







SUPPLEMENT ARTICLE

Reproduction in Domestic Animals

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Teaching small animal reproduction via virtual patients

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Abstract

Virtual patients have become an interesting alternative in medical education. Due to increasing demands regarding theoretical and clinical teaching and to improve an interdisciplinary approach, a new blended learning concept including virtual patients was developed and implemented in the veterinary curriculum of the Freie Universität Berlin. In the presented project, three virtual patients from the field of canine reproduction were developed. They focus on pregnancy diagnosis with suspected luteal insufficiency, pyometra and benign prostatic hyperplasia, respectively. The results of an evaluation by veterinary students of the 7th semester showed a high acceptance of virtual patients in a blended learning reproduction module in the interdisciplinary lectures. Students especially preferred videos, such as video lectures, hands-on videos and animations as well as a glossary for background information, to successfully and autonomously work on a virtual case. The content covered by the new modules that were developed in the context of this project is part of a spiral curriculum; they will be revised and enhanced during the clinical year.

KEYWORDS

dogs/cats, general reproduction, interdisciplinary research, online learning, simulation training, veterinary education

1 | INTRODUCTION

The project QuerVet focuses on improving the interdisciplinary lectures offered to veterinary students at the Faculty of Veterinary Medicine, Freie Universität Berlin, by presenting relevant virtual patients and cases in veterinary public health (VPH).

In the German regulations of licensing to veterinary medicine (TAppV, 2006), the curriculum time available for interdisciplinary lectures is 196 hr; most of it in study semesters 6–8.

These interdisciplinary lectures are supposed to offer case-based content that is relevant in veterinary practice. The listed clinical

subjects, for example, should address health problems related to internal medicine, surgery and reproductive medicine with consideration of pathology, animal nutrition and anatomy. The clinical focus should lie on identifying the origin, diagnosis and therapy of diseases through specific cases (TAppV, 2006).

Until 2016, the interdisciplinary lectures offered at our faculty did not follow a coherent course concept. Lecture slots were assigned to the different institutions and lecturers, and the selection of topics was heterogeneous. Most lectures were given as an in-class lecture with a duration of three hours, and less than half of the topics were presented in an interdisciplinary or case-based structure. In a

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survey in 2014, over 50% of the interviewed students evaluated the interdisciplinary lectures as not efficient for teaching interdisciplinary topics (Schunter, 2016).

Education of veterinary students must include practical clinical training on live animals. For this, students have to be prepared through a learning cascade starting with demonstration of certain practical procedures, repetition of those procedures under supervision and the refinement of the procedure. Since the use of animals in education is classified as an animal experiment according to the European Directive 2010/63/EU on the protection of animals used for scientific purposes (Directive, 2010/63/EU, 2010) and this has been implemented into the German Animal welfare act in 2013 (German Animal Welfare Act, 2006), it has to be applied for authorization to the competent authorities. Everyone using animals for educational purposes is obligated to implement the 3R principles, which means to replace animal use by alternative teaching methods wherever possible (Replace). If animal use is unavoidable, the number of animals has to be reduced to the minimum requisite (Reduce) and techniques should be used which pose the minimal burden to the animal (Refine).

Virtual patients are 'interactive computer simulations of real-life clinical scenarios for the purpose of medical training, education, or assessment' (Ellaway, Candler, Greene, & Valerie, 2006). It has been shown that the interactive format of virtual patients enhances diagnostic and clinical reasoning skills of veterinary students (Kleinsorgen et al., 2018) and that virtual patients make students feel better prepared for real patients with similar clinical symptoms (Lehmann et al., 2015). The combination of virtual patients with face-to-face teaching is important for their successful integration, which is called 'blended learning' (Lehmann et al., 2015). More benefits of virtual patients are avoiding risks for patients and learners, standardizing learning experiences and mediating learning experiences using practice-like situations (Ellaway, Topps, Lee, & Armson, 2015).

Virtual patients, therefore, could offer a feasible solution to the problems of interdisciplinary education as well as help to further refine and reduce animal experiments in practical veterinary education.

However, to this extend virtual patients have not yet been systematically integrated in veterinary education for teaching interdisciplinary lectures in a mandatory blended learning format in Germany.

