EDUCATIONAL RESEARCH REPORT

Efficacy of an Antimicrobial Reality Simulator (AMRSim) as an Educational Tool for Teaching Antimicrobial Stewardship to Veterinary Medicine Undergraduates

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ABSTRACT

Purpose: Simulation-based medical education has changed the teaching of clinical practice skills, with scenario-based simulations being particularly effective in supporting learning in veterinary medicine. In this study, we explore the efficacy of simulation education to teach infection prevention and control (IPC) as part of Antimicrobial Stewardship (AMS) teaching for early years clinical veterinary medicine undergraduates. **Methods:** The intervention was designed as a 30-minute workshop with a simulation and script delivered online for 130 students as a part of hybrid teaching within the undergraduate curriculum. Learning outcome measures were compared between an intervention group and waitlist-control group using one-way between-groups analysis of covariance tests. **Results:** Significant differences between groups were found for outcomes measures related to short-term knowledge gain and confidence in IPC and AMS in small animal clinical practice. However, lateral knowledge transfer to large animal species clinical practice showed no significant differences. Student feedback indicated that the intervention was an enjoyable and engaging way to learn AMS. **Conclusions:** The intervention provided short-term knowledge gain in IPC protocols and enhanced procedural skills via active learning and motivation to learn in large groups of students. Future improvements would be to include large animal clinical scenario discussions and evaluate longer-term knowledge gain.

Key words: simulation-based medical education, active learning, antimicrobial stewardship

INTRODUCTION

Active Learning Using Simulation Education

Active learning approaches have been evidenced to be effective in improving student learning outcomes in medical education (Michael 2006; Graffam, 2007). The process involves students engaging in an activity that encourages them to reflect upon ideas and how they use these in their learning (Michael, 2006). Engagement, observation, and critical reflection are some of the principal and inter-related components of active learning (Graffam, 2007). They can be used in scenario-based simulations to assist self-paced learning in a less stressful virtual environment (Baillie, 2007; Braid, 2022; Gaba, 2004).

Well-planned simulation-based medical education (SBME) has been shown to enhance learning and change the teaching of clinical practice skills (McGaghie et al. 2010). In veterinary medical education, simulation-based clinical teaching scenarios have been shown to outperform traditional didactic lecture-style presentations, reflecting better student engagement and motivation (Kneebone 2005; Chan, 2004). Simply providing a simulated experience of clinical practice does not, however, ensure effective learning (Motola et al. 2013).

It is important to consider how, within the simulation, theory is translated into practice and students' previous experiences are built upon, using appropriate debriefs and guidance to improve students' engagement and learning (Hall and Tori, 2017). This increases the learning potential of students towards "knowledge restructuring," as opposed to "knowledge acquisition" alone (Boshuizen et al. 1995). This can result in increased confidence, better preparedness, and readiness for work in the learner, as found in a study conducted using an anesthesia simulation for veterinary undergraduate teaching (Jones et al. 2019).

In a systematic review of 109 articles on the features and uses of medical simulations, it was identified that educational feedback (47% of the articles reviewed) was the most important feature. The authors noted that the atmosphere in the session should be positive and energetic, and not focus on learner deficiencies (Issenberg et al.

2005). A central characteristic is making (and learning) from mistakes, which can be a powerful educational experience (Ziv et al. 2005). Teachers therefore need to encourage student participation in simulation to aid motivation (Acharya, 2001), which enables effective learning (Chan 2004). Additionally, the simulation needs to be fully integrated into the curriculum (McGaghie et al. 2010).

Antimicrobial Stewardship (AMS) and Infection Prevention and Control (IPC) Teaching in Veterinary Curricula

Antimicrobial resistance (AMR) is a global public health issue and a profound threat to human and animal health (WHO, 2015). AMS involves the understanding of what drives prescribing behaviors among professionals (O'Neill, 2015; Dyar et al. 2016). Prescribers are influenced by a variety of factors, one of which is poor Infection Prevention and Control (IPC), especially around surgery. Improving IPC can reduce antibiotic use, thereby improving AMS (Currie et al. 2018; King et al. 2018). Studies conducted in human healthcare settings have proposed strategies that address surface transfer and hand hygiene (HH) compliance in clinical environments (Gardner et al. 2012; Kupfer et al. 2019).

