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RESEARCH ARTICLE

Using a pharmacist-led educational tool to teach elementary and middle-school students in Lebanon about microbes, antibiotic use and antimicrobial resistance: A pilot study

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Abstract

Background: Teaching school students about antibiotic use and antimicrobial resistance (AMR) can shape their future behaviour to become antibiotic guardians. This study aims to assess the impact of a pharmacist-led educational tool in boosting knowledge of these topics at elementary and middle school educational stages. **Methods**: A prospective web-based cross-sectional pre-post study was conducted in Lebanese private schools from April 2020 to December 2021. **Results**: The results showed that the pharmacist-led intervention increased the general knowledge (p = 0.01) and understanding of microbes (junior versus senior, p = 0.003 versus p = 0.004). In middle school, the spread of infection ($p < 0.001$) and the AMR concept (p = 0.001) significantly changed post-test, while antibiotics use and AMR concept remained unchanged in elementary students. **Conclusion**: The successful learning impact of the educational tool designed and led by pharmacists shows their importance as antibiotic experts in influencing early pedagogic learning about antibiotics and AMR starting at the middle-school stage.

Introduction

Infections due to antimicrobial-resistant bacteria are a global health issue (Cassini *et al.,* 2019; Murray *et al.,* 2022), substantially affecting newborn babies, infants, and children (Balasegaram *et al.,* 2019; Murray *et al.,* 2022). Antimicrobial resistance (AMR) is a leading cause of death worldwide, with a high predilection in developing countries (Murray *et al.,* 2022). It is a documented cause of morbidity and mortality in the pediatric age groups and a particular threat to newborn babies and premature neonates with infections due to drug-resistant bacteria (Laxminarayan & Bhutta, 2016; Balasegaram *et al.,* 2019). Children are the highest consumers of antibiotics intended mainly to treat respiratory tract infections (M Dassner *et al.,* 2017; Hsia *et al.,* 2019) predominantly of viral origin (Leung *et al.,* 2019), leading to inappropriate antibiotic use and subsequently driving AMR (WHO, 2021).

General public education about AMR is a component of the response to this crisis (Kvint, Palm, & Farewell, 2020). A scoping review assessed the impact of public education campaigns in fostering health behaviour change on AMR and showed positive results towards raising public AMR awareness and embracing positive behavioural changes to impact AMR and maintain antimicrobial viability (McParland *et al.,* 2018; Fletcher-Miles *et al.,* 2020). Students have repeatedly been a focus of educational activities targeting AMR, whether at post-graduate (Eveillard *et al.*, 2016), college (Valderrama *et al.,* 2018; Kvint, Palm, & Farewell, 2020; Antunes *et al.,* 2021) or high school (Azevedo *et al.,* 2009; Fonseca *et al.,* 2012; Ambusaidi *et al.,* 2022) levels. Plenty of reports in the literature describe effective education as a means to foster the appropriate use of antibiotics, and combat AMR, relying on surveys, oral questionnaires, and a variety of teaching modalities to address gaps in knowledge and misconceptions about the topic (Ambusaidi *et al.,* 2022). To address the irrational use of these drugs, the focus of the educational interventions and awareness campaigns is shifting to junior (7-11 years) and senior (12-15 years) school students (Taylor *et al.,* 2003; Cebotarenco *et al.,* 2008; Young *et al.,* 2017; Zhang *et al.,* 2018) to spread awareness in this stratum of the population (Cebotarenco *et al.,* 2008; Young *et al.,* 2017; Zhang *et al.,* 2018). Although published studies failed to show sustained behavioural changes toward AMR and the efficacy of this method is still debated (Fletcher-Miles *et al.,* 2020), educating this age group about antibiotics and AMR may yield a beneficial long-term impact (Young *et al.,* 2017; Zhang *et al.,* 2018). Children can influence their parent's behaviors and incite them into making healthy choices (Little *et al.,* 2015; Hayes *et al.,* 2020).

Children's elementary knowledge of antibiotic use seems poor, despite the highest antibiotic prescription rate in this age group (Lecky *et al.,* 2010). Teaching children the concepts of microbiology, antibiotic use, hygiene, and antimicrobial resistance can shape their future behaviour to become antibiotic guardians (Lecky *et al.,* 2010; Young *et al.,* 2017; Zhang *et al.,* 2018;).

The correct dissemination of information on antibiotics enables behavioural modification toward antibiotic use. It is critical to incorporate student involvement, namely active learning, into traditional teaching to stimulate their minds and improve learning in their natural learning setting (Azevedo *et al.,* 2013). A successful example of popular educational material for school children is the European e-Bug tool based on agreed-upon learning outcomes with proven effectiveness in raising awareness and educating school children, teachers, and parents (Farrell *et al.,* 2011; Hayes *et al.,* 2020).

