Characterizing Artistic Bacterial Cells Attributes as New Approach to Antimicrobial Resistance Awareness through Soft Toys Design

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ABSTRACT

Antimicrobial resistance (AMR) occurs when bacteria, fungi, viruses, and parasitic microorganisms lose their capacity to respond to antibiotics, making infections more difficult to treat. As a result, disease transmission, severe sickness, and death will increase. Antimicrobial resistance (AMR) is a global health and development threat, and urgent multi-sectoral action is required to achieve the Sustainable Development Goals (SDGs). The World Health Organization has named AMR one of the top 10 global public health threats facing humanity. Antimicrobial misuse and abuse are the leading causes of drug-resistant infections. Science is increasingly being communicated to the general public through the arts. Tracking new methodologies, such as community-engaged learning and challenges and goals, can help build metrics for attaining more meaningful outcomes and measuring the success of arts-based scientific communication in raising awareness and influencing public policy. This project aims to create a medium - 'Designed Soft -toys Character' with the elements of 'cuteness' that conveys critical information, tells complicated stories about the interaction between bacteria and antibiotics and raises awareness about the rapid spread of antibiotic-resistant diseases through QR code information. By investigating avenues that connect science and society, we are confident that this project will surely assist in breaking down communication barriers between research scientists and the general public of all ages.

Keywords: antimicrobial resistance, soft toy design, bacterial cells, awareness, science communication

BACKGROUND

Antibiotic resistance is linked to antibiotic abuse, such as when antibiotics are used to treat viral illnesses. It also originates from antibiotic overuse, which is caused by patients asking doctors for antibiotic prescriptions for minor diseases and doctors giving inefficient medications and high doses. Patients must be trained on the proper use of antibiotics. We're dealing with a significant public health issue when it comes to antibiotic use and resistance. As a result, by educating populations about antibiotics and antibiotic resistance, we can make a difference in the usage of antibiotics. Nevertheless, there's a need for a medium that conveys critical information, tells complicated stories about the interaction between bacteria and antibiotics and raises awareness about the rapid spread of antibiotic-resistant diseases.

As art and design are increasingly being used to communicate science to the general audience, emerging techniques, such as community-engaged learning and difficulties and goals, can aid in developing measures for achieving more meaningful results and determining the success of arts-based scientific communication in increasing awareness and influencing public policy.

Antimicrobial resistance (AMR) poses a serious danger to antibiotic efficacy and raises the risk of illness, death, and medical expenses. It is a major worldwide health concern. Multimodal approaches that include policy initiatives, public involvement, and education are needed to address AMR. Conventional strategies for increasing public awareness of AMR frequently depend on instructional techniques, which might not be well-received by a variety of audiences, especially young ones. This research uses the physical and visual appeal of toys to communicate scientific ideas in an approachable way, offering a novel and entertaining way to raise awareness of AMR through toy design.

Characterising Artistic Bacterial Cells

Through artistic characterization, a group of bacterial species known as "superbugs"—the main agents of antimicrobial resistance are shown in designs for soft toys. Superbugs can be defined as pathogens which are highly virulent and resistant to multiple antibiotics, typically associated with infections that are difficult to treat. With tactile and visual components that mirror each strain of bacteria's distinct characteristics, each toy represents a different bacterial species. To illustrate various bacterial morphologies and structures, plush toys, for example, might have a range of textures, colours, and shapes. Furthermore, instructional materials that go along with them include information on the biology of bacteria, virulence factors, and the mechanisms underlying antimicrobial resistance and their clinical significance. Art and science are deeply interconnected, and art can play a crucial role in the advancement of science in several ways:

- **Visualization**: Art helps scientists visualize complex concepts and data. For instance, scientific illustrations and diagrams make it easier to understand structures like cells, molecules, or astronomical phenomena.
- **Communication**: Art is a powerful tool for communicating scientific ideas to the public. Infographics, educational animations, and other visual tools make science more accessible and engaging.
- **Inspiration**: Artistic thinking can inspire scientific breakthroughs. The creativity and imagination inherent in art can lead to innovative approaches and solutions in scientific research.
- **Modeling and Simulation**: In fields like computer graphics and virtual reality, artistic techniques are used to create simulations that help scientists model and explore scenarios that are difficult to study directly.
- **Cultural Impact**: Art can shape how society perceives and values science. It can influence public opinion and ethical considerations, thereby affecting funding and policy decisions related to scientific research.

In essence, art enriches science by making complex ideas more understandable, by inspiring new ways of thinking, and by enhancing communication and public engagement.

LITERATURE REVIEW

Artists' work has been employed as a significant component of protest movements against war, social injustice, poverty, AIDS, and Third World debt, as well as the peaceful, environmental protest movement (Doyle 2001, Branagan 2003 a,b,c, Educational Broadcasting Corporation 2005, Jordaan 2008).

At least there's a small number of contemporary scientists use the arts in a practical way to assist in their research, to gain insights that feed into their research, or to communicate their research to the general public. Nalini Nadkarni studies forest canopy biota and establishes connections with non-scientific audiences and artists for the purposes of heightening awareness of canopy ecology (Nadkarni 2004, 2007, 2008). Other scientists manage to merge an interest in aesthetics and science (e.g., Sullivan and McCrary 2002).

The literature indicates how the arts can be used to communicate scientific information to a lay audience. Despite the wide range of international collaborations between science and the arts, only a small percentage of scientists are involved, and the environmental and sustainability literature is largely silent on the role of the arts in mass communicating science (see, for example, Mercer 2000, Dodds and Middleton 2001, Goldie et al. 2005). This is mirrored in sustainability courses in higher education. None of the 77 undergraduate and graduate environmental programs surveyed included the arts as a subject (Sherrin 2008). This raises issues about why scientists don't utilize the arts to communicate their findings more often, if they would contemplate using the arts in the future, and if so, in what capacities.

