

ORIGINAL RESEARCH

Survey of students' learning experience using a virtual slaughterhouse simulator in three UK veterinary schools during the COVID-19 pandemic

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Abstract

Background: Although visiting an abattoir is mandatory for all UK veterinary students, this was challenging during the COVID-19 pandemic and virtual simulators were temporarily approved by the Royal College of Veterinary Surgeons. Subsequently, the virtual slaughterhouse simulator (VSS) was used by the University of Nottingham School of Veterinary Medicine and Science, the University of Liverpool School of Veterinary Science and the Royal (Dick) School of Veterinary Studies in Edinburgh. This study aimed to evaluate the student learning experience using the VSS.

Methods: An online survey containing satisfaction and assessment questions was distributed to all final-year students who used the VSS from September 2020 to August 2021.

Results: A total of 207 students completed the survey ($n = 207/488$, 42%). Students were mostly highly satisfied and found the VSS very useful for their learning ($n = 164/207$, 79%); however, anxiety levels to visit a real abattoir lowered for less than half of the students ($n = 97/207$, 46%). Most students obtained an overall mark over 50% in the assessment questions ($n = 197/207$, 95%).

Limitations: Although the findings were very positive, extrapolation to other veterinary schools and postgraduate curricula should be done cautiously.

Conclusion: The VSS is a valid tool for training veterinary students. However, more research is advised to compare virtual and real experiences and assess students' long-term performance.

INTRODUCTION

Veterinary services, including official veterinarians (OVs) at abattoirs, are considered a public health good and are key for safeguarding public health and animal welfare.¹ According to the retained EU legislation (paragraph d of Section V.4 of Annex V of the Directive 2005/36/EC on the recognition of professional qualifications), all veterinary students must visit a primary food facility, where slaughtering and processing of food animals takes place, during their practical training.² It is also recommended that they visit an abattoir as part of their working experience. However, the latter is becoming increasingly difficult to achieve due to health and safety issues as well as privacy concerns of food business operators (FBOs). Additionally, students might be unable or unwilling to gain such

experience through abattoir extramural placements.³ Recognising these challenges, since 2009, the Royal College of Veterinary Surgeons (RCVS) has stated that a commercial primary food production site should be visited as part of the core curriculum of all UK veterinary schools.⁴ Hence, all veterinary schools in the UK incorporate at least an abattoir visit during their training. However, during the academic year 2020–2021, most UK veterinary students were not allowed access to any food processing facility due to COVID-19 restrictions. Different approaches were taken by the UK veterinary schools, in agreement with the RCVS, to mitigate this situation and achieve the same learning outcomes in the absence of an abattoir visit. These included additional online discussions, access to extra visual resources, and notably, the use of virtual abattoir simulators.

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Simulators are machines or software that are able to provide the user with an experience similar to reality, replicating substantial aspects of what they try to substitute and allowing guidance and interaction throughout the process.⁵ There is an extensive list of simulation practices commonly used in veterinary medicine, including animal mannequins in veterinary clinical skills laboratories and haptic models, all mostly used as a response to the increasing number of students and reduced placement opportunities over time and to reduce the use of live animals due to animal welfare concerns.⁶ Virtual simulators are novel simulator tools that range from screen-based platforms to immersive 3D virtual reality that recreates reality on a computer screen.⁷ In the medical and veterinary environment, this could include the use of augmented and virtual reality for anatomical models,⁸ the use of videogame-like software⁹ and the use of virtual reality multi-user simulators for natural and man-made disasters to improve preparedness and response.¹⁰ Although there are some challenges regarding the level of compassion, empathy and engagement shown in a non-real situation,¹¹ the majority of reviews support the use of simulators in veterinary and medical education,^{12,13} report positive student experiences when using simulators¹⁴ and encourage their continuous use post-pandemic.¹⁵ In particular, using simulators in a virtual learning setting has been found to be useful to improve knowledge retention, clinical reasoning and student satisfaction.¹⁶ Another potential advantage of the simulators in veterinary training is the ability to reduce anxiety levels in students when faced with real world scenarios. Negative emotions, such as high levels of stress and anxiety, have a negative impact on learning,¹⁷ especially when the students are exposed to non-familiar environments.¹⁸ However, existing studies report contradictory outcomes using virtual tools, with some finding simulator users less anxious,¹⁹ while others find no significant difference in anxiety levels before and after using the tool.²⁰ Virtual simulators can be used as part of a distance learning experience or as a face-to-face experience, adding flexibility to their usage. While internet access is not always required, minimal technology, such as a mobile device, computer or laptop, and brief user training are needed.²¹ To deepen student learning, it has been suggested that students should be initially guided throughout the process and allowed time for reflection and debriefing after its use.¹³

