Article

Not peer-reviewed version

DIVULSUPERBAC: A Service Learning Project to Raise Awareness of Antimicrobial Resistance

Sergi Maicas * and Belén Fouz *

Posted Date: 19 June 2024

doi: 10.20944/preprints202406.1376.v1

Keywords: Antibiotics; Antimicrobial resistance; Service Learning; Superbugs

 doi:10.20944/preprints202406.1376.v1

Article

DIVULSUPERBAC: A Service Learning Project to Raise Awareness of Antimicrobial Resistance

Sergi Maicas [1,*] and Belén Fouz [2,*]

[1] Departament de Microbiologia i Ecologia (Universitat de València)
[2] Departament de Microbiologia i Ecologia and Institute BIOTECMED (Universitat de València)
* Correspondence: sergi.maicas@uv.es (S.M.); belen.fouz@uv.es (B.F.); Tel.: +34-963543214 (S.M.); +34-963543104 (B.F.)

Abstract: Divulsuperbac (DSB) is a Service Learning project targeted at the educational community. It started in 2019 and has engaged Biology degree students in a Microbiology-focused initiative in the Valencian Community (Spain), for four academic years. The DSB project comprises various outreach activities intending to raise awareness of the superbugs' threat to pre-university students. We created an exhibition that contained 14 infographics on the topic of antimicrobial resistance which was presented every week in high schools. The infographics were presented by university students, who explained the problem to the pre-university students and subsequently assessed their comprehension of the topic. The surveys conducted yielded satisfactory results, which motivated us to extend this project to other regions of the world.

Keywords: antibiotics; antimicrobial resistance; service learning; superbugs

1. Introduction

Antimicrobial resistance (AMR) is a growing global threat to health and social development. Mitigating its harmful effects is an arduous task that requires the involvement of different sectors, as a matter of urgency, to achieve the Sustainable Development Goals (SDGs) [1,2]. The WHO has declared AMR to be one of the top 10 global public health threats facing humanity, and action on different fronts is crucial. The scientific community agrees that both the misuse and overuse of antimicrobials are the main contributors to the development of pathogens resistant to today's drugs [3,4]. Lack of safe water and sanitation and inadequate infection prevention and control favour the spread of microbes, some of which may be resistant to antimicrobial treatment [5,6]. The cost of AMR to the economy is significant. In addition to death and disability, it prolongs the time of suffering from the disease, with longer hospital stays, requires more expensive drugs and creates financial problems for those affected [6,7]. Everyone should be aware that without effective antimicrobials, the success of modern medicine in treating infections, including during major surgery and cancer chemotherapy, is compromised. The risk of being affected by this will increase if we do not hedge against its uncontrolled development [8,9]. The DIVULSUPERBAC project encompasses a series of outreach activities aimed at transmitting information about a health problem of growing importance, the threat of superbugs, among pre-university students in the Valencian Community (Spain). The two main objectives of this project are: a) to involve university students from the Faculty of Biology of the Universitat de València (UV), who will act to stimulate the vocation of pre-university students for scientific training/research in Experimental and Health Sciences, and b) to raise awareness among the educational community (students, teachers, families) about the health problem posed by bacteria that are multiresistant to antibiotics [2,10,11]. The project involves university students in a Service Learning (SL) activity [12], which continues previous activities carried out by members of our team, Small World Initiative-Tiny Earth-MicroMundo [13]. These projects focused on bringing scientific culture and biomedical research closer to HS students using a crowdsourcing strategy to isolate antibiotic-producing microorganisms [14] and laid the foundations for DIVULSUPERBAC. Every academic course, since 2019/20, the activity begins with World Antimicrobial Awareness Week (WAAW), which is held in November. WAAW is a global campaign that aims to raise awareness of antimicrobial resistance worldwide and encourage best practices among the general public, health workers and

 doi:10.20944/preprints202406.1376.v1

policymakers to slow the development and spread of drug-resistant infections. This project aims to disseminate, in a didactic way, information about superbugs in the form of infographics among pre-university students. The proposal represents the consolidation of a teaching innovation network in which teachers from the UV participate, involving Bachelor's/Master's degree students and pre-university teachers and students. The SL activity, in which the dissemination and training tasks are carried out by a group of volunteers or a community (university students coordinated by professors from the Department of Microbiology and Ecology of the UV) has had the invaluable collaboration of teachers from High Schools (HS) in the Valencian Community.

2. Materials and Methods

2.1. Exhibition: Conception and Preparation of Infographics

An effective approach to raising awareness within society about the problem of Antimicrobial Resistance (AMR) is through the creation of infographics. Infographics are visual representations of information or data designed to present complex concepts or data clearly and concisely. They combine text, images, charts, and other graphical elements to effectively communicate information and engage the viewer.[15–17]. A collaborative and sequential approach was formulated, involving a group of partners working together (Figure 1).

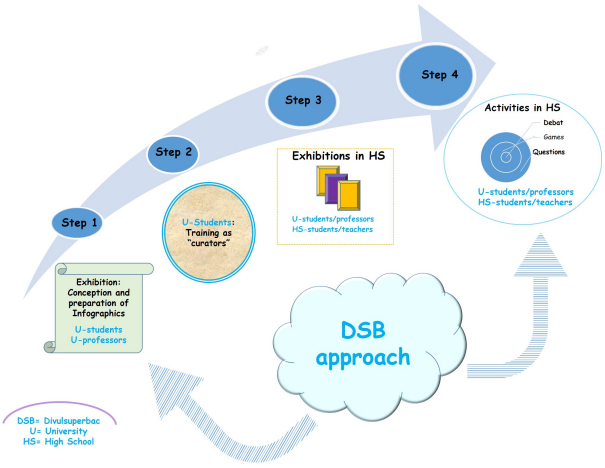

Figure 1. Scheme of Divulsuperbac approach involving different educational levels in the Valencian Community.