There is evidence that undergraduate medical and veterinary students (future prescribers) only take partial responsibility for AMR and often lay the blame on animal owners and the general public (Hardefeldt et al. 2018; Kovacevic et al. 2020). Based on a survey of self-reported behavior among UK-based veterinary medicine students, Golding et al. (2022) recommended that AMS training be embedded across the veterinary curricula, including IPC teaching. However, there are no studies exploring the use of an early intervention simulation experience aimed to address these gaps in knowledge.

The current study was conducted with veterinary undergraduates to assess the efficacy of a novel digital simulation tool (AMRSim) to visualize what cannot be seen (i.e., contamination), delivered as an interactive workshop to support learning of key elements of veterinary IPC protocols leading to AMS around surgical procedures in practice.

METHOD

The Intervention (Antimicrobial Reality Simulator: AMRSim and Workshop Transcript)

The novel digital teaching tool used for the intervention, AMRSim, is an interactive, 3-Dimensional, monochrome graphical simulator of a veterinary practice within which humans, animals, and bacteria interact, and contamination is transferred. AMRSim mimics a real-life veterinary clinical practice scenario: a dog being prepared for a hind limb surgical procedure. The intervention was designed as a 30-minute workshop able to be delivered face to face or as a part of hybrid teaching conducted with triple layered video clips, together with a standardized workshop transcript to avoid facilitator bias and ensure greater consistency (Figure 1).

[INSERT FIGURE 1 HERE]

Procedure and Participants

Favorable ethical approval was obtained from University of Surrey ethics review committee. The pilot study included 41 University of Surrey BVMSci programme undergraduates and aimed at optimizing the questionnaires and the teaching script.

The main study included 130 participants (from 141 eligible level 6 veterinary medicine students in the entire cohort) who gave informed consent to participate in the study. The intervention was a compulsory component in the level 6 veterinary medicine curriculum delivered as four online workshops via zoom (35–37 students per group) with facilitators adhering to the script. Participants completed a pre-test questionnaire and were randomly assigned to an intervention group (IG; $n = 64$) or waitlist-control group (WLCG; $n = 66$). The full questionnaire can be found in the supplemental online material, but a summary of the learning outcomes measured by this questionnaire are described in Table 1. All experimental tasks were completed individually by each student online. During the workshop, an online workbook was used by the participants to make notes. Where consent was given, these were submitted for data analysis to assess intervention related learning and feedback. The workshop was recorded and made available to all students post intervention. The same questionnaire was completed by participants from both groups a week later (post-test), prior to participants in the WLCG participating in the workshop. Participants also completed a feedback questionnaire about their learning gain and experience of the intervention (see Table 2 for items). To avoid confounding effects, a further 11 participants (seven in the IG and four in the WLCG) were excluded from the analysis due to their prior participation in the pilot study. Most of the final sample that was analyzed ($n = 119$) consisted of females (88.2%), aged 20–25 years old (93.3%), and from the United Kingdom (89.9%). After completion of the pre-test measures, 12 participants allocated to the IG did not receive the intervention due to absence. A further eight participants in the IG, and 30 participants in the WLCG were lost to follow-up (i.e., they did not complete post-test measures) (Figure 2).

[INSERT FIGURE 2 AND TABLE 1 HERE]

Data Analyses

To confirm that randomization achieved two equivalent groups in terms of understanding across learning outcomes, the pre-test measures, as well as background and experience variables were compared between the IG and WLCG using crosstabulations and *t*-tests. Post-test scores were compared between the two groups using one-way between-groups analysis of covariance (ANCOVA) tests, controlling for pre-test scores on the same measures. ANCOVA is often the favored approach when using a randomized design with follow-up measurements, as it has greater statistical power and precision than comparable tests and can control for non-equivalence between groups at pre-test (Vickers and Altman, 2001; Rausch et al. 2003).

RESULTS

Learning Outcomes

Data were screened for univariate outliers, which resulted in some extreme scores ($Z > 3.29$) being winsorized prior to analyses being performed. Missing data were excluded using listwise deletion. Pre-test comparisons showed some minor significant differences between groups at baseline (see supplemental online material), demonstrating the importance of controlling for pre-test scores in the post-test comparisons to avoid potential confounding effects (Twisk et al. 2018).

Covariance-adjusted means for each of the outcome measures, split by treatment group at post-test, are displayed in Table 1, along with *p*-values from the ANCOVA results (full ANCOVA statistics and effect sizes can be found in the supplemental online material). As Table 1 shows, significant differences between groups were found for outcomes measures related to knowledge about: general knowledge and perceived confidence about IPC, sources, and spread of infection in veterinary practice, HH, AMR, the relationship between IPC and AMR, the role of IPC in AMS, and knowledge and confidence about the role of PPE and disinfection use for IPC. In all of these cases, the IG had significantly higher mean scores than the WLCG. There were no significant differences between groups for outcomes related to transferable knowledge.