In Lebanon, the actual burden of AMR is not determined yet due to the lack of national surveillance data, a limited number of well-designed national studies, poor epidemiological monitoring, and a lack of proper funding, infrastructure, and governance (Osman *et al.,* 2021). The alarming increase in AMR in Lebanon, potentially to an endemic level (Daoud, 2018), raises the voice toward better practices and purposeful education. The documented knowledge and awareness of antibiotics and AMR among the Lebanese population is low to moderate and varies according to their educational background and socio-economic status (Mouhieddine *et al.,* 2015; Sakr *et al.,* 2020; Henaine *et al.,* 2021). The gap in knowledge calls for more focus on promoting nationwide awareness about the topic (Sakr *et al.,* 2020). In 2019, the Ministry of Public Health published a national action plan to fight AMR (Mouhieddine *et al.,* 2015) and set several awareness campaigns to address the use of antibiotics. Previous campaigns in Lebanon did not address knowledge of AMR in school children, and the educational awareness campaigns about the topic have not targeted the pediatric age groups to promote education about AMR at an early age. This study aims to assess the impact of a pharmacist-led educational interventional tool on boosting baseline knowledge and awareness about microbes, infection spread and prevention, antibiotics, and AMR.

Methods

Study design

A prospective cross-sectional pre-/post study was conducted in Lebanese private schools from April 2020 to December 2021.

Selection of schools and study participants

Elementary and middle-school students from private and public schools across Lebanon were eligible to participate in the study after obtaining the assent of their parents. The secretary of the Ministry of Education in Lebanon showed a high interest in the project but could not approve of conducting the study due to the COVID-19 pandemic and the difficulties of students' access to the online educational system. Out of 67 contacted schools from the private sector, eight responded favourably. Others schools showed high interest but decided to postpone the project for another year to avoid overwhelming the students already facing difficulties with online learning. Due to these circumstances, a pilot study was conducted (Figure 1).

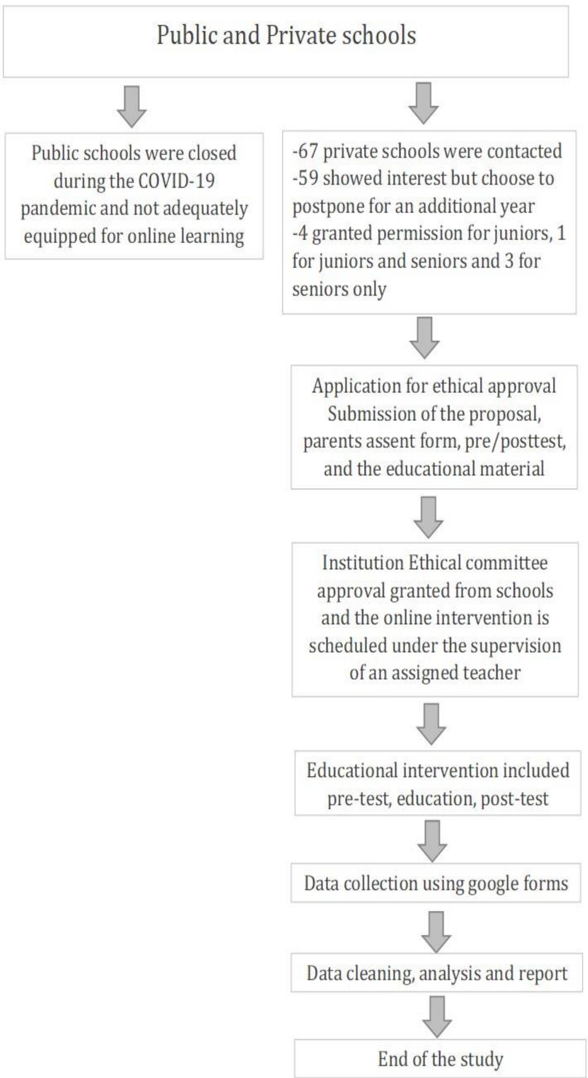

Figure 1: An overview of the study methodology

Educational tool

The two separate educational tools intended to educate school children about AMR were translated to English and French in a PowerPoint format and adapted to the junior (7 - 11 years old) and senior (12 - 15 years old) students' educational needs. The content was examined by pharmacists, school teachers, and parents and piloted with junior and senior students to address any pitfall related to the verbatim, the slide design, and the pertinence of the content. The topics covered in the educational tools were: an overview of bacteria and viruses, the role of good and bad bacteria, hand and respiratory hygiene, immunity, the use of antibiotics, an overview of the concept of AMR, and how to fight this problem.

The educational tools are available at the following link address: https://inspect-lb.org/antimicrobial-resistance/

Pre/Post-test

The pre/post questionnaire included the same questions formulated as closed-ended to simplify the process. It consisted of five sections:

[1] introduction to microbes

[2] the spread of infection

[3] prevention of infection

[4] use of antibiotic

[5] introduction to the concept of antimicrobial resistance

The questionnaire included 24 closed-ended questions for juniors (Table I) and 38 for seniors (Table II). The questions were adapted from previously published studies (Lecky *et al.,* 2010; Fernandes *et al.,* 2019).

