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A Model of How Antibiotics Work

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ABSTRACT

Almost all children have taken antibiotics as a result of ear infections, strep throat, or other bacterial infections. Some of them feel better soon and don't understand why they have to keep taking the medication for the full ten days as prescribed. Others forget to take the medicine, and then often have to be put on a stronger type of antibiotics. This game enables students to experience a model of the effects of antibiotics on a population of disease-causing bacteria during an infection. Students learn how variables such as skipping a day of medication affect the persistence of the disease. A key concept is that almost every naturally occurring population of bacteria that cause disease has a component that is resistant to antibiotics. By graphing data, students can visually understand why it is important to take a complete course of antibiotics to kill all the bacteria and decease the likelihood of bacteria becoming resistant, which can be harmful to human health and is a major public health problem

Keywords: Antibiotic resistance, Antibiotic education, Model, Simulation game

1. Introduction

As As a Professor of Education, and not a research scientist, the 3rd International Caparica Conference on Antibiotic Resistance (IC2AR) opened my eyes to the widespread and serious problem of antibiotic resistance which continues to be a global public health issue. Dr. Jose Capelo[1], in his welcome speech and introduction in the book of abstracts, stated the problem has escalated to levels where the need to "require medical assistance in a hospital has become a Russian roulette, as such is the risk to get infected with a bacteria resistant to antibiotics." This statement rang so true when a friend of mine, who recently had surgery, had a raging infection in his incision. It has been estimated that by 2050, 10 million lives per year will be at risk from antibiotic-resistant infections [2]. Professor Jose Capelo (2019) stated we are all "soldiers in the battle of antibiotic resistance." [1]

Because antibiotics still provide highly effective treatments for common diseases with important implications for human health, their proper use is essential. The challenge for public education is to achieve a meaningful reduction in unnecessary antibiotic use without adversely affecting the management of bacterial infections. [3] Antibiotics are the most commonly prescribed therapy among all medications given to children [4].

"Children have the highest rates of antibiotic use and they also have the highest rate of infections caused by antibiotic-resistant pathogens, but antibiotics are not necessary for the majority of infections seen in the pediatrician's office. Parent pressure can influence a doctor's decision about using antibiotics. Doctors prescribe antibiotics much more often for children if they think parents expect them, but less often if they feel parents do not expect them" [5].

By using a model of how antibiotics work which is actually a game, students can learn why it is important to take antibiotics as prescribed. Using a partial dose or stopping because they feel better leads to antibiotic resistance. As stated in the Stanford medical health bulletin to parents:

"When an illness does require antibiotic treatment, it's important that your child take the medication exactly as prescribed by your pediatrician. Don't stop having your child take the medication because he or she starts to feel better. Just as overuse of antibiotics leads to resistant

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bacteria, so does using only a partial dose. Each time antibiotics are taken, sensitive bacteria are killed, but resistant ones may be left to grow and multiply, according to the CDC" [5].

The objective of this article is to describe the use of a simple model to educate young people and their parents, in fact any person who is not scientifically knowledgeable, on why antibiotics should be taken as prescribed to avoid the development of antibiotic resistance.

2. Materials and Methods

2.1. Background

Have you ever taken antibiotics? Imagine you are sick with a bacterial infection. Your doctor prescribes an antibiotic, normally taken for 10 days. Did you follow the directions completely? All antibiotics need to be taken as directed, which usually means taking all the pills and not stopping even if you begin feeling better. Why? When harmful bacteria appear on the scene, your body's immune system can usually keep a small population of them under control. If, however, these bacteria reproduce too quickly, you suffer the consequences of an infection. Antibiotics help your body fight off an infection by killing these harmful bacteria. Unfortunately, a small number of bacteria in any population may not be affected by the antibiotic as quickly. These bacteria, which are considered more resistant to the treatment, continue to reproduce and grow. Completing the full course of the antibiotic as prescribed by your doctor helps to make sure that these bacteria do not survive and therefore won't make you ill or infect someone else. This game is a model of how it works.

2.2. Materials needed

Colored disks- any three colors, available on Amazon (transparent colored counting chips), playing dice – one for each pair of players. In this activity, we used green or yellow, blue or purple, and orange or red.

Colored disks represent the bacteria in your body: Green (or yellow) disks represent the least resistant bacteria, blue (or purple) represent the resistant bacteria, and orange (red) represents the most resistant bacteria. Follow the directions below.

