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Original Article

Virtual Workshop on Antibiotic Use and Resistance for Malaysian Secondary School Students

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ABSTRACT

Background: Antibiotic-resistant infections, which cause significant global morbidity and mortality, are exacerbated by inadequate knowledge about antibiotic use, highlighting the need for improved education to prevent resistance. The e-Bug educational workshop potentially mitigates the global threat of Antibiotic Resistance (ABR). **Aim:** This study evaluated the effectiveness of the virtual e-Bug workshop on antibiotic Awareness and Knowledge, and Practice (AKP) among Malaysian secondary school students. **Materials and Methods:** The e-Bug workshop was conducted over 1 hr with four educational videos with Form 4 (Science stream) students from a national-type secondary school in Malacca, Malaysia. In pre- and post-workshop, a validated 20-AKP-items questionnaire was distributed. **Results:** Among 65 students involved in this study, the pre-workshop practice score was positive with a median (M) score of 67% and Interquartile Range (IQR) of 37.5. Awareness (M: 60%, IQR: 25) and knowledge (M: 50%, IQR: 17) were recorded as moderate. Following the e-Bug workshop, both awareness (M: 80%, IQR: 20) and knowledge (M:100%, IQR: 0) increased significantly ($p<0.001$). **Conclusion:** The e-Bug workshop is an effective tool to enhance students' AKP on antibiotic use and resistance. This promises great scope for the design and implementation of future workshops and seminars.

Keywords: Antibiotic resistance, Awareness, Educational workshop, Knowledge, Practice.

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INTRODUCTION

Antibiotic-resistant infections have become increasingly prevalent, rising by 20% during the COVID-19 pandemic and peaking in 2021, with rates remaining above pre-pandemic levels in 2022.[1] Antibiotic Resistance (ABR) occurs when bacteria mutate or adapt over time, making antibiotics ineffective against them.[2] These antibiotic-resistant infections result in higher medical expenses, prolonged hospital stays, and increased morbidity and mortality worldwide.[3] One of the significant factors in the development of ABR is the inadequate knowledge about the risks of antibiotic use or overuse. Studies have shown that 84% of Nepalese and about 14% of Americans were unfamiliar with ABR.[4,5] Similarly, young adults also showed poor knowledge and awareness of ABR, with only 32.4% of secondary school students in Selangor, Malaysia being familiar with ABR.[6,7] This emphasizes the crucial need for proper education on the proper use of antibiotics and the risk of resistance.

The e-Bug program, led by Public Health England (PHE), is an evidence-based educational resource designed for schools and communities. It covers microorganisms, infection transmission, prevention, and treatment specifically tailored to engage young children and hard-to-reach individuals.[8] Schools and other learning environments serve as vital hubs for promoting better practice among young children, who can then share this knowledge to their families, friends, and communities. This dissemination of information raises public awareness about ABR and ultimately helps curb ABR globally.[8] Educating both the public and young adults proves to be crucial in tackling ABR, promoting the proper use of antibiotics and preventing their overuse and misuse.[9,10]

Digitalization in teaching and learning has garnered considerable interest among educators, particularly in the wake of the COVID-19 pandemic. Over the past decade, the integration of

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digital video technology into the classroom has emerged as a recommended pedagogical tool to enhance student learning in terms of their engagement, attention, knowledge retention and understanding.[11] Consistently, this audiovisual aid has demonstrated significant benefits in educating Indonesian patients about antibiotic use.[12] This suggests the potential of using educational videos as a promising tool for bridging gaps in health-related knowledge. Notably, prior to the COVID pandemic, the e-Bug program was exclusively delivered via face-to-face mode.[9,13] The effectiveness of its online delivery remains unexplored, raising intriguing questions about the program's adaptability and effectiveness in an online format. Hence, this study aimed at exploring the effectiveness of a virtual synchronous e-Bug video-based workshop on antibiotic use and resistance among Malaysian secondary school students, in terms of their awareness and knowledge. Unlike previous research, this study adopted a video-based approach with a focus on young adults.[7,14]

MATERIALS AND METHODS

Study Design

The workshop was conducted over 1-hr according to the e-Bug lesson plan for Key Stage (KS) 4 and 5 (15-18 years old) (available in Supplemental material). During the workshop, four educational videos (1-2 mins each) were shown. The first video explained how antibiotics work, the distinction between bacteriostatic and bactericidal antibiotics and why antibiotics are ineffective against viruses. The second video addressed the development of ABR and its contributing factors. The third video explained the various mechanisms through which ABR is transmitted between humans and bacteria. The final video provided guidance on the correct way to use antibiotics.

