Empowering Youth to Create a Healthier Future Through STEM Education About Antimicrobial Resistance

Hector Palala, University of Nebraska, Lincoln

Héctor de Jesús Palala Martínez is a doctoral student in Curriculum Studies and new technologies in the Department of Teaching, Learning and Teacher Education at the University of Nebraska-Lincoln. Héctor teaches courses related to the integration of technology for future high school teachers as well as bilingual education and in all his classes he promotes justice, dignity and human rights. Previously, he was a professor of education at the Universidad de San Carlos in Guatemala, and before that, an elementary teacher. His research centers on the intersection of bilingual/multilingual education and technology (in particular, Mayan languages), literacy programs in Indigenous languages, pedagogy of tenderness, and artificial intelligence for education.

Amy Millmier Schmidt, University of Nebraska, Lincoln
Mara Zelt, University of Nebraska, Lincoln

Mara Zelt is the program manager for the Schmidt Research and Extension Team at the University of Nebraska-Lincoln in the Department of Biological Systems Engineering. In her role Mara is responsible for supporting the team's outreach and research programs including the nationwide iAMResponsible project, a partnership of multi-disciplinary Extension faculty across the country developing innovative programing and resources related to antimicrobial resistance. Mara did her graduate work at the University of Nebraska focused on mitigating the risk of resistance in key food production and environmental pathways. That experience revealed the central importance of individual behavioral change in combating resistance and has shaped how she has approached outreach and educational efforts. Mara continues to focus on finding ways to empower every person to identify how they can reduce their or their family's risks for resistant infection and to act accordingly.

Bethany Zelt, University of Nebraska, Lincoln

Bethany Zelt is a communications manager and content creator at the University of Nebraska -Lincoln. Her area of focus is spreading awareness about the global health crisis, antimicrobial resistance, and improving soil and environmental health through the use of manure as a fertilizer. She has a background in education, with over 10 years as an interventionist with Lincoln Public Schools, teaching at-risk students and students that had fallen below the academic standards of their grade level. With a background in both education and antimicrobial resistance, she brings a unique perspective the the topic of empowering youth about antimicrobial resistance through STEM education.

Andrew Stiven Ortiz Balsero, University of Nebraska, Lincoln

As a Master's student at the University of Nebraska-Lincoln (UNL) in Agricultural and Biological Systems Engineering, I have maintained a solid academic record while growing considerably as a leader and young professional. I am recognized for outstanding self-management; I independently explored new fields and was able to substantively impact research directions by applying some of my newly developed understanding of machine learning to my lab's work. I have also been privileged to work in an extension-oriented team, thereby significantly improving my science communication, outreach, team building, and collaboration skills. My journey is marked by a commitment to excellence and a readiness for the challenges of doing research in the biological field. I am now poised to contribute my blend of foundational knowledge and new competencies to a Ph.D. program. I aspire to drive progress in food science with passion and dedication.

Maria Jose Oviedo Ventura, Cornell University

María José is an Extension Support Specialist for the Cornell Small Farms Program; her work mainly focuses on working and supporting farmers and other stakeholders in the agricultural community, primarily Latino/a/x, while learning together to overcome technical, environmental, and cultural challenges, as well

as building climate resiliency during agricultural production. María José brings expertise in environmental education and soil and water conservation agricultural practices. She holds a Bachelor's degree in Environmental Science and Development from Zamorano University and a Master's degree (MSc) in Mechanized Systems Management with a specialization in Water Resources Planning and Management from the University of Nebraska-Lincoln. During my graduate studies, my research focused on nutrient management and short-term indicators of soil health improvements driven by applying organic amendments.