Table I: Descriptive of school student demographics and percentage of knowledge at baseline

Description	Junior students	Senior students
Gender	**n (%)**	**n (%)**
Male	71 (38.6%)	63 (55.3%)
Female	113 (61.4%)	51 (44.7%)
Age (Mean ± SD)	10.07 ± 1.00	12.80 ± 0.77
Knowledge at baseline		
Introduction to Microbes	82.1%	88.1%
Spread of infection	86.8%	86.6%
Prevention of infection	91.9%	94.9%
Use of antibiotics	59.1%	73.1%
Introduction to the concept of AMR	68.1%	72.6%

Table II: Comparison of correct pre- and post-test percentage scores of participating students

	Junior students			Senior students		
	Pre-test (%)	Post-test (%)	*p-value*	Pre-test (%)	Post-test (%)	*p-value*
General knowledge	81.3	83.4	**0.001**	82.6	85.1	<0.001
Introduction to Microbes	82.1	85.7	**0.003**	88.1	91.2	0.004
Spread of infection	86.8	90.0	0.058	86.6	76.5	0.001
Prevention of infection	91.9	92.7	0.228	94.9	93.9	0.402
Use of antibiotics	59.1	62.5	0.064	73.1	74.6	0.458
Introduction to the concept of AMR	68.1	68.1	1.000	72.6	77.4	0.001

Educational intervention

Due to the COVID-19 pandemic, public and private schools were closed during the study period. The private schools were contacted for the first time by mail and chosen as a convenient sample. A file containing the project proposal, the pre-and post-test questions, the parent's consent form, and the educational material was submitted to the interested school's ethical board for examination and approval. After approval, the schools designated a teacher to follow up and supervise the process. The presenters of the project were either a pharmacist with teaching experience or a newly graduated pharmacist. The duration of the educational session per age group was 50 minutes conducted online, including the pre-test (15 minutes) followed by the teaching session (20 minutes) and a post-test (15 minutes). The pre/post-test was done via google forms and mandated the help and supervision of the parents and the teacher for juniors (7 - 11 years old). The presence of the parents was highly encouraged.

Statistical analysis

The IBM SPSS software version 25 was used to perform the data analysis. The pre/post-test analysis was undertaken for elementary and middle schools. The descriptive analysis considered the categorical variables expressed as absolute frequencies and percentages and quantitative variables as means and standard deviations. The comparison of means pre- and post-educational intervention was performed using the non-parametric tests of the Wilcoxon signed-rank test since the assumption of normality was not normally distributed (*p*-value of the Shapiro-Wilk test < 0.05). For each question, Wilcoxon signed Rank and Kruskal–Wallis tests were applied to analyze the pre-and post-test responses of students. The overall percentage of correct answers was computed as (Sum of students with correct answers from schools/Total number of participating students) × 100. A repeated measure ANOVA was performed to evaluate the change in knowledge after the intervention, adjusted for age and gender. Secondary data was created that included information from the previous two datasets to undertake the multivariate analysis. A multivariate analysis of covariance (MANCOVA) was used to compare the increase in knowledge between being a junior/ senior student taking into account the following confounding variables: age, gender, and school level. A *p*-value less than 0.05 was considered significant.

Results

Of the eight private schools covered, four were elementary schools, one elementary and middle school, and one middle school (Figure 1). The enrolled junior students were 184 with a mean age of 10.07 ± 1.00 years with a majority of girls (61.4%) and 114 senior students with a mean age of 12.80 ± 0.77 years with a small majority of boys (55.3%). Baseline knowledge evaluation about microbes and the prevention of bacterial infection was above 50% (n = 33), while knowledge about the concept of anti-microbial resistance (68.1% versus 73.1%) was below 75% in both age groups (juniors versus seniors) (Table I).

A significant improvement in the general knowledge (p = 0.001), and introduction to microbes (junior versus seniors, p = 0.003, and p = 0.004) is noted post-test among participants from both age groups. In senior students, knowledge about the spread of infection and the concept of AMR significantly increased (p = 0.001) (Table II).

In senior students, questions related to the prevention of infection remain unchanged. The pre-and post-test percentage scores of correct and incorrect answers among participating students are detailed per question and section (Table IIIA). The percentage of correct answers remains unchanged post-test in junior students regarding the prevention of infection, and introduction to the concept of AMR (Table IIIB).