A cross-sectional, questionnaire-based study was conducted among 17-year-old secondary school students from Sekolah Menengah Jenis Kebangsaan (SMJK) Yok Bin, a national-type secondary school, using a self-administered questionnaire. Following ethics approval, subjects were recruited via universal sampling. The inclusion criteria were: (i) 17-year-old Form 4 (Science stream) students (equivalent to KS4 Year 10 in the British National Curriculum) and (ii) those who attended the workshop. The exclusion criteria were: (i) students who had previously participated in the pilot study; (ii) those who answered the questionnaire incompletely; and (iii) those who requested to withdraw from the study.

Questionnaire and Measurement of Variables

The research questionnaire comprised 20 items, of which the knowledge section were adopted from the e-Bug program, while the items for awareness and practice were adopted from a validated questionnaire by Neni *et al*., with permission.[7] It was validated by a panel of experts for content validity and pre-tested in a pilot study with secondary students aged between 17-18 years old (n=10).

This questionnaire comprised four sections: socio-demographic, awareness, knowledge and practice of antibiotic use and resistance. The awareness and knowledge were assessed both before and after the workshop, with the latter evaluated immediately post-workshop. The practice section was assessed only before the workshop. The scoring method awarded positive statements as follows: Yes (2 points), Not Sure (1 point), and No (0 points), while negative statements were scored: Yes (0 points), Not Sure (1 point), and No (2 points). The maximum scores for awareness, knowledge, and practice were 10, 18, and 12, respectively, expressed as percentages (maximum score: 100%). The level for each domain was interpreted as low/negative: ≤34%; moderate/indifferent: 33.9%-65.9%; and high/positive: ≥66%.

Data Collection

All subjects received a printed participant information sheet outlining the research project along with a consent form that required their signature prior to engaging in this research. A week before the workshop, participants were allocated approximately 10 minutes to complete the printed pre-workshop questionnaire. The workshop was held synchronously by e-Bug trainers via an online video-conferencing platform, lasting 1 hr. It followed a structured agenda, starting with a 10-min introduction, a 20-min video intervention, a 10-min session on antibiotic facts and myths, and concluding with a 10-min worksheet activity. After the workshop, a 10-min questionnaire, identical to the pre-workshop version but excluding the practice section, was administered.

Data Analysis

All data were analyzed using SPSS software, version 27.0 (IBM Corporation, Armonk, New York, U.S.). Demographic characteristics were summarized using descriptive statistics and results were expressed in frequencies and percentages. Tests such as Wilcoxon signed ranks, McNemar and Spearman's rank correlation were performed to analyze the differences between pre-and post-educational e-Bug workshops in relation to Awareness, Knowledge, and Practice (AKP). Whitney U and Kruskal-Wallis tests were performed to evaluate the association of categorical variables in the socio-demographics section with AKP. A p-value<0.05 was considered statistically significant in two-tailed tests.

RESULTS

The virtual educational e-Bug workshop was held on February 17, 2022, involving 67 Form 4 (Science stream) students from SMJK Yok Bin, Malacca, Malaysia. All recruited students completed both pre- and post-workshop questionnaires, achieving a 100% response rate. Three students were absent from the workshop, and two provided incomplete responses, thus were not included in the study. Table 1 presents the socio-demographic data of the respondents. Over half were male (56.9%), the majority resided in urban areas (78.5%), and 98.5% had never attended an antibiotic-related workshop, webinar, or seminar. Additionally, 63.1% of respondents reported their last antibiotic use was over a year ago, while 69.2% indicated they use antibiotics at least once a year.