Our aim was to develop and implement an interdisciplinary course with virtual cases starting with a small animal reproduction module consisting of three virtual patients. They were implemented in a blended learning concept, adapted to the existing curriculum and addressed topics relevant in veterinary practice. The evaluation of this reproduction module by students focussed on the acceptance of virtual patients. For this context, we examined the didactic use of media and the usability and the self-assessed learning outcome. Also, we analysed the assessment of the blended learning concept in an overview of the complete semester with several modules.

2 | MATERIALS AND METHODS

2.1 | Design

2.1.1 | First step—Choice of Topics and learning objectives

Relevant clinical topics for the virtual patients were identified in a survey sent to veterinarians working at Freie Universität Berlin and other veterinary clinics or practices in Germany. From this list, topics were chosen in consultation with the clinical lecturers at our faculty for the blended learning approach. According to the specifications for interdisciplinary lectures (TAppV, 2006), we created a general case structure and then aligned it to real scenarios with specific diagnoses. We defined learning objectives for each case and made them available to the students at the beginning of the case. The learning objectives were categorized according to Bloom's Taxonomy for learning objects for systematic classification of the process of learning (Bloom, 1976). In addition, for each specific topic, we created individual modules containing different virtual patients or cases.

2.1.2 | Second step—Curriculum and implementation

The curriculum was analysed for the most appropriate time to implement the specific topics, so that the students are able to work on each module while having enough prior knowledge. This analysis was a first step to establish a learning spiral, that is that specific information will be refreshed and enhanced during the curriculum. Furthermore, the relevant prior knowledge necessary to understand and work on the case was listed at the beginning of each case. For the implementation of the modules within this blended learning approach, free slots were provided in the timetable for students to work on the online cases. However, they could also use other times during the respective time periods, generating a high flexibility in time and place. Students had usually one week to work on each case. To increase autonomous and active learning in the online phase, the students received virtual patients with necessary background information and if needed the opportunity to get support for technical or content-related problems. To enable face-to-face discussions on a higher level during the in-class lecture, we scheduled one 90-min lecture after the completion of the reproduction module with three online cases.

2.1.3 | Third Step—Learning platform and case structure

We used the learning platform tet.folio, an online web application developed at Freie Universität Berlin, Department of Physics, Physics education unit (Haase, Kirstein, & Nordmeier, 2016). It was created with

an emphasis on customized interactive content. Students work page by page through the online course-book. Answers, notes and other activities are always saved individually. The platform was integrated into the learning management system Blackboard (Washington DC, USA) used at the Freie Universität Berlin. This had the advantage that students had a familiar platform to access the modules, that tet.folio activities were automatically transferred into the Blackboard grade centre and that users only needed to login once (single-sign-on).

Within the case structure, realistic scenarios of decision-making and assessing clinical findings were simulated. In addition, feedback tools were implemented to provide the students with visual and textual feedback depending on the correctness of the given answer or decision. For each virtual patient, a glossary with relevant background information including hands-on videos and animations regarding the patient and its diagnosis was created and selectively linked to the suitable position within the case. Also, students had the opportunity to use a virtual notepad to keep their notes about the patient at hand all the time. After completion of the case, students were given access to download and print a modified glossary.

2.1.4 | Fourth step—Material and media

Whenever possible, already existing material such as radiographs, ultrasound images or videos of patients and their symptoms was used to build realistic virtual patients.

In addition, educational videos including videos showing practical procedures (hands-on videos) or short lectures as well as animations were created to give the students more insight into or understanding of specific topics regarding the patient.

Interactive elements such as an abdominal ultrasound examination and a swab-sample taking were created in a close cooperation with the Department of Physics. For the interactive element of the abdominal ultrasound, for example, the movable picture of an ultrasound probe was linked to the playback of a sagittal abdominal ultrasound of a bitch using a specific html5 programming routine. The students were asked to move the probe with the mouse cursor to control the video which would move accordingly to the student's mouse cursor motion (Figure 1).

2.1.5 | Fifth step—Realization

For the clinical part, one pilot case concerning small animal reproduction and a related in-class lecture for further discussion were implemented. In a short introduction prior to the implemented case, the concept and web application were explained, and students had the opportunity to log in with our assistance and ask further questions.

The following year, two additional cases were added to this reproduction module. After completion and implementation of this reproduction module, students worked on three virtual patients in a three-week online period and finished the module with an interactive in-class lecture for discussing questions and problems (Figure 2).

2.1.6 | Ethic votum and animals in research

An ethics proposal for the evaluation by the students was submitted with the application number EA4/125/18 and approved by the Ethics Committee of the Charité at Campus Benjamin Franklin.