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Abstract

The iAMResponsible™ project was initiated by a team of US university faculty in 2018 to develop and deliver education and outreach programming to address the growing global health challenge of antimicrobial resistance (AMR). This project aims to increase awareness and foster responsible behavior towards AMR among food producers and consumers. Expanding its scope, the initiative has recently embraced collaboration with school systems to engage young students in AMR education. This case study evaluates a specialized summer course offered by the iAMResponsible™ team at the University of Nebraska-Lincoln to elementary school students in Lincoln, Nebraska, USA. The course employs a free-to-use, 8-lesson plan curriculum introducing AMR to upper elementary students (grades 3-5) that integrates interactive tools, aiming to enhance students' understanding of microbiological and public health concepts. This case study assessment focuses on the curriculum's impact on students' ability to understand and disseminate AMR knowledge, as observed by instructors and classroom observers, and on curriculum ease-of-use for non-expert instructors. Methods involve interviews and observations to gather comprehensive data for a qualitative analysis of the course's design and impact. Findings reveal the curriculum's effectiveness in integrating complex scientific topics into early education, employing a variety of teaching techniques to cater to different learning styles. The study also highlights the curriculum's adaptability to various educational contexts and for students with diverse backgrounds and educational needs. However, challenges such as ensuring clarity of complex concepts and evaluating long-term behavioral change are acknowledged. Continuous refinement, based on stakeholder feedback, is essential for long-term success. The study underscores the curriculum's role as a catalyst for change in combating antimicrobial resistance, emphasizing the importance of embedding sustainability planning and adopting a dynamic, evidence-based approach for maximizing student engagement and impact.

Introduction

Antimicrobial resistance (AMR) poses a major threat to global health, necessitating creative solutions to lessen its effects [1]. In 2018, a team of US university faculty launched the "iAMResponsible™" project to address needs for outreach and education to food producers and consumers about the pressing global issue of AMR [2]. The project's key goals are to increase educational capacity related to AMR through resource development, training, and targeted dissemination; and to empower behavioral changes by promoting individual and shared responsibility in combating AMR. Educating young people, the future guardians of antimicrobial stewardship, is crucial in this effort. Thus, a developing component of the iAMResponsible™ team's programming involves active engagement with young people about AMR.

Evidence demonstrates the potential for embedding AMR education in STEM curricula to spark interest in healthcare and STEM [3]-[4]. Early exposure to microbiology can spark a lifelong science and health interest. Nevertheless, in STEM health education, simplifying complex topics

like infection and drug resistance for young audiences is challenging [5]. Previous research in this area stressed the need for better microbiology awareness, noting microbes' role in health, environmental sustainability, and climate, necessitating educational resources which focus on microbiology's impact on personal, societal, and global levels [6].

Research has identified key approaches for developing engaging educational methods to tackle complex issues, such as AMR. Evidence from youth programming to teach AMR suggests that a multi-faceted approach, encompassing active learning, storytelling, visual presentations, hands-on activities, and animations is valuable for conveying AMR knowledge [7]. There is also value in utilizing interactive tutorials, 3D models, and group projects to help in understanding biomedical topics, increasing motivation, and understanding [8]. Hands-on workshops have also been effective in stimulating microbiology interest [9]. Relating STEM to real-life situations, like antibiotic discovery, enhances understanding and career interest. These programs also raise students' awareness of their role and encourage critical thinking about antibiotic resistance and prudent antibiotic use [10].

Games and activities specifically are key features for engaging learners in a wide variety of complex topics. One group, looking to improve antibiotic stewardship developed an online game that used a snakes and ladders format with questions and case studies [11]. Participants navigating the game were periodically given the opportunity to more quickly progress or regress based on their responses to questions and case studies. Players progress by answering correctly, advancing up ladders, or face setbacks by descending snakes for incorrect answers, making the experience interactive and educational. The game received positive feedback, enhanced knowledge, confidence, and promoted referrals and knowledge sharing. Similarly, the Small World Initiative (SWICEU), a partnership of communication and health students working on outreach related to AMR, includes the development of educational gamification materials as one of their primary outputs. The SWICEU team has developed multiple card games, board games, and even an escape room type game related to AMR to educate youth and the public about AMR and sensible antibiotic use through gamification [12].