A total of 14 infographics (Table 1) were created by 3-4 students of the Biology degree (2018/19) during the academic year 2018/19 as part of their coursework in Microbiology, within the Biology program at the Universitat de València in Spain.

Table 1. List of infographics included in the exhibition.

Code	Title
01.	The threat of multi-resistant bacteria to antibiotics
02.	How much do you know about antibiotic resistance?
03.	How did we get here?
04.	ESKAPE
05.	One health
06.	Rebellion in the hospital!
07.	Antibiotics: from the farm to the plate
08.	Problems of antibiotics in agriculture
09.	Intestinal dysbiosis: a serious unknown problem
10.	Microbial resistance in the main sexually transmitted diseases
11.	It will take your breath away! Tuberculosis
12.	Alternatives to antibiotics
13.	Economic impact of antimicrobial resistance
14.	And you, what can you do against microbial resistance?

 doi:10.20944/preprints202406.1376.v1

Each infographic was prepared by an initial group of three-four students. Subsequently, each infographic was reviewed by two other groups of students in successive rounds, and finally by the subject teachers.

2.2. Participants and Partner High Schools

University professors responsible for the project contacted the network of teachers who had participated in previous innovative projects (October-November), as well as other teachers who had expressed interest in the exhibition. The option to join was also publicised among university students. Subsequently, a calendar of weekly exhibition dates was scheduled between February and May of each year. Every year, the infographic exhibition is first exhibited in the WAAW, which contributes to some students joining the campaign. In the following phase (December -January) the Universitat de València (UV) teaching staff, supported by the junior monitors, train the students on the activities to be developed (1-day workshop per group of 20 students). Lastly, groups of two to three students with their junior monitor and their tutor (UV teacher) go to the HS and carry out the outreach and training action (Figure 1).

2.3. Activities in High Schools (HS)

The university students were distributed among the HS, acting as curators of the exhibition in pairs. They were given the contact details of the HS teachers who had requested the exhibition so that they could outline and agree on the activities to be carried out during the week. The basic activities were the assembly/disassembly of the panels in the HS and a guided visit with the HS teacher in charge. In addition, the curators proposed a series of complementary activities. Assembly and guided visits to the Infograms exhibition with the university monitors and the teacher responsible for the group/groups of pre-university students (from several levels and several subjects) are foreseen. The exhibition remained in each HS for 1-2 weeks. Then, we hold a debate at the HS on the problem of bacterial resistance and its socio-economic impact. Finally, interactive tools (question/answer, software Kahoot, games) to assess the understanding of the exhibition were carried out. This activity involved a direct collaboration between university and pre-university students, as well as teachers from both educational levels.

2.4. Design of Surveys and Evaluation Procedure

Once the activity was over, three types of anonymous surveys were carried out aimed at pre-university students (Appendix A1), teachers (Appendix A2), and exhibition curators (university students) (Appendix A3) to assess the level of satisfaction of all the participants.

The surveys consisted of different blocks and with responses based on a Likert scale of 5 values, with 1 being the most negative and 5 the most positive [18]. This scale was used to measure the attitudes, opinions and perceptions of the different participants in relation to the problem of bacterial resistance to antibiotics and whether carrying out these practices could improve their knowledge and awareness of a real problem, as well as increase their interest in science. An open block was included to provide opinions and make proposals to improve the activity. The surveys of HS students consisted of three closed blocks to evaluate their opinion on the scientific interest of the project, emphasizing the concept of resistance to antibiotics and other general aspects of the project. The survey was based on previous models developed to evaluate different aspects of the SWI-Tiny Earth/MicroMundo projects in the US and the Iberian Peninsula [19]. The surveys of HS teachers consisted of two closed blocks on the interest of the project for their students and their personal opinions. The commissioners of the activity-filled out a survey in which they were consulted on scientific interest, antimicrobial resistance and work in the centers).

Moreover, we concurrently created an online survey utilizing the Google Forms tool [20]. The anonymous questionnaire comprised 13 questions, encompassing not only scientific inquiries but also personal ones. This approach allows us to categorize the outcomes according to sociological data, in

 doi:10.20944/preprints202406.1376.v1

addition to the scientific aspects. The form was written in Spanish, since it is the language in which we thought we could obtain a greater number of responses. Further, the results were translated into English for publication purposes.

3. Results

The appearance of super-resistant bacteria is one of the main threats facing humanity in the 21st century. One of the strategies to combat this phenomenon focuses on disseminating the problem among society to raise awareness of the problem at all levels.

3.1. Dynamics of the Activities

One of the strategies developed by our group has focused on the development of different explanatory panels in large formats. The exhibition was distributed in 23 HS in the Valencian Community during the academic years 2019-2023 (Figure 2).