Antimicrobial resistance (AMR) is currently a major global public health concern that is expected to shorten life expectancy and raise national health spending (Nadgir & Biswas, 2023). Globally, bacterial AMR-related deaths were projected to have caused 1.27 million deaths in 2019 (Ranjbar & Alam, 2023). Regardless of socioeconomic level, AMR raises health costs, health-related mortality, and health-related problems in all countries. However, its effects are more pronounced in low- and middle-income countries with inadequate healthcare systems (Dadgostar, 2019). AMR is a complex phenomenon that is impacted by a number of factors, including the overuse and improper use of antibiotics. The improper use of antibiotics, whether for viral infections in humans or animals, or the use of antibiotics at dosages that are too high or too low might promote the emergence of resistant strains (Chinemerem Nwobodo et al., 2022). When it comes to the usage of antibiotics, there are common attitudes, behaviours, and practices that many individuals follow that can be highly inappropriate. There are numerous misunderstanding and misconception's regarding the nature of antibiotic resistance, its transmission, and its effects (Amábile-Cuevas, 2022). Therefore, changing the societal norms and behaviours that contribute to the antibiotic resistance issue is the aim of increasing awareness. Since the primary cause of AMR is antibiotic overuse, it is imperative that the community be made aware of this issue.

AMR is a phenomenon where the microorganisms are no longer susceptible to the antimicrobial agents that were used to treat it due to genetic mutations or acquisitions of genetic material encoding resistant phenotypes (Uddin et al., 2021). There are two types of resistance which are intrinsic resistance and acquired resistance. Acquired resistance often involves the acquisitions of antibiotic resistance genes residing in mobile genetic elements that can be transferred via horizontal gene transfer (Wu-Wu et al., 2023). Meanwhile, intrinsic resistance is the natural ability of the bacteria to resist the mode of actions of antibiotics. It typically involves a limited drug uptake due to the bacterial cells' natural composition and structure (Wu-Wu et al., 2023). For example, because of the existence of an lipopolysaccharides (LPS) layer that functions as a permeability shield at the outer membrane of the bacterium, Gram-negative bacteria are naturally less permeable to some antibiotics than Gram-positive bacteria (Uddin et al., 2021).

SUPERBUG

The term "superbug" can be defined as bacterial strains, especially multidrug-resistant and extensively drug-resistant bugs that are resistant to the mode of actions of majority of existing antibiotics (Parmanik et al., 2022). The World Health Organisation (WHO) has listed six prime superbugs for which new development of novel antimicrobials are urgently needed (Salam et al., 2023). This group of superbugs are also known as ESKAPE pathogens, which is an acronym for these bacterial species; *Enterococcus* sp., *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* sp (WHO, 2017). ESKAPE pathogens were designated under priority status due to their association with nosocomial infections that are hard to treat (Mulani et al., 2019). In this study, some key members of ESKAPE superbugs were chosen to be featured as the model in developing and designing soft toys to raise awareness regarding antibiotic resistance. On top of that, *Clostridioides difficile* was also chosen as one of the bacterial models due to their important role as a reservoir of AMR genes that could be potentially transmitted to other bacterial cells (O'Grady et al., 2021). The goal of this engaging and playful teaching approach is to help young people better grasp the health issue of bacterial resistance and how antibiotics work.

Staphylococcus aureus is a spherically-shaped, nonmotile, non-spore former, Gram-positive bacteria belonging to the Staphylococcaceae family. The cells appears as grape-like clusters with round golden-yellow colonies. It is often found on the skin and in the upper respiratory tract. A notable percentage of mortality globally from antimicrobial-resistant infections are attributed to Methicillin-resistant *Staphylococcus aureus* (MRSA), which is well known as the first bacteria to develop antibiotic resistance (Salam et al., 2023). MRSA is responsible for both minor and potentially fatal infections (Palavecino, 2020). can induce a variety of site-specific infections, with the skin and subcutaneous tissues being the most prevalent, followed by internal infections such as in the lungs (pneumonia, lung abscess and empyema), blood (sepsis), inner lining of the heart (endocarditis), bone and bone marrow (osteomyelitis) (Palavecino, 2020). Methicillin resistance in *S. aureus* is mainly caused via a mutation in *mec*A, a gene encoding penicillin-binding protein (PBP) which was integrated into the Staphylococcal cassette chromosome mec (SCCmec). SCCmec is a mobile genetic element (MGE) that can be transferred via horizontal gene transfer contributing to the spread of resistant determinant across bacterial phyla (Lade & Kim, 2023). MRSA has also been known as the "hospital-superbug" as it is usually associated with the hospital acquired infections.

Klebsiella pneumoniae is a facultatively anaerobic, non-motile, encapsulated, lactose-fermenting Gram-negative bacteria belonging to the family of Enterobacteriaceae (Chang et al., 2021). It is typically occurring as straight rods with rounded or slightly pointed ends. It can be found singly, in pairs, or in short chains (Chang et al., 2021). *K. pneumoniae* can cause various of healthcare-associated infections, such as meningitis, wound or surgical site infections, bloodstream infections, and pneumonia (Wyres et al., 2020). *K. pneumonia* is one of the most well-known superbugs to emerge in the last 20 years (Sleiman et al., 2021). The prevalence of multi-drug resistant *Klebsiella pneumoniae* (MDRKP) has dramatically increased worldwide in recent decades, posing an urgent concern to public health (Chang et al., 2021). *K. pneumoniae* have been reported to be resistant to all beta-lactam antibiotics, except carbapenems due to their ability to synthesize extended-spectrum beta-lactamases (ESBL). However, recently *K. pneumoniae* have been reported to develop antibiotic resistance to carbapenems as well, making it an extensively drug-resistant (XDR) and multidrug-resistant (MDR) bacteria (Pu et al., 2023). Multiple processes contribute to the resistance of *K. pneumoniae* to carbapenems, including the synthesis of carbapenemases (degradation enzymes), changes in the permeability of the outer membrane mediated by the loss of porins, and the activation of efflux systems (Sleiman et al., 2021).