The iAMResponsible™ team sought to incorporate these methods, such as games, videos, infographics, online challenges, and storytelling, to make AMR more accessible and engaging and improve understanding and management of antimicrobial resources. The iAMResponsible™ team developed a curriculum including eight, complete 1-hour lesson plans designed to integrate complex scientific topics into 3rd-5th grade elementary education within varied educational settings. Each lesson includes:

- A detailed teacher’s guide for all the student activities and discussions,
- A short video lesson,
- A power point slide deck with additional visual aids for lesson components,
- Instructions and material lists for one or more student activities or games related to the lesson materials,
- Student worksheets for additional learning and assessment,
- A link for a short instructor survey to provide feedback on the curriculum materials and observations of student learning.

The curriculum components are publicly available via a link from the team's website iamrproject.com. As a part of developing these materials iAMResponsible™ team members from the University of Nebraska-Lincoln delivered a one hour twice weekly summer school program for students who had recently finished 3rd grade using this curriculum.

This reflection examines the experiences of curriculum designers and instructors during the first use of the materials to understand the efficacy of the curriculum to meet key learning objectives related to AMR. This case study reflection also examines the quality of student engagement and ease of use to instructors for interactive components developed in this curriculum, like animated videos and hands-on activities. All the data and insights presented in this paper are based on the perspectives and feedback provided by iAMResponsible™ team members who developed the curriculum, summer program instructor, student teaching assistants, and educational observers. While each lesson asks student participants to reflect and share their learning in their student materials, in the case study students were not required to turn in their reflections, thus all statements about student knowledge gains are based on instructor's observations of student responses to discussion questions, group conversations, and the content of their story telling projects.

Methodology

This reflection examines the curriculum development and delivery through the lens of its designers and the experiences of graduate students who assisted as teaching aides. Qualitative case studies delve deeply into specific instances or experiences, often centering on an individual, group, or event [13]. This approach harnesses qualitative tools such as interviews and observations to collect comprehensive data, which encapsulates the subjective viewpoints and experiences of the participants [14]. The aim is to unravel the unique nuances and complexities of the case at hand, rather than extrapolate these findings to a broader audience. In this instance, the case study scrutinizes the reflections of those involved in an AMR awareness course, seeking to unearth crucial insights for the enhancement of future program iterations.
Our assessment approach involves presenting open-ended questions to the summer course instructors and the course designers by interviewer Hector Palala and capturing responses in a conversational setting [13]. Notably, the subjects of the paper are also contributors to this case study reflection.

The initial development and delivery of the program featured a varied group of participants. It consisted of the program development team, made up of individuals with extension appointments and backgrounds in public school systems. The team was further supported by three graduate students, who contributed as assistants to the instructor in the classroom. Among the development and delivery team, four members contributed significant observations to this case study reflection: Interviewee 1 was involved only in curriculum design, Interviewee 2 was the lead classroom instructor and was involved in curriculum design and revision, Interviewee 3, an education researcher was involved as a classroom observer during the delivery phase, and Interviewee 4 was one of the graduate student instructors. Student participants in one of the local elementary schools' summer school programs were the student cohort for the first delivery of the microbiology program. Fifteen students participated, all after completing their 3rd grade year.

Following the interviews, the collected data was analyzed to evaluate qualitative reflections on the respective experiences of participants, particularly focusing on their involvement in either the creation or instruction of the course aimed at promoting AMR awareness. The insights obtained from these interviews provide valuable evidence for the development and delivery of future AMR awareness programs within educational settings.

Findings

The findings of this case study assessment reveal a well-considered, innovative curriculum development approach and opportunities for continued improvement for subsequent delivery of educational materials.

Developing curriculum for student comprehension: Learning models employed.

In developing the curriculum, the team employed expansive learning models designed to cater to the diverse needs of students. Expansive learning models incorporate active learning, storytelling, visual presentations, hands-on activities, and animations, all of which assist to contextualize microbiology, stimulate meaningful discussions at home, enhance parental comprehension, and foster positive attitudes toward the roles individuals can play in combatting the spread of AMR.