Table 2 shows the analysis of the influence of the socio-demographic factors on the scoring in AKP. Prior to the educational workshop intervention, there was a significantly higher median score of awareness among respondents who had engaged with recent antibiotics use (p=0.020) and those who consumed antibiotics less than a year ago (p=0.005). However, following the educational intervention, these factors did not maintain a significant difference in the awareness scores. Conversely, considering knowledge and practice scores, the recent use of antibiotics or the frequency of taking antibiotics did not lead to any significant variations.

Looking at the influence of gender on the knowledge and practice scores, a significant difference was observed where female students scored higher than male students in the pre-workshop phase (p<0.001 and p=0.010, respectively) (Table 2). Interestingly, this gender-based difference was not maintained in knowledge scores post-workshop. On the other hand, no significant correlation was observed between residential areas and their AKP scores regarding antibiotic use and resistance.

The pre- and post-educational interventional workshop responses for each question were further analyzed using the McNemar test as shown in Table 3. Only 33.8% were aware of ABR pre-workshop, but this increased significantly post-workshop phase to 92.3% (p<0.001). Similar positive trends were also observed for bacteria transmissibility (Q2) and infection treatment (Q3) questions (p<0.001 and p=0.004, respectively). Furthermore, recognizing that ABR was not limited to regular antibiotic users significantly increased by 23.1% (p=0.014).

In terms of knowledge, initially, 67.7% believed that antibiotics could eliminate viruses, yet after the workshop, a significant change was observed (p<0.001), with only 13.8% retaining this misconception. In the pre-workshop, nearly half of them believed that completing antibiotic courses was unnecessary (43.1%) and that unused antibiotics could be saved (49.2%). Following the workshop, these misconceptions were significantly reduced to 1.5% and 7.7%, respectively (p<0.001). A similar trend was observed in their knowledge regarding antibiotic sharing (Q9), antibiotic use (Q10) and resistance (Q11) pre-and post-workshop (p<0.001). Moreover, only a minority recognized that antibiotic use in animals (7.7%) and hospitals (16.9%) did not predominantly contribute to ABR pre-workshop. However, this increased significantly (90.8% and 93.8%, respectively) in the post-workshop phase. Regarding hand hygiene's role in the prevention of ABR (Q14), there was a ten-fold increase in knowledge post-workshop (p<0.001).

In terms of practice, only 40% demonstrated good practice in completing their antibiotics pre-workshop. Conversely, more than half displayed malpractices, including the tendency to retain antibiotics as leftovers (56.9%), and discontinuing antibiotics pre-maturely with symptom relief (63.1%). 70.8% of respondents refrained from using leftover antibiotics for colds, sore throats, or fevers prior to medical consultation. A similar positive pattern was also observed in requiring prescriptions for antibiotics practice (Q19).

The effect and correlation between awareness, knowledge, and practice in pre- and post-workshop is tabulated in Table 4. Prior to the educational intervention, participants demonstrated positive practice (Median (M)=67, interquartile range (IQR)= 37.5), but moderate awareness and knowledge (M= 60, IQR= 25 and M=50, IQR=17, respectively) (Table 4). The educational intervention notably resulted in a significant positive shift (p<0.001), increasing the awareness and knowledge levels regarding antibiotic use and resistance (M= 80, IQR= 20 and M=100, IQR= 0, respectively). Moreover, the finding revealed a significant moderate positive correlation between knowledge and practice prior to the workshop (p<0.001; Table 4).

DISCUSSION

With the increasing trends of antibiotic resistance, educational interventions on the use of antibiotics and resistance are crucial. Such interventions are pivotal in fostering responsible antibiotic practices, which, in turn, aids in diminishing the surge of ABR. This study presented the first report on the evaluation of a virtual video-based education intervention using an e-Bug workshop exploring the AKP of antibiotic use and resistance among secondary students in Malaysia.

