Combating the Spread of Antibiotic Resistance Negotiation Simulation: Using Serious Games to Simulate Policy Deliberation

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Introduction

Antimicrobial resistance (AMR) is a critical public health threat both in the United States and globally. AMR is when microorganisms, such as bacteria, fungi, and parasites, no longer respond to the medications that are intended to kill them [1]. In 2019 alone, 1.27 million people globally died as a direct result of antibiotic-resistant infections, and it has been estimated that AMR could be responsible for over 10 million deaths per year by 2050[2], [3]. Microorganisms mutate to resist medications both spontaneously and as a result of the overuse and misuse of antimicrobial drugs, poor infection control practices, environmental exposure, and easy travel [4], [5], [6], [7]. The World Health Organization has determined that this is a worldwide public health threat and has urged all countries to develop plans for managing and decreasing AMR within their countries. The United States has made a National Action Plan that outlines the nation's priorities for combatting AMR. It has been found that the overall number of U.S. AMR-related deaths fell by 18% from 2012 to 2017, though some of this progress has been attributed efforts prior to the development of the U.S. National Action Plan in 2015 [8]. While the efforts of the United States to address AMR are working, stronger policy efforts addressing AMR are necessary to continue progress.

Combating AMR requires "collective action, political momentum, and robust multisectoral collaboration and partnerships between all stakeholders" [1]. Collaborative governance can better identify and develop holistic policy solutions, and allow for ease of implementation due to all stakeholders understanding and agreeing to what is included in the policy solution [9]. Collaborative community-based practices can help form policies that have better outcomes than traditional solutions that lack stakeholder engagement. However, they do face several limitations. One limitation to collaborative governance is limited communication and negotiation skills among stakeholders. Additionally, experience working at the science-policy interface is not common, especially for those working in academia and research development teams, yet it remains critical for collaborative governance [10].

To mitigate these limitations, researchers have looked into alternative methods to develop stakeholders' skills in effective collaboration. Over the years, novel methods of teaching have emerged in order to stimulate interest and improve retention of knowledge, such as game-based learning (GBL). GBL stems from game research in the 1950s and quickly grew interest in the field when it started to be implemented into classrooms with the rise of digital gaming in the 1980s and again in the 2000s with the advent of online games and smartphone apps [11]. One form of GBL are serious games, which were first defined as games that have an educational purpose and are not played primarily for entertainment [12]. Serious games have erupted in

popularity since 2007, with over 200 games being published every year [13]. Serious games have many educational benefits as they place the players into situations that they may not otherwise have been able to experience due to time, cost, security, and safety issues [14], [15]. Serious games also target the players' skill sets, allowing many players to collectively develop skills such as critical thinking, problem solving, communication, and negotiation skills[14], [16]. One particular benefit is that this learning is social (i.e., shared) rather than individual [17]. Serious games are widely used in the military, policy and stakeholder engagement, education, and public health sectors.

This study examines the efficacy of a serious game designed to simulate multisectoral collaboration and stakeholder engagement to tackle AMR. The goal of the study is to determine if serious games can teach the necessary skills and knowledge to research and academic community members for work at the science-policy interface. The study was guided by the following two research questions:

1. Does the designed serious game provide skills and knowledge of the ways in which scientific information is used in policy deliberations around how to address AMR, and if so, in what ways?
2. What skills, if any, are gained after playing the designed serious game with respect to how stakeholders can approach policy deliberations around combating AMR?

Game Overview and Design

In the game *Combating the Spread of Antibiotic Resistance*, players are given roles attending the second meeting of the U.S. Federal Antibiotic Resistance Task Force (US-FAR). In the first meeting of US-FAR, they heard the call of the World Health Organization that AMR is a serious issue and that all countries should create a National Action Plan to identify their goals and strategies to reduce the burden of AMR. The first meeting also created a general set of questions that will be used to direct the second meeting. During this meeting, stakeholders with different values, interests, and goals (Table 1) deliberate to form a set of policy recommendations for consideration about what should be included in the U.S. National Action Plan.