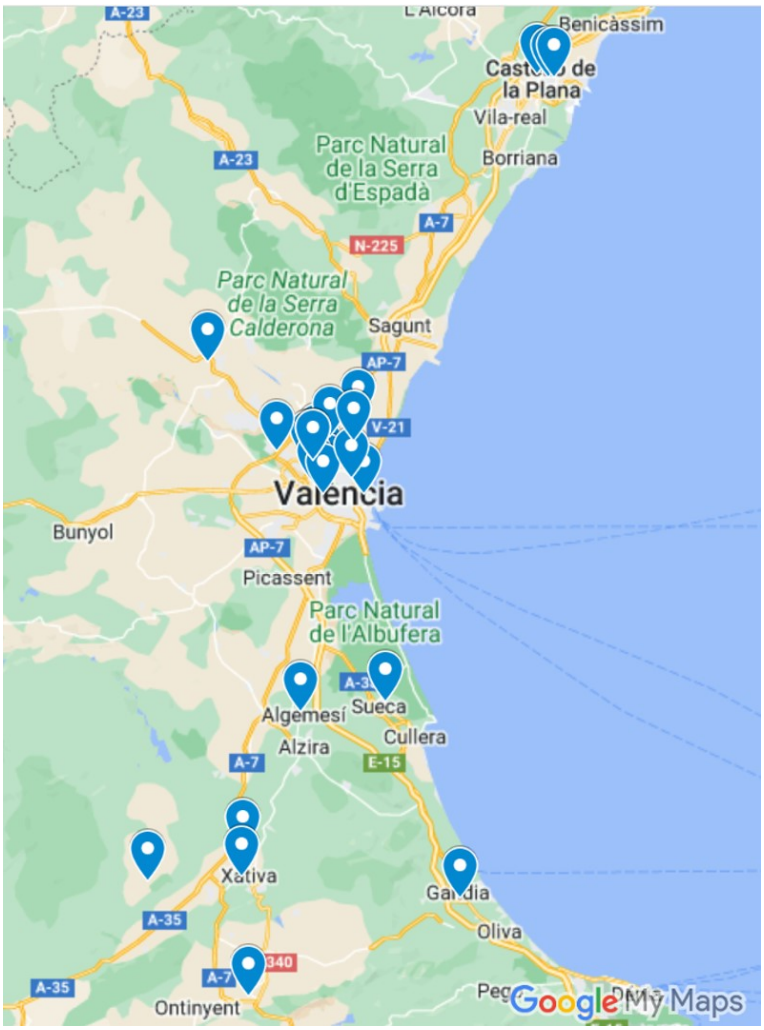

Figure 2. Location map of high school participants in Divulsuperbac activities in the Valencian Community.

During 1-2 weeks the infographics were exhibited in the common rooms of the HS to reach visibility (Figure 3).

 doi:10.20944/preprints202406.1376.v1

Figure 3. Examples of exhibition setup in different high schools.

The high school professors visited the exhibition and explained briefly to their students the main contents. Further, the students can visit it at free time, and also download the complete pdf series on their own convenience. More than 2500 students visited the exhibitions. The results of the satisfaction survey show that participation in this project has helped to increase interest and curiosity in science, which is declining in Europe. According to Eurobarometer 55.2, the lack of interest in science among Europeans over 15 years of age is attributed to the unattractiveness of science classes (59%) and a poor image of science in society (30%), which is even more noticeable for women (https://europa.eu/eurobarometer/screen/home). Girls think that the science they study at school is not useful for their daily lives, so the practical aspect of science seems to be an important factor to take

 doi:10.20944/preprints202406.1376.v1

into account [21]. This practical aspect is addressed in this project and the satisfaction survey supports the approach to a real problem. It, therefore, makes visible the service of science to society and shows knowledge from a practical, attractive and useful perspective. Unlike in the United States, Spain and other European countries, the decision to follow a scientific path is made during the baccalaureate, as the curricula of higher education degrees are not openly flexible.

For this reason, this study has been carried out in the fourth year of compulsory secondary education (students aged 15-16) because, from this year onwards, they will be able to choose humanities or science pathways that will condition their choice of career and professional future. This project can therefore help to inspire scientific vocations.

In a second line of action, this experience ensures that students improve their knowledge and awareness of antimicrobial resistance, statistically demonstrated in this study by the questionnaire analysis, and supported by other studies that used practical activities [22]. This is important to overcome students' ignorance about the exclusivity of antibiotics in killing bacteria, and their usefulness in treating infectious diseases [23]. In this study, students claim that antibiotics should be used only in case of bacterial infection and not in cases of influenza. Today, more than ever, in this state of alarm, one-way, comprehensive, appropriate and practical education that reaches all students is required, both for their own health and for the safety of society. This research can help the new National Plan against Antibiotic Resistance [24], which includes antibiotic resistance education in early childhood (0-6 years), primary (6-12 years) and high school (12-18 years). It is therefore important to work on more complete and current content, which should include the study of microorganisms [25], their relationship with infectious diseases, co-responsibility in their treatment and the problem of antibiotic resistance.

3.2. Evaluation of the Activities

Once the different activities were completed, specific questionnaires were provided to the participants so that they could evaluate them anonymously (academic surveys). In the case of the broad public one (online survey), these were distributed by email, and mobile applications (Whatsapp groups and others) to have the widest possible distribution.

3.2.1. Academic Survey

The final point of the activities carried out in HS was the completion and subsequent analysis of surveys (Figure 4a). The surveys were completed by 680 students and allowed us to determine their scientific perception of the exhibition, which was rated around 3.5/5 (blue bars A1-A4), the knowledge acquired about antimicrobial resistance 3.75/5 (orange bars A5-A7), and other related aspects 4/5 (black bars A8-A9).

The results obtained from surveys completed by HS teachers scored around 4.5/5 regarding the perception of students' learning and their interest in the project (conference, exhibition, and final game). Their opinion was nearly 5/5 (Figure 4b).