There are currently two abattoir simulators in use in UK veterinary schools, the virtual slaughterhouse teaching tool, which uses virtual reality,³ and the virtual slaughterhouse simulator (VSS), which is the focus of this study. The VSS was fully developed in 2015 by the Royal (Dick) School of Veterinary Studies in Edinburgh (R(D)SVS) and shared with other UK veterinary schools during the COVID-19 pandemic. Subsequently, the University of Nottingham School of Veterinary Medicine and Science (SVMS), the University of Liverpool School of Veterinary Sci-

ence (ULSVS) and the R(D)SVS included this resource in the delivery of the veterinary public health (VPH) final-year core clinical rotations during the academic year 2020–2021 to replace abattoir visits. The VSS was pioneered and evaluated as a positive experience by the R(D)SVS in 2013²²; however, at that time, it was used to complement rather than substitute the abattoir visit. The VSS consists of a screen-based virtual simulator with a 'videogame-like' appearance, where a cattle abattoir can be toured and virtually inspected from lairage to dispatch. Furthermore, it includes outside buildings such as feed sheds, animal by-products stores, transport cleaning facilities and animal transport parking lots (Figure 1). The VSS enables students to explore an abattoir fully and find embedded educational activities (authentic case scenarios). It includes 54 information points and eight additional informational boards throughout to access the relevant food safety and animal welfare legislation.

By applying the first two principles of reaction and learning of Kirkpatrick's model (i.e., reaction to the training experience and learning by acquiring the intended learning outcomes),²³ this study aimed to evaluate students' learning when using the VSS to inform further developments and uses of the VSS, enhance the students' learning experience and potentially prepare them better for real-life situations.

MATERIALS AND METHODS

Running of the VSS session in the three participating schools

Students doing their final-year VPH core rotation at the three participating universities (ULSVS, R(D)SVS and SVMS) were divided into groups of four to seven participants and given instructions for the VSS in hard copy and digital formats. A member of staff briefed the students on the use of the VSS for 15–30 minutes, after which they were left alone for around 60–90 minutes to explore the VSS and identify potential VPH-related issues. After this, a staff member would join them to discuss their findings for 60–90 minutes. The total time spent with the VSS was approximately 3 hours per student in all the schools. The R(D)SVS students were also asked to produce an audit report during this session, and a staff member was in the room with the students during the whole session. Human ethical approval was granted by the Committee for Animal Research and Ethics of the SVMS at the University of Nottingham (project number 3201200707).

Questionnaire design and distribution

To achieve the aim of this study, a survey was developed using online questionnaire software (Jisc 2019) that produced a random identifier for each participant. The survey was piloted with 22 students at the University of Nottingham and distributed from



FIGURE 1 Screenshots of virtual slaughterhouse simulator videogame appearance showing outside buildings (left) and shackling area after stunning (right)

TABLE 1 Highlights of the questions used for the virtual slaughterhouse simulator (VSS) student survey

Section	Theme	Questions
1	Demographics and previous abattoir experience	Demographics: age/country where they spent most of their lives/veterinary school they attend/previous studies/specific areas of interest after graduation. Previous abattoir experience (had the students visited an abattoir before veterinary school, during veterinary school or both and who guided their visit).
2	Experience and satisfaction using the VSS	Usefulness of the VSS towards their learning experience/understanding the official veterinarian role/easiness of navigation through the VSS/reduction of anxiety for a visit to real-life abattoir/usefulness to learn specific legal requirements.
3	Learning value of VSS	Scenario 1: Welfare Scenario 2: Professionalism Scenario 3: Postmortem inspection

17 September 2020 to 29 August 2021 to all final-year students using the VSS in their VPH core rotation at the three participating universities. The survey was sent for completion immediately after using the VSS. Participation was voluntary, but to further improve response rate, faculty at Nottingham allocated a specific time to complete the survey after the VSS session, while Liverpool and Edinburgh lecturers asked the students to complete the survey either at the end of the session or during the self-study periods of the rotation. The survey included three main sections and 22 questions. The general survey structure and highlights of these questions can be found in Table 1.

Section 1 included students' demographics and previous abattoir experience. For Section 2, the students could score the agreement with each of the statements as 0–5, where 5 meant they were fully in agreement with the statement and 0 being in full disagreement. This section also allowed for free-text boxes where the students could give their suggestions for other possi-

ble uses of the VSS and other ways in which the VSS had helped them, suggestions to improve the resource and any further comments.

In Section 3, scenarios selected for the students focused on the OV role regarding animal welfare (Scenario 1), professionalism (Scenario 2) and postmortem inspection (Scenario 3). Table 2 describes each scenario, questions and the rationale for a correct answer. Answers were discussed between the main authors to agree on the scoring of correct and partially correct answers. Answers were classified as correct, partially correct, wrong and no answer. All answers were reviewed and scored by the corresponding author.