Table 1. Overview of Stakeholders in "Combating the Spread of Antibiotic Resistance"

Stakeholder	**Description**
Agricultural Agency	Regulatory agency that focuses on ensuring a stable food supply and economic prosperity in American agriculture.
Environmental Conservation Agency	Regulatory agency that focuses primarily on providing safeguards to protect the environment and American citizens from health risks
PHARMA	Organization that represents the pharmaceutical industry

Farmers United	Organization devoted to protecting livelihoods of American farmers
One Health America	Non-profit organization specializing in the One-Health arena
American Healthcare Association	Organization representing doctors, nurses, and other actors across the healthcare system
Responsible Care Campaign	Non-profit organization started by people who have or are currently losing loved ones due to antibiotic resistance
Human Health Agency	Chair of the task force. Focus is to create a set of recommendations

Each player receives the same set general instructions, which provide information about how the game will be played and information about the scenario. The general instructions also provide the list of questions that will guide the meeting, as well as some policy recommendations that the players can consider as potential courses of action. Stakeholders are, however, free to form their own recommendations, which can arise from the negotiations of the game. The questions asked are:

1. Should further regulation and/or stimulation of human antibiotic production be included within the scope of the National Action Plan?
2. Should regulating the removal of antibiotic resistance drivers from wastewater be included within the scope of the National Action Plan?
3. Should regulating the use of antibiotics for growth promotion in agriculture be included within the scope of the National Action Plan?
4. Should regulating the prescription of antibiotics for humans and/or further education of health workers be included within the scope of the National Action Plan?

Players also receive a technical report that contains all the current available information that is applicable to the questions that are addressed during the meeting. Last but not least, each player receives a role-specific set of confidential instructions that give them an overview of the position of the stakeholder that they are playing, and their preferred outcome for each policy recommendation. The confidential instructions are aimed to provide the players a jumping off point during the negotiation, but they are not meant to be a script that players must adhere to. Players are encouraged to use their judgment and take on the role of their stakeholder.

Social Learning Theory

This game was designed using the Social Learning Theory developed by Albert Bandura [18]. The Social Learning Theory focuses on how observation and imitation are important in the learning process. Bandura also focuses on learning through direct experience, which is simulated in this game. The serious game was designed to have realistic stakeholders representing all areas of the AMR problem, including the pharmaceutical industry, the agricultural sector, the environmental sector, both public and private entities, and a variety of stakeholder values. This

places the participants in a scenario where observing how their actions can impact the negotiation process can help encourage the adoption of strategies in future negotiations. The game was also specifically developed to have a reinforcement loop, where there is no "correct" policy outcome, allowing the actions of the players to be amplified and reflections to be more authentic. Two key concepts within the social learning theory are vicarious reinforcement and allowing learners to understand the feedback and reflect on their actions [18].

Learning Outcomes of the Game

While the game has a general theme of antibiotic resistance, the overall goal is not simply to elucidate what stakeholders surrounding antibiotic resistance believe and are seeking, but also to gain a more nuanced understanding of the ways that scientific information is used within a policy deliberation. This game was designed primarily for actors with at least some knowledge of and experience addressing antibiotic resistance. For this reason, the learning outcomes primarily focus on skills development and fostering knowledge about how policy is created or deliberated. There were six major learning objectives from the game, which are generally organized among two major topics: the role of science in policy deliberations and how stakeholders influence negotiations. By the end of the game, players will:

1. Gain insight into the ways in which science is and is not used within policy deliberations.
2. Understand that science can be misinterpreted or used to misrepresent a particular position or bias during negotiations.
3. Advance their ability to synthesize information, communicate, and deliberate about technical information.
4. Develop their knowledge about the basics of AMR, as well as the role that antibiotic resistance plays in the pharmaceutical, environmental, agricultural, and clinical contexts.
5. Understand the values of each of the sectors as they relate to antibiotic resistance and how these values influence negotiations.
6. Develop skills in deliberating with other stakeholders to pursue a common agenda on antibiotic resistance.

Methods

The *Combating the Spread of Antibiotic Resistance* game was run at Virginia Tech in August of 2023. Participants were recruited from the Convergence at the Interfaces of Policy, Data Science, Environmental Science and Engineering for Combating Antimicrobial Resistance National Science Foundation Research Traineeship (CIP-CAR NRT), as well an invited guest who graduated from the CIP-CAR NRT program. Participants were primarily graduate students and faculty from Civil and Environmental Engineering, Biological Systems Engineering, the School of Public and International Affairs, and Agricultural, Leadership, and Community Education.

The invited guest who participated works in the U.S. Environmental Protection Agency. Virginia Tech is a large, R1 (i.e., research-intensive) public institution in the Southeastern United States.

Game participants were divided into groups of eight, with one participant in each group playing each of the eight stakeholders. All tables were within the same room, but each game was played in real-time and with distance between tables so as to limit the amount of information shared between groups.

Research data was collected in three ways: pre- and post-exercise surveys, participant observation, and a post-game debrief (i.e., focus group). Participant observation was important to documenting what happened in each group during their game play. An observer was assigned to each table to take notes about what happened during the game instead of playing. Observers, who were also developers of the game, were briefed beforehand to not influence gameplay and take on a silent role. They were also given an observation protocol (*appendix A*) to follow, which also contains an observation notes section to document what happened during the game. Additionally, observers completed a reflective summary immediately following the exercise, documenting key inflection points, tactics used, the role of the facilitator, and the activity of the parties within the game.