Our study revealed no gender-based awareness differences but found a positive association between recent and frequency of antibiotic use with higher awareness scores. In contrast, Islahudin *et al*. revealed that antibiotic consumption within a year is linked to negative attitudes and practices toward antibiotic use among the public in Kuala Lumpur and Kuantan, Malaysia.[15] This is translated to the decreased recognition of ABR as a serious health issue and the need for the completion of antibiotics.[15] Despite population differences, these findings further enforced the need for educational interventions to increase the awareness of antibiotic use and resistance across different populations. Nevertheless, this study found a significant difference between knowledge, practice scores and gender distribution pre-workshop, revealing lower antibiotics knowledge and practices among males compared to females. This variation might be attributed to the inclination of women to actively seek health-related information and their greater attentiveness.[16]

This study revealed moderate levels of awareness with approximately two-thirds lacking in awareness of ABR prior to engagement in the educational workshop. These results were consistent with prior published studies that reported inadequate awareness of ABR in Malaysian students, ranged between 66.9-67.0%.[7,17] Despite the incorporation of human health topics into the Science stream Form 2 (equivalent to KS4 Year 8) curriculum content in Malaysia, this study revealed that there is a gap in the student's understanding, specifically of antibiotic use and resistance.[18] Besides, about one-third of respondents were aware that antibiotic-resistant bacteria can spread among people, surpassing the 25% reported in previous studies in Selangor, Malaysia.[7] This could be due to differences in the target population, in which our study focused on Form 4 students while most of the respondents in Neni *et al*., were Form 1 and 2 (equivalent to KS3 Year 7 and 8, respectively), representing lower secondary education.[7]

Interestingly, the impact of the e-Bug workshop was notable, resulting in a significant increase in awareness shifting from moderate to high level. This is evidenced by the increase in participants' understanding of bacteria transmissibility and the challenges of resistant strains. This finding is consistent with Kristina *et al*., study, whereby didactic educational intervention complemented with case presentations, increased Indonesian public awareness of antibiotic resistance from 19% to 49%.[19] Hence, the e-Bug video-based educational intervention positively impacts the participants' awareness of antibiotic use and resistance in this study, demonstrating its effectiveness.

Moreover, the participants demonstrated only an intermediate level of knowledge during the pre-workshop phase, aligned with the findings reported by Neni *et al*.[7] This could be explained by the limited exposure to antibiotic-related educational activities such as webinars, seminars or lectures. Prior to the workshop, 67.7% of the respondents believed antibiotics could kill viruses. This was relatively lower compared to secondary school students in Selangor (93.4%)[7] and the general public in Malaysia (ranged from 82.2% - 86.6%).[20-22] Yet, this surpassed international communities such as Eastern Ethiopia (63.3%),[23] Iraq (57.6%),[24] United States (35%)[25] and Sweden (26.8%).[26] This disparity could be explained by the misconceptions about "bacteria" and "viruses," as Malaysian doctors often use the term "germs" during their consultations.[20,27] Furthermore, approximately 43.1% believed they could discontinue antibiotics upon symptom relief, similar to the trend reported in other studies.[6,7,21]

Importantly, through the e-Bug educational workshop, there was a ten-fold increase in the understanding that handwashing can help to reduce ABR. This aligns with Fernandes *et al*., study, which showed a marked improvement in hand hygiene knowledge post-e-Bug program.[13] This further highlights the effectiveness of virtual e-Bug sessions in educating students on antibiotic use and resistance. Consistently, targeted education and school interventions in other studies substantially increase the knowledge of the proper use of antibiotics.[9,13,19,28]

The respondents displayed positive practices pre-workshop, in contrast to previous Malaysian studies showing negative attitudes towards antibiotic use and resistance.[14,17,20-22] This might be due to the COVID-19 pandemic having positively influenced infection control practices. Around half of the respondents intended to discontinue antibiotics upon symptom relief, compared to Neni *et al*., showing 66.2%.[7] This percentage surpasses other studies conducted among the Malaysian public (ranged from 40.2-45.6%),[20,21] likely due to target populations differences.

Most respondents acknowledged that antibiotics should require a doctor's prescription and not be purchased without a prescription. This finding is consistent with Choo *et al*., where 87.9% of respondents displayed similar reluctance to acquire antibiotics without prior medical consultation.[17] About half admitted storing leftover antibiotics for future use, exceeding findings observed in other states in Malaysia: Selangor (36.8%)[7] and Penang (19.9%)[20] and Kuala Lumpur (17.0%).[21] Besides, 70.8% agreed not to use leftover antibiotics for colds, sore throats, or fevers without consulting a doctor, higher than Selangor (59.6%),[7] but lower than Penang (88.5%),[20] Kuala Lumpur (85.3%).[21] Our results revealed that there was limited awareness of antibiotics' consequences which potentially lead to misuse of antibiotics. This might be due to inadequate doctor-patient information on the proper storage and usage of antibiotics.[29] The respondents' practices were only assessed in the pre-workshop phase. Thus, the

Table 1: Socio-demographic background of the respondents (*n*=65).