Pseudomonas aeruginosa is an aerobic, encapsulated, non-spore forming Gram-negative bacterium belonging to the Pseudomonadaceae family. It is a rod-shaped bacterium and typically motile by one or more polar flagella (Qin et al., 2022). *P. aeruginosa* is a significant opportunistic pathogen that mainly affects immunocompromised individuals with cystic fibrosis, burns, sepsis, and cancer. It is also typically associated with hospital acquired infections with treatments involving invasive devices such as catheters and ventilator causing chronic obstructive pulmonary disease, and ventilator-associated pneumonia (VAP) (Gu et al., 2018, Qin et al., 2022). Antibiotic-inactivating enzymes, efflux systems, and decreased permeability are a few of the resistance mechanisms employed by *P. aeruginosa*. The main cause of their antibiotic resistance is the synthesis of enzymes that inactivate antibiotics. Many of these strains produce extended-spectrum beta-lactamases (ESBLs) and beta-lactamases that break down beta-lactam antibiotics (Botelho et al., 2019). On top of that, *Pseudomonas* bacteria can become more resistant to antibiotics and evade host defences by forming a biofilm (Sinha et al., 2021).

Clostridioides difficile is an anaerobic, spore-forming, toxin-producing Gram-positive bacterium. The vegetative cells of *C. difficile* are rod shaped, pleomorphic, and occur in pairs or short chains (Zhu et al., 2018). This pathogen is responsible for a broad-spectrum manifestation of infections that include mild to severe diarrhoea and colitis (an inflammation of the colon) (Zhu et al., 2018). *C. difficile* is known to be resistant to a variety class of antibiotics, such as tetracycline, aminoglycosides, lincosamide (clindamycin, lincomycin), macrolide (erythromycin) beta-lactams (penicillins, cephalosporins), and fluoroquinolones, which are often employed in clinical settings to treat bacterial infections (Kartalidis et al., 2021). Antibiotic-induced alteration of the gut microbiota is linked to *C. difficile* infections (CDIs). Administration of antibiotics in patient can disrupt the balance of normal gut microbiota followed by overgrowing of resistant *C. difficile* and the production of toxins, increasing the CDIs (Markovska et al., 2023). *C. difficile* acquired resistance via multiple mechanism such as modification and degradation of antibiotics, alteration of the target site, production of ribosomal protectant proteins (RBP) and activation of efflux pumps (Wickramage et al., 2021). Furthermore, natural characteristics of *C. difficile* such as the ability to form biofilm and latent spores, enhance its pathogenicity and antimicrobial resistance (Markovska et al., 2023). *C. difficile* is one of the most obstinate superbugs. In addition to being potentially fatal, *C. difficile* infection symptoms prolonged, particularly in those with recurrent infections (Song et al., 2019).

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METHODOLOGY

The methodology of this research will be grounded in a multidisciplinary approach, integrating principles from microbiology, art, and design. The study will begin with a comprehensive review of literature on antimicrobial resistance, educational strategies, and the role of art in science communication. Building on this foundation, the research will proceed to the design phase, where artistic representations of bacterial cells will be developed in collaboration with illustrators and designers. Soft toys frequently act as a link between a child's imagination and the surrounding material reality. The importance of games and toys in childhood development has been well-recognized (Tipsey, 2022). Children learn to connect with their surroundings and develop cognitively while playing, which progressively improves their capacity to perform a variety of tasks at progressively higher levels (Brossard & Lewenstein, 2010). Furthermore, toys and games from childhood can have a lasting impact on an adult's lifestyle decisions and behaviours (Norman & Verganti, 2014). Given the widespread influence of games and toys on behaviour and cognitive development, soft toys present a valuable platform for promoting awareness of critical concerns like antimicrobial resistance (AMR) (World Health Organisation, 2020). Soft toy designers can use the natural attraction of toys to encourage learning about difficult subjects in both children and adults by incorporating instructional messages into their creations. The purpose of this project is to investigate the potential of soft toys as educational aids for AMR, acknowledging the profound impact that early experiences can have on attitudes and behaviours as adults. The goal of this project is to learn more about how toy makers may best take advantage of toys' powerful ability to raise awareness and understanding of critical societal issues like AMR. Through the implementation of a methodical approach to design and development, designers can optimize the pedagogical value of plush toys and concurrently promote children's ongoing cognitive growth (3DTotal Publishing, 2020). This value-creating practice drives the development and introduction of new products.