Participants also completed surveys pre- and post-exercise, which were administered via QuestionPro (attached as *appendix B*). The participants were asked to complete the consent process and pre-survey two days in advance to the game, and the period for submissions was open until the game started. Participants were then sent a post-survey via email four days later, which contained the same questions as the pre-survey and additional questions added to ask for their direct assessment of the game vis-a-vis the established learning outcomes.

Immediately following the game, participants took part in a debriefing focus group comparing and contrasting what happened in each of the groups, as well as detailing how they felt about what happened during the game in a reflexive questioning style (attached as *appendix C*). In this method, general questions were formulated beforehand, but further guiding questions were developed on the spot as to empower the participants to remain talking in a relaxed environment. For the purposes of this study, the results of the focus group have not been included.

All of the survey data was cleaned to include only the participants who took both the pre- and post-surveys, as this provides the most accurate representation of the effectiveness of the game. Pre-survey responses from participants who did not take the post-survey were omitted from the analysis. All data were analyzed and visualized using Microsoft Excel and RStudio (v.4.3.1),. Qualitative results were analyzed using thematic analysis within Excel. Quantitative results were analyzed using descriptive statistics, as well as a two-tailed Wilcoxon signed-rank test.

Results

Open-Ended Questions

The first open-ended question (Table 2) was coded into five different themes: knowledge, research, intra-personal skills, audience, and collaboration/team skills. The knowledge theme contained ideas such as “knowledge of the subject” or “understanding of technical information related to the subject matter”. Within the research skill theme, respondents mentioned the need for technical writing skills, data visualization, and analytical skills. The intra-personal skills theme contained responses such as patience, humility, and attention to detail. Finally, the collaboration and team skills theme contained responses such as conflict management, networking, teamwork, and collaboration.

There was a significant decrease in the number of responses that mentioned research skills, dropping from 20% of the coded responses to 14%. There was also an increase in responses related to collaboration and team building skills, which raised from 24% to 31%. All other themes remained relatively the same, varying by only several responses.

Table 2. Thematic Analysis of Open-Ended Question 1

Open-ended Question 1: What skills are needed to effectively synthesize, communicate, and deliberate about technical information?				
	Pre-Survey		**Post-Survey**	
Themes	**Number of Coded Responses**	**Percentage of Coded Responses**	**Number of Coded Responses**	**Percentage of Coded Responses**
Theme 1: Knowledge	7	13%	8	16%
Theme 2: Research	11	20%	7	14%
Theme 3: Intra-Personal Skills	13	24%	11	22%
Theme 4: Audience	10	19%	9	18%
Theme 5: Collaboration/Team Skills	13	24%	16	31%

The second open-ended question (Table 3) was coded into 12 different themes, which included both specific issues and sectors. Of particular note, the demographics theme contains all responses related to socio-economic status, geographic location, or poverty level. The education/research and development (R&D) contains responses about education from all levels, from public to industry education and research. Theme 8, which is policy/regulatory agencies contains policymakers, governmental agencies, regulatory agencies, and decision-makers. Theme 9 is a broad theme to include organizations outside of those that would be in Theme 8, and can include private sector, non-governmental organizations, watchdogs, and civil organizations.

Finally, Theme 12 was reserved for responses where the public should either have information distributed to them or be part of the policy process.

The range of responses did not vary significantly within the second open-ended question, but the mention of the pharmaceutical sector being included in the policy process increased from 7% to 13% when comparing the pre- and post-surveys. Responses for the inclusion of the AMR in the environment as an issue to be addressed, as well as a sector that should be included in AMR policy recommendations increased from 7% to 12%. Additionally, there was a drop in antibiotic use and overprescription as an issue that should be addressed when tackling AMR, dropping from 7% to just 2%. There was also a decrease in the mention of policy or regulatory agencies being involved in the process, dropping from 12% to 6%.

Table 3. Thematic Analysis of Open-Ended Question 2

Open-ended Question 2: What issues should be addressed when tackling AMR? What sectors and thus stakeholders should be included in AMR policy recommendations?				
	Pre-Survey		**Post-Survey**	
Themes	**Number of Coded Responses**	**Percentage of Coded Responses**	**Number of Coded Responses**	**Percentage of Coded Responses**
Theme 1: Public Health/Healthcare	16	19%	19	19%
Theme 2: Demographics	3	4%	0	0%
Theme 3: Agriculture/Animal Sector	10	12%	14	14%
Theme 4: Antibiotic Use and Overprescription	6	7%	2	2%
Theme 5: AMR Surveillance/ Wastewater	5	6%	10	10%
Theme 6: Education/R&D	6	7%	7	7%
Theme 7: Pharmaceutical Sector	6	7%	13	13%
Theme 8: Policy/Regulatory Agencies	10	12%	6	6%
Theme 9: Organizations	5	6%	6	6%
Theme 10: Economics	6	7%	4	4%
Theme 11: Environment	6	7%	12	12%
Theme 12: Public	4	5%	5	5%