Characteristic	n (%)
Gender	
Male	37 (56.9)
Female	28 (43.1)
Age (years±SD)	17.0±0.0
Residential Area	
Urban	51 (78.5)
Suburban	11 (16.9)
Rural	3 (4.6)
Experience of attending any webinar/ courses/ programme on antibiotic use or antibiotic resistance	
Yes	1 (1.5)
No	64 (98.5)
Recent use of antibiotic	
Within 1 year	24 (36.9)
More than 1 year	41 (63.1)
Frequency of taking antibiotics	
Less than 1 time a year	20 (30.8)
At least 1 time a year	45 (69.2)

Table 2: Influence of socio-demographic factors towards the awareness, knowledge and practice scores in antibiotic use and resistance in pre- and post-educational intervention workshop.

Variables	Category	Pre-workshop total score*		Post-workshop total score*	
		Median (IQR)	*p*-value	Median (IQR)	*p*-value
Awareness					
Gender	Male	60 (30)	0.989[a]	80 (20)	0.279[a]
	Female	60 (20)		80 (17.5)	
Residential Area	Urban	60 (20)	0.633[b]	80 (20)	0.500[b]
	Suburban	60 (30)		80 (20)	
	Rural	60 (-)		80 (-)	
Recent use of antibiotic	≤1 year	70 (20)	0.020[a]	80 (20)	0.525[a]
	>1 year	60 (20)		80 (25)	
Frequency of taking antibiotics	<1 /year	60 (15)	0.005[a]	80 (25)	0.384[a]
	≥1 /year	70 (20)		80 (20)	
Knowledge					
Gender	Male	50 (12)	<0.001[a]	100 (11)	0.203[a]
	Female	61 (17)		100 (0)	
Residential Area	Urban	50 (17)	0.855[b]	100 (11)	0.094[b]
	Suburban	56 (17)		100 (0)	
	Rural	50 (-)		100 (0)	
Recent use of antibiotic	≤1 year	50 (20)	0.207[a]	100 (22)	0.128[a]
	>1 year	56 (11)		100 (16.5)	
Frequency of taking antibiotics	<1 /year	50 (17)	0.320[a]	100 (5.50)	0.389[a]
	≥1 /year	53 (11)		100 (0)	
Practice					
Gender	Male	58 (21)	0.010[a]		
	Female	83 (50)			
Residential Area	Urban	67 (33)	0.185[b]		
	Suburban	100 (50)			
	Rural	50 (-)			
Recent use of antibiotic	≤1 year	67 (51.75)	0.896[a]		
	> 1 year	67 (37.50)			
Frequency of taking antibiotics	<1 /year	67 (42)	0.088[a]		
	≥1 /year	54(48)			

IQR = Interquartile Range; Practice domain was evaluated for pre-workshop only.*Interpretation of score: low/negative = <33%, moderate/indifferent = 34%-66%, high/positive = >67% [a]Mann Whitney U Test was used where $p<0.05$ showing statistical significance. [b]Kruskal-Wallis Test was used where $p<0.05$ showing statistical significance.

impact of this educational intervention on the practice domain was not evaluated due to the expected delay in behavioral changes post-workshop. This aspect may warrant further investigations.

A positive relationship between knowledge and practice on antibiotic use and resistance was observed in the pre-workshop. This suggests that respondents with higher knowledge levels were more likely to have positive antibiotic use practices, thus reducing ABR incidences. Zhu *et al.*, highlighted that lesser-educated university students were more likely to assume that antibiotics expedited respiratory infections' recoveries.[30] As only a moderate relationship between knowledge and practice, other factors like parental role models and social media may also influence the participants' practices.