Student Feedback

Student feedback on the learning gain and experience of the intervention is detailed in Table 2.

[INSERT TABLE 2 HERE]

Student feedback commended the visual representation of the clinical scenario with red and green as opposed to didactic teaching or a handout; "*It was useful to visualise the contamination as this is difficult to do when it is just in writing.*" The intervention also stimulated self-reflection with most students stating that they would be more aware of their own IPC practice and role in AMS in future placements, indicating a motivation to change behaviour: "*before the workshop I was more inclined to use antibiotics but now I realise that was foolish.*"

The students indicated that immediate feedback from the facilitator and open peer discussion helped their learning: "*I really liked the discussion we had as a group, it was very helpful and confirmed/solidified my knowledge around this topic.*" Peer learning was commonly cited as beneficial, providing *"ideas from other people that I would have missed."* In addition, they were less hesitant to discuss controversial issues, such as: "*I can use antibiotics to compensate for poor IPC protocols,*" particularly if others shared similar opinions.

The formative nature of the intervention helped reduce stress and fostered open discussion and reflection. For example: "*There was no pressure to answer correctly as we weren't being assessed. Therefore, more people put suggestions forward.*" The online workbook was found to be a useful learning aid: *"Jotting down the notes then discussing what we had each written was helpful in learning the topic."*

Students also suggested some potential improvements, for example, expanding the species included to add production and equine species. Some students also said they would have preferred a self-learning tool as opposed to a workshop.

DISCUSSION

The novel educational intervention, using a digital simulation tool (AMRSim) to support IPC protocols leading to AMS around surgical procedures in practice, was found to have high efficacy in short-term knowledge gain. This was statistically significant (i.e., 1 week post intervention) for the following key learning outcomes: general IPC knowledge, sources and spread of infection in veterinary practice, HH, AMR, the relationship between IPC and AMR, the role of IPC in AMS, knowledge and confidence about the role of PPE, and disinfection use for IPC in veterinary practice. Additionally, most of the student feedback indicated that the tool helped with self-reflection and the motivation to behave in a more responsible manner when applying IPC protocols in future clinical practice (extra mural studies placements). Together with engagement in discussions about controversial AMS opinions, these indicate the success of active learning, as described in the literature (Michael, 2006; Graffam, 2007). There was also evidence of greater self-confidence and competence resulting from greater control of their own learning (Chan, 2004).

The motivation to develop practice can be achieved when a student feels that their learning activities are purposeful, rewarding and enjoyable (Miller, 1990).

Students stated that the AMRSim was a fun and an engaging way to learn IPC. Additionally, in line with previous research (Michael, 2006), the students preferred to learn with a facilitator as opposed to independently. In the current study, the intervention allowed for discussion and peer learning in a structured and expert facilitated format. The intervention, as a virtual scenario-based simulation, provided a stress-free self-paced learning activity both during and after the learning experience aligned with other similar learning activities (Baillie, 2007; Braid, 2022; Gaba, 2004). Student feedback, together with the statistically significant knowledge gains, indicate that the intervention outperformed traditional didactic lecture-style presentations with better student engagement and motivation (Kneebone, 2005; Chan, 2004).

The intervention provided students with an opportunity for immediate feedback from the facilitator and peers within a relaxed atmosphere focusing on learning gain and not their deficiencies, which is the desirable outcome of an efficacious SBME intervention (Issenberg et al. 2005; Acharya, 2001; Chan, 2004). The repeatability of the intervention post-session using the recording provided the opportunity to make and learn from mistakes (Ziv et al. 2005). In a busy clinical practice, the subtleties of surface contamination and human to animal transfer of infections and vice versa may be missed when both clinicians and students are concentrating on lifesaving medicine and surgery skills. However, in a classroom intervention, such as this, there is an opportunity to embed good practice in advance to enable improved future practice.

While it was disappointing that there were no statistically significant gains for outcomes related to transferable knowledge, students did identify the need for more lateral thinking, stating that a pre-surgical prep of large animal species (farm animals and equine), and other clinical scenarios, would be a further improvement. One way to do this could be for the simulation script to be adapted to include signposting and discussion points on field surgery in large animal and equine environments for a more holistic veterinary practice related overall AMS learning experience.