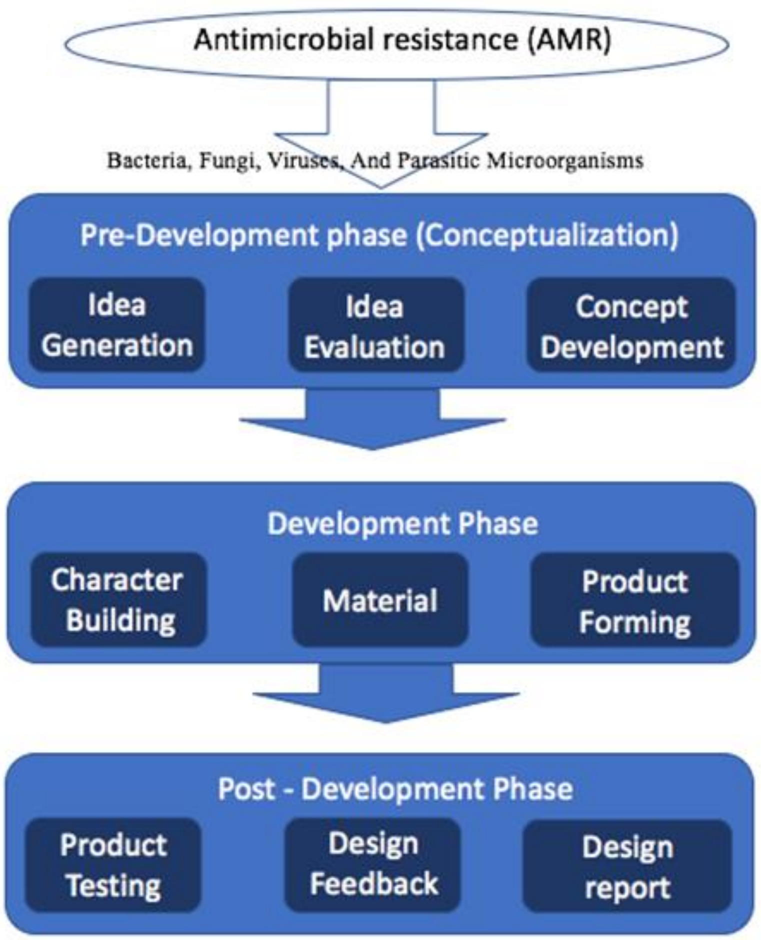

Fig. 1: Three Phases of (AMR) Design Development

A soft toy can bring a game to life, and a game, as it develops, requires more and more toys. A toy in a cognitive sense acts for a child as a kind of generalized standard of the surrounding material reality. But the value of games and toys lies not only in the fact that they introduce the child to live, the main thing is that they are an important factor in the gradual movement of the mental development of the child, which provides him with the opportunity to carry out all types of activities at an ever-higher level. It is therefore, it is hoped through this study, the soft toy developed will be the medium in bridging the awareness of the danger of Antimicrobial resistance (AMR).

Overall the methodology of this study will be segregated into three distinct phases and eight steps, following the classic Stage-Gate Model. This value-creating practice drives the development and introduction of new products: -

- **Pre-Development / Ideation Phase**

Every new product or upgrade to an old one begins with a concept. The bad news is that great ideas don't just arise out of nowhere. The chances of designers being struck by creative lightning are slim to none. The good news is that modern businesses can tap into the full potential of idea management, also known as ideation, which is a collection of tools and techniques for capturing, evaluating, and developing ideas in a methodical manner. The ideation stage, often known as the fuzzy front-end (FFE), is a less formal pre-development stage that involves creativity and inspiration. The stage consists of three steps: idea generation, idea appraisal, and concept development and testing, whichever name you give it.

- **Idea Generation**

Long before any possible product is realized, the first stage of brainstorming takes place. It all starts with identifying market gaps or identifying ways to improve your current offers and procedures. Marketing research targeted at uncovering client demands and shifting preferences, internal brainstorming meetings, examining new successful technologies supplied by competitors, and social media polls, to mention a few, are all good places to start.

SCAMPER is a popular technique for brainstorming that produces fresh concepts. It was initially developed to foster greater creativity in the students. Businesses currently use it significantly to improve or change what they currently offer. The acronym SCAMPER stands for Substitute, Combine, Adapt, Modify, Purpose, Eliminate, Rearrange / Reverse. Each verb encourages reevaluate to offer by answering a sequence of questions that might be put like this:

- *Substitute*— Which features can be replaced to make your product better?
- *Combine* — How do you combine your technology with something else to extend its functionality?
- *Adapt* — Can you adapt this product to other customers and markets?
- *Modify* — What can you add to change this product?
- *Purpose* — Can you use this product in some other way?
- *Eliminate* — Which features can be removed to make the product cheaper, faster, lighter or simpler?
- *Rearrange / Reverse*— Can the product evolve into something new? What if you turn it upside-down or inside-out?

SCAMPER is only one of tons of techniques for enhancing creativity, from mind maps for visualizing and organizing ideas to idea contests among employees that encourage innovation across the organization. Usually, the key to success lies not in a particular method, but in collaborative work attracting different people (and different visions).

Anyone can use idea management software with mind map templates, built-in video and text chats, facilities to submit images and documents, and other valuable features to engage more people in communal brainstorming. The limitless virtual whiteboard Miro, the intuitive mind mapping program iMindQ, and the mind map editor for brainstorming MindMeister are all examples of such solutions. Concept management software frequently includes capabilities for basic idea evaluation.

- **Idea evaluation / screening**

After ideas are generated, a business should decide which of them will work best and which are not worth investing in. This is the very first of many screening points new products go through, and its main goal is to reject poor ideas, those not aligned with the research objectives, and thus prevent time to be wasted.

Techniques used to select and rate ideas will be observed through:

Pass-fail evaluation is applied when you need to sift through hundreds of ideas and reduce their number to form a manageable pool. Each initiative is checked against a set of important criteria such as compliance with company culture and strategy, feasibility (or availability of proper knowledge and technology to develop the idea), budget acceptability, and more. Ideas that don't meet basic requirements are cast away; those satisfying all criteria move forward.

Actually, if you initially have just a few ideas, you can omit this step of the evaluation and switch straight to more sophisticated methods of idea scoring.