The full survey can be found in Appendix A1. All efforts have been made to adhere to the Strengthening the Reporting of Observational Studies in Epidemiology guidance for reporting observational studies,²⁴ as it stands at the time of writing.

Statistical analysis

Descriptive statistics were reported as numbers and percentages. Descriptive data analysis was performed using Microsoft Excel (Corporation M. Microsoft Excel. 2018. www.microsoft.com/en-gb/microsoft-365/excel). Qualitative data were analysed using a combination of deductive and inductive approaches.²⁵ These were further analysed to produce a set of overarching themes. Not all questions were responded to by all the respondents; hence, quantitative results are presented with a denominator when not all students answered a particular question. Quotes may include typing mistakes and grammatical errors as they were directly taken from the data without correction to accurately represent students' answers.

RESULTS

Demographics

A total of 488 students participated in the VSS experience (174 from SVMS, 152 from ULSVS and 189 from

TABLE 2 Section 3 scenarios, questions asked and correct answers

Scenario	Main area of focus	Questions	Correct answer (different wordings accepted)
1: A cow was found at antemortem with a prolapsed uterus.	Welfare	Q1. What would be your first action? Q2. Which further actions would you consider?	Ensure the animal is slaughtered as soon as possible. Collect all the evidence and report to the competent authorities (Animal and Plant Health Agency and Trading Standards).
2: The body of an emergency slaughtered (killed on farm) cow was brought into the abattoir, the FCI form for emergency slaughter of an animal was signed by the PV stating the animal suffered from chronic lameness and withdrawal periods were not complied with.	Professionalism	Q1. If called as a PV to the farm, would you have considered this animal as eligible for emergency slaughter? Explain why. Q2. What would be your judgement for the carcass and why? Q3. What are the potential consequences for the PV who signed the FCI?	No, the animal suffered a chronic condition so cannot be signed as emergency slaughtered, plus withdrawal periods had not been complied with. Full rejection as it contains veterinary residues. Could face disciplinary action by the RCVS.
3: A bovine heart rejected due to <i>Cysticercus bovis</i> .	Postmortem inspection	Q1. What is the condition affecting this heart? Q2. No other lesions or conditions were found, what is your judgement on the heart and on the carcass?	<i>C. bovis</i> . Heart rejected as category 2 animal by-products, carcass will need freezing under OV supervision before releasing for human consumption.

Abbreviations: FCI, food chain information; OV, official veterinarian; PV, private veterinarian; RCVS, Royal College of Veterinary Surgeons.

R(D)SVS), of which 207 completed the survey ($n = 207/488$, 42.4%), with a higher response rate to the survey from Nottingham ($n = 111/207$, 53.6%), followed by Liverpool ($n = 70/207$, 33.8%) and Edinburgh ($n = 26/207$, 12.6%). Most of the students were under 26 years old ($n = 178$, 86%) and had spent most of their lives in the UK ($n = 179$, 86.5%). Some students ($n = 37$, 18%) had a professional degree before starting their current veterinary degree, most of which were animal related, except for two students whose degrees were in law or in history and social studies.

When asked about their main area of interest for future jobs, students could select up to two options. The area most frequently chosen was small animals ($n = 157$, 75.9%), followed by farm animals ($n = 59$, 28.5%) and horses ($n = 51$, 24.6%). Wildlife was in the fourth position ($n = 21$, 10.1%), followed by VPH ($n = 11$, 5.3%), mixed practice ($n = 10$, 4.8%), poultry ($n = 7$, 3.4%), research ($n = 6$, 2.9%), pathology ($n = 1$, 0.5%) and non-veterinary ($n = 1$, 0.5%) (Figure 2).

Previous abattoir experience

Less than half of the students who completed the survey had been to an abattoir ($n = 95/207$, 46%). Of those who had visited an abattoir before, 55.8% ($n = 53/95$) had been to an abattoir only before they started veterinary school, 27.4% had been to an abattoir only during their veterinary degree years ($n = 26/95$) and 16.8%

of the students had been to an abattoir before and after they started their degree ($n = 16/95$) (Figure 3). When visiting an abattoir, the students were accompanied only by the OV ($n = 17/95$, 17.9%), the FBO ($n = 16/95$, 16.8%), a meat inspector ($n = 3/95$, 3.2%), teaching staff ($n = 8/95$, 8.4%) or different combinations of OV/FBO/meat inspector/others ($n = 37/95$, 38.9%). There were 13 students who were unsure or could not remember or were accompanied by others ($n = 13/131$, 16.7%), and one student did not respond to this question ($n = 1/95$, 1%).

Students' experience with the VSS

Students' opinions after using the VSS were overall positive, with most statements receiving ratings of 4 or 5 from the majority of students, except for the 'I feel less anxious/nervous to visit a real abattoir' statement, which received just under 50% of 4 or 5 ratings combined (Figure 4).