The evaluation of the curators was the most complex process. The 57 surveyed curators rated their scientific interest with values higher than 4.5/5 (Figure 4c, blue bars). The same occurred regarding their knowledge about antimicrobial resistance (orange bars). Their self-assessment of the activities in the HS and collateral aspects also scored around 4.5/5 (black and gray bars) (Figure 4c).

 doi:10.20944/preprints202406.1376.v1

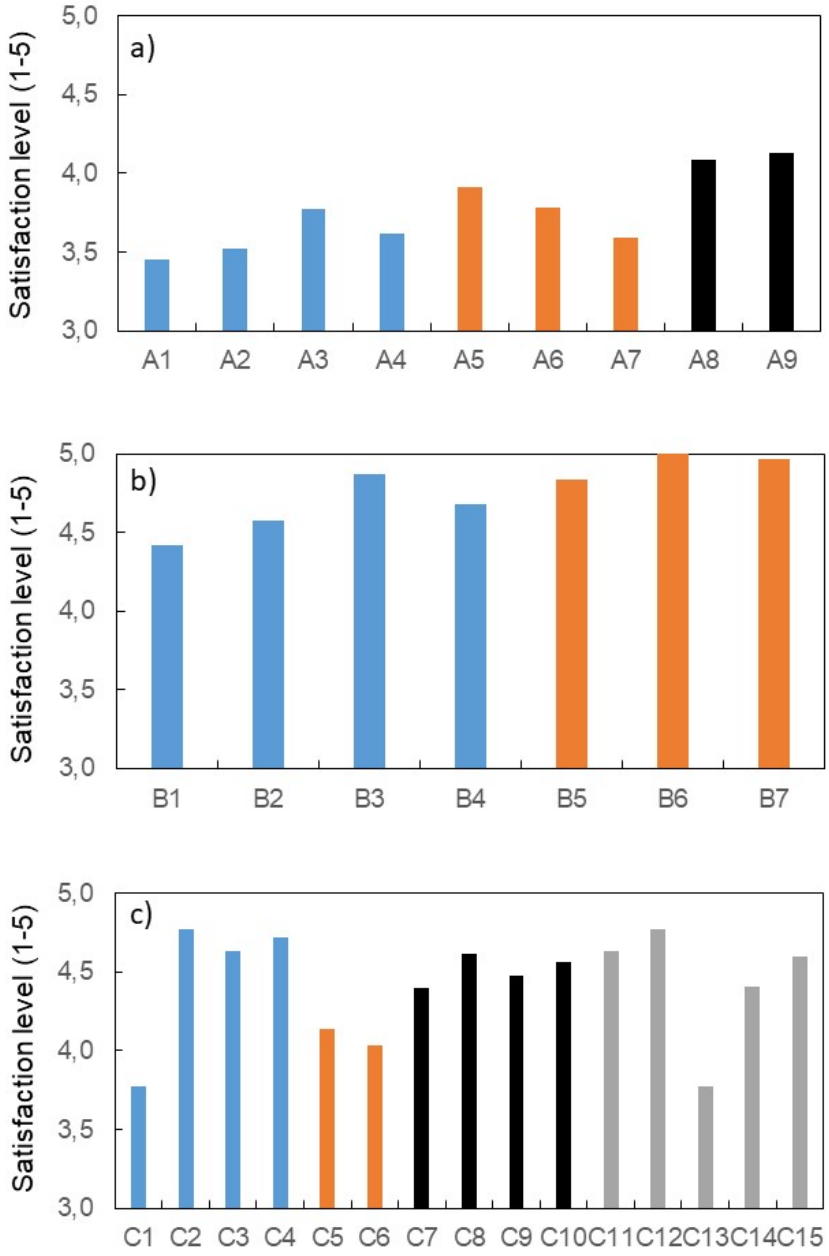

Figure 4. Results of the Likert surveys from the different groups evaluated. The bars have been represented in different colours for each group of questions on similar topics: a) high school (HS) students: blue (scientific interest), orange (antibiotic resistance), black (others); b) HS teachers: blue (students learning and interest), orange (personal opinion); c) exhibition curators (university students): blue (scientific interest), orange (antibiotic resistance), black (performance at the HS) and gray (others).

3.2.2. Public Survey

The questionnaire was completed by 785 people, distributed among different age ranges (Figure 5a). The purpose was to obtain data from a heterogeneous population representative of broad social groups, with varying levels of knowledge (Figure 5b). Almost the whole population surveyed admitted to have consumed antibiotics during their lives (96.6%) (Figure 5c) and have got them by prescription (93.0%) (Figure 5d). The majority of participants completed the treatment, following their doctor's prescriptions (82.5%) (Figure 5e). However, small group (8.7%) openly admit that they had not finished the treatment, generally due to the improvement during the first days (Figure 5f). Unconsumed

 doi:10.20944/preprints202406.1376.v1

antibiotics were regularly discarded (35.8%), but some people recognized that they were stored at home if some pills were not used (55%) (Figure 6g). However, consumers know where and how leftover antibiotics should be recycled (82.2%) (Figure 6h). Almost half of the participants (43.7%) were not aware that antibiotics are also used in veterinary medicine (Figure 6i).

The consequences of the reckless use of antibiotics are not known. In fact, the majority of respondents (60%) underestimate the number of deaths derived from it (Figure 6j). Likewise, the economic cost of such practice (extra hospitalization expenses and collateral damages) was underestimated (Figure 6k).