An evaluation matrix is a simple rating scale prompting experts to evaluate how well the idea meets different criteria. The matrix lets you compare ideas by each criterion as well as by the total score, giving you a clear review of competitive concepts

- **Concept Development and Testing**

The final step of the ideation phase helps you understand whether customers really need your innovation. To prove its viability, you should develop a new product concept or a detailed description of the idea from the customer's point of view. The concept reflects the core benefits of a new solution in terms of:

- price,
- convenience,
- usability.
- performance,
- quality, and
- functionality.

When the detailed description is ready, the researcher will take it to the targeted user, the respondents. Concept testing usually involves opinion polls conducted among potential users. By reaching out to them with a detailed product description, the researcher can prove it viable or, vice-versa, reject it as not workable (at least currently). The survey will also help in giving an understanding of the expectations of real customers and make improvements to increase the chances of achieving product/market fit.

The designs of soft toys provide a fun and engaging way to raise awareness of AMR in kids, parents, and teachers. Creative depictions of bacterial cells encourage memorable learning experiences that go beyond conventional teaching methods by capturing viewers' imaginations and emotions. Additionally, the research may start AMR-related discussions in communities, schools, and families, which could raise awareness and influence people's behaviour when it comes to using antibiotics

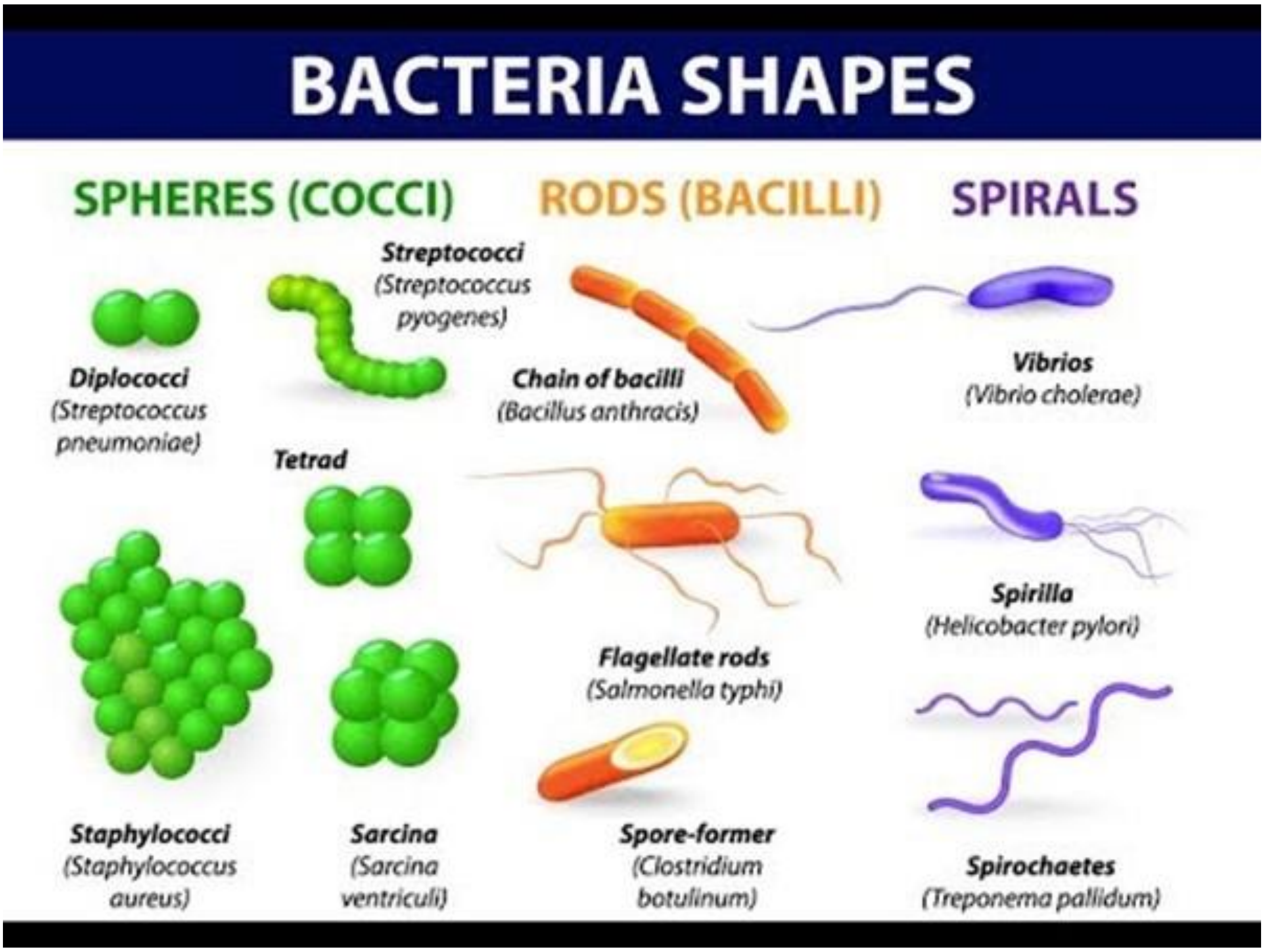

Fig. 2: Basic shapes of a bacteria (Source available on https://www.quora.com/What-are-the-types-of-bacteria-according-to-shape)

Three main categories of bacteria are distinguished by their shapes: spiral-shaped, bacilli, and cocci. The spiral-shaped bacteria are either flexible (spirochetes) or rigid (spirilla), while the bacilli are rod-shaped and the cocci are spherical.

- Spherical or oval bacteria are called cocci (singular: bacillus)
- Rods are called bacilli (singular: bacillus). Very short rods that can sometimes almost be mistaken for cocci are called cocobacilli (singular: coccobacillus).
- Some bacteria are club-shaped and can be twisted, curled, or comma-shaped (Vibrios). Rod-shaped bacteria with tapering ends are referred to as fusiform.
- Bacteria with spiral shapes are referred to be spirochetes when their cells are more flexible and undulating, and spirilla when their cells are hard.

