrounds.

The findings of this study have the potential to catalyse the development of targeted and equitable educational initiatives, not only in Armamar but also in regions facing similar challenges.

Taking into account the aforementioned objectives, the primary research question of this study is: *'How does 'The Invisible Life of Bacteria' influence the perceptions of microbiology and engagement with science among fourth-grade students in Armamar?'*

2 METHODOLOGY

2.1 'The Invisible Life of Bacteria' workshop context within GOMA

'The Invisible Life of Bacteria' workshop was held at Gomes Teixeira Science Academy (GOMA), a collaborative initiative established in 2022 by the Armamar Public School Cluster (AEGT), the Municipality of Armamar and the University of Porto - Faculty of Arts and Humanities. GOMA received funding from the Portuguese Agency - Ciência Viva. It strives to improve scientific literacy, nurture curiosity, empower students, promote inclusivity and encourage active engagement with science in the rural region of Armamar. This workshop was one of forty science-based activities organised by GOMA during the 2021/2022 and 2022/2023 academic years, involving more than a thousand students, thirtyfive teachers and ten scientists. As part of the 'Cientista regressa à escola' initiative [13], this workshop was tailored to spark scientific curiosity and raise awareness of microbiology.

2.2 The workshop students

The workshop participants consisted of a diverse group of primary school students in the fourth grade, aged 9 to 10. The selection process prioritized inclusivity, ensuring participation from various socioeconomic backgrounds and students with special educational needs. This aligns with GOMA's commitment to equal learning opportunities and promotes cross-cultural exchanges. Fourth grade in Portuguese primary schools marks the end of the 1st Cycle of Basic Education (CEB), which covers grades 1 to 4.

2.3 The workshop design approach

The workshop employed a student-centered, active-learning approach rooted in STEAM education principles [18]. It aimed to simplify complex scientific concepts and enhance scientific literacy and microbiology awareness through the use of visual aids, interactive elements, and games.

Influenced by the constructivist educational principle, which asserts that learners actively construct their understanding through hands-on experiences and interactions [19], the workshop integrated hands-on activities and interactive discussions. This approach enabled students to become active participants in their learning process [18], promoting collaborative learning and idea exploration, and creating a supportive environment for deeper comprehension and sustained curiosity in scientific exploration. Additionally, the workshop played a vital role in bridging the gap between science and society, particularly in rural contexts like Armamar. It supported enriching science education in underserved rural communities by establishing strong links between science and primary and secondary education institutions.

2.4 The workshop structure and format

The workshop was structured using a canvas approach (Table 1), which was tailored to the target audience, activity formats, and content. Collaborative discussions between the facilitator and educators were used to align content with objectives and student curricula, ensuring resonance with students' curiosity, interests, and cultural context.

The workshop comprised a 90-minute session (Table 2) and began with a 5-minute introduction, setting the stage for an interactive session. Recognising the importance of challenging stereotypes in educational settings [14, 20], the workshop proceeded with the 'Who is Who' interactive game, introducing diverse scientists in a 15-minute activity. The dynamic and thought-provoking nature of this game aimed to increase the visibility of scientists, inspire students to envision themselves in similar roles, and deconstruct prevalent stereotypes, fostering an environment of equitable representation and inclusivity.

To enhance primary-level microbiology literacy, 'The Invisible Life of Bacteria' workshop laid a foundation for understanding this discipline [16]. The workshop uses captivating materials to guide students through a storytelling journey (Table 2) about microbes. Interactive discussions, powered by exploratory questions, encourage active participation and knowledge exchange. Additionally, a 3D prokaryotic cell model facilitates discussions on cell structures and functions. The workshop then delved into microscopes' utility and the observation of bacterial cultures, lasting 30 minutes.

The 30-minute hands-on "Imagine your microbe pet" activity fostered students' creativity, communication and collaboration [21]. During the activity, students created and shared their 'microbe pet' models using plasticine sticks placed within an empty petri dish. They also presented scientific insights about their unique microbes to their colleagues.

The workshop concluded with final remarks, a comprehensive summary and student feedback collection.

Table 1. Canva for preparing science-based activities.