2.3. Mathods

1. In this activity you will work with your partner to collect data. Begin with 20 disks, 13 green, 6 blue, and 1 orange. These disks represent the harmful bacteria living in your body before you begin to take the antibiotic. Set the extra disks aside for now.
2. It is time to take your antibiotic. Toss the die and follow the directions on Table 1.
3. Record the number of each type of bacteria in your body in Table 2.
4. Repeat #2 until all bacteria have been killed!
5. Use the data to graph the population for each type of bacteria and for the total number of bacteria on the graph paper provided (Supplementary material, Figure S1). In this example (Supplementary material, Table S1), the bacteria took 12 days to die completely because the antibiotic was forgotten three times.

Table 1 | Game Instructions

You Toss	What Happened	What to Do	Notes:
1,3,5,6	You took the antibiotic on time, so bacteria are being killed!	Remove 5 disks, starting with the green disks first, since they are least resistant, then the blue, and last the orange.	The bacteria are reproducing all of the time! As long as any disks of any color remain, each time add one disk of each color to show they are still multiplying! For example, if you have resistant (blue) and extremely resistant (orange) bacteria in your body, add 1 blue disk and 1 orange disk to your population.
2,4	You forgot to take the antibiotic.	If there are any disks of any color remaining, add one disk of each color remaining to represent the fact that they are still multiplying!	

Table 2 | Chart for recording number of harmful bacteria in your body [6] (SEPUP, 2010, C-269).

Round Number	Least resistant Bacteria	Resistant Bacteria	Extremely Resistant Bacteria	Total
Initial	13	6	1	20
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

After the data is collected, it should be graphed to show how the least resistant bacteria die first, followed by the next resistant bacteria, and finally, the most resistant bacteria. The graph should visually show, if the antibiotic was forgotten for a day or two, how the bacteria immediately reproduce (Supplementary Material, Figure S1).

3. Results and discussion

To assess the value of this presentation, pre (dispositions) and post (perceptions) surveys were conducted. Fifteen respondents answered the following questions, using a Likert scale from strongly agree (5), agree (4), neutral (3), disagree (2), strongly disagree (1).

Pre survey:
1. I use modeling in my own work.
2. I was aware of using games to model antibiotic resistance prior to this session.
3. I believe models are an effective tool for the training and education of future scientists.
4. Most people without a science background understand how antibiotics work.

Post survey:
1. This particular game appears to be an effective illustration for people to gain an understanding of how antibiotics work.
2. The presentation enhanced my belief in the usefulness of modeling in engaging the interest and understanding of scientific thinking.
3. The presentation contained practical examples and useful techniques that applied to current work.
4. The presentation made me think of things in a new way or see a different perspective.
5. The presentation had a lot of good information and ideas.
6. I was aware of this type of model prior to this session.
7. The presentation was concise and informative.
8. The presenter answered questions effectively.
9. The presenter maintained my interest during the entire presentation.
10. The presenter was knowledgeable about the topic and any related issues.
11. The presentation got people involved and interacting in a comfortable environment.
12. The presentation should be offered again.

4.Discussion

Overall, the presentation was well-received and perceptions of the use of model(s) were improved by this presentation.

The averages of the Pre survey are showed in Supplementary Material Table S2 and the averages of the post survey are showed in Supplementary Material Table S3.

In addition, when the activity was originally done with sixth grade students [7], the following feedback was received:

“I learned that even if you take antibiotics, the bs acteria keep multiplying. That is why you must take antibioticfor an extended period of time.”

“I liked this project because it helped me understand how an infection works; if you don’t treat it the bacteria get stronger.”

“I learned that bacteria grow in a certain way. I thought it was cool and I had a lot of fun on learning about bacteria.”

“I liked the activity. Something I learned is [that] the bacteria still grow when you are getting better.”

“It showed me how to take care of myself better.”

According to the Next Generation Science Standards, adopted by over 20 states in the United States, and representing about 36% of all students, modeling is one of the practices used by scientists and engineers. Students are encouraged to use models as a helpful tool for representing ideas and explanations. This model is a fun way for students and others to interactively see and understand what happens when antibiotics are misused.