Table IIIA: Comparison of pre- and post-percentage scores among senior students

Introduction to microbes		**Test**	**Correct (%)**	**Incorrect (%)**	***p*-value**
Q1	Bacteria and viruses are invisible	Pre Post	70 74	30 26	0.273
Q2	You need a microscope to see the bacteria and the viruses	Pre Post	100 99	0 1	1
Q3	Bacteria and Viruses are the same size	Pre Post	91 **81**	9 **19**	**0.003**
Q4	Bacteria are found in the water, air and soil	Pre Post	94 97	6 3	0.096
Q5	Bacteria are found on animals	Pre Post	97 97	3 3	1
Q6	Bacteria are found on plants	Pre Post	83 89	17 11	**0.021**
Q7	Bacteria are found on our hands	Pre Post	97 95	3 5	0.414
Q8	Bacteria are found in our mouth	Pre Post	86 94	14 6	**0.013**
Q9	Bacteria are found in our intestines	Pre Post	77 87	23 13	**0.005**
Q10	Bacteria are found on our skin	Pre Post	94 99	6 1	0.059
Q11	There are good and harmful bacteria	Pre Post	94 96	6 4	0.157
Q12	Good Bacteria can help us grow and stay in good health	Pre Post	89 94	11 6	0.109
Q13	Good Bacteria can help making food like yogurt	Pre Post	84 91	16 9	0.108
Q14	Good Bacteria can help the plants to grow	Pre Post	85 88	15 12	0.346
Spread of infection					
Q15	Harmful Bacteria can spread by shaking hands	Pre Post	93 104	21 10	**0.002**
Q16	Harmful Bacteria can spread by sneezing or coughing	Pre Post	108 108	6 6	1
Q17	Harmful Bacteria can spread by touching objects and surfaces without washing our hands	Pre Post	110 110	4 4	1
Q18	Bacteria can survive on surfaces	Pre Post	35 56	79 58	**<0.001**
Q19	Viruses can only survive on surfaces	Pre Post	57 58	57 56	0.882
Prevention of infection					
Q20	We should always wash our hands before and after eating	Pre Post	99 97	1 3	0.083
Q21	We should always wash our hands after a sport activity	Pre Post	98 96	2 4	0.083
Q22	We should always wash our hands after going to the toilet	Pre Post	98 98	2 2	0.317
Q23	We should always wash our hands when we touch a pet like cat or dog	Pre Post	94 94	6 6	1

Introduction to microbes		Test	Correct (%)	Incorrect (%)	*p*-value
Q24	If we are sick, sneezing into a tissue can stop bacteria	Pre	86	16	0.67
		Post	88	14	
Q25	Our body can fight bad bacteria through the immune system	Pre	95	5	0.206
		Post	93	9	
Use of antibiotics					
Q26	Antibiotics can help our body fight the bacteria	Pre	100	0	**0.034**
		Post	94	6	
Q27	Antibiotics kill or stop the bacteria	Pre	88	12	0.467
		Post	90	10	
Q28	Antibiotics kill viruses	Pre	33	67	0.088
		Post	40	60	
Introduction to the concept of AMR					
Q29	If you have cold or flu you should not take antibiotics	Pre	65	35	0.857
		Post	66	34	
Q30	You should take an antibiotic only if the doctor say so	Pre	93	7	0.096
		Post	97	3	
Q31	You should NOT stop the antibiotic when you feel better but only if the doctor say so	Pre	95	5	1
		Post	94	6	
Q32	Antibiotic resistance means that harmful bacteria are stronger than antibiotics	Pre	63	37	**0.009**
		Post	77	23	
Q33	Antibiotic resistance means that antibiotics will not work and you cannot make you better	Pre	53	47	**0.037**
		Post	66	34	
Q34	Wrong use of antibiotics lead to antibiotic resistance	Pre	76	24	**0.003**
		Post	89	11	
Q35	Wrong use of antibiotic can make harmful bacteria win	Pre	84	16	**0.05**
		Post	93	7	
Q36	We can all help to stop antibiotic resistance	Pre	77	23	0.162
		Post	82	18	
Q37	Only doctors and pharmacist can protect antibiotic and keeping them stronger than bacteria	Pre	72	28	**0.033**
		Post	19	81	
Q38	You can help antibiotic win if you listen to your doctor	Pre	94	6	0.763
		Post	94	6	

Table IIIB: Comparison of pre- and post-percentage scores among junior students

Introduction to microbes		Test	Correct (%)	Incorrect (%)	*p*-value
Q1	If you cannot see the bacteria, it does not exist	Pre	85	15	0.346
		Post	87	13	
Q2	Bacteria and Viruses are the same size	Pre	84	16	**<0.001**
		Post	80	20	
Q3	There are good and bad bacteria	Pre	91	9	**0.033**
		Post	96	4	
Q4	Bacteria that live in our intestines and on our skin are good bacteria	Pre	70	30	0.274
		Post	74	26	
Q5	Good bacteria can help produce food	Pre	75	25	**0.003**
		Post	85	15	
Q6	Good bacteria can help plants grow	Pre	82	18	**0.012**
		Post	89	11	