The third open-ended question (Table 4) appeared only on the post-survey, as it asked specifically about the game and debrief. One-third (33%) of the responses indicated the players felt that working with people that have different perspectives or understanding that there are

many perspectives to think about when managing a large problem, such as AMR, was the most important aspect that they learned. Many responses also talked about how hard it was to negotiate or deliberate, and participants felt that they learned a lot about how policy deliberations are conducted. Very few responses were AMR specific, with only 6% of the responses mentioning how complex the problem of AMR is.

Table 4. Thematic Analysis of Open-Ended Question 3

Open-ended Question 3: Briefly, what is the most important thing you learned from the game and debrief?		
Theme	**Number of Coded Responses**	**Percentage of Coded Responses**
Theme 1: Role of Scientific Information	5	15%
Theme 2: Different Perspectives	11	33%
Theme 3: Deliberation Complexity	9	27%
Theme 4: Policy Process	6	18%
Theme 5: AMR Problem Complexity	2	6%

The final open-ended question (Table 5) asked about how the serious game was different from how they would otherwise learn. Almost one third (31%) of the responses mentioned that they felt that the role playing was unique and that this helped them grasp the information and points of the game more effectively. Players also mentioned that they found the game more engaging than other more common methods of teaching (28%) and that it was much better than reading (14%), which is one of the primary ways that they receive information.

Table 5. Thematic Analysis of Open-Ended Question 4

Open-ended Question 4: What made learning through the serious game different from how you otherwise learn?		
Theme	**Number of Coded Responses**	**Percentage of Coded Responses**
Theme 1: Scenario-Based Learning	5	17%
Theme 2: Role-Playing	9	31%
Theme 3: Negotiation	3	10%
Theme 4: Better Than Reading	4	14%
Theme 5: More Engaging	8	28%

Likert Scale Questions

Participants were asked the same seven Likert scale questions before and after the game with response choices ranging from one (strongly disagree) to five (strongly agree). The questions

focused on how much they thought scientific information guides discussions around the shaping of AMR policies and plans (LQ1); how much scientific information should guide discussions around policies and plans to tackle AMR (LQ2); how important it is that representatives from multiple government agencies are involved (LQ3); how important it is that stakeholders representing different interest groups are involved (LQ4); how much they thought that stakeholders' values, interests, and priorites guide discussions around policies and plans to tackle AMR (LQ5); how much should stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR (LQ6); and how confident they felt in their ability to synthesize, communicate, and deliberate about technical information (LQ7). This allowed us to gauge how their perspectives may have changed in two main areas: (1) the use of scientific information in political decision-making and (2) stakeholder involvement and influence.

Results from the two-tailed Wilcoxon signed-ranked test comparing pre- and post-survey data (Table 6) showed that two out of four of the questions oriented toward stakeholder involvement and influence in the deliberation process (questions LQ5 and LQ6) showed significant changes between the pre- and post-surveys (Table 6). After the game, there was a significant increase in participants' understanding of how much stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR (LQ5; $p = 0.038$) with the mean score increasing from 3.74 to 4.37 (Fig. 1). When asked about how much stakeholders' values, interests, and priorities *should* guide policies and plans (LQ6), post-survey results decreased significantly ($p = 0.025$) from 4.06 to 3.58 (Fig. 1). Although not significant, participants' confidence in their ability to synthesize, communicate, and deliberate about technical information (LQ7) increased notably ($p = 0.097$) from a mean score of 3.47 to 3.84 after taking part in the game.

Table 6. Results from two-tailed Wilcoxon signed-rank tests comparing pre- and post-game Likert scale survey data, including p-values, test statistics (W), mean pre- and post-survey response (x_1, x_2), pre- and post-survey standard deviation (s_1, s_2), and sample size (n). Data used for the analysis includes participants who took both the pre- and post-surveys.