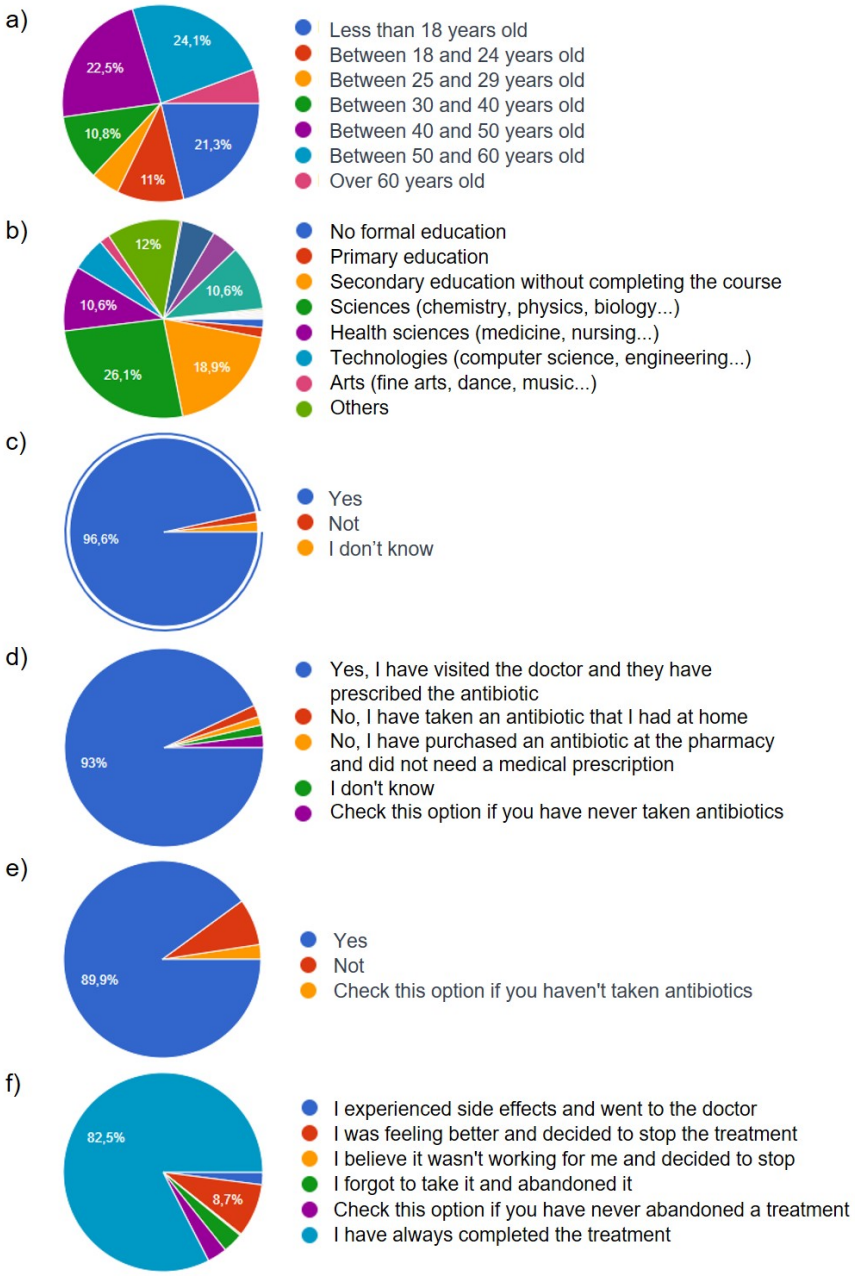

Figure 5. On-line survey on the awareness of the use of antibiotics. a) How old are you?, b) What is your level and area of education, if any?, c? Have you ever taken antibiotics to treat an illness?, d) If the answer was affirmative, did you acquire this antibiotic under medical prescription?, e) have you completed the treatment?, f) If the answer is negative, why?