All animal-patient-related examinations, procedures and handling protocols used in the respective modules were approved by the local competent authorities, which is in Berlin the Regional Office for Health and Social Affairs (LAGeSo, L 0001/17). All applicable national and institutional guidelines for the use and care of animals used in education were respected. Experimental procedures were assessed as minor discomfort experienced by the animals, and therefore the severity was categorized as mild.

2.2 | Evaluation

For the pilot case, we chose a more complex survey, which, in addition, concentrated on the didactic use of media and the case-related usability. Both we examined immediately after completion of the online case. For the didactic use of media, the usefulness of provided functionalities (description of learning outcome, textual feedback, visual feedback, notepad, mail button for support, introductory tutorial) and material such as the video lecture, hands-on videos, animations, interactive element (swab-sample taking/abdominal ultrasound) and the glossary were examined (Appendix S1). The survey of the usability focused on availability of necessary information, comprehensibility of texts, structure of texts, availability of important content for processing of tasks, association of the case with clear tasks and objectives and the level of difficulty of the exercises (Appendix S2). The case-related usability was also evaluated in the following semesters 2017/18 and 2018/19.

Moreover, with a focus on the overall concept, we asked the students in a paper-based survey about the self-assessed learning outcome of the reproduction module in the three categories knowledge, comprehension and application (Appendix S3) and the blended learning concept (Appendix S4). These two surveys were conducted in the semesters 2017/18 and 2018/19. The survey of the self-assessed learning outcome in the first three categories is already implemented in the quality assurance at the Faculty of Veterinary Medicine, Freie Universität Berlin. This survey questionnaire was adjusted to the new reproduction module with a total of 26 specific statements in the three categories.

The survey of the blended learning concept consisted of five statements regarding the explanation of the overall concept, preference of face-to-face teaching over online teaching for the learned topics, preference of blended learning, wish for expansion of the concept to other lectures and the meaningful combination of contents of online cases with face-to-face lecture in the modules of the semester. Here a veterinary public health module was integrated into the winter semester besides the reproduction module and examined equally.

An overview of the conducted surveys can be seen in Figure 3.