Question	*p*	*W*	x_1	x_2	s_1	s_2	*n*
LQ1	0.2842	25.5	3.37	3.68	0.955	1.00	19
LQ2	0.5297	13.5	4.58	4.68	0.607	0.478	19
LQ3	1.000	1.5	4.79	4.79	0.419	0.419	19
LQ4	0.5877	17.5	4.63	4.53	0.597	0.612	19
LQ5	*0.03795	16	3.74	4.37	1.15	0.761	19
LQ6	**0.02475	40.5	4.06	3.58	0.802	0.902	18
LQ7	0.09727	15	3.47	3.84	1.12	0.688	19

*Significant increase from pre- to post-survey responses ($\alpha = 0.05$)

**Significant decrease from pre- to post-survey responses ($\alpha = 0.05$)

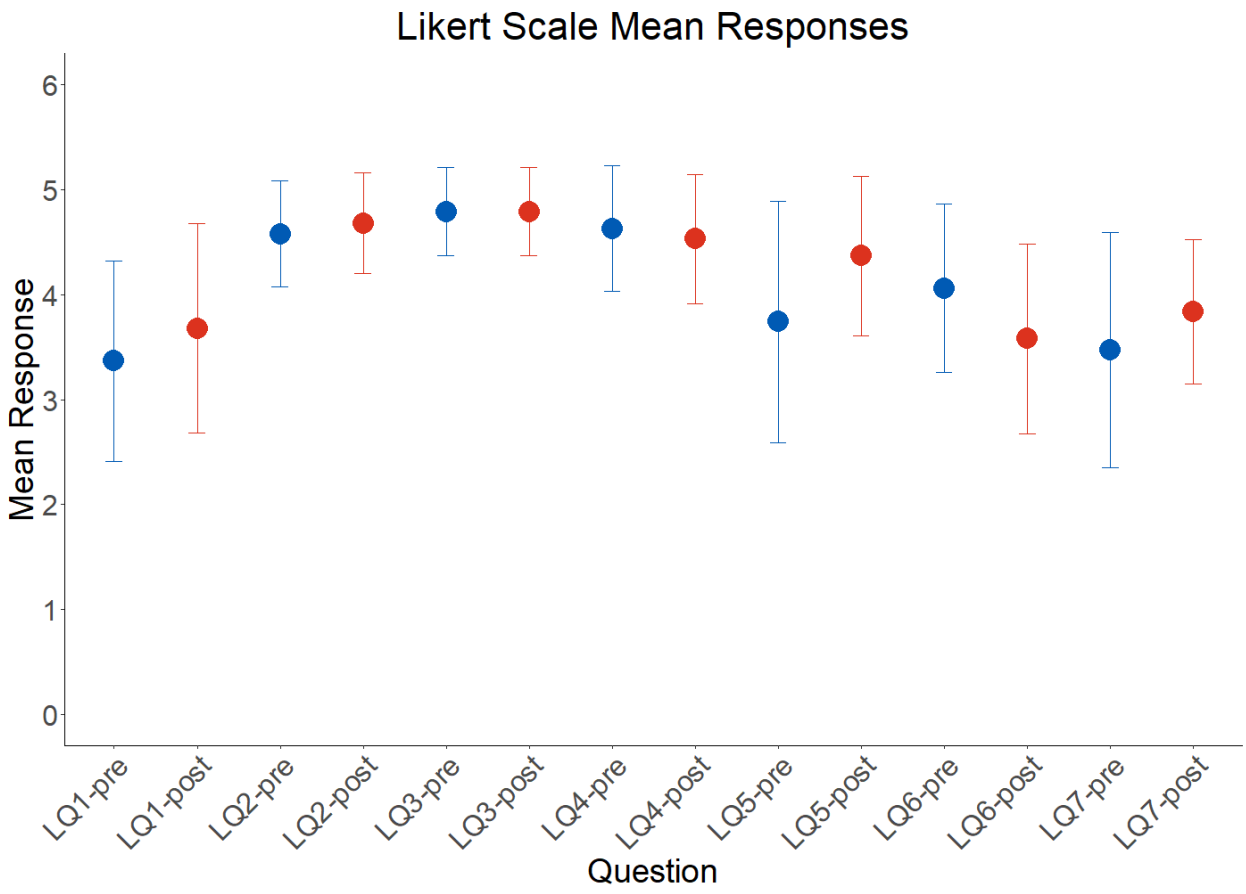

Figure 1. Mean responses with standard deviation for Likert scale questions LQ1-7, highlighting changes between pre- and post-survey reponses. These data include only participants who took both the pre- and post-surveys. Significant differences occurred between pre- and post-survey responses for LQ5 ($p = 0.038$) and LQ6 ($p = 0.025$).

In addition to questions that were asked on both the pre-and post-survey, LQ8 through LQ11 were asked to assess the perceived level of learning of the participants. Participants were asked to rate on a scale of one to five, how well the game increased their understanding of: how stakeholders approach the issue of AMR (LQ8); how scientific information is used in the deliberation process on how to address AMR (LQ9); how to synthesize communicate, and deliberate about technical information with various stakeholders (LQ10); and the basics of AMR and the roles it playes in various contexts (LQ11). The means ranged from 4.26 to 4.58 with standard deviations ranging from 0.11 to 0.17, indicating that most of the responses on all of the questions were either a 4 or a 5.