Audience	Format options	Structure	Topics
- Define students' age - Define students' grade (target group) - Define students' maximum number (per class)	1. Individual activities 2. Group/pair activities 3. Class discussion	**Beginning** - Personal introduction /description - Motivation/context - Opening question, ice-breaker Content/activities - Demonstrations, hands-on activities, gamified exercises, sample images. End - Learning consolidation - Closing question - Feedback	**- What will be the key-message?** **- Which microbiology topics/concepts will be covered?** **- What will be the main keywords for each topic?** **- What will be shown?**

2.5 D prokaryotic cell model construction

The design of the 3D prokaryotic cell model was realised in Solidworks® CAD software, ensuring optimal visualization without compromising portability. The CAD model was then processed using MatserCAM® CAM software to generate CNC code for manufacturing. Manufacturing was carried out using an OUPLAN 2515 CNC machine with an 8 mm round-tip mill over blue extruded polystyrene material, resulting in a final model with dimensions of 500 x 200 x 200 mm. To ensure precision, the cutting speed (Vc), feed rate, and axial depth of cut (ap) parameters were adjusted. The model was designed using Adobe Photoshop® software and printed on cardboard.

2.6 Workshop assessment and evaluation

An assessment approach was implemented to evaluate the effectiveness and impact of the workshop, incorporating both direct and indirect evaluation methods.

Feedback Questionnaire: A color-coded questionnaire consisting of four questions (Supplementary Material, Table 1), was given to students to assess their engagement, interest and perceived learning outcomes. Schoolteachers used an evaluation form (Supplementary Material, Table 2) to provide feedback on a scale ranging from 1 ("strongly disagree") to 5 ("strongly agree") and an open-ended question for qualitative feedback. To comply with GDPR regulations, AEGT formally approved the questionnaires, and all responses were voluntary and anonymous.

Observations and semi-structured conversation: During the workshop, indirect evaluations were conducted through observations and informal dialogues with students in a flexible format. The conversations with students focused on their engagement levels, comprehension of microbiology concepts, and the workshop's impact on their perceptions of science. At the end of each workshop, schoolteachers were also engaged in informal conversations. These conversations examined student participation and the workshop's long-term impact on student attitudes towards microbiology and science.

3 RESULTS

3.1 Workshop participation and demographics

The effectiveness and impact of 'The Invisible Life of Bacteria' workshops were evaluated across four sessions, two in the academic year 2021/2022 and two in 2022/2023. The workshops engaged a total of 60 fourth-grade students, aged 9 to 10, with a diverse gender distribution of 66.7% (n=40) female students and 33.3% (n=20) male students. A small percentage of students, n=2 (3.3%), faced language difficulties, while n=2 (3.3%) had specific needs. These demographic details highlight the workshop's inclusive approach, emphasising its adaptability and accessibility to diverse student requirements.

3.2 Students' perceptions of scientists and diversity in science

Prominent scientists' recognition: Most students (≈80%) recognized Albert Einstein and Francisco Gomes Teixeira, correctly identifying their contributions to physics and mathematics, respectively.

Knowledge gap on Elvira Fortunato and Marie Curie: Only a small percentage of students recognized Elvira Fortunato as a scientist, with approximately 6% associating her primarily with her role as the Minister of Science, Technology, and Higher Education in Portugal. None identified her scientific contributions. Similarly, only a small number (≈3%) were aware of Marie Curie and her work in radioactivity.

Unfamiliarity with other scientists: The students were not familiar with the contributions of scientists such as Katherine Johnson, Jane Goodall, George Washington Carver and Raquel Branquinho to the field of science.

3.3 Students' perceptions of becoming a scientist

During the game, students were also asked a thought-provoking question, "Do you think anyone can become a scientist, no matter where they come from?" The responses revealed interesting viewpoints:

Reservations about accessibility: Approximately 70% of students expressed reservations regarding the accessibility of a career in science. Barriers cited included extensive study requirements, the difficulty of scientific pursuits, and the belief that exceptional intelligence is necessary.

Positive outlook: Around 20% of students believed that anyone could become a scientist, indicating a need for further exploration of contributing factors.