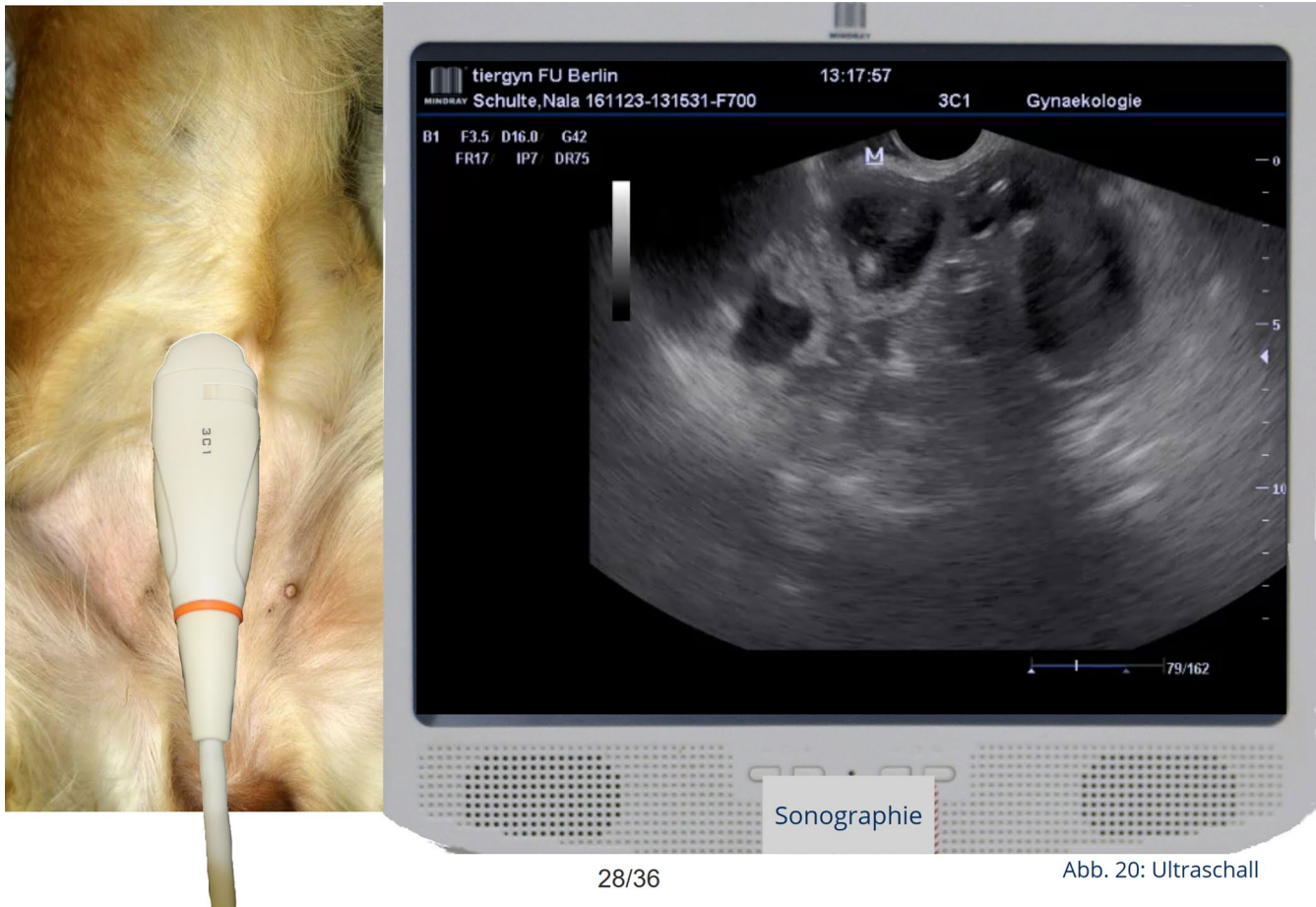


FIGURE 1 Screenshot of an interactive element in the pilot case. By moving the probe up and down with the mouse cursor the ultrasound-video on the right moves accordingly. Students were asked to analyse the ultrasound findings and determine if the bitch is pregnant

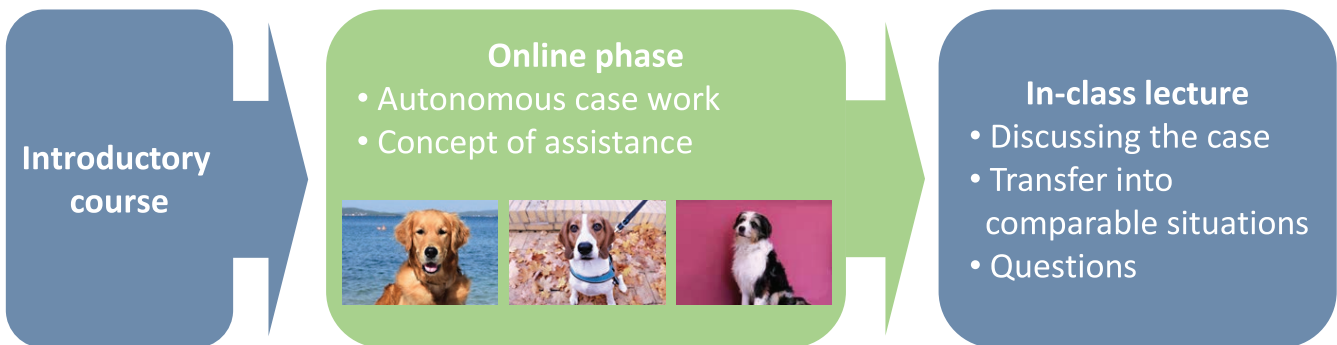


FIGURE 2 Chart showing the blended learning concept of the reproduction module with an introductory course, an online phase for working autonomously on the three virtual patients and an in-class lecture for further questions

In cooperation with the Center for Digital Systems at Freie Universität Berlin, we developed survey tools. This survey included questions and statements to which students were asked to indicate their level of agreement on a response scale consisting of items of the Likert type. The surveys were carried out with Unizensus 5.4.14 (Blubbsoft GmbH). Unizensus is the central evaluation software of the Freie Universität Berlin for teaching and course evaluations.

The results of the surveys were analysed and used for improvement of the following cases.

All surveys were anonymous and voluntary.

After having conducted the pilot case, newly developed e-learning cases were continuously evaluated with both paper-based and online surveys depending on the phase within the modules, but the size of the surveys was reduced.