Abattoir usefulness in specific areas

The students were asked if the VSS had helped them to understand different legal requirements and potential issues they may encounter in a real abattoir. Most students scored 4 or 5 out of 5 for all of them (Figure 5).

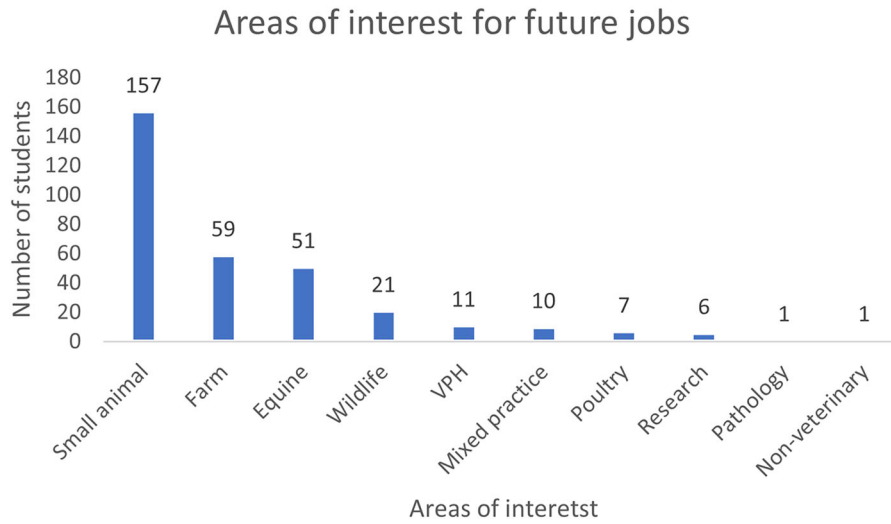


FIGURE 2 Main areas of students' interest for future jobs when asked to select two main areas of interest. VPH, veterinary public health

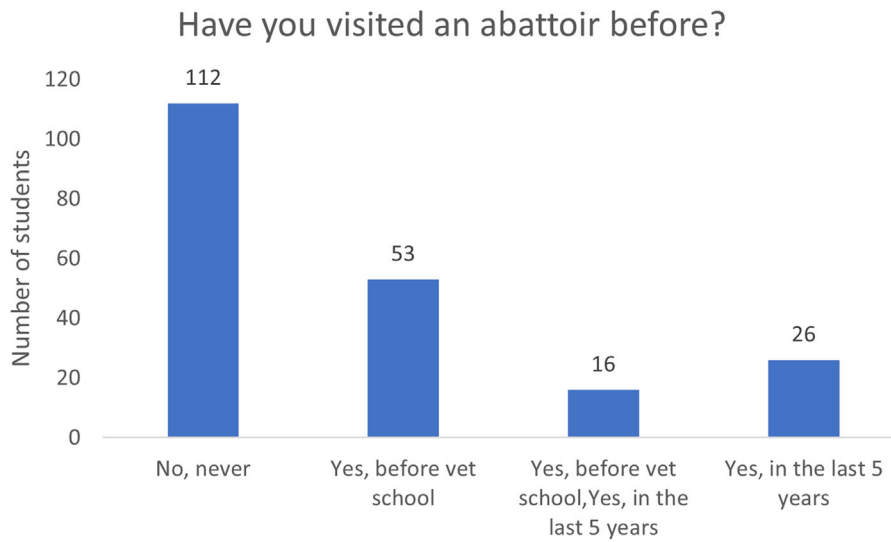


FIGURE 3 Students' previous abattoir experience (*n* = 207)

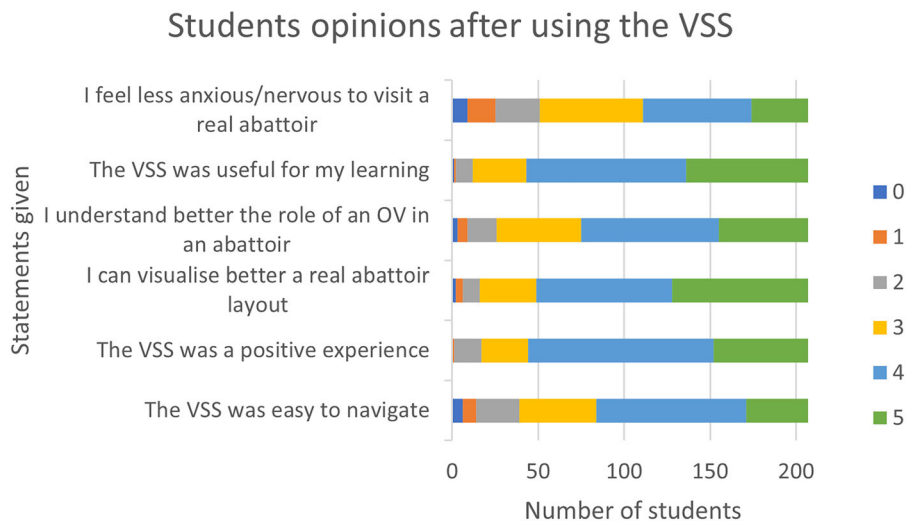


FIGURE 4 Students' opinions of the five statements given regarding the use of the virtual slaughterhouse simulator (VSS). Students could score each statement from 0 (full disagreement) to 5 (full agreement). OV, official veterinarian