Table 7. Descriptive statistics of Likert scale post-survey questions LQ8-11

Question	Mean	Median	Mode	Standard Deviation
LQ8	4.68	5	5	0.11

LQ9	4.58	5	5	0.14
LQ10	4.26	4	5	0.17
LQ11	4.58	5	5	0.14

Discussion

The most significant results were around questions LQ5 and LQ6, which ask about participants' opinions on how much stakeholders' values, interests, and priorities currently do and should guide policy discussions. These findings are also consistent with responses to open-ended question 4. Participants' experiences in the game led to an increase in their understanding of how much stakeholders' values, interests, and priorities guide policy discussions, and to a decrease in the degree to which they think stakeholders' values, interests, and priorities *should* guide discussions. This outcome was an unintended consequence of the game as one of the goals of the game was to appreciate the value of engagement and participation. This may come, in part, from the idea that scientists should remain objective throughout the process, thus framing incorporating interests and values as negative.

Participants also expressed surprise and concern around how little scientific information was used during policy deliberations, because stakeholder values, interests, and priorities tend to dominate the negotiation process when making policy decisions. This confirms that the game was successful vis-a-vis learning objectives 1 and 2, which points to how science is or is not used within policy deliberations, as well as how it could be misinterpreted or misused to confirm a particular position or interests. Throughout the open-ended questions, participants consistently talked about how scientific or technical information was often "cherry-picked" or chosen to ensure that it supports their stakeholder's position.

Beyond the use of science, learning objective 3 aims to advance players' abilities to synthesize, deliberate, and communicate about technical information. The results of survey question LQ7, using a Wilcoxon signed-rank test, are not significant at the $p \leq 0.05$ level, but are statistically significant at the $p \leq 0.1$ level. Given that this is the first full study of *Combating the Spread of Antibiotic Resistance*, we must not ignore this result. Furthermore, participants reported, on a scale of one (strongly disagree) to five (strongly agree), that the game helped them synthesize, deliberate, and communicate about technical information with a mean response of 4.26. There were several changes from the pre-survey to the post-survey on open-ended question 1. One of the most surprising changes was that participants felt like research skills were less important, while collaboration and team skills were more important. This demonstrates that the participants gained understanding of the types of skills that are needed to deliberate about technical information, especially in the presence of multiple stakeholders.

Furthermore, many of the participants felt that this game was useful in understanding how to work with individuals that have different perspectives and priorities than their own, as represented by many of their responses to open-ended question 3. One-third (33%) of the coded responses contain a direct connection to how the players enjoyed that there were varying perspectives from stakeholders in all sectors of AMR. Participants also noted that, while it was difficult to work with individuals who have different perspectives from their own stakeholder's, it was useful to understand how to deliberate with them. This was the main goal with learning objective 6, and it was one of the main underlying themes when considering the development of the game. This learning objective is also directly tied to learning objective 3, which further supports the success of both learning objectives.

The final two learning objectives are specific to the AMR space, looking at the basic knowledge increase of participants about AMR and the different types of stakeholders that work within this policy space. Question LQ11 in the post-test specifically targeted these two learning objectives and achieved a mean rating of 4.58, indicating that many of the participants felt that they learned about the AMR policy arena. Also, open-ended question 2 looked into the types of stakeholders and issues that participants felt should be addressed in policy. There was a noticeable increase in the number of responses that included environmental issues and sectors, the pharmaceutical industry, and AMR wastewater monitoring and surveillance. There was also a decrease in the number of responses that indicated regulatory agencies and the government, which suggests that the participants are including a diversity of stakeholders and issues. This addresses both of the learning objectives as a concrete understanding of foundational knowledge is required to encapsulate the scale of the AMR problem, as well as the types of stakeholders and issues that need to be included to adequately address this problem.

Implications

This study demonstrates that serious games can effectively educate participants about policy deliberations on AMR. This study also shows that negotiation-style serious games are useful in developing skills needed to deliberate about technical information and educate about the policy process at large. Serious games are multi-faceted in that they are useful in not only showing, but encouraging stakeholder engagement, development and implementation of science- informed policy and demonstrating the usefulness of science within a policy context. It also explores, in real time, the challenges of decision-making and how complicated large issues can be. Role-playing games can explore the multifaceted nature of a problem that may be inaccessible if they were just being read about. Outside of academic and research domains, serious games have the potential to facilitate participatory policy-making by allowing both stakeholders and decision-makers to have a seat at the table to develop and evaluate potential policy solutions in a simulated environment.