	Introduction to microbes	Test	Correct (%)	Incorrect (%)	*p*-value
Q7	Good bacteria can help us stay in good health. They can help us grow	Pre Post	85 87	15 13	0.394
Spread of infection					
Q8	Bad Bacteria can spread by shaking hands	Pre Post	80 83	20 17	0.433
Q9	Bad Bacteria can spread in the air by sneezing or coughing	Pre Post	82 94	14 6	0.011
Q10	Bad Bacteria can spread by touching objects and surfaces without washing our hands	Pre Post	92 95	8 5	0.251
Prevention of infection					
Q11	We should always wash our hands before eating	Pre Post	99 98	1 2	0.18
Q12	We should always wash our hands after eating	Pre Post	96 98	4 2	0.414
Q13	We should always wash our hands after going to the toilet	Pre Post	96 98	4 2	0.157
Q14	We should always wash our hands when we arrive at home after school	Pre Post	99 99	1 1	0.564
Q15	We should always wash our hands when we touch a pet like cat or dog	Pre Post	98 99	2 1	0.414
Q16	Soap and water can help remove bacteria and virus	Pre Post	92 94	8 6	0.257
Q17	If we are sick, sneezing into a tissue can stop bacteria	Pre Post	71 75	29 25	0.274
Q18	Our body is strong and can fight bad bacteria	Pre Post	84 82	16 18	0.317
Use of antibiotics					
Q19	Antibiotics can help our body fight the bacteria	Pre Post	92 96	8 4	0.033
Q20	Antibiotics kill viruses	Pre Post	62 38	38 62	1
Q21	If you have cold or flu you should not take antibiotics	Pre Post	46 51	54 49	0.199
Introduction to the concept of AMR					
Q22	Antibiotic resistance means that Bad bacteria are stronger than antibiotics	Pre Post	56 54	44 46	0.777
Q23	Antibiotic resistance means that antibiotic are not working anymore. They cannot make us better	Pre Post	54 56	46 44	0.68
Q24	We can all help antibiotics win by listening to the doctor and to our parents	Pre Post	95 94	5 6	0.527

Repeated measure ANOVA

A repeated-measures ANOVA was done among junior and senior answers databases to determine if there were any changes in knowledge between time points. The results among junior participants showed a statistically significant increase in general knowledge (M pre-test = 81.35 *versus* M post-intervention =83.56; p = 0.001) and introduction to microbes (M pre-test = 82.04 *versus* M post-test = 85.79; p = 0.002) from baseline to post-interventions. No significant change was found for the other sections (Figure 2).

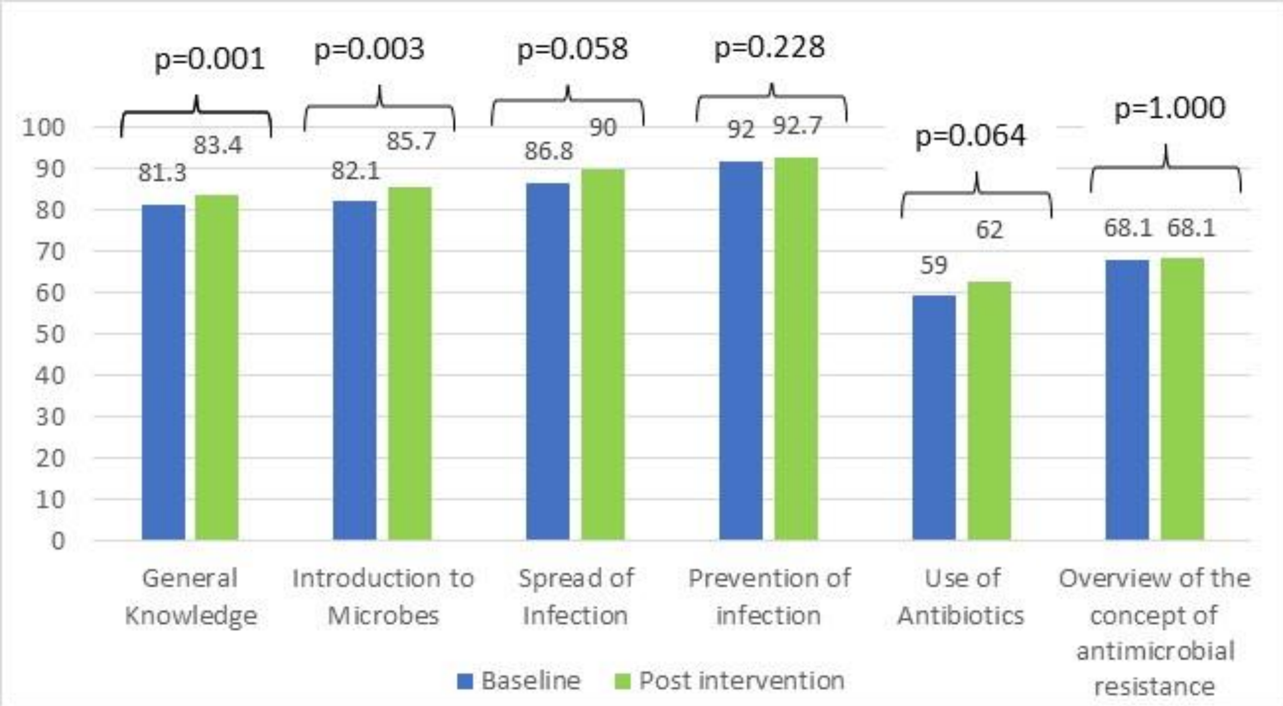

Figure 2: Changes in knowledge from baseline to post-intervention among junior students adjusted for age and gender