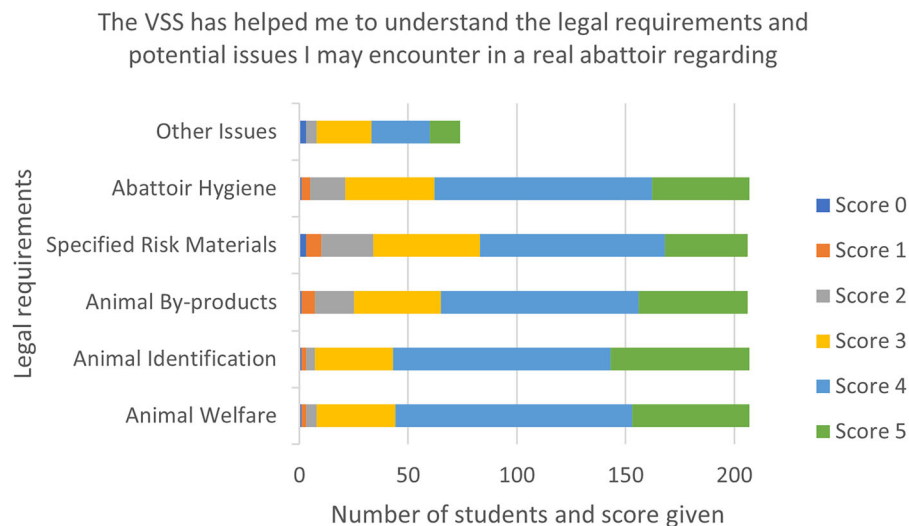


FIGURE 5 Students' responses regarding the usefulness of the virtual slaughterhouse simulator (VSS) to understand legal requirements and potential issues that they could encounter when inspecting an abattoir

A total of 36 students wrote comments after the question: If you selected 'other issues', please let us know which other legal requirements and potential issues you learned about with the VSS. The themes most mentioned were what, who and how to report issues and general design requirements (Table 3).

Students were then asked if the VSS had helped them in any other ways and were given the opportunity to explain their answer. A total of 40 responses were grouped into themes. Revision and visualisation of potential scenarios were the most frequently mentioned uses (Table 4).

In the free-text boxes, a total of 103 students gave ideas for how to improve the VSS, with making the VSS easier to navigate and improving the graphics being most mentioned (Table 5).

The last free-text box question offered the students the possibility to add any other comments; 23 students commented, with most being thankful and praising the usefulness of the VSS. One student addressed that a real abattoir visit would have been preferred or added to the VSS session, while another student specifically mentioned that the VSS was a good substitute and/or complement to a real abattoir visit: 'Overall, the VSS is a great tool and helps a student in lieu of an actual visit to an abattoir or as a supplement to a real visit!' (student 638036-638027-67913947).

Learning experience assessment

For the first scenario, all students who answered recognised that the animal had to be emergency slaughtered on welfare grounds ($n = 196/196$); however, only 58.9% of students considered this option as their first action, with the rest of the students suggesting isolating the animal instead or reporting the issue to the authorities first. Similarly, 59.7% correctly considered reporting to the competent authorities as a further action.

For the second scenario, the paperwork wrongly completed by the private veterinarian was correctly

TABLE 3 Other legal requirements and potential issues students reported learning about with the virtual slaughterhouse simulator

Theme	Examples of quotes for the theme and student unique response number
What, who and how to report ($n = 11/36$)	To whom you have to report certain issues to (student 638036-638027-66372618). Who you would report issues with (i.e., Animal and Plant Health Agency, Trading Standards or RCVS) (student 638036-638027-71810985).
Specific design requirements for an abattoir ($n = 11/36$)	The layout of the actual buildings (student 638036-638027-65849909). Actual physical/architectural navigation of an abattoir and how those practical considerations are incorporated with the legal/hygienic/welfare practicalities and how the physical design of the abattoir plays into these considerations (student 638036-638027-68379001).
Animal transport regulations ($n = 6/36$)	Transportation requirements (student 638036-638027-67888853). Transport legislation and who to go to with issues (student 638036-638027-66071864).
Emergency slaughter regulations ($n = 5/36$)	Emergency slaughter (student 638036-638027-66870172).
Rejections conditions ($n = 2/36$)	Parasites (not legalities of them but what parasites to look for and what can be done in regards to disposal) (student 638036-638027-74094816).
OV role in an abattoir ($n = 2/36$)	What the OV has the authority to do (student 638036-638027-67930516).