The present study employed universal sampling, focused solely on a single age group of science secondary school students. While conducting the study at a single site may limit the generalizability of the findings to schools with comparable characteristics, the selected school, which is a national secondary school in

Table 3: The comparison between pre- and post-educational intervention workshop regarding AKP towards antibiotic use and resistance (*n*=65).

Statements		Correct n (%)	Incorrect n (%)	*p* value*
Awareness				
1. Have you ever heard about 'Antibiotic Resistance'?	Pre	22 (33.8)	43 (66.2)	<0.001
	Post	60 (92.3)	5 (7.7)	
2. Bacteria which are resistant to antibiotics can be spread from person to person.	Pre	21 (32.3)	44 (67.7)	<0.001
	Post	57 (87.7)	8 (12.3)	
3. If bacteria are resistant to antibiotics, it can be very difficult or impossible to treat the infection they cause.	Pre	40 (61.5)	25 (38.5)	0.004
	Post	53 (81.5)	12 (18.5)	
4. Antibiotic resistance is only a problem for people who take antibiotics regularly.	Pre	19 (29.2)	46 (70.8)	0.014
	Post	34 (52.3)	31 (47.7)	
5. Antibiotic resistance occurs when your body becomes resistant to antibiotics and they no longer work as well.	Pre	36 (55.4)	29 (44.6)	0.024
	Post	50 (76.9)	15 (23.1)	
Knowledge				
6. Antibiotics can kill viruses.	Pre	21 (32.3)	44 (67.7)	<0.001
	Post	56 (86.2)	9 (13.8)	
7. You don't need to finish a course of antibiotics if you are feeling better.	Pre	37 (56.9)	28 (43.1)	<0.001
	Post	64 (98.5)	1 (1.5)	
8. Leftover antibiotics can be saved for use at a later date.	Pre	33 (50.8)	32 (49.2)	<0.001
	Post	60 (92.3)	5 (7.7)	
9. You should not share antibiotics.	Pre	39 (60.0)	26 (40.0)	<0.001
	Post	62 (95.4)	3 (4.6)	
10. Taking antibiotics weakens your immune system.	Pre	30 (46.2)	35 (53.8)	<0.001
	Post	61 (93.8)	4 (6.2)	
11. Healthy people carry antibiotic-resistant bacteria.	Pre	11 (16.9)	54 (83.1)	<0.001
	Post	56 (86.2)	9 (13.8)	
12. Antibiotic use in animals is causing most of the antibiotic resistance seen today.	Pre	5 (7.7)	60 (92.3)	<0.001
	Post	59 (90.8)	6 (9.2)	
13. Antibiotic use in hospitals is causing most of the antibiotic resistance seen today.	Pre	11 (16.9)	54 (83.1)	<0.001
	Post	61 (93.8)	4 (6.2)	
14. Washing my hands helps to reduce antibiotic resistance.	Pre	6 (9.2)	59 (90.8)	<0.001
	Post	60 (92.3)	5 (7.7)	
Practice				
15. Do you stop taking antibiotics when you start feeling better?	Pre	26 (40.0)	39 (60.0)	<0.001
16. Do you only take antibiotics when prescribed by a doctor?	Pre	57 (87.7)	8 (12.3)	0.180
17. Do you keep leftovers at home because they might be useful in the future?	Pre	28 (43.1)	37 (56.9)	<0.001
18. Do you use leftover antibiotics when you have a cold, sore throat, or fever without consulting a doctor?	Pre	46 (70.8)	19 (29.2)	0.007
19. Do you buy antibiotics without a prescription?	Pre	53 (81.5)	12 (18.5)	0.006
20. If symptoms improve before the full course of antibiotics is completed, you can stop taking them.	Pre	24 (36.9)	41 (63.1)	<0.001

*McNemar Test was used where $p<0.05$ is statistically significant.

Table 4: The effect and relationship between the AKP scores towards antibiotic use and resistance pre- and post-workshop (*n*=65).