The intervention demonstrated greater short-term learning, and improved confidence in the learning outcomes. Golding et al. (2022) emphasized the gap in undergraduate knowledge and the need for improved learning outomes in undergraduate teaching in IPC and the role of IPC in AMR. The intervention was able to address this gap, which could lead to benefits in future clinical practice and public health.

One of the limitations of this study was that no long-term retention of knowledge was assessed. A 3-month post intervention and a 1-year follow-up may address this. The novelty of the simulation and intervention itself could have led to changes and the different teaching methods may have influenced the facilitators' attitude. The level of enthusiasm in the workshop may have then impacted on students' responses to the online questionnaire surveys, a phenomenon known as the Hawthorne effect (Mayo, 1977). Finally, recall and retention evaluations were based solely on open-ended questions marked using a rubric. With general objectives of a veterinary curriculum in mind, this only achieves a ``tells how'' rather than ``shows how'' level of knowledge (Miller, 1990), as the study did not include practical evaluations made for the retention of knowledge and skills from the intervention. Therefore, conclusions about the benefits of the intervention in improving knowledge and retention at a ``shows how'' level of competence cannot be made.

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AVAILABILITY OF DATA AND MATERIALS

The data supporting the conclusions of this article are included within the article and supporting documents. Any queries regarding these data may be directed to the corresponding author.

CONTRIBUTIONS

DWDS designed, carried out the study and wrote the majority of the manuscript. KB was responsible for carrying out the data analysis and assisted in study design and writing the manuscript. ED assisted in data analysis of student feedback and worked as a student researcher in the study. SLB was involved in study design and provided manuscript revisions. RLG provided manuscript revisions. MC, one of the inventors of the AMRSim, was involved in study throughout and provided manuscript revisions. All authors read and approved the final manuscript.

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ABBREVIATIONS

AMRSim = antimicrobial reality simulator; SBME = simulation-based medical education; IPC = infection prevention and control; AMS = antimicrobial stewardship; AMR = antimicrobial resistance; WHO = World Health Organisation; HH = hand hygiene; BEME = best evidence medical education; WLCG = waitlist-control group; IG = intervention group.

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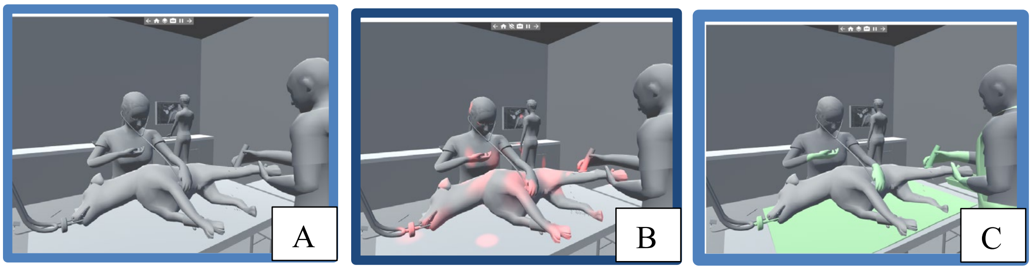

Figure 1: The tool has three layers; A: Layer 1 shows the pre-surgical procedure with in-built risky behaviors. B: Layer 2 shows (in red) presence of ``invisible'' bacterial contamination. C: Layer 3 shows (in green) IPC measures in place. Reproduced with permission (http://amrsim.org/theproject.html)