Table 2. Comprehensive overview of the scientific themes and activities covered in the 90-minute workshop 'The Invisible Life of Bacteria'.

Moment	*Content Overview/ Scientific Topics*	*Description*	*Key questions explored*	*Duration*
a. Presentation and Ice Breaker	*Facilitator introduction* *Class introduction* *Workshop introduction*	Facilitator introduced themself and engaged students in an ice breaker activity for class introduction. Workshop is presented.	*What is the 'Invisible Life of Bacteria' workshop about?*	5 min
b. Who is Who Game	*The importance of diversity in science* *Challenging stereotypes Inspiring* *Careers in science*	Interactive game where students immersed in images of diverse scientists, challenging stereotypes and broadening their perceptions.	*Who are these scientists, and what contributions have they made to science?* *Do you think anyone can become a scientist, no matter where they come from?* *Why do you think it's important to learn about scientists from different backgrounds?*	15 min
c. Storytelling: Unveiling the Microbial World	*General microbiology introduction* *Microbial ubiquity* *Beneficial and harmful aspects*	Engaging storytelling session introducing students to microbiology, exploring microbial biology, their ubiquity and their dual nature.	*What are microbes?* *Where do microbes live?* *What do microbes do?*	30 min
c1. Exploring Prokaryotic Cells (Supplementary Material, Figure 1)	*Prokaryotic cells: structures and functions*	Introduction to prokaryotic cells, their structure and functions	*What is a prokaryotic cell?* *What do prokaryotic cells look like?* *What cell parts does a prokaryotic cell have?*	
c2. Microscope and Petri Dish Exploration	Colonies observation	Microbes' exploitation through microscopes and petri dishes.	*How do we see microbes in a Petri dish, and why do we need a microscope to see them?*	

d. Hands-on activity: "Imagine Your Microbe Pet."	Creative role-play, Microbial characteristics Knowledge consolidation or synthesis of what students had learned	Students engage in a hands-on activity, embody real-life scientists, to create their 'microbe pet,' stimulating creativity and understanding of microbial characteristics (cell count, flagella, chromosomes, functions, habitat, name, among others). Presentation of the "pet" to peers.	*What characteristics would your microbe have?*	30 min
e. Recap, Feedback, and Farewell	Reflection, Student impressions, Feedback	Concluding phase addressing workshop summary, feedback collection, and students' takeaways.	*Was it the first time you met a scientist?* *Did you learn something new?* *Did you like to meet a scientist?* *Which word best describes the workshop?*	10 min

Uncertain or no response: Approximately 10% of participants did not respond or expressed uncertainty, indicating the need for additional investigation.

3.4 Significance of learning about scientists from different backgrounds

Following the "Who is Who" game, students were asked, "Why do you think it is important to learn about scientists from different backgrounds?" The responses provided valuable insights:

Inclusivity and accessibility: Most students (≈80%) recognized that anyone, including themselves, could become a scientist, emphasizing inclusivity, accessibility, challenging stereotypes and broadening horizons.

Diverse scientist image: Some students (≈35%) acknowledged that scientists do not fit a single stereotype, promoting a broader understanding of scientific roles and appearances.

Varied scientific activities: Approximately 20% understood that scientists engage in various activities beyond lab work, dispelling misconceptions about science's nature and fostering a more comprehensive view of the different scientific disciplines.

Emphasis on racial and ethnic diversity: All students recognized the significance of racial and ethnic diversity among scientists, which aligns with equity goals in STEAM fields [14,20].

Positive attitude towards science: Many students (≈50%) found science enjoyable and crucial for understanding the world.

Inspiration for science careers: Some students (≈8%) expressed aspirations to pursue science-related paths, indicating the intervention's impact on career considerations.

These findings underscore the potential of the 'Who is Who' game in challenging preconceived stereotypes, inspiring exploration of science-related careers, and fostering positive attitudes towards science, consistent with previous studies [22,23].

However, future research should focus on the following aspects:

Exploring reservations: Understanding the sources of students expressing reservations about pursuing science careers, enabling targeted interventions to dispel misconceptions.