Creating accessible learning materials: Games, animation, and demonstrations facilitate student engagement.

The curriculum, *Microbes: The Ultimate Survivors*, integrates gamification and animation videos into traditional instructional styles. During its delivery, this approach yielded observable educational advantages, most notably in enhancing student engagement as reported by the summer school's teaching staff.

Based on the course creators' previous experience in education, gamified components are one of the most effective ways to incorporate delivery of complex concepts, such as those found in STEM, to students. Indeed, during the course's delivery, the instructors found that the inclusion of gamification was particularly effective in maintaining the interest of students who struggle with concentration, behavioral management, and retention. These observations align with previous studies which underscore the ability of gamified learning environments to greatly increase student motivation and engagement [15].

Figure 1. “Race Against Superbugs” Part 8 of Sofi the Scientist video series. This animated series utilized narrative style, humor, and characters appropriate for student self-identification to engage students in complex concepts, such as in this example, how the overuse of antibiotics can lead to bacterial adaptation.

However, course instructors’ observations were mixed. Reports were that video activities notably excelled in engaging participants. However, some hands-on tasks faced implementation hurdles, such as limited space, technical dependency, and time constraints.

Engaging multiple learning styles: Promote participation and comprehension.

The curriculum, Microbes: The Ultimate Survivors, utilized educational scaffolding, a crucial method for supporting diverse learning levels and promoting skill acquisition. Examples of this are opportunities for small groups and partner learning, student-led modeling and storytelling, and frequent alignment to background knowledge through metaphor and visual examples. This aligns with research observing improved problem-solving in scaffolded environments [16]. Incorporating diverse learning approaches was another key aspect employed in the curriculum development and delivery. The curriculum catered to various learning styles through workshops, visual storytelling, discussion, and music, incorporating both visual and auditory methods (Figure 2). This aligns with the research on effective teaching-learning methods in different classroom environments [17].

Figure 2. Examples of curriculum components designed for multiple learning styles. Race to survive, a physical activity for learning about the immune system (above), and Microbe Jeopardy, a team-based quiz game at the end of the program (below).

Building knowledge through repetition: Repeated AMR concepts instill foundational understanding.

In examining the role of curriculum in AMR education, insights from structured interviews conducted in December 2023 were invaluable. Interviewee 3 highlighted the natural propensity of children towards absorbing new information, attributing it to their developmental stage which renders their minds more adaptable. They noted, "*Children are in a phase of life where they are taking in a lot of information, and their minds are a bit more flexible.*" This observation underscores the curriculum's strategic use of repetition to enhance knowledge retention concerning AMR, as depicted in Figure 4. Echoing this sentiment, Interviewee 1 emphasized the importance of repeated exposure to health messages from multiple sources for effective behavioral change. They suggested that impactful messaging requires that information be

"*received many times and from many directions to have behavioral change*," a principle that aligns with the curriculum's approach to teaching about AMR.