Apart from their distinct forms, the configuration of bacteria is crucial. As an illustration, some cocci are found in pairs (diplococci), some in chains (streptococci), and still others in clusters that resemble grapes (staphylococci). Kaiser, Gary (2023) The orientation and level of adhesion of the bacterium at the time of cell division dictate these configurations. It has less of an impact on medicine how the rods and spirochetes are arranged.

Name	Shape	Colour	Special Character
Pseudomonas aeruginosa	Rod	Dusty red – bluish green	Sigle rod; white hairy
Staphylococcus aureus	Cocci/ Round	Golden yellow	Grape arrangements
Klebsiella Pneumoniae	Rod	blood-tinged" or "rust-colour Pink	Dual rod; bright pinkish colour

AESTHETIC VALUES OF IN VISUALIZING THE BACTERIA

Through artistic characterization, bacterial cells—the main agents of antimicrobial resistance—are shown in designs for soft toys. With tactile and visual components that mirror each strain of bacteria's distinct characteristics, each toy represents a different bacterial species. To illustrate various bacterial morphologies and structures, plush toys, for example, might have a range of textures, colours, and shapes. Furthermore, instructional materials that go along with them include information on the biology of bacteria, antibiotic stewardship, and the mechanisms underlying antimicrobial resistance. According to Heljakka,2013, toys with a recognizable character are referred to as character toys. These toys are frequently dolls, plush toys, figurines, or action figures. Character toys typically have a face on them. Toys are purposefully constructed for both functional and recreational purposes—to entertain and educate (or to combine these in the name of "edutainment"), depending on the sort of toy and its audience. In contrast, play is frequently thought of as a free-form activity with no goals. Toys for adults are typically positioned as collector objects to be used for pure enjoyment, whereas toys for children are often designed with their educational (practical) possibilities emphasized

RESULTS AND DISCUSSION

In order to produce an engaging and memorable figure, character design is a comprehensive process that incorporates numerous components like physical appearance, behavioural qualities, and backstory. Creators can effectively characterise their characters and elicit feelings or reactions from their audience by making careful design decisions. Based on book by Scott Mcloud (2006), Making Comics: Storytelling Secrets of Comics, Manga and Graphic Novels a character's surroundings, body language, attire, and facial expressions can all reveal details about the person they are and the ideas they stand for. Character design is more than just aesthetics; it takes into account the motives, personality, and objectives of the character. Characterization done this way makes sure that every facet of the character—be it appearance or behavior—feels true to and consistent with the world of the story.

By following basic design process guidelines, implement the goal of creating plush toys that are inspired by beautiful bacterial cells and raise awareness of antimicrobial resistance in a fun and original way. The process of sketching for creating a character inspired by artistic bacterial cells involved several steps especially for designers.

- Research and inspiration by learning about the many kinds of bacteria and their distinct appearances. Seek for creative colours, shapes, and patterns that can be incorporated into the designs of soft toys.
- Concept Development are created with the based on the results of the earlier research, doodle out preliminary concepts. Varying the sizes, forms, and configurations to effectively convey the essence of bacterial cells through visual attractiveness. Every design element clearly conveys the idea of artful bacterial cells by going over your ideas again and paying special attention to detail. Using various materials and textures might improve the overall look.
- Finalisation and Prototypes phase comes after the final sketches and the technical drawing, that also consider elements like the viability of production and the safety requirements for plush toys. Using completed sketches as a guide, make prototypes of the plush toys. This could entail stuffing, stitching cloth, and adding any other features or decorations.
- Testing and Evaluation process is where the prototypes are being tested through their paces to make sure they work as intended and are safe to use. Consider aspects including general appeal, comfort, and durability. Production: Move forward with the soft toy's mass production if the prototypes prove viable. To guarantee that the finished goods closely resemble your original concepts, collaborate closely with the producers.

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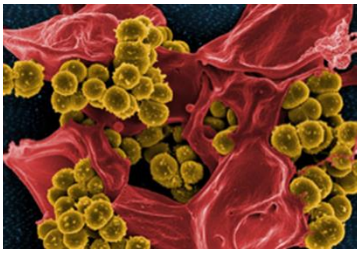
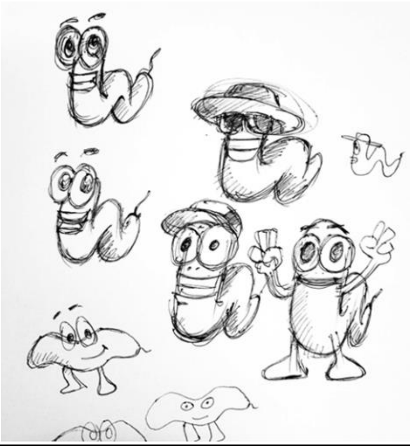
Microscopic Image	
	
	
Sketch Idea	
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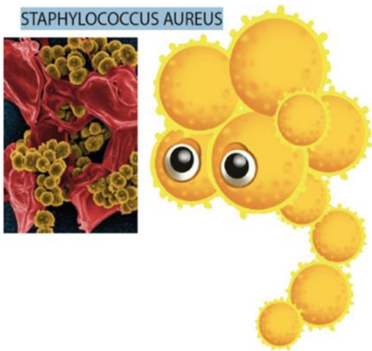	
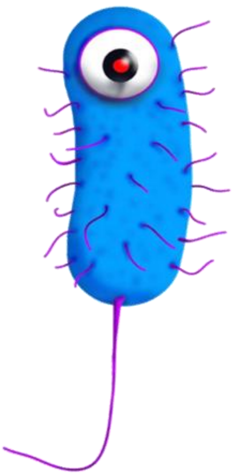	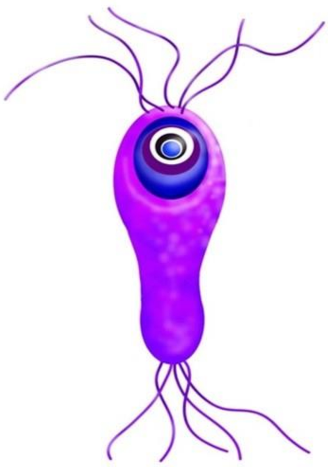