Even those with a great deal of scientific and medical knowledge recognized the value of modeling antibiotic resistance. After the presentation at the IC^{2}AR, one immunologist commented, “The model surprised me when I drew the graph! (It) made me realize how (a) simple model can help understanding of a complex issue.” Another participant said, “You provided me a new form to teach to my students the ARM phenomenon.”

5.Concluding Remarks:

One of the major contributors to the inappropriate use of antibiotics is based on insufficient knowledge and therefore education about prudent antibiotic use aimed at both the prescribers and the public is important [8]. Educating young people by using this model of antibiotic resistance may be one key to meeting the challenges of the battle against antibiotic resistance. If the young people and their parents are more knowledgeable, perhaps parents would not put pressure on doctors to prescribe antibiotics when not really needed, and each generation will become more savvy about the proper use of these valuable drugs to combat infections.

Perhaps we are fighting a losing battle as bacteria continue to evolve. But we can make some progress by educating the public about this global problem. Malala Yousafzai said it eloquently, “There are many problems, but I think there is a solution to all these problems; it's just one, and it's education.”

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SUPPLEMENTARY MATERIAL

Table S1: Random exemple of the activity. In this case it took 12 days to kill all the bacteria.

Round Number	Roll of Die	Meaning	Least Resistant Bacteria	Resistant Bacteria	Extremely Resistant Bacteria	Total	Action Taken
Initial			13	6	1	20	Removed 5 green, added 1 of green, blue, and orange
1	3	Took antibiotics	9	7	2	18	Removed 5 green, added 1 of green, blue, and orange
2	2	Forgot to take antibiotics	10	8	3	21	Added 1 of each color
3	1	Took antibiotics	6	9	4	19	Removed 5 green, added 1 of each color
4	3	Took antibiotics	2	10	5	17	Removed 5 green, added 1 of each color
5	5	Took antibiotics	0	8	6	14	Removed 5 (2 green, 3 blue) added 1 blue and 1 orange
6	6	Took antibiotics	0	4	7	11	Removed 5 blue, put back 1 blue and added 1 orange
7	4	Forgot to take antibiotics	0	5	8	13	Added 1 blue and 1 orange
8	1	Took antibiotics	0	0	9	9	Removed 5 blue, added 1 orange
9	3	Took antibiotics	0	0	5	5	Removed 4 orange
10	4	Forgot to take antibiotics	0	0	6	6	Added one orange
11	6	Took antibiotics	0	0	2	2	Removed 4 orange
12	5	Took antibiotics	0	0	0	0	Removed remaining 2 orange