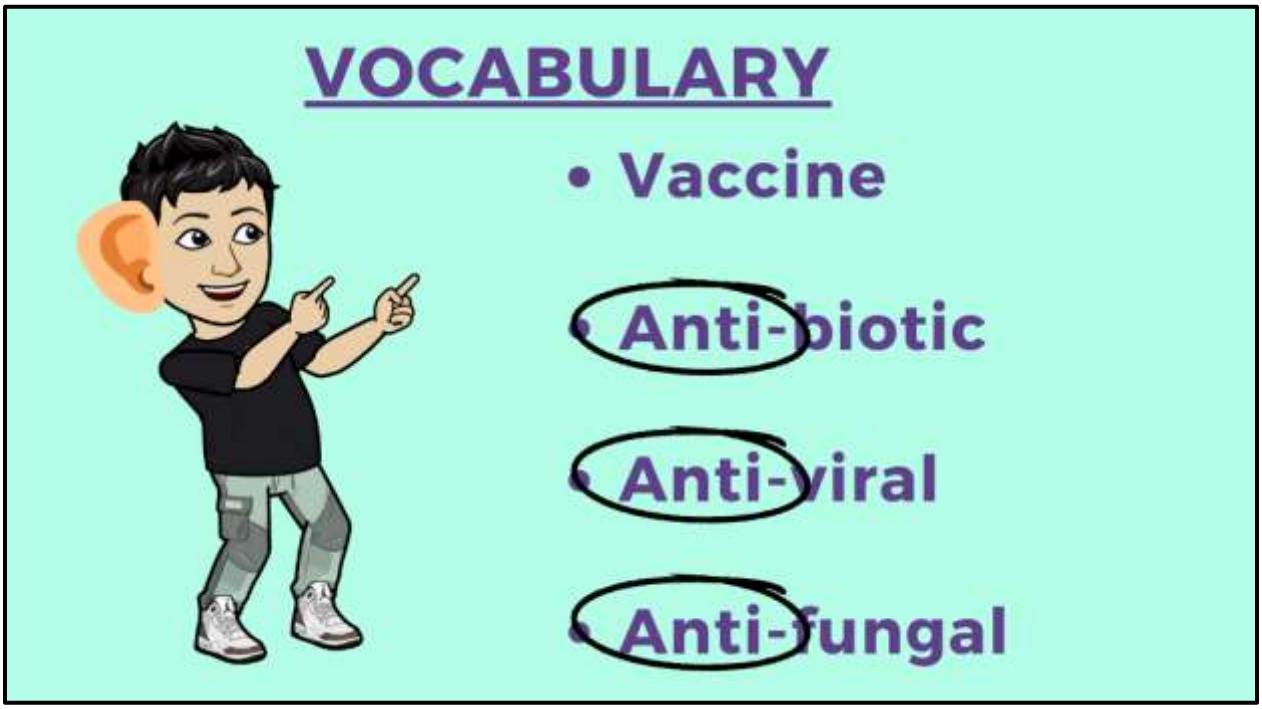


Figure 3. Each lesson first introduces concepts in slides with vocabulary, emphasizing connections to previous knowledge. Vocabulary is then used in the lesson's video(s) and again in lesson activities to enhance understanding in context and provide repetition.

By and large, these educational tools were effective for building basic microbiological knowledge in the first elementary cohort. During the first lesson, instructors observed student responses to questions about general microbiological concepts (relative size of microorganisms, types of organisms, potential habitats, etc.) and used this discussion as a base to understand knowledge gains. Student instructor, Interviewee 4, observed that by the end of the course students had achieved an "entry-level" understanding of microbiology, pointing out that during the Jeopardy game in lesson 8 most student groups correctly answered questions about types of microbes and helpful vs pathogenic effects that microbes can have. However, Interviewee 4 also emphasized that some of the complexities and nuances of AMR, such as the inefficiency of using antibiotic medication to treat viral infections and connecting microbial evolution to over-use of antibiotics, were less well understood by the students, creating potential areas for confusion. These challenges present opportunities for iterative improvements that account for team member observations and feedback provided in subsequent outings by non-team members. These insights enrich the understanding of engagement and learning styles, highlighting the potential for tailoring interactive approaches for better outcomes in the future.

Developing student science-communicators: Narratives for learning, reinforcement, and dissemination.

In previous community engagements, the iAMResponsible™ team applied the value of narratives and storytelling to communicate scientific topics to lay audiences in keeping with recommendations from communication research that concludes that narratives enhance comprehension by exploring cause-and-effect relationships [18].

Recognizing the potential of storytelling in the youth educational context, the curriculum designed by the iAMResponsible™ team aimed to position students as pivotal communicators within their communities. As Interviewee 2 mentioned during the interviews, "*...they [the students] are going to be the messengers that carry the message of AMR forward to their peers, into their homes, to their parents.*" The curriculum incorporated storytelling elements in the form of narrative-based educational videos, retellings of student experiences, and humanizing pathogens in story building (Figure 5).