Prototyping result	
	

Fig. 3: Transformation of bacteria through characterizing process

CONCLUSION

The designs of soft toys provide a fun and engaging way to raise awareness of AMR in kids, parents, and teachers. Creative depictions of bacterial cells encourage memorable learning experiences that go beyond conventional teaching methods by capturing viewers' imaginations and emotions. Additionally, the research may start AMR-related discussions in communities, schools, and families, which could raise awareness and influence people's behaviour when it comes to using antibiotics. Figure 3 summarizes the findings of standard form of arrangement derive from the data collected. As mentioned earlier, there are three basic form of bacterial that are commonly found in human body. Thus this finding shows that the three basic arrangement could definitely be use in the process of visualizing the bacteria into fun and functional used while added the aesthetic value in between it. In conclusion, the purpose of incorporating the used of using soft toy design for representing the characteristics of artistic bacterial cells offers a fresh take on spreading knowledge of the resistance to antibiotics. This strategy provides an effective way to engage a variety of audiences and promote a deeper understanding of AMR by fusing scientific knowledge with creative expression. Soft toy designs have the ability to support international efforts to address antimicrobial resistance and encourage ethical antibiotic use by acting as a catalyst for public discourse and action. The outcome of this paper is hoped to provide a better understanding and appreciation of the resistance to antibiotic among the stakeholders that leads to more successful implementation of public awareness and expands its roles for a better quality of the public realm.

REFERENCE

1. World Health Organization. (2020). Antimicrobial resistance. https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance
2. O'Neill, J. (2016). Tackling drug-resistant infections globally: Final report and recommendations. The Review on Antimicrobial Resistance.
3. Davies, J., & Davies, D. (2010). Origins and evolution of antibiotic resistance. Microbiology and Molecular Biology Reviews, 74(3), 417–433.
4. Brossard, D., & Lewenstein, B. V. (2010). A critical appraisal of models of public understanding of science: Using practice to inform theory. In L. Kahlor & P. Stout (Eds.), Communicating science: New agendas in communication (pp. 11–39). Routledge.
5. Norman, D. A., & Verganti, R. (2014). Incremental and radical innovation: Design research vs. technology and meaning change. Design Issues, 30(1), 78–96.

6. Carlianne Tipsey, (2022), How to Draw Adorable: Joyful Lesson for Making Cute Art, Girl Friday Books, Seattle
7. Gary Kaiser, 2023, Microbiology, Libre texts, Bio.Libretexs.org/ bookshelves
8. Kevin Crossley (2014), Character Design From The Group Up, Ilex Press
9. Louis Bou (2014), We are Indie Toys: Make Your Own Characters, Harper Paperbacks, US
10. Matthew Killough, Aoife Maria Rodgers, Rebecca Jo Ingram ,Pseudomonas aeruginosa: Recent Advances in Vaccine Development
11. Michale T. Madigan, (2014), Microbiology, Libretexts.org/bookshelves.
12. Moselio Schaechter (2003), Desk Encyclopedia of Microbiology, Elsevier Academic Press, USA
13. 3DTotal Publishing, (2020), Fundamentals of Character design: How to Create Engaging Character, 3DTotal Publishing
14. Smirnova, E. O. (2011). Character toys as psychological tools. International Journal of Early Years Education, 19(1), 35–43. https://doi.org/10.1080/09669760.2011.570998
15. Amábile-Cuevas C. F. (2022). Myths and Misconceptions around Antibiotic Resistance: Time to Get Rid of Them. *Infection & chemotherapy*, *54*(3), 393–408.
16. Botelho, J., Grosso, F., & Peixe, L. (2019). Antibiotic resistance in *Pseudomonas aeruginosa* - Mechanisms, epidemiology and evolution. *Drug resistance updates : reviews and commentaries in antimicrobial and anticancer chemotherapy*, *44*, 100640.
17. Chang, D., Sharma, L., Dela Cruz, C. S., & Zhang, D. (2021). Clinical Epidemiology, Risk Factors, and Control Strategies of *Klebsiella pneumoniae* Infection. *Frontiers in microbiology*, *12*, 750662.
18. Chinemerem Nwobodo, D., Ugwu, M. C., Oliseloke Anie, C., Al-Ouqaili, M. T. S., Chinedu Ikem, J., Victor Chigozie, U., & Saki, M. (2022). Antibiotic resistance: The challenges and some emerging strategies for tackling a global menace. *Journal of clinical laboratory analysis*, *36*(9), e24655.
19. Dadgostar P. (2019). Antimicrobial Resistance: Implications and Costs. *Infection and drug resistance*, *12*, 3903–3910.
20. Gu, D., Dong, N., Zheng, Z., Lin, D., Huang, M., Wang, L., Chan, E. W., Shu, L., Yu, J., Zhang, R., & Chen, S. (2018). A fatal outbreak of ST11 carbapenem-resistant hypervirulent Klebsiella pneumoniae in a Chinese hospital: a molecular epidemiological study. *The Lancet. Infectious diseases*, *18*(1), 37–46.
21. Kartalidis, P., Skoulakis, A., Tsilipounidaki, K., Florou, Z., Petinaki, E., & Fthenakis, G. C. (2021). *Clostridioides difficile* as a Dynamic Vehicle for the Dissemination of Antimicrobial-Resistance Determinants: Review and In Silico Analysis. *Microorganisms*, *9*(7), 1383.
22. Lade, H., & Kim, J. S. (2023). Molecular Determinants of β-Lactam Resistance in Methicillin-Resistant *Staphylococcus aureus* (MRSA): An Updated Review. *Antibiotics (Basel, Switzerland)*, *12*(9), 1362.
23. Markovska, R., Dimitrov, G., Gergova, R., & Boyanova, L. (2023). *Clostridioides difficile*, a New "Superbug". *Microorganisms*, *11*(4), 845.
24. Mulani, M. S., Kamble, E. E., Kumkar, S. N., Tawre, M. S., & Pardesi, K. R. (2019). Emerging Strategies to Combat ESKAPE Pathogens in the Era of Antimicrobial Resistance: A Review. *Frontiers in microbiology*, *10*, 539.
25. Nadgir, C. A., & Biswas, D. A. (2023). Antibiotic Resistance and Its Impact on Disease Management. *Cureus*, *15*(4).
26. O'Grady, K., Knight, D. R., & Riley, T. V. (2021). Antimicrobial resistance in Clostridioides difficile. *European journal of clinical microbiology & infectious diseases : official publication of the European Society of Clinical Microbiology*, *40*(12), 2459–2478.
27. Parmanik, A., Das, S., Kar, B., Bose, A., Dwivedi, G. R., & Pandey, M. M. (2022). Current Treatment Strategies Against Multidrug-Resistant Bacteria: A Review. *Current microbiology*, *79*(12), 388.
28. Palavecino E. L. (2020). Clinical, Epidemiologic, and Laboratory Aspects of Methicillin-Resistant Staphylococcus aureus Infections. *Methods in molecular biology (Clifton, N.J.)*, *2069*, 1–28.
29. Pu, D., Zhao, J., Chang, K., Zhuo, X., & Cao, B. (2023). "Superbugs" with hypervirulence and carbapenem resistance in Klebsiella pneumoniae: the rise of such emerging nosocomial pathogens in China. *Science bulletin*, *68*(21), 2658–2670.