The results among senior students showed a statistically significant increase in general knowledge ($M_{pretest}$=82.64 *vs* $M_{post\text{-}test}$=85.13; *p*=0.002), introduction to microbes ($M_{pretest}$=88.09 *vs* $M_{post–test}$= 91.22; *p*=0.006), the spread of infection ($M_{pretest}$=70.70 *vs* $M_{post–test}$=76.49; *p*=0.001) and overview of the concept of antimicrobial resistance ($M_{pretest}$=72.63 *vs* $M_{post\text{-}test}$=77.36; *p*=0.001) from baseline to post-interventions. No significant change was found in the prevention of infection and the use of antibiotics sections (Figure 3).

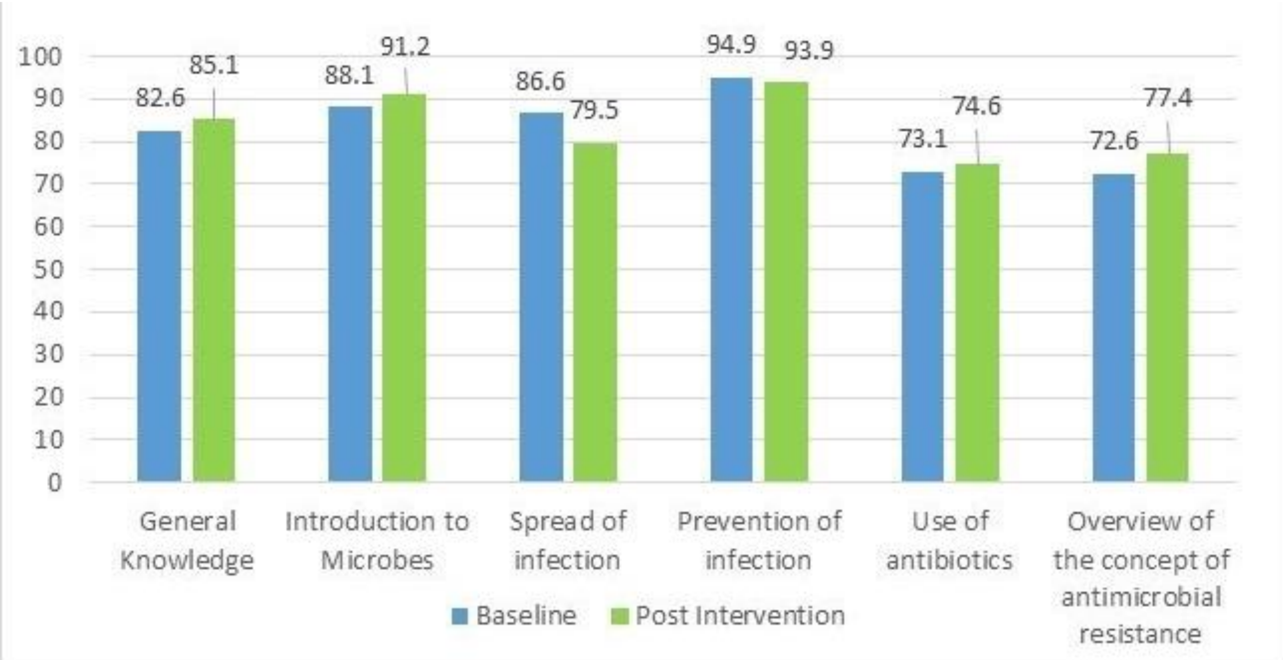

Figure 3: Changes in knowledge from baseline to post-intervention among Senior students adjusted for age and gender

Multivariable analysis

The authors carried out the MANCOVA analysis by taking the increase in knowledge as the dependent variable and being a junior/senior student as the independent variable, adjusting for the covariates (age and gender). The results showed that the increase in general knowledge and knowledge about microbes, the spread, and prevention of infection, antibiotics use, and the concept of AMR found was not associated with age, gender, or being a junior or senior student (p>0.05 for all) (Appendix A).

Discussion

This study is the first in Lebanon to teach junior and senior school students about microbes, hand and respiratory hygiene, antibiotics use, and AMR using an age-appropriate educational tool. Results show that pre-test knowledge about antibiotic use and AMR is low in elementary and middle-school students (less than 75%) (Barua *et al.*, 2013), a finding previously documented in the literature (Lecky *et al.*, 2010; Lecky *et al.*, 2011; Azevedo *et al.*, 2013; Appiah *et al.*, 2022). On the other hand, the pre-test knowledge about microbes and the spread and prevention of infection was high (above 75%) in both age groups. The pharmacist's contribution in increasing awareness about infection spread and prevention during the pandemic and the recommended presence of parents during the educational session have contributed to enhancing the knowledge of school students about these topics.