Fostering diversity and representation: Build on the recognition of diverse scientists and the importance of role models to enhance diversity and inclusivity in science education.

Promoting positive attitudes: Sustain and strengthen students' positive attitudes towards science to ensure continued enthusiasm.

Tracking career aspirations: Assess whether students' aspirations translate into career choices through long-term studies.

Inclusivity and Equity: Explore how changes in perception influence students' further school performance and participation in STEAM activities, emphasizing inclusivity and equity.

3.5 Students’ microbiology understanding throughout the "Imagine Your Microbe Pet" activity

This sub-section explores the specific outcomes of the hands-on activity "Imagine Your Microbe Pet" and discusses its implications for participants' understanding of microbiology. Although lacking specific quantitative data, the activity provided a valuable opportunity to assess the application of microbiology knowledge in a practical setting.

Completion and Incorporation: All students (100%) successfully completed the activity within the designated time, incorporating at least one characteristic or structure learned about prokaryotic cells into their "microbe pets".

Broadcasting phase: During this phase, students introduced their pet microbes, with notable considerations including:

- **Identity**: All students (100%) identified their pet microbes as bacteria and correctly emphasised their single-cell nature, showcasing creativity through diverse colour representations.
- **Habitat**: Responses varied, with students demonstrating a grasp of microbial ubiquity. They referenced locations such as the intestine, yogurt, bedroom, space, the deep ocean, backpack, skin, and shoe sole.
- **Functions**: Most students recognised the beneficial roles of microbes, such as curing diseases, while acknowledging their potential to cause diseases or contribute to broader well-being. This demonstrates the students' awareness of the dual nature of microbial activities.

Communication competencies: All students demonstrated their ability to present their individual "science message" to the class (Supplementary Material, Figure 2). Although some expressed discomfort and embarrassment, they overcame these feelings with encouragement and incentives. It is worth noting that elementary school children may experience some degree of nervousness when it comes to public speaking [24]. Even two students with language difficulties agreed to have the facilitator share their findings, showcasing adaptability and inclusivity.

The results of the workshop suggest that our approach successfully facilitated elementary students in exploring and comprehending fundamental microbiological concepts. It fostered the importance of microbial ubiquity, emphasized science's role in understanding microbial interactions and aimed to establish mental connections between routine experiences and acquired knowledge [25]. This awareness is expected to positively influence the decision-making processes of young learners as they progress in their education, contributing to the development of critical citizens.

3.6 Students’ feedback

The feedback from students, gathered through four direct questions, revealed highly encouraging results. Approximately 80% of students reported their first encounter with a scientist, and all confirmed that they had gained substantial new knowledge, demonstrating the workshop's efficacy. Impressions of the workshop were notably positive, with 91% describing it as "spectacular" and 7.4% finding it "fun." In the aspect of meeting a scientist, 100% expressed positive sentiments, indicating a solid connection to this workshop element.

3.7 Schoolteachers' feedback

The feedback received from schoolteachers provided valuable insights into the impact of the workshop on students' scientific curiosity, engagement, and learning, affirming its success. The positive feedback confirms the workshop's ability to ignite scientific interest, facilitate direct interactions with scientists, and encourage exploration of scientific concepts such as microbiology. The key findings are summarised as follows:

Meeting expectations and learning opportunities: All schoolteachers (100%) agreed that the workshop exceeded expectations, citing students' active engagement and exposure to new microbiology concepts.

Igniting interest and understanding significance: The schoolteachers unanimously (100%) acknowledged that the workshop stimulated or developed students' interest in science and microbiology and contributed significantly to their understanding of the importance and relevance of microbiology in our lives.

Enhanced comfort and promoting equality: The workshop significantly increased students' comfort levels when discussing science topics, particularly microbiology. Moreover, schoolteachers noted that the workshop promoted equality and inclusion in science by introducing students to diverse scientists as role models.

Recommendations: Schoolteachers expressed a solid willingness to recommend the workshop to other colleagues. It was also suggested by some to extend the duration of the workshop to increase its impact further. They praised the scientist/facilitator's effective communication, content delivery and valued interaction with students.