Abbreviations: OV, official veterinarian; RCVS, Royal College of Veterinary Surgeons.

spotted by almost all the students who answered this question ($n = 175/185$, 94.6%), most also stated correctly that the carcass could not enter the food chain ($n = 175/185$, 94.6%) and 97.8% ($n = 181/185$)

TABLE 4 Students' responses to the question 'Did the virtual slaughterhouse simulator help you in any other ways?'

Theme	Examples of quotes for the theme and student unique response number
For revision (<i>n</i> = 13/40)	In general it was useful to go over and revise as VPH was taught in third year (student 638036-638027-66609480). Good revision (student 638036-638027-68404389).
To visualise potential scenarios (<i>n</i> = 12/40)	Useful to think about how different animals may be dealt with, for example, a prolapse cow is a welfare issue so should be killed immediately; however, this may be different with an infectious disease (student 638036-638027-65849889). The examples of common findings at PMI were also extremely useful to practice (student 638036-638027-67913947).
For a better understanding of the abattoir and process overall (<i>n</i> = 12/40)	It helped me to visualise an abattoir and solidified my learning in a much better way than just reading legislation (student 638036-638027-68746106). Visualising the production line (student 638036-638027-67606252).
Promoted useful discussions (<i>n</i> = 6/40)	Good discussion about the role of OV and reporting (student 638036-638027-65338670).
It was fun/interactive (<i>n</i> = 2/40)	Interactive which was nice! (student 638036-638027-67888740).
Legislation (<i>n</i> = 3/40)	Understanding the legislation in the UK (student 638036-638027-65767734). Laws behind emergency slaughter as a veterinarian in practice, when you can and cannot, and the consequences of being reported if you wrongly emergency slaughter (student 638036-638027-71810926).

Abbreviations: OV, official veterinarian; PMI, postmortem inspection; VPH, veterinary public health.

mentioned that the private veterinarian could face disciplinary action.

The postmortem lesion in the third scenario was correctly identified by most students who answered the question (*n* = 161/190, 84.7%), as well as the acknowledgement of rejection of the heart. The need to freeze the carcass prior to release for human consumption, which granted full marks to this scenario, was mentioned by just over one-third of the students who answered this question (*n* = 68/183, 37.1%) (Figure 6).

DISCUSSION

In the UK, all veterinary students need to visit an abattoir during their veterinary training and ensure that they meet the related Day One Competences.²⁶ During the COVID-19 pandemic, students' access to abattoirs was compromised, and the use of the VSS was introduced in three veterinary schools in the UK. To evaluate the student learning experience with the VSS, a survey aimed at exploring their overall experience

TABLE 5 Students' responses to the question 'How would you improve the virtual slaughterhouse simulator?'

Theme	Examples of quotes for the theme and student unique response number
Could be easier to navigate (<i>n</i> = 34/103)	Better map, ability to search and go to an information point (student 638036-638027-74088770). A better map to find places more easily (student 638036-638027-74088697).
Better graphics (<i>n</i> = 27/103)	Better graphics, make it more obvious what you're supposed to be looking at (student 638036-638027-72577510). Difficult to see some graphics such as the '2D' cows in the bleeding room. Would like to see more case photos of issues in abattoirs (student 638036-638027-72577417).
More information provided (more scenarios, printouts, disclosure of scenarios ...) (<i>n</i> = 15/103)	Having the option to see where the compliance issues are would be useful, but I understand you want us to find them ourselves too (student 638036-638027-70484557). It doesn't work from an assessment point of view but as a revision tool if there was a feature where you could skip through all the issues and had an explanation associated that would be useful. It is a bit annoying to have to 'walk' around trying to find things (student 638036-638027-68949346).
Videos of real abattoirs embedded (<i>n</i> = 13/103)	Maybe video clips of real animals in the lairage/production line (student 638036-638027-71810985). Would be nice to have a clip from a real abattoir to see what a real one is like rather than all virtual (student 638036-638027-69553997).
Provide more interaction opportunities (<i>n</i> = 14/103)	Maybe some questions which you could then click on to reveal the answers to test yourself (student 638036-638027-65338634). More interactive. The information points are hard to read on screen and worded difficultly—would be nice to have a simplified summary of some of them (student 638036-638027-75661497).
More accessible/help (<i>n</i> = 4/103)	I would prefer to be guided around instead of making my own way around. I felt there were a lot of things I missed when I was navigating myself (student 638036-638027-65760258). It's not very easy for people with dyslexia to read, having a feature where the computer reads it out to you or at least being able to enlarge the text and have a filter colour to make it easier to read would really help (student 638036-638027-69554034).

with the software and its learning value was distributed to the students who participated. The results of the study suggest that the VSS was successful at both levels, with most students being satisfied with the experience and capable of correctly answering the different scenarios following the VSS session.