Domain	Median (IQR)*		*p*-value**	Correlation 'ρ' (*p*-value)^{φ}		
	Pre-workshop	Post-workshop		Awareness	Knowledge	Practice#
Awareness	60 (25)	80 (20)	<0.001		Pre-workshop: 0.230 (*p*=0.065) Post-workshop: 0.214 (*p*=0.086)	0.136 (*p*=0.279)
Knowledge	50 (17)	100 (0)	<0.001			0.409 (*p*<0.001)
Practice	67 (37.5)					

IQR = Interquartile Range; The score was expressed in percentile and maximum score for each domain is 100%*Interpretation of score: low/negative = <33%, moderate/indifferent = 34%-66%, high/positive = >67%. **Wilcoxon Signed Ranks Test was used where $p<0.05$ is statistically significant.. #Practice domain was evaluated for pre-workshop only.^{φ}Spearman's rank correlation; significant level at $p<0.05$.

Malaysia, was purposefully chosen to align with the research objectives and scope. The respondents, being part of the science stream curriculum, provided data highly relevant to the study's aims. The insights generated offer a strong foundation for understanding the impact of the e-Bug educational workshop on national science students. The sample size was relatively small, comprising only 65 respondents, which potentially impacted the statistical power, increased the margin of error and limited the generalizability of the findings. However, statistical tests employed in this study were considered for the small sample size, thus helping to mitigate the concerns related to generalizability. Despite the limitations, this study offers valuable insights into the effectiveness of e-Bug educational workshops in terms of awareness, knowledge and practice of antibiotic use and resistance among Form 4 (Science stream) students. To further enhance the reliability and applicability of the findings, future studies should consider expanding the sample to include multiple schools and larger populations. This would ensure that the results reflect a broader demographic.

On the other hand, the evaluation in this study was assessed only at one time point, i.e. immediately after the workshop. Therefore, the change of practice could not be reflected immediately after the workshop. The retention of knowledge from this workshop for a longer duration was not assessed. Follow-up assessments of multiple time points should be incorporated in future studies to gauge knowledge retention and the potential impact on practice over time. Future investigations are necessary to address the current limitations, including adopting a study design with a control group, increasing the sample size, conducting multi-center studies, incorporating follow-up assessments, and integrating qualitative evaluations. Such efforts would provide a more comprehensive understanding of the e-Bug workshop's effectiveness and its potential for integration into the regular school curriculum, thereby enhancing its sustainability and broadening its reach.

The application of the e-Bug model in public health shows its immense potential benefits. This is an intervention which has the potential to be very effective in the fight against ABR. The findings of this study provide a solid basis for designing and incorporating similar workshops into school curricula to enhance early education in the development of responsible antibiotic prescription practices that may in turn contribute towards the sustainability of global public health interventions.

CONCLUSION

In conclusion, the virtual e-Bug video-based educational workshop intervention positively improved students' awareness, knowledge, and practice of the use of antibiotics and resistance. It was evident that antibiotic misuse and misconception were critical issues within current society, and they can be resolved through proper technology in education. Thus, this intervention can be further employed in other educational settings and together with experimental activities, potentially will promote long-term knowledge retention. The current research findings also provide great scope for future workshop and seminar design.

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ABBREVIATIONS

ABR: Antibiotic resistance; **AKP:** Awareness and knowledge, and practice; **IQR:** Interquartile range; **KS:** Key stage; **M:** Median; **PHE:** Public Health England; **SMJK:** Sekolah Menengah Jenis Kebangsaan.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICAL APPROVAL AND INFORMED CONSENT STATEMENTS

The subjects were recruited by universal sampling following the ethics approval from Taylor's University Human Ethics Committee (HEC 2021/135). Informed consent was obtained prior to the study. All data were collected with a unique study identity number, where there was no personal identifiable information within the records.

SUMMARY

Inadequate knowledge about the risks of antibiotic use or overuse is one of the contributors to the development of antibiotic resistance globally. Educating both general public and young adults is essential for addressing antibiotic resistance, ensure proper antibiotic usage and preventing overuse and misuse of antibiotics. This study presented the evaluation of an online video-based education intervention using an e-Bug workshop, which investigated the awareness, knowledge and practices regarding antibiotic use and resistance among secondary students in Malaysia. The Online e-Bug workshop significantly enhanced students' awareness and knowledge concerning antibiotic resistance.

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