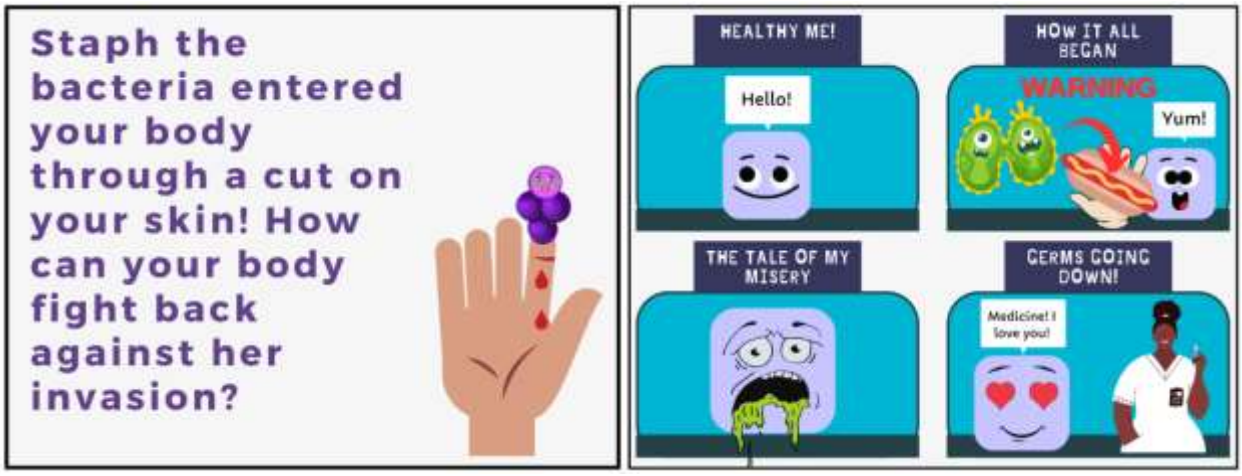


Figure 4. Examples of the curriculum's utilization of storytelling elements. (Left) Discussion slides use human-scaling for pathogens to create context, (Right) narrative-based storytelling in student activities.

Preparing the students to become the "messengers" to their communities required the ability to articulate the concept of AMR orally. With the goal of fostering communication skills, concept articulation, and necessary vocabulary, the curriculum included group discussion with "Heads Together" small group discussions, as well as the recuring review activity "Your Turn" (Figure 7).

Interviewees 2 and 3 reported observations of a rich environment of peer interactions fostered by the above activities and others. However, Interviewee 4 did not observe any substantial instances of peer-to-peer teaching of AMR concepts, though he was afforded an alternative perspective to observing peer-to-peer interactions than the primary instructor, Interviewee 2. However, Interviewee 2's observations were based on instructing the full 8-lesson course while Interviewee 4 assisted for four of those lessons. These differing observations highlight the need for further study of the curriculum in practice.

Assessing instructor experience: Developing user-friendly materials.