 doi:10.20944/preprints202406.1376.v1

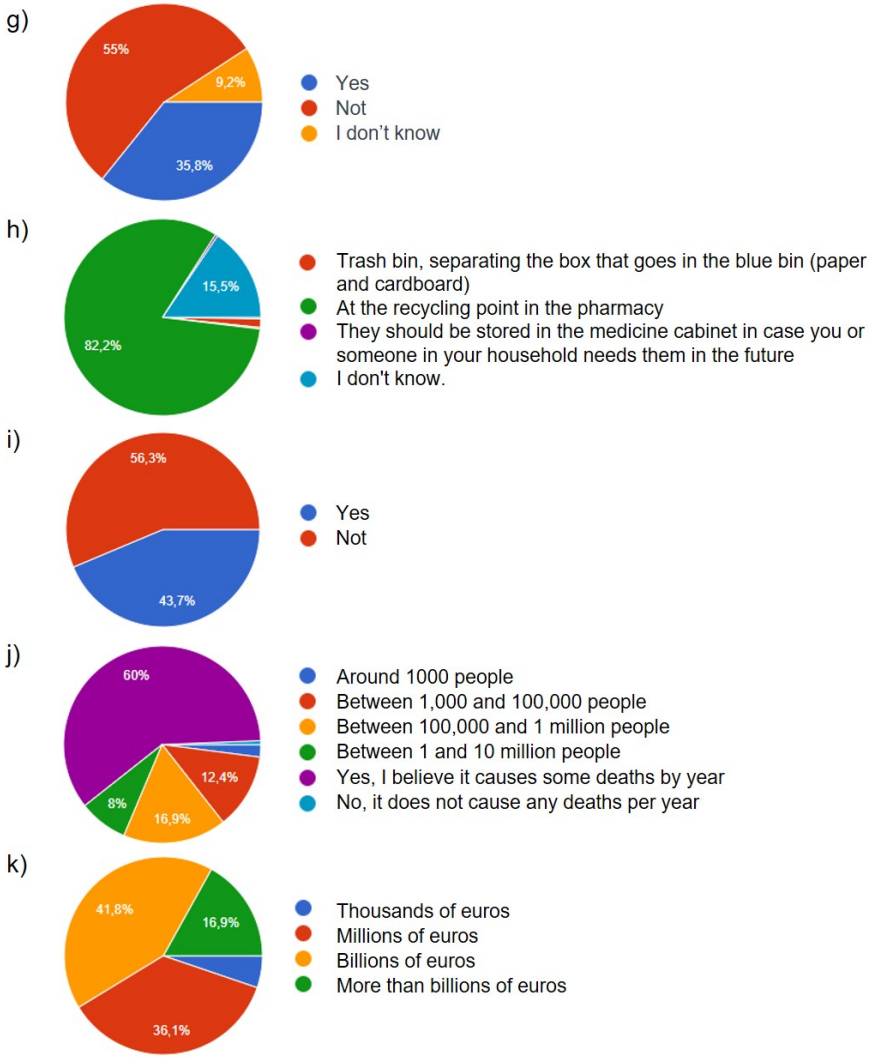

Figure 6. Continuation of Figure 5. g) Do you have leftover boxes of antibiotics at home?, h) do you know where expired drugs should be recycled?, i) do you think that antibiotics can be used for the treatment of diseased animals?, j) do you know the mortality levels associated to the reckless use of antibiotics, K) Which is the cost of overconsuming antibiotics?

4. Discussion

Antimicrobial resistance (AMR) has emerged as a major global health challenge in the XXI century. It poses a significant threat to public health, agriculture, animal husbandry, and the economy worldwide [2,5–7,26]. The overuse and misuse of antibiotics and other antimicrobial drugs in humans and livestock have fuelled the rise of resistant bacteria, rendering once-effective treatments ineffective [27–29]. The consequences of this attitude are increased morbidity and mortality, healthcare system burden, and significant economic losses. Any strategy aimed at combating antimicrobial resistance should be embraced. While disease prevention, control measures, and the research and development of new therapeutic strategies are crucial, enhancing antibiotic stewardship must not be overlooked. Prioritizing the promotion of responsible antibiotic use through educational and awareness campaigns is imperative. Implementing inter-generational citizen campaigns could effectively reduce unnecessary antibiotic consumption. In response to this need, we have developed an affordable program targeting young students to raise awareness about antibiotic misuse [13]. The Divulsuperbac (DSB) initiative introduces an innovative approach that engages university students in dissemination activities within

 doi:10.20944/preprints202406.1376.v1

the pre-university community. This initiative can be categorized as a Service Learning (SL) strategy with significant social impact, as it establishes a direct link between the university and citizens, bridging the gap between educational levels. One of its key strengths lies in the application of new methodologies and innovation in face-to-face teaching. In this initiative, university students serve as curators of an infographic exhibition on the topic of AMR and facilitate gaming activities to assess the learning process. This experience requires prior knowledge acquisition and specific competencies to ensure successful knowledge transmission and awareness building. Consequently, university students develop tailored learning tools for younger generations to address real-world problems and acquire pedagogical skills. Moreover, the program fosters teamwork by promoting shared responsibility among university and pre-university teachers in an outreach activity. The entire project has been conducted with a focus on promoting equality and inclusion, as well as enhancing employability and entrepreneurship by incorporating the programs of each high school. Through a four-year sustained campaign, hundreds of students, and indirectly their families, raised awareness about the serious threat of the irresponsible use of antimicrobial substances. As a society, we must reconsider the use of antimicrobials to preserve this valuable resource for future generations. The implementation of our strategy has not only increased awareness about the responsible use of antibiotics but has also sparked an interest in research and scientific inquiry among pre-university students. Furthermore, following this pioneering experience, the learning tools, dynamics, and networks of contacts (both within universities and high schools) established will remain available for the development of similar programs in the future all over the world.

Author Contributions: Conceptualization and writing, analysis of results S.M.; B.F.

Funding: This project was supported by the Staff Development and Educational Innovation Service (SFPIE, Universitat de València). Grants PID19-1096021 and PID20-1353053.

Informed Consent Statement: The parents or legal supervisors of the pre-university students authorized their children to participate in the activity by a written consent form. Consent for the study was also obtained from the high school directors and teachers. All the participants were invited to take part in the study and informed of its purpose and objectives. Student participation was voluntary and anonymous.

Data Availability Statement: Data of our inquiries can be accessed after request.

Acknowledgments: Thanks to professors Eva Sanjuán and María Consuelo Pina-Pérez for the instruction of students. We appreciate the voluntary participation of the students of the Biology Degree, who taught the programme at the HS as well as the participating students and their biology teachers. María Martínez-Solsona helped with the Googleforms online surveys. We are indebted to the Scientific Culture and Innovation Unit Chair for Scientific Dissemination (Universitat de València) for supporting this activity.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AMR	Antimicrobial resistance
DSB	Divulsuperbac
HS	high school

 doi:10.20944/preprints202406.1376.v1

Appendix A

SURVEY A. SATISFACTION SURVEY FOR SECONDARY STUDENTS. "DIVULSUPERBAC" (DSB) PROJECT

The team involved in the project "Divulsuperbac" is very interested in collecting the opinion of secondary students about the development of this initiative, with the purpose of evaluating the level of compliance of the proposed objectives. Your collaboration answering this survey will provide useful information to improve the activity.

The data you provide us are anonymous and will be treated confidentially. We request you, therefore, to answer as honestly as possible.
Evaluate the different sections between 1-5, understanding the value of 1 as the most negative and 5 the most positive value.