30. Qin, S., Xiao, W., Zhou, C., Pu, Q., Deng, X., Lan, L., Liang, H., Song, X., & Wu, M. (2022). Pseudomonas aeruginosa: pathogenesis, virulence factors, antibiotic resistance, interaction with host, technology advances and emerging therapeutics. *Signal transduction and targeted therapy*, *7*(1), 199
31. Ranjbar, R., & Alam, M. (2023). Antimicrobial Resistance Collaborators (2022). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Evidence-based nursing*, ebnurs-2022-103540. Advance online publication.
32. Salam, M. A., Al-Amin, M. Y., Salam, M. T., Pawar, J. S., Akhter, N., Rabaan, A. A., & Alqumber, M. A. (2023). Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. *Healthcare*, *11*(13), 1946.
33. Sinha, M., Ghosh, N., Wijesinghe, D. S., Mathew-Steiner, S. S., Das, A., Singh, K., El Masry, M., Khanna, S., Inoue, H., Yamazaki, K., Kawada, M., Gordillo, G. M., Roy, S., & Sen, C. K. (2023). Pseudomonas Aeruginosa Theft Biofilm Require Host Lipids of Cutaneous Wound. *Annals of surgery*, *277*(3), e634–e647.
34. Sleiman, A., Awada, B., Mocadie, M., Sherri, N., Haraoui, L. P., Baby, V., Araj, G. F., Kanj, S. S., Rizk, N., Matar, G. M., & Abou Fayad, A. G. (2021). An unequivocal superbug: PDR Klebsiella pneumoniae with an arsenal of resistance and virulence factor genes. *Journal of infection in developing countries*, *15*(3), 404–414.
35. Song, J. H., & Kim, Y. S. (2019). Recurrent *Clostridium difficile* Infection: Risk Factors, Treatment, and Prevention. *Gut and liver*, *13*(1), 16–24. https://doi.org/10.5009/gnl18071
36. Uddin, T. M., Chakraborty, A. J., Khusro, A., Zidan, B. R., Mitra, S., Emran, T. B., Koirala, N. (2021). Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects. *Journal of Infection and Public Health*, *14*(12), 1750-1766.
37. Wickramage, I., Spigaglia, P., & Sun, X. (2021). Mechanisms of antibiotic resistance of Clostridioides difficile. *The Journal of antimicrobial chemotherapy*, *76*(12), 3077–3090.
38. Wu-Wu, J. W., Guadamuz-Mayorga, C., Oviedo-Cerdas, D., & Zamora, W. J. (2023). Antibiotic Resistance and Food Safety: Perspectives on New Technologies and Molecules for Microbial Control in the Food Industry. *Antibiotics*, *12*(3), 550.
39. Wyres, K. L., Lam, M. M. C., & Holt, K. E. (2020). Population genomics of Klebsiella pneumoniae. *Nature reviews. Microbiology*, *18*(6), 344–359.
40. WHO. Media Centre. News Release. WHO publishes list of bacteria for which new antibiotics are urgently needed. 2017 [cited 2017 March]. Available from: http://www.who.int/mediacentre/news/releases/2017/bacteria-antibiotics-needed/en/.
41. Zhu, D., Sorg, J. A., & Sun, X. (2018). *Clostridioides difficile* Biology: Sporulation, Germination, and Corresponding Therapies for *C. difficile* Infection. *Frontiers in cellular and infection microbiology*, *8*, 29.