CONSORT 2010 Flow Diagram

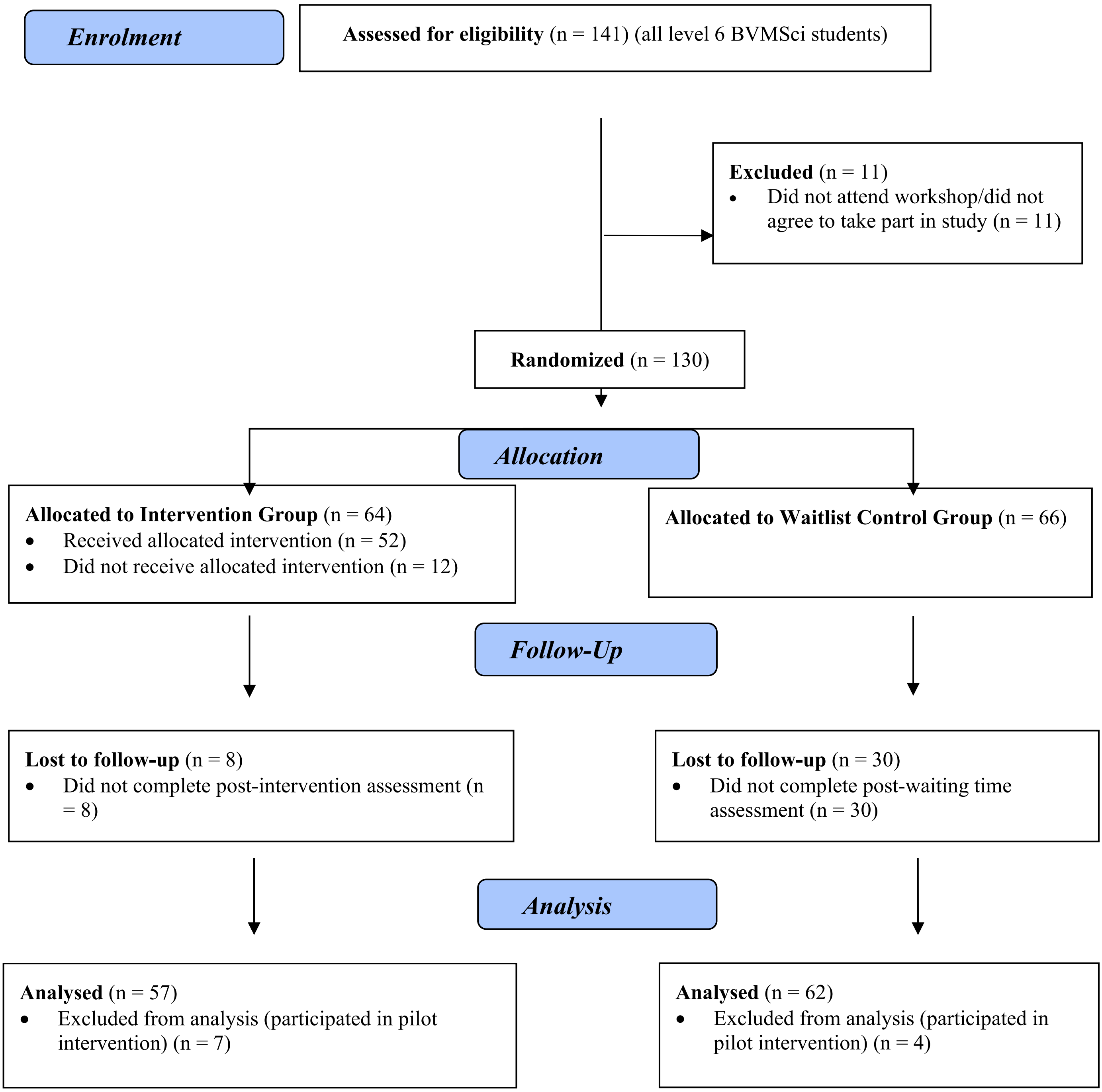

Figure 2: CONSORT flow diagram for the study

Table 1: Learning outcome measures and covariance-adjusted means and standard errors with *p*-values from the ANCOVA results for all outcome variables at post-test, controlling for pre-test scores

			IG	WLCG	
Background to learning outcome	Learning outcome description	Measures of learning outcome	*M* (*SE*)	*M* (*SE*)	*p*
Animal–animal and human–animal interactions contribute to bacterial transfer in veterinary practice and resultant AMR development (Guardabassi et al. 2004**;** Pomba et al. 2017).	A. Knowledge about causes, sources and spread of infection in veterinary practice	A1. Knowledge about causes of infection	1.78 (0.08)	1.90 (0.08)	.29
		A2. Understanding sources of microbial contamination	6.30 (0.14)	5.50 (0.14)	<.001
		A3. Considering risk of pathogens	6.15 (0.15)	5.70 (0.16)	.04
		A4. Actions to reduce pathogen transfer	2.04 (0.12)	1.79 (0.13)	0.15

		A5. Knowledge about animal sources of infection	18.67 (0.31)	16.35 (0.33)	<.001
		A6. Knowledge about equipment as a source of infection transfer	18.66 (0.37)	16.15 (0.40)	<.001
HH is the most cost-effective means by which IPC, including AMR, can be minimised (WHO. 2016). Providing opportunities to learn about HH could improve compliance (Kupfer et al. 2019).	B. Knowledge about and confidence about HH/personnel as a source of infection transfer	B1. Confident to use appropriate ICM	6.41 (0.10)	5.56 (0.11)	<.001
		B2. Hand to surface transfer	18.80 (0.32)	16.56 (0.35)	<.001
		B3. Self-infection	6.12 (0.19)	5.46 (0.20)	.02
Known prescriber behaviours that can lead to		C1. Defining the term asepsis	1.50 (0.13)	1.58 (0.14)	.68