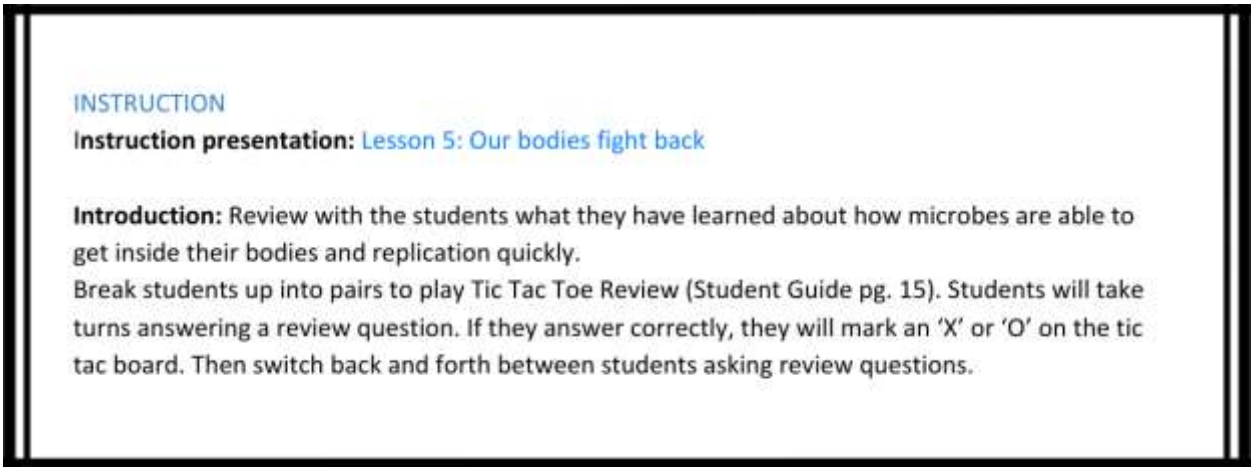
Curriculum development emphasized user-friendly materials such as pre-developed videos, activity materials, and a detailed teacher's manual. In the initial development discussions, the team concentrated on crafting materials that non-expert instructors would find approachable and easy to use. Interviewee 1 highlighted the importance of user-friendliness given that the original creators wouldn't always be available to teach the class: "*We were concerned because we weren't going to be teaching the class every time... it needs to be super, super user friendly.*" This emphasis on simplicity and minimal preparation time for teachers aligns with other researcher observations regarding the need for accessible educational resources [19].

The team conducted an initial internal testing session to walk through lesson delivery and instruction with the undergraduate students participating as classroom assistants. These sessions also allowed the designers to observe and adjust the curriculum to meet the needs of instructors who were not involved in the initial design process. One major component which was identified during the preparation period was the need for a visual presentation to follow along with the classroom instruction, which would support the text in the teacher outline and allow for a single file which included video links, activity descriptions, and other visual demonstrations into a PowerPoint presentation for each lesson (see Figure 6).

Figure 5. Excerpt from Lessons 1 and 2 of the Instruction PowerPoint Presentations which introduce a student activity from the student worksheets (left) and a "Heads Together" small group discussion (right).

Moreover, the team continued to improve the curriculum materials to meet instructor needs during the pilot summer program. Classroom observers noticed a gap in the curriculum regarding student recall of past lesson concepts that was hindering long-term concept retention. As such, instructors revised the curriculum to include various review elements including peer-led class reviews, gamified reviews, and heavy use of visual learning (Figure 7). After the inclusion of these elements, Interviewee 2 stated, "*The lesson reviews worked wonders, helping the students connect the dots between one lesson and the next. This was one of the reasons, I believe, the course was so successful in building the concept ladder from 'What is a Microbe?' to 'What is*

AMR?'." Interviewee 1 felt that the adjustments made to improve instructor experience were positive, and illustrated why continued success of the program would require feedback from subsequent classroom instructors, *"I'm glad we were able to make that pivot quickly... it was one of the reasons we included lots of opportunities for users to submit feedback through the online platform, but we haven't had any outside user feedback yet...we will have to get more creative with how we connect with classroom instructors who are not iAMResponsible team members.*"


INSTRUCTION

Instruction presentation: Lesson 5: Our bodies fight back

Introduction: Review with the students what they have learned about how microbes are able to get inside their bodies and replication quickly.
Break students up into pairs to play Tic Tac Toe Review (Student Guide pg. 15). Students will take turns answering a review question. If they answer correctly, they will mark an 'X' or 'O' on the tic tac board. Then switch back and forth between students asking review questions.

Figure 6. Examples of lesson review activity. The teacher's manual outline includes space for review of previous materials in lesson plans.

Furthermore, during the creation process, the curriculum's creators identified socioeconomic accessibility factors as a high priority. Interviewee 2 articulated this commitment in the interviews, expressing a desire for widespread accessibility: "*We wanted to make it available to a diverse audience...we wanted to make it as affordable as possible, so that the expense is not a barrier in its [the curriculum's] ability to be used."* In alignment with this vision, the curriculum was designed to be freely accessible, with activities crafted to minimize costs. Interviewee 1, providing further details during the interviews, estimated the expense for materials at about $100.00 US dollars for a standard class size of 25-40 students. They noted that many of these materials are readily available in typical school, household, and art supply settings.