General knowledge about the topic

The findings indicate that the educational intervention significantly improved the general knowledge in both age groups (p < 0.001). Multiple studies have highlighted the importance of educational tools in shaping behaviours and educating school children, youth, teachers, and parents (Lecky *et al.,* 2011; Touboul *et al.,* 2011; Brito Avô *et al.,* 2011; Gennimata *et al.,* 2011; Rodríguez *et al.,* 2011; Holt *et al.,* 2011; De Castro *et al.,* 2013; Lee *et al.,* 2015; Appiah *et al.,* 2022). The e-Bug project is a successful example of an educational tool about these topics implemented in 29 countries and translated into 27 languages (Lecky *et al.,* 2011; Touboul *et al.,* 2011; Brito Avô *et al.,* 2011; Gennimata *et al.,* 2011; Rodríguez *et al.,* 2011; Holt *et al.,* 2011; De Castro *et al.,* 2013; Lee *et al.,* 2015; Appiah *et al.,* 2022) that gained high acceptance among teachers and school children and have proven effective in raising awareness about the topic.

Introduction to microbes

The knowledge about microbes has significantly increased among participants (junior versus seniors, p=0.003 *vs* p=0.004) post-test. Results show that although the pretest knowledge about the topic was high (>80%), the education has improved the understanding of the good bacteria concept in juniors and the idea about bacteria found on plants, in the mouth, and intestines in senior students as noted post-test.

The spread of infection

Knowledge about the spread of infection is enhanced among junior and senior students (p=0.001). The comparison of answers pre-and post-test shows that the spread of bacteria by sneezing or coughing significantly changed post-test in juniors. In seniors, a significant improvement was noted in the knowledge post-test about the presence of bacteria on surfaces and the spread of bacteria by shaking hands. Previous studies also showed that students were unaware of bacteria on door handles and other surfaces such as desks and cell phones (Lecky *et al.,* 2010; Gawai *et al.,* 2016; Fernandes *et al.,* 2019).

Prevention of infection

The high levels of pre-test knowledge in both age groups (> 90%) about the prevention of infection may be one of the beneficial impacts of the pandemic, in that, awareness was spread about the importance of hand hygiene and the incorporation of this topic into the school curriculum. Previous studies highlighted the role of training in schools in enhancing knowledge and fostering appropriate behaviour toward infection prevention among students (De Castro *et al.,* 2013; Little *et al.,* 2015; Young *et al.,* 2019; Fernandes *et al.,* 2019). Studies conducted in Sub-Saharan Africa and southwest England used AMR-themed PowerPoint animations to improve students' knowledge of infections (Lecky *et al.,* 2011; Touboul *et al.,* 2011; Young *et al.,* 2019; Appiah *et al.,* 2022). Interventions tackling hand, respiratory and dental hygiene should be part of the school's curriculum or ongoing extracurricular activities.

Antibiotic use and antimicrobial resistance

In this study, the lack of improvement in knowledge about antibiotic use and AMR noted in juniors may be related to the need for a different learning style (Lecky *et al.,* 2011) and the difficulty of understanding this topic at this age. The educational tool helped to improve knowledge about antibiotic use to help the human body fight bacteria (juniors versus seniors, p =

0.033 versus p = 0.034). A recent survey of school educational curricula conducted in Europe and Palestine pointed to the variation of antibiotic education across different countries and the lack of education on the topic for children eleven years and below (Hayes *et al.,* 2020). A study conducted in Moldova showed the usefulness of student-taught programmes in reducing antibiotic use intended to treat colds and flu (Cebotarenco *et al.,* 2008). The findings from this study suggest that introducing the concept of antibiotics use, knowledge about microbes, the spread, and prevention of infection may be a good starting point in elementary schools, followed by an introduction to the concept of AMR later in middle-school levels (Fonseca *et al.,* 2012; Hayes *et al.,* 2020; Azevedo *et al.,* 2022). Similar studies conducted in different European countries showed that awareness of AMR significantly improved post-teaching intervention (Fonseca *et al.,* 2012; Fernandes *et al.,* 2019; Hayes *et al.,* 2020; Appiah *et al.,* 2022). Pedagogic inclusion of antibiotics and AMR in the education modules of the school's curriculum is strongly encouraged to shape behaviors about antibiotic use and enhance awareness about AMR (Hayes *et al.,* 2020).