Students' experience using the VSS

The response rate varied per school, with Nottingham being overrepresented in the study. However, the

Assessment of students answers to each question

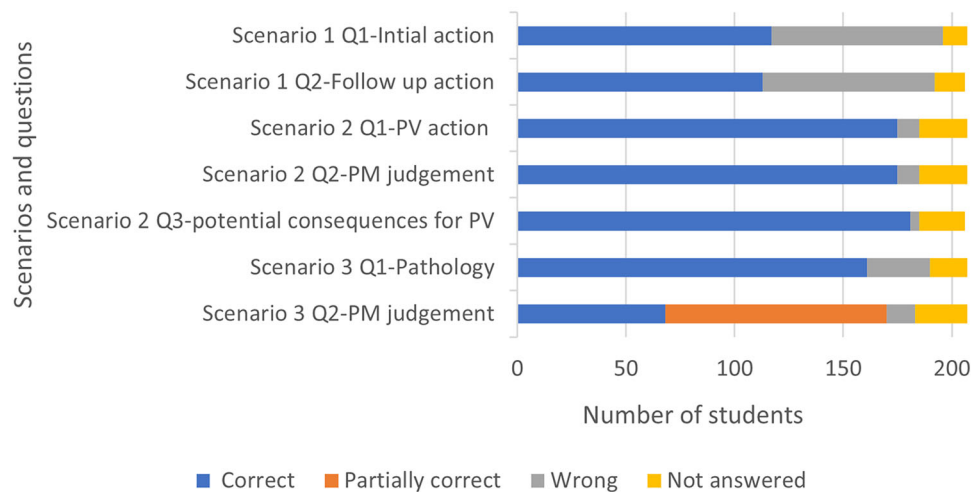


FIGURE 6 Summary of assessment of all answers given by the students to each of the questions in the scenarios. Scenario 1 is a cow with a uterine prolapse found in the abattoir lairage. Scenario 2 is an emergency slaughtered (on-farm) cow arriving at the abattoir where the private veterinarian (PV) has wrongly signed the food chain information. Scenario 3 is a heart with *Cysticercus bovis* presented at postmortem (PM)

demographics, including areas of interest, age and previous studies, are in line with the expected UK veterinary student profile and similar to those found elsewhere in the literature.²⁷ It was encouraging to see a higher interest in VPH over mixed practice, poultry, pathology or research; however, this could be biased, as students interested in VPH would have been more likely to participate in this study.

Less than half of the students had visited an abattoir before engaging with the VSS and could compare it with a real abattoir, while only 12% had seen an abattoir before and during their veterinary degree. Interestingly, most of those who had seen abattoirs would have done so before veterinary school when they had minimal VPH knowledge. Therefore, depending on the level of guidance received during the visit, it is difficult to tell if students could put the process into context and remember key concepts from this experience.²⁸ A lack of opportunities to visit an abattoir during the pandemic could account for the low proportion of students who could visit an abattoir more than once; however, it can also be a reflection of the lack of student interest in exploring these opportunities. The lack of external placements to explore other non-clinical paths and its correlation with students' limited interest to apply for jobs in those areas would warrant further research.

Students' satisfaction and the VSS

Most of the students in this study were satisfied with the VSS at all levels, and encouraging comments revolved around the VSS being a positive experience and being useful for their learning, which is further supported by many praising the tool as a good learning resource, especially for revision. This is in line with

previous reviews in relation to simulators used in veterinary education.^{29,30} However, around 20% of the students found the VSS not easy to navigate, which was unexpected, as 90% of the respondents found it easy to use in a previous VSS study that used a similar approach.²² The VSS was highlighted by one student as not user-friendly for students with dyslexia, which deserves further attention, as dyslexia affects approximately 10% of the population³¹ and around 0.5% of UK university students.³²

VSS and abattoir visits

The least positive result was about anxiety levels, with over half of the students not feeling less anxious to visit a real abattoir after using the VSS. However, the survey did not ask why they felt this way or about anxiety levels before using the VSS; a pre-use survey would have identified this, and this approach would be advisable for future studies. Some students mentioned the limitations of the experience due to the lack of comparison to a real abattoir visit. Similar limited use of simulators to replace the surgery theatre experience, while good for learning, has been reported in human medicine.³³ A recent study with veterinary students also found this outcome; the students who used the simulator felt more knowledgeable and competent, but there was no significant reduction in the level of anxiety.²⁰ Nevertheless, the VSS provides enough information to enhance learning without exposing the students to potentially anxiety-inducing experiences, which enabled them to focus on their learning and enjoy the experience. In fact, two students mentioned 'it was fun' when asked about other uses of the VSS. Previous studies have analysed the relationship between fun and learning, and despite not having found a

significant relationship between those two concepts, they found there is a positive relationship between fun and the attitude towards the topic, which may influence the actual learning experience.³⁴ Similarly, another study that used a simulated cow to teach rectal palpation found that motivation and expectations were determinants of students' learning experience.³⁵ Advantages for safety have also been reported when using simulators for microbiology teaching, which concluded that a mixture of simulation with traditional teaching (virtual–actual approach) was the best way to enhance the learning experience,³⁶ which is supported by this study.