Furthermore, implementing serious games into curricula can bridge the gap between STEM education areas, such as the participants in our game, with the process of policymaking. STEM areas are becoming increasingly more interconnected and transdisciplinary [19], and it is becoming necessary for engineers and scientists to have a more nuanced understanding of policy and policymaking surrounding their fields. Policymakers require more information to make both ethically sound and science-informed policies [20]. Serious games allow an interactive learning approach to bridge these two areas, stimulating critical thinking and equipping young and future professionals with the skills needed for more effective decision-making. However, it is important to be aware that, in order to gain these learning outcomes, the game needs to be designed effectively with diverse stakeholder perspectives, effective and substantial worldbuilding and representation of complex issues, and a focus on accessibility and inclusivity. Serious games can move beyond strict disciplinary boundaries and positively impact both policy and STEM education.

Limitations

Not all participants who completed the pre-survey also completed the post-survey. However, when analyzing pre-survey responses of participants who only took the pre-survey ($n = 10$) and participants who took both the pre- and post-survey ($n = 19$), responses for six out of the seven questions showed no significant difference ($p > 0.05$). This indicates that omitting pre-survey responses from participants who did not take the post-survey likely had little to no impact on the trends seen in our results. Only question LQ1 showed a significant difference between pre-survey responses ($p = 0.0203$). However, for participants that took both the pre- and post-surveys, responses for LQ1 exhibited no significant difference (Table 6), indicating that the significant difference between LQ1 pre-survey responses likely had minimal impact on the final results.

Additionally, this study consists of a single focus event, serving as an exploratory analysis investigating different learning strategies and outcomes from a single serious game. Our results came from a relatively small sample size of 19 or 18 participants depending on the question. Additionally, the choice of individuals who already have an interest in both science and policy may have impacted the results. Nevertheless, the results highlight key trends, including an increased understanding of the roles that different stakeholder groups play, as well as the importance of stakeholder perspectives during AMR policy deliberations. Lastly, conducting this study on another focus group, particularly one composed of participants previously unfamiliar with AMR or those that do not have a prior interest in policy, could strengthen our results or possibly lead to different outcomes.

Conclusion

In this study, we have demonstrated that a negotiation-style serious game was effective in teaching individuals in the STEM arena about AMR policymaking and increasing their ability to synthesize, communicate, and deliberate about technical information. Specifically, participants learned about the role of stakeholders in the AMR policymaking process, the role that science can play in policymaking, and how values can influence policy deliberations. Overall, participants had a positive experience with the game, citing that it changed the way that they look at the AMR problem. Future directions of this research include working with different audiences to educate about science-informed policy and to tweak the game to place heavier emphasis on the role of science in policy, though this still remains a vital piece of current gameplay. Science and engineering research remains critical in the process of science informed policy. Serious games have the potential to change how policy is presented to individuals associated with and within the policy domain.

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Appendix A- Observation Protocol

CIP-CAR Game Group Observation - Table #[INSERT TABLE #]

Your name (observer): [NAME]

People at table: [NAME], Human Health Agency (HH); [NAME], Agricultural Agency (AA); [NAME], Environmental Conservation Agency (EC); [NAME], PHARMA (P); [NAME], Farmers United (FU); [NAME], One Health America (OHA); [NAME], American Healthcare Association (AH); [NAME], Responsible Care Campaign (RCC)

Protocol instructions: This document should be used to systematically capture your observations of a group participating in the *Combating the Spread of Antibiotic Resistance: Second Meeting of the Federal Antibiotic Resistance Task Force* role play simulation exercise. The goal is to document how the deliberations unfold–including key inflection points (e.g., statements made that seem to change the direction of the conversation), facilitative interventions, and how information is used–and your reflections on what led to the outcomes the group reached. Please use the acronyms above when ascribing an action or statement to a particular party (e.g., *FU passionately expressed that the food supply would be threatened if option X were chosen*). Note that this template has two parts: The first should be used in real-time as the deliberations unfold. The second is a space for you to reflect later (but no later than six hours after the conclusion of the session).

OBSERVATIONAL NOTES (in real-time during the exercise):

- Please insert quotes, general statement summaries, notes on when information is introduced/used and how, actions parties' take, interventions the facilitator makes, etc.

REFLECTIVE SUMMARY (to be completed within six hours post-exercise):

- What outcome did the group arrive at (whether a consensus recommendation or not)?
- Looking back, what were the key inflection point(s) that led to this outcome?
- Were some parties more or less active? How did this influence the outcome?
- Did parties employ different tactics? How did those different tactics influence the outcome?
- What role did the facilitator play in both the process and shaping the outcomes?
- How did the group use the technical information provided (or not)?