Limitations of this study are the small sample size of participating schools and the lack of representativeness of public schools. The limited number of participating schools was due to the lockdown regulations during the COVID-19 pandemic and the complex access to online teaching tools. Students and parents struggled with manipulating these tools, predominantly when taking the pre/post-test via Google Forms. The lack of direct contact and interactive sessions was also a limitation in boosting the interest, focus, and understanding of participants from different age groups. The number of participants, in addition to the limited number of questions tackling the use of antibiotics, may have contributed to the lack of significant improvement in knowledge detected in seniors and juniors.

Future directions

This study highlighted the pharmacist's role as a medication and public health expert in conceptualising, designing, and leading interactive educational tools and other types of educational activities (video games, games, live experiments, etc) that target different health-related topics to enhance knowledge of all age groups.

Overall, this pharmacist-led educational tool effectively enhanced the general knowledge of middle and elementary school students. The questions analysis highlighted the need to review and set separate age-appropriate educational tools that focus on antibiotics for both age groups and AMR starting at the level of middle school. Undertaking a pre-test assessment of the related topics covered in the schools' curricula is advised. The results of this study can orientate the adaptation and modification of the educational tool content and design. The ultimate aim is to introduce the concept of antibiotics and AMR at a younger age to foster appropriate behaviours and raise a knowledgeable generation. Additional recommendations include limiting the educational intervention to 15 minutes and reviewing the test questions concerning the obtained results and their importance in determining the level of acquired knowledge. A cross-disciplinary collaboration on the topics is highly recommended, involving for example child psychotherapists, pedagogic social workers, school teachers, and the child's carer.

Conclusion

The educational tool succeeded in enhancing the knowledge of middle school students about antibiotic use and AMR, highlighting the importance of pharmacist-led educational interventions at an early pedagogic level to prepare future antibiotic guardians.

Ethical approval and consent to participate

The study protocol was approved by the Lebanese International University ethics committee under the number 2020RC-059-LIUSOP. Prior to answering the online questionnaire, participants were informed of the study objectives. Parents gave their consent to enrol their children in the study.

Availability of data and materials

Raw data are available at the INSPECT-Lb data repository.

Link: https://inspect-lb.org/using-an-educational-tool-to-teach-elementary-and-middle-school-students-in-lebanon-about-microbes-antibiotic-use-and-antimicrobial-resistance-a-pilot-study/

Competing interests

The authors declare no conflict of interest.

Authors contribution

KI contributed to the conception and design of the study, the supervision of the research and drafted the manuscript. PS participated in the design of the study, supervised the research, planned and supervised the statistical analysis. CH performed the statistical analysis and wrote the results. DH supervised the execution of the survey and helped to draft the manuscript. EM conducted the survey and the educational sessions and helped drafting the manuscript. IJ carried out the survey and the educational sessions and revised the manuscript. SK contributed to the design of the educational tool, and revised the manuscript. MVD and NK contributed to the design of the study and revised the manuscript. All authors read the manuscript and approved the final manuscript.

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Appendix

Appendix A: Multivariate analysis of covariance (MANCOVA)

	Beta	p-value	95% Confidence Interval	
			Lower Bound	Upper Bound
Increase in general knowledge				
Senior vs Junior*	1.149	0.527	-2.421	4.718
School type (Private vs public*)	0.432	0.710	-1.851	2.715
Gender (Female vs male*)	0.569	0.571	-1.407	2.546
Age	-0.287	0.598	-1.357	0.783
Increase in knowledge related to introduction to Microbes				
Senior vs Junior*	-1.622	0.607	-7.827	4.583
School type (Private vs public*)	-0.727	0.719	-4.695	3.242
Gender (Female vs male*)	1.549	0.376	-1.887	4.985
Age	0.470	0.619	-1.389	2.330
Increase in knowledge related to spread of infection				
Senior vs Junior*	-5.206	0.257	-14.223	3.811
School type (Private vs public*)	4.667	0.112	-1.100	10.434
Gender (Female vs male*)	-0.098	0.969	-5.091	4.895
Age	-1.951	0.156	-4.654	0.751
Increase in knowledge prevention of infection				
Senior vs Junior*	-0.162	0.942	-4.545	4.221
School type (Private vs public*)	-0.009	0.995	-2.812	2.794
Gender (Female vs male*)	0.981	0.427	-1.446	3.408
Age	-0.531	0.427	-1.845	0.782
Increase in knowledge Use of antibiotics				
Senior vs Junior*	2.901	0.563	-6.954	12.755
School type (Private vs public*)	-7.831	0.015	-14.133	-1.529
Gender (Female vs male*)	0.099	0.972	-5.358	5.555
Age	-1.706	0.257	-4.659	1.247
Increase in knowledge Overview of the concept of antimicrobial resistance				
Senior vs Junior*	-5.411	0.278	-15.213	4.390
School type (Private vs public*)	5.574	0.081	-0.694	11.843
Gender (Female vs male*)	-0.844	0.760	-6.271	4.583
Age	1.857	0.214	-1.081	4.795

Note: In the global model, the independent variable is senior or junior. Covariates are age, gender, and school type.

*Reference group