Impact on the Classroom: All schoolteachers confirmed that students found the activities memorable and incorporated scientific concepts into post-workshop conversations. Additionally, they referred that the workshop had a positive impact on students' perceptions of science, enabling them to view science as enjoyable, relevant, and accessible.

Open-ended Feedback: Schoolteachers appreciated the direct interaction between scientists and students and found it particularly motivating. In addition, some suggested incorporating practical laboratory experiences and increasing hands-on activities in regular science lessons.

The positive schoolteacher feedback emphasizes the workshop's success in exceeding expectations, fostering scientific interest and promoting inclusivity in science. Their recommendations will be crucial in shaping future educational initiatives.

4 FUTURE RESEARCH: CHALLENGES AND OPPORTUNITIES

'The Invisible Life of Bacteria' workshop has proven to be an effective initiative for improving students' understanding of microbiology and has triggered positive changes in their perception of science. Delve into the future, challenges and opportunities are proposed:

Ongoing educational challenges: Educational challenges persist despite the workshop's success. Providing equitable access to scientific education is essential in a rural context marked by economic constraints and distinctive sociocultural factors. More resources to deepen students' understanding of microbiology, language barriers and unique community dynamics can impact students' engagement with science and should be considered.

Program expansion: A thrilling opportunity lies in expanding the program's reach, tailoring it to the specific needs of rural contexts. This can be achieved by collaborating with schools and communities in similar settings or adapting the program for different age groups, broadening students' horizons in underserved areas and making microbiology more accessible and engaging for a diverse audience.

Feedback and cultural sensitivity: Incorporating feedback from students, teachers, and facilitators, particularly in the rural context, is essential to ensure cultural sensitivity. It allows for the customization of the program to resonate with the unique perspectives that meet the specific needs of participants. Additionally, it is important to acknowledge and respect local knowledge and traditions.

Interdisciplinary and practical approach: Adopting an interdisciplinary approach that connects microbiology concepts with practical aspects of rural life can be a powerful strategy. Linking microbiology concepts to agriculture, health, or environmental sustainability can enhance relevance and impact in the daily lives of rural students.

Building solid partnerships: Establishing robust partnerships with local institutions, community organizations, or non-governmental organizations can extend the program's reach and secure additional resources. These collaborations provide additional resources and resources, ensuring a sustained impact that remains accessible to all participants.

Long-term assessment: Assessing the program's long-term impact on students' perceptions and engagement with science in the rural context is crucial. This ongoing evaluation guides adaptive transformations aligned with community needs, offering valuable insights into the program's sustained effectiveness.

Inclusion and community empowerment: Promoting inclusivity and empowering the community is a crucial opportunity. Tailoring the workshop to meet the needs of students from diverse backgrounds ensures equal educational opportunities. This approach establishes a sustainable foundation for promoting scientific curiosity and engagement in economically disadvantaged rural areas.

Therefore, the results presented here can offer valuable insights for informed interventions, expanding the comprehension of effective strategies in underserved communities. This research can also direct future initiatives to improve scientific literacy in economically challenged rural areas.

5 CONCLUSIONS

In conclusion, the 'Invisible Life of Bacteria' workshop stands out as a transformative initiative that bridges the gap between young, curious minds and the world of microbiology. Our study aimed to assess its effectiveness in sparking scientific curiosity and fostering a lasting interest in science, particularly among underprivileged students in places like Armamar.

Empowering young minds: The interactive activities successfully empowered elementary school students, fostering a deep understanding of microbiological concepts and sparking lasting scientific curiosity. Their unwavering enthusiasm during and after the workshops demonstrates the enduring impact of these educational efforts. The workshops also challenged stereotypes by exposing students to scientists from diverse backgrounds.

Future research: Despite promising findings, it is necessary to conduct further to explore the long-term effects on students' attitudes toward science and their future scholarly performance. Investigating the effectiveness of similar programs in diverse educational contexts will provide a foundation for ongoing evolution in scientific education. It is equally essential to understand how understanding how these early experiences shape lifelong perceptions of science.