		1	2	3	4	5
Scientific Interest	1. Participation in this project has awaken your interest or curiosity about Science					
	2. This experience has brought you closer to a problem of interest					
	3. These types of exhibitions contribute to increasing my interest in Science, in general					
	4. The level of the infographics is appropriate to the knowledge I have about biology					
Antibiotic resistance	5. The exhibition has contributed to a better understanding of the problem of the antibiotic resistance of bacteria					
	6. The exhibition has modified your perception about the use of antibiotics					
Others	7. The activities around the exhibition (lectures, visit to the infographics, *Kahoot*...) carried out in your school have improved your scientific training					
	8. Would you recommend other schoolmates/schools to participate in this project?					
	9. Has the interaction with university students been positive for you?					

THE BEST OF THE ACTIVITY
THE WORST OF THE ACTIVITY
IMPROVABLE ASPECTS

THANK YOU FOR YOUR COLLABORATION!

Figure A1. Survey A. Satisfaction survey for high school students.

 doi:10.20944/preprints202406.1376.v1

SURVEY B. SATISFACTION SURVEY FOR SECONDARY SHOOL TEACHERS. "DIVULSUPERBAC" (DSB) PROJECT

The team involved in the project "Divulsuperbac" is very interested in collecting the opinion of secondary school teachers about the development of this initiative, with the purpose of evaluating the level of compliance of the proposed objectives. Your collaboration answering this survey will provide useful information to improve the activity.

The data you provide us is anonymous and will be treated confidentially. We request you, therefore, to answer as honestly as possible.
Evaluate the different sections between 1-5, understanding the value of 1 as the most negative and 5 the most positive value.

		1	2	3	4	5
Evaluation of the students'learning and interest	1.Taking part of this project has arisen scientific interest and curiosity of the students					
	2. This project has contributed to the scientific training of your students					
	3.The interaction between secondary school and university students is useful					
	4.The students have become aware of the problem on antibiotic resistance of bacteria					
Personal opinion about the project	5.Your global opinion about this project					
	6.Your opinion about the work carried out by university students/teachers at your school					
	7.Would you recommend other schools to participate in this project					

We would like to know some numerical data. If you don't get the exact number, an approximate one will be also useful.

How many students of your school visited the exposition?	
How many students did complementary activities?	
If they performed a *Kahoot* (or similar activity), how many students participated?	
If there was an inaugural lecture, how many students attended?	

If you want to make any general comment, feel free to write it below.

Figure A2. Survey B. Satisfaction survey for high school teachers.

 doi:10.20944/preprints202406.1376.v1

SURVEY C. SATISFACTION SURVEY FOR UNIVERSITY STUDENTS. "DIVULSUPERBAC" (DSB) PROJECT

The team involved in the project "Divulsuperbac" wants to collect the opinion of university students about the development of this initiative with the purpouse of evaluating the level of compliance of the proposed objectives. Your collaboration answering this survey will provide useful information to improve the activity.

The data you provide us with, is anonymous and will be treated confidentially. We request you, therefore, to answer as honestly as possible.
Evaluate the different sections between 1-5, understanding the value of 1 as the most negative and 5 the most positive value.

		1	2	3	4	5
Scientific interest	1. Participation in this project has increased your interest for research					
	2. This experience has brought you closer to a problem of interest					
	3. These types of exhibitions contribute to increase my interest in science in general					
	4. The project has contributed to know better the problem of antimicrobial resistance					
Antibiotic resistance	5. The exhibition has modified your perception about the use of antibiotics					
	6. The theoretical explanations were done in a way that secondary students were able to understand them					
Performance at the high school	7. The explanations and complementary activities were done in a way that secondary students were able to understand them					
	8. I was able to respond to unexpected situations					
	9. I was able to answer the students' questions					
	10. This Project has contributed to improve your scientific formation					
Others	11. The participation in this project improved your transversal skills: autonomous problem solving, public speech, organization...					
	12. Would you recommend other students to participate in this project ?					
	13. Would you participate in this project again if you stay the next years in this university?					
	14. Do you believe that the dissemination of this project in the secondary schools has been adequate?					
	15. Rate your global opinion of this project					

THE BEST OF THE ACTIVITY

THE WORST OF THE ACTIVITY

IMPROVABLE ASPECTS

Figure A3. Survey C. Satisfaction survey for university students.

References

1. Centers for Disease Control and Prevention (CDC). The threat of antimicrobial resistance: Time for action. *CDC Drug Resistance Report* **2013**.
2. O'Neill, J. Antimicrobial resistance: Tackling a crisis for the health and wealth of nations. *The Review on Antimicrobial Resistance* **2014**. doi:10.1016/j.banm.2014.05.002.
3. World Health Organization (WHO). Global action plan on antimicrobial resistance. *World Health Organization* **2019**.
4. Laxminarayan, R.; Duse, A.; Wattal, C.; Zaidi, A.K.M.; Wertheim, H.F.L.; Sumpradit, N.; Vlieghe, E.; Hara, G.L.; Gould, I.M.; Goossens, H.; others. Antibiotic effectiveness: balancing conservation against innovation. *Science* **2014**, *345*, 1299–1301. doi:10.1126/science.1254163.