VSS and its learning opportunities

When the students were asked about other uses of the VSS, several students mentioned the VSS was a useful tool for revision purposes. This result is in line with other studies that evaluated the use of software to study and revise areas such as anatomy.³⁷

Another use mentioned by the students was that the VSS promoted discussion. Discussion sits at the higher level of the Bloom's taxonomy cognitive objectives and would suggest that the VSS enables the students to be more capable of evaluating the information given and creating their own ideas, as well as suggesting judgement and potential solutions to a given problem.³⁸ Additionally, according to Brookfield and Preskill,³⁹ discussion brings a range of benefits to learning. These include showing respect for students' voices and experiences, developing the clear communication of ideas, collaborative learning or making students more empathetic,³⁹ which can all be linked to the personal leadership and professional commitment of the RCVS Day One Competences.²⁶

In the present study, discussions were facilitated by experienced staff, and this was appreciated by the students, who mentioned that time spent with staff was essential for their learning. This finding supports the existing literature and is in line with the review done in virtual simulation for healthcare students' clinical competency by Coyne et al.,¹⁴ where debriefing with students was one of the main themes to enhance learning in a virtual environment. Debrief post-simulation also provides opportunities to highlight and learn from mistakes and allows critical analysis of the situation.^{40,41}

VSS and student learning

The learning value of the VSS was investigated by exposing the students to three clinical reasoning scenarios in a comparable way to an open-book exam situation. The results showed that around 95% of the students who had attempted to answer all the scenarios would have passed the assessment, achieving more than 50% of the total marks, which provides evi-

dence that the VSS is a good learning resource and useful for staff to identify areas where students struggle and reinforce them in the teaching. This suggests that both experiences, real and virtual, are valid and complementary rather than one being a substitute for the other. This result is in line with other studies that found no superior performance of students using the virtual simulations versus traditional methods^{41,42} and supports further research in the veterinary environment in relation to learning outcomes when virtual simulators are used.⁴³

Student suggestions for improvement

The students suggested several improvements to the VSS. Aside from the graphics and user-friendliness, a common suggestion was to embed videos of real abattoirs into the VSS layout. Video clips are frequently used by undergraduate students for their learning and have been found to be particularly useful in a recent study, which also addresses the importance of creating good video clips to prevent the use of arbitrary YouTube videos.⁴⁴ Students also suggested improving the interactivity of the VSS by adding options that could provide feedback when answered. This approach has also been used in virtual farm visits to increase realism through role-playing and was reported to improve student engagement.⁴⁵ While the study results support investment in all the students' suggestions, adding and updating meaningful feedback can be technologically demanding and time consuming and could be better provided by facilitators. This would be similar to simulated consultations with actors, used in veterinary teaching for history taking and for developing clinical reasoning.⁴⁶ The improvements suggested would also align with the Universal Design for Learning, which is a proactive approach to addressing barriers in education and focuses on ensuring accessibility by creating resources that can deliver the curriculum through multiple means of expression, representation and engagement techniques.⁴⁷

Limitations of the study

Although the results of the study are encouraging, the survey included students from only three of the nine UK veterinary schools; therefore, extrapolation of the results to other schools in the UK and abroad as well as their use at the postgraduate level should be done carefully. Similarly, the results regarding students' learning need to be considered with caution, as all students in this study undertook only the virtual experience. Further research to compare the different virtual abattoir simulators available with the real abattoir experience and assess students' long-term performance would help to fully evaluate the potential of the VSS.

CONCLUSION

In conclusion, this study shows that the VSS is a useful teaching and learning resource for veterinary students. When the VSS is the only available option, it can successfully provide an adequate learning experience; however, it should not replace a real abattoir visit. The results of the study encourage further investment to improve this technology for the benefit of the veterinary workforce in any country.

AUTHOR CONTRIBUTIONS

Study conception and design: Amelia Garcia-Ara and Alessandro Seguino. *Literature search and data collection:* Amelia Garcia-Ara and Elsa Sandoval-Barron. *Analysis and interpretation of results:* Amelia Garcia-Ara and Elsa Sandoval-Barron. *Draft manuscript preparation:* Amelia Garcia-Ara and Elsa Sandoval-Barron. All authors reviewed the results and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

In line with standard ethical review processes, human ethics approval for this student survey study was granted by the University of Nottingham's Committee for Animal Research and Ethics (project number 3201200707).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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