Considering diversity: Emphasizing diverse populations and perspectives in teaching.

Microbes: The Ultimate Survivors embraced diversity and inclusion as core principles, aligning with work on communicative literacies in K-12 engineering education. Previous work has identified issues of access for underrepresented populations in engineering as one of the core themes for improving engineering education [20].

The team's emphasis on inclusion is evident in the deliberate portrayal of characters within the educational materials. As noted during the post interviews discussion, Interviewees 1 and 2 shared their vision which involved showcasing a variety of different people from different races and ethnicities in the animations and videos. They were conscious about ensuring that the characters in the videos would not only represent a single demographic but wanted to create characters with whom everyone in the audience could relate.

Figure 7. Example of diversity in the curriculum's design. Sofi meets Alan in the second instalment of the ‘Sofi the Scientist’ series: What Are Pathogens and How Do We Stop Them from Making Us Sick? (From https://www.youtube.com/watch?v=4.) Sofi, the protagonist of the Sofi the Scientist video series, was designed to be ethnically ambiguous. While Alan, another protagonist in the series, was designed with less ambiguity but with the history of East Asian stereotypes in mind. Alan possesses a lighthearted, jock personality and fills the role of the learner.

This aligns seamlessly with the growing emphasis on representation in educational resources and gamified learning experiences [15]. By celebrating diversity through its characters, the project not only fosters a sense of belonging and cultural awareness, but also empowers young learners to see themselves reflected in the world around them, potentially boosting engagement and fostering a more inclusive learning environment. This emphasis on representation stands as another testament to the project's well-rounded approach to education and solidifies its potential to inspire and educate young minds effectively.

Conclusions, Implications and Future Directions

This reflection yielded several notable conclusions about the curriculum's development and potential impact. Firstly, collaboration among the multidisciplinary team enabled the incorporation of diverse abilities into an engaging curriculum that resonated with elementary students. Various teaching techniques were integrated to appeal to different learning styles and maintain student interest. The curriculum incorporates adaptability to diverse backgrounds and educational contexts and ease of implementation for educators. These strengths underscore its future promise as a user-friendly tool to educate elementary school students on issues related to antimicrobial resistance.

The study team acknowledges limitations in the curriculum's development process and evaluation. Assessing the curriculum's long-term success is a complex problem for educational programs of this kind to demonstrate linkages between the program and behavioral change. Similarly, evaluating the curriculum's impact on student interest in STEM fields across different educational contexts continues to be an evolving process with gaps to be addressed through future research. The team identified two groups of potential participants which should be included in subsequent assessments of curriculum delivery to explore and more fully understand educational impacts: students and regular classroom teachers. This initial offering was part of a summer school, but subsequent offerings in classroom settings should incorporate feedback from the students' regular classroom instructors. The curriculum, as originally designed included a link to an online form where instructors could provide feedback on their experiences using the materials and, on their students', learning of the materials based on aggregate performance in graded materials and end-of-program questionnaire. However, as of this writing the team has not received input from curriculum users who were not iAMResponsible^{TM} team members. As a result, the development team is pivoting to scheduled phone interviews and hopes to have more rigorous feedback on instructor experience and student learning, based on further classroom observations and on reported student performance.

The design and delivery of this elementary level program on microbiology and antimicrobial resistance was deeply considered and creatively constructed. The program goals of substantially increasing 3rd-5th grade students' knowledge of microbiology and awareness of AMR are lofty and some were met by this first delivery of the program, but opportunities for refinement remain. The authors and program participants clearly envision the product (the publicly available lesson plans and materials – *Microbes: The Ultimate Survivors*) to be iterative in nature and look forward to its wide-ranging use and evolution across a diverse educational landscape.

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