5. Prüss-Ustün, A.; Bartram, J.; Clasen, T.; Colford Jr, J.M.; Cumming, O.; Curtis, V.; Bonjour, S.; Dangour, A.D.; De France, J.; Fewtrell, L.; others. Safer water, better health: Costs, benefits and sustainability of interventions to protect and promote health. *World Health Organization* **2019**.
6. Laxminarayan, R.; Matsoso, P.; Pant, S.; Brower, C.; Røttingen, J.A.; Klugman, K.; Davies, S. Economic costs of antibiotic resistance: a systematic review. *The Lancet infectious diseases* **2016**, *16*, e270–e278. doi:10.1016/S1473-3099(16)00153-0.
7. O'Neill, J. The economic burden of antimicrobial resistance. *The Review on Antimicrobial Resistance* **2016**. doi:10.1016/j.jgar.2016.09.007.
8. Laxminarayan, R.; Duse, A.; Wattal, C.; Zaidi, A.K.; Wertheim, H.F.; Sumpradit, N.; Vlieghe, E.; Hara, G.L.; Gould, I.M.; Goossens, H.; others. Access to effective antimicrobials: a worldwide challenge. *The Lancet* **2016**, *387*, 168–175. doi:10.1016/S0140-6736(15)00474-2.
9. Ventola, C.L. The antibiotic resistance crisis: part 1: causes and threats. *Pharmacy and Therapeutics* **2015**, *40*, 277–283.
10. Collignon, P. The importance of a One Health approach to preventing the development and spread of antibiotic resistance. *Curr. Top. Microbiol. Immunol.* **2013**, *366*, 19–36.
11. Harbarth, S.; Theuretzbacher, U.; Hackett, J.; DRIVE-AB consortium. Antibiotic research and development: business as usual? *J. Antimicrob. Chemother.* **2015**, *70*, 1604–1607.
12. Puig, J. *Aprendizaje-Servicio: Educación para la Ciudadanía*; Ed. Octaedro: Barcelona, Spain, 2007.
13. Maicas, S.; Fouz, B.; Figas-Segura, A.; Zueco, J.; Rico, H.; Navarro, A.; Carbó, E.; Segura-García, J.; Biosca, E.G. Implementation of Antibiotic Discovery by Student Crowdsourcing in the Valencian Community Through a Service Learning Strategy. *Frontiers in Microbiology* **2020**, *11*, 564030. doi:10.3389/fmicb.2020.564030.
14. Piddock, L.J. The crisis of no new antibiotics-what is the way forward? *Lancet Infect. Dis.* **2012**, *12*, 249–253.
15. Cairo, A. *The Functional Art: An Introduction to Information Graphics and Visualization*; New Riders: Berkeley, CA, 2012.
16. Harris, R.L. *Information Graphics: A Comprehensive Illustrated Reference*; Oxford University Press: New York, NY, 2000.
17. Kirk, A. *Data Visualisation: A Handbook for Data Driven Design*; SAGE Publications Ltd: Thousand Oaks, CA, 2016.
18. Likert, R. A technique for the measurement of attitudes. *Arch. Psychol.* **1932**, *140*, 1–55.
19. Valderrama, M.J.; González-Zorn, B.; de Pablo, P.C.; Díez-Orejas, R.; Fernández-Acero, T.; Gil-Serna, J.; others. Educating in antimicrobial resistance awareness: adaptation of the Small World Initiative program to service-learning. *FEMS Microbiol Lett.* **2018**, *365*. doi:10.1093/femsle/fny161.
20. Google Forms. https://docs.google.com/forms/d/19NQ0Lq9B1h6UA2BR3aZLyhklaNvUiNtzN_ULCk9eWn4/edit?ts=6061ab70. Accessed: May 25, 2023.
21. Archer, L.; DeWitt, J.; Osborne, J.; Dillon, J.; Willis, B.; Wong, B. Not girly, not sexy, not glamorous: Primary school girls' and parents' constructions of science aspirations. *Pedagogies: An International Journal* **2012**, *7*, 261–287.
22. Azevedo, F.S.; diSessa, A.A.; Sherin, B.L. An evolving framework for describing student engagement in classroom activities. *The Journal of Mathematical Behavior* **2012**, *31*, 270–289. doi:https://doi.org/10.1016/j.jmathb.2011.12.003.
23. William L. Romine, L.H.B.; Folk, W.R. Exploring Secondary Students' Knowledge and Misconceptions about Influenza: Development, validation, and implementation of a multiple-choice influenza knowledge scale. *International Journal of Science Education* **2013**, *35*, 1874–1901, [https://doi.org/10.1080/09500693.2013.778439]. doi:10.1080/09500693.2013.778439.
24. AEMPS. Plan nacional frente a la resistencia a los antibióticos 2022-2024, 2022. https://resistenciaantibioticos.es/es/publicaciones/plan-nacional-frente-la-resistencia-los-antibioticos-pran-2022-2024 [Accessed: (06/06/2024].
25. Byrne, J. Models of Micro-Organisms: Children's knowledge and understanding of micro-organisms from 7 to 14 years old. *International Journal of Science Education* **2011**, *33*, 1927 – 1961.
26. Magnusson, U.; Moodley, A.; Osbjer, K. Antimicrobial resistance at the livestock-human interface: implications for Veterinary Services. *Rev Sci Tech* **2021**, *40*, 511–521. doi:10.20506/rst.40.2.3241.

 doi:10.20944/preprints202406.1376.v1

27. Ardakani, Z.; Canali, M.; Aragrande, M.; Tomassone, L.; Simoes, M.; Balzani, A.; Beber, C.L. Evaluating the contribution of antimicrobial use in farmed animals to global antimicrobial resistance in humans. *One Health* **2023**, *17*, 100647. doi:10.1016/j.onehlt.2023.100647.
28. Shallcross, L.J.; Davies, S.D. Antibiotic overuse: a key driver of antimicrobial resistance. *Br J Gen Pract* **2014**, *64*, 604–605. doi:10.3399/bjgp14X682561.
29. Cusimano, M.; Schillaci, D. It is Time for Action in the Struggle against Antibiotic-Resistance, Let's Start Reducing or Replacing Antibiotics in Agriculture. *Journal of Microbial & Biochemical Technology* **2016**, *08*. doi:10.4172/1948-5948.1000334.