AMR development (King et al. 2018; Currie et al. 2018) and poor IPC practices include possible post-surgical antibiotic use in companion animal practice (Singleton et al. 2017).	C. Knowledge about general IPC and perceived confidence about IPC	C2. Understanding what asepsis is	6.19 (0.14)	5.69 (0.15)	.02
		C3. Informed about ICM	3.70 (0.11)	2.82 (0.12)	<.001
		C4. Confidence about IPC	4.07 (0.09)	3.57 (0.09)	<.001
The Intervention covered IPC and bacterial contamination. Veterinary students may lack knowledge about AMS impact on their future prescribing behaviours	D. Knowledge about AMR	D1. Knowledge about AMR	12.69 (0.24)	11.82 (0.26)	.02
	E. Knowledge about the relationship between IPC and AMR	E1. Knowledge about the relationship between IPC and AMR	6.01 (0.17)	5.36 (0.19)	.01
	F. Knowledge about the role of IPC in AMS	F1. Preparing a 32 kg golden retriever for surgery	11.94 (0.40)	11.44 (0.43)	.41

(Golding et al. 2022; Anyanwu et al. 2018; Espinosa-Gongora et al. 2021).		F2. Preparing a dog for an operation on the distal limb	1.54 (0.16)	1.05 (0.17)	.05
	G. Knowledge about the role of disinfection and PPE use for IPC in practice	G1. Knowledge about PPE use and disinfection for IPC in practice	25.27 (0.42)	23.04 (0.46)	<.001
		G2. Reducing pathogen transfer	1.71 (0.10)	1.72 (0.10)	.94
		G3. Ranking knowledge about PPE use and disinfection for IPC in practice			
		G3a. Disinfection of hands using alcohol after touching every animal	3.49 (0.33)	3.00 (0.36)	.32
		G3b. Staff having a shower at the end of the day	5.82 (0.35)	5.63 (0.39)	.72
		G3c. Washing uniforms every day	5.24 (0.21)	5.03 (0.23)	.52

		G3d. Changing uniforms when moving from one part of the practice to the next	4.97 (0.34)	5.58 (0.37)	.23
		G3e. Washing the whole animal prior to surgery	6.04 (0.33)	5.47 (0.36)	.25
		G3f. Washing hands with soap and water after touching every animal	3.47 (0.35)	3.34 (0.38)	.81
		G3g. Cleaning the consultation room table after every animal with a disinfectant	2.97 (0.34)	3.23 (0.38)	.61
		G3h. Cleaning the consultation room every day at least once	4.07 (0.28)	4.63 (0.31)	.19
AMR infections are prevalent in livestock and		H1. Transferable knowledge for use in companion animal practice			

poultry establishments and in manure (Adams et al. 2018 Wang et al. 2021). Additional Public Health England information on zoonotic IPC indicate the same (Gormley et al. 2011). It is useful to explore students' ability to apply the intervention learning laterally.	H. Knowledge transferable to other veterinary and non-veterinary IPC scenarios	H1a. Performing perineal surgery in a tom cat	1.25 (0.14)	1.10 (0.15)	.44
		H1b. Choosing small animal surgeries that may/may not require preventative antibiotics	3.50 (0.32)	2.63 (0.34)	.06
		H2. Transferable knowledge for use in large animal practice	2.59 (0.27)	2.27 (0.28)	.42
		H3. Transferable knowledge for use in non-practice environments			
		H3a. Cleaning kitchen tabletop after cutting raw chicken	4.09 (0.22)	3.61 (0.24)	.15
		H3b. Visiting petting zoos and farms	4.64 (0.51)	4.20 (0.55)	.57

Table 2: Participant feedback as a percentage of respondents in IG

	Agree	Neither agree nor disagree	Disagree
I will change my behaviour in terms of IPC when on all practice and extra mural studies placements	96	2	2
Enjoyable way to learn IPC	88	9	3
Engaging way of learning IPC	87	5	8
Effective in teaching the role of asepsis in AMS	92	4	4
Changed my attitude towards asepsis and its role in AMR	82	15	3
Greater understanding of asepsis	83	12	5
Require additional resources to learn AMS	59	19	22
Enhanced learning through discussion	88	9	3