Appendix B- Pre- and post- Survey Questions

Pre-survey

Through this form, we ask you to consent to participate in the pre- and post-workshop questionnaire and focus group for antimicrobial resistance serious game research, which is associated with the Antimicrobial Resistance Serious Game (VT IRB #23-813). We are seeking your consent to fully participate in pre- and post- workshop questionnaire and a focus group which would include playing the game at the CIP-CAR NRT workshop. You should have received an Information Sheet for Participation in this Research Study via email, outlining our plans and protocol for the use of your data. We ask you to please review it before providing your consent. If you have any questions about this request please contact Todd Schenk at tschenk@vt.edu.

Name

Email Address

I hereby provide my consent to participate in the Antimicrobial Resistance Serious Game Research, in accordance with the protocols outlined in the Information Sheet for Participation in this Research Study.

1. Yes
2. No

I consent to being video recorded during the focus group portion of this study.

1. Yes
2. No

Thank you for your willingness to participate in the Antimicrobial Resistance Negotiation Game. We kindly ask you to complete this pre-game questionnaire.

Please answers these questions by moving the slider, ranging from 1 to 5. 1 indicates not at all, and 5 indicates very

How much do you think scientific information guides discussions around the shaping of AMR policies and plans in practice?	❑
How much should scientific information guide discussions around policies and plans to tackle AMR?	❑
How important is it that representatives of multiple government agencies (e.g., health and agriculture) are involved in discussions around policies and plans to tackle AMR?	❑
How important is it that stakeholders representing different interest groups (e.g., the pharmaceutical industry, the agriculture sector, environmental groups) are involved in discussions around policies and plans to tackle AMR?	❑
How much do you think stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR?	❑
How much should stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR?	❑
How confident do you feel in your ability to synthesize, communicate, and deliberate about technical information?	❑

What skills are needed to effectively synthesize, communicate, and deliberate about technical information?

What issues should be addressed when tackling AMR? What sectors and thus stakeholders should be included in AMR policy recommendations?

Post-survey

Thank you for participating in the Antimicrobial Resistance Game and workshop. Through this form, we ask you to complete the post-workshop questionnaire, which is the last step in this research. This form should take you no more than 20 minutes. We thank you for your participation.

Name

Email Address

Thank you for your willingness to participate in the Antimicrobial Resistance Negotiation Game. We kindly ask you to complete this post-workshop questionnaire.

Please answer these questions by moving the slider. 1 indicates not at all, and 5 indicates very.

How much do you think scientific information guides discussions around the shaping of AMR policies and plans in practice?	❑
How much should scientific information guide discussions around policies and plans to tackle AMR?	❑
How important is it that representatives of multiple government agencies (e.g., health and agriculture) are involved in discussions around policies and plans to tackle AMR?	❑
How important is it that stakeholders representing different interest groups (e.g., the pharmaceutical industry, the agriculture sector, environmental groups) are involved in discussions around policies and plans to tackle AMR?	❑
How much do you think stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR?	❑
How much should stakeholders' values, interests, and priorities guide discussions around policies and plans to tackle AMR?	❑
How confident do you feel in your ability to synthesize, communicate, and deliberate about technical information?	❑

Please answer these questions by moving the slider. 1 indicates not at all, and 5 indicates very. The workshop (serious game and debrief) enhanced your understanding of:

The ways in which different stakeholders approach the issue of antimicrobial resistance (AMR)	❑
How scientific information is used within a policy deliberation on how to address AMR	❑
How to synthesize, communicate, and deliberate about technical information with various stakeholders	❑
The basics of AMR and the roles it plays in various contexts	❑

What skills are needed to effectively synthesize, communicate, and deliberate about technical information?

What issues should be addressed when tackling AMR? What sectors and thus stakeholders should be included in AMR policy recommendations?

Briefly, what is the most important thing you learned from the game and debrief?

What made learning through the serious game different from how you otherwise learn?

Appendix C- Focus Group Questions

- Talk about how you used scientific information in your groups' deliberations.
- Were there any instances of misrepresentation of science or bias in your groups' deliberations? How did that impact the negotiation?
- How did having the Antibiotic Resistance Technical Report impact the negotiations? Do you think it helped or hurt? Was all the information presented in this report unbiased? If not, in what way do you think it was biased?
- Have your opinions about what should be included in AMR policies changed from before the game?
- What elements drove forward or brought the negotiations to a standstill?
- What impact did values of the stakeholders have in the negotiations? How were any significant value differences managed?
- How did you decide on the final policy recommendations? Were there any "packages" made or coalitions formed?
- What do you think about the outcome of the deliberation process? Would your group have been happy with the outcome?