Figure S1: Graph to simulate the bacterial growth when antibiotics are forgotten

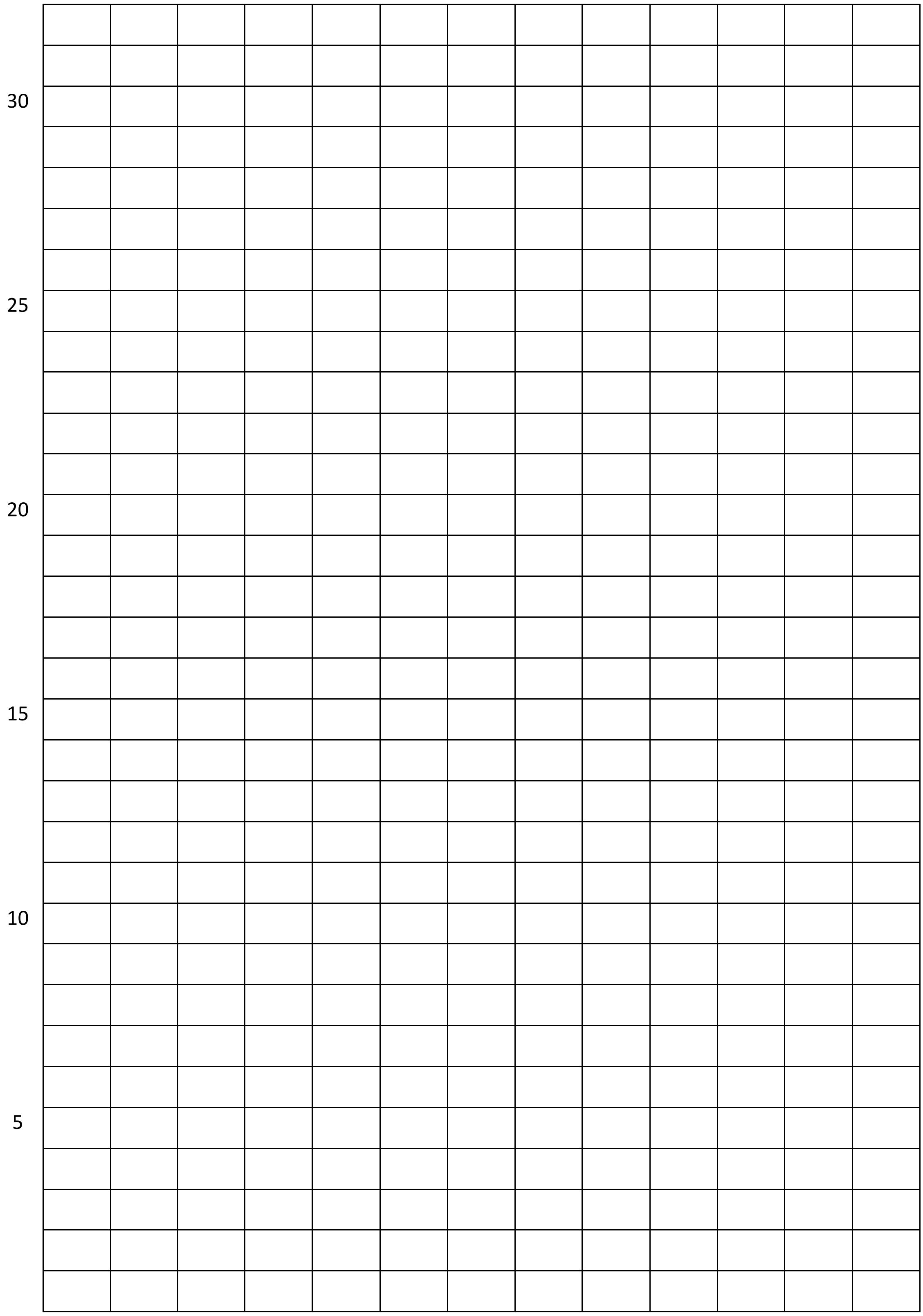

Table S2: Pre survey answers and average.

Before Presentation (Pre Dispositions)

Respondent	Q1	Q2	Q3	Q4
1	4	4	4	5
2	4	1	5	1
3	1	1	3	2
4	4	2	5	1
5	4	1	5	3
6	-	-	-	-
7	3	4	5	2
8	1	1	5	1
9	5	3	5	4
10	4	3	4	1
11	2	1	5	3
12	2	3	5	1
13	3	4	4	4
14	4	5	5	1
15	2	4	5	1
16	4	2	4	1
Average	3.1	2.6	4.6	2.1
	Neutral	**Neutral (Leaning Disagree)**	**Agree (Leaning Strongly Agree)**	**Disagree**

Table S3: Post survey answers and average. Note: "--" means no response

After Presentation (Post Perceptions)

Respondent	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
1	4	-	3	4	4	4	3	3	4	4	4	4
2	5	5	3	4	5	3	5	5	3	5	5	5
3	4	4	4	4	4	5	4	4	4	4	4	4
4	5	3	5	5	4	4	5	5	5	5	5	5
5	-	-	-	-	-	-	-	-	-	-	-	-
6	3	4	3	4	4	2	2	4	4	2	4	3
7	4	4	3	3	3	2	2	3	2	3	4	4
8	5	5	5	5	4	1	3	3	5	5	5	5
9	5	4	5	4	5	3	5	5	5	5	5	5
10	4	4	4	-	3	5	5	4	4	4	5	4
11	5	5	5	4	2	5	5	5	5	5	5	5
12	5	4	3	5	3	1	1	1	3	5	5	5
13	4	4	4	4	5	4	4	4	3	3	3	3
14	5	4	4	3	4	5	4	4	5	5	5	5
15	4	5	3	4	3	1	4	4	4	3	5	4
16	4	3	3	3	2	2	2	4	2	4	4	3
Average	4.4	4.1	3.8	4.0	3.7	3.1	3.6	3.9	3.9	4.1	4.5	4.3
	Agree	**Agree**	**Neutral (Leaning Agree)**	**Agree**	**Neutral (Leaning Agree)**	**Neutral**	**Neutral (Leaning Agree)**	**Agree**	**Agree**	**Agree**	**Agree (Leaning Strongly Agree)**	**Agree**