Equity: In a world grappling with critical issues like the COVID-19 pandemic, the importance of microbiology literacy for informed decisions cannot be ignored. The pressing need for microbiology literacy underscores the significance of educating and inspiring children through similar initiatives. The 'The Invisible Life of Bacteria' workshop dismantled barriers, nurtured curiosity and established a precedent for accessible and equitable science education that reached rural underprivileged populations, creating a foundation for a more inclusive and informed future.

In summary, this initiative paves the way for a promising future by creating opportunities for direct engagement with scientists, dispelling stereotypes, and actively promoting the exploration of scientific concepts, especially those related to microbiology. We firmly believe that its impact has the potential to resonate through generations, propelling us towards a more aware, inclusive, and scientifically robust future.

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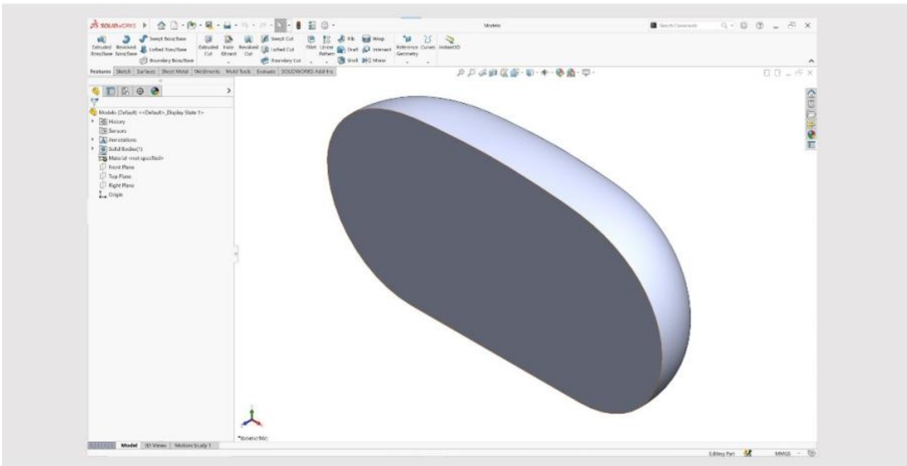
SUPPLEMENTARY MATERIAL

Figures

a. The model projected throughout Solidworks® CAD software.



b. The model designed throughout Adobe Photoshop® software.

c. The final Prokaryotic cell model.

Supplementary Material - Figure 1. The Prokaryotic Cell Model for 'The Invisible Life of Bacteria' Workshop: (a) projections created using Solidworks® CAD software; (b) refinement with Adobe Photoshop® software; (c) representation of the final model.

Supplementary Material - Figure 2. Data collected from 'The Invisible Life of Bacteria' workshop, featuring students presenting their creations to the class and including examples of the developed pet microbe models.

Tables

Supplementary Material Table 1. A description of the pupils' feedback evaluation system.

Was it the first time you met a scientist?	Did you learn something new?	Did you like to meet a scientist?	Which word best describes the workshop?
Yes No I don’t know	Many Few None	A lot More or less No	Difficult Boring Spectacular Fun

Supplementary Material Table 2. Schoolteachers’ evaluation form.

Question Number	Topic Covered
	About the workshop
1	Students had the opportunity to contact with new concepts or methodologies they didn't know
2	Students had the opportunity to carry out practical activities
3	Students understood the importance of the research work of the scientist
4	The workshop awakened or increased students' interest in science
5	The workshop awakened or increased students' interest in microbiology
6	The workshop made students feel more comfortable discussing science issues or formulating new questions
7	The duration of the workshop was adequate
8	The topic was helpful and will be useful in the future
9	Based on this science workshop, I would repeat or recommend a program based on experimental microbiology to another colleague
	About the scientist/facilitator
1	The language used by the scientist was appropriate for my level of knowledge
2	The scientific content was appropriate
3	I had the opportunity to talk/interact with the scientist
4	The scientific content was presented with enthusiasm
5	The scientists' explanations were enlightening and/or enriching
6	It was the first time that my students had contact with a scientist
7	It was the first time that a similar workshop was realized in my classroom
	Open-ended question
1	Any (other) suggestion(s)