Case-based Survey			Concept-based Survey		
CATEGORY	ITEM	TARGET	CATEGORY	ITEM	TARGET
Didactical usage of media	<ul style="list-style-type: none"> Usefulness of the given materials (videos, animations, interactive elements, glossary, notepad, tutorial) 	Pilot case only Winter semester 16/2017	Self-assessed learning outcome	<ul style="list-style-type: none"> Knowledge Comprehension Application 	complete module Winter semester 17/18, 18/19
Usability	<ul style="list-style-type: none"> Structure and comprehensibility of content Association with clear tasks Difficulty of tasks 	Pilot case and complete module Winter semester 16/17, 17/18, 18/19	Blended Learning concept	<ul style="list-style-type: none"> Explanation of the overall concept Preference of online or face-to-face learning Expansion of the concept to other lectures Combination of online and in-class lectures 	Entire course including the complete reproduction module Winter semester 17/18, 18/19

FIGURE 3 Concept of case-based and concept-based surveys, showing items and targets of each survey

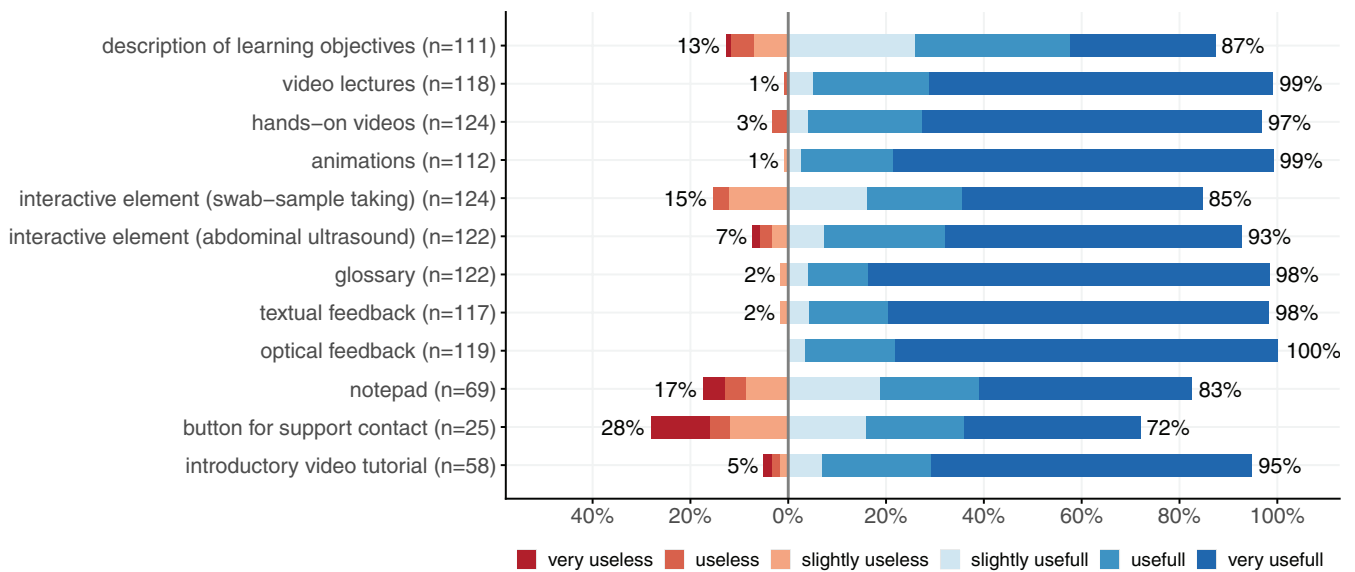


FIGURE 4 Diverging stacked bar charts showing results of didactic use of media of the pilot case in the winter semester 2016/2017 (n = 156) in a response-scale consisting of items of the Likert type (1 = very useless to 6 = very useful). The negative and positive proportions of 12 items are included. The question was: 'Did you find the following functions and materials of the online case helpful'? See Table S1 for exact numbers

2.3 | Statistics

Responses to Likert-type questions were expressed as overall, positive and negative proportions per item. The internal reliability was calculated with Cronbach's α coefficients, and a value greater than 0.60 for all scales was valued for a good reliability (McKinley, Manku-Scott, Hastings, French, & Baker, 1997). The binominal 95% confidence intervals were calculated after Wilson (Agresti & Coull, 1998). All answer proportions were considered significantly different from values

outside their confidence intervals. For all statistical calculations and the creation of related figures, we used the software R version 3.6.0 (R Foundation for Statistical Computing) using the package sjPlot version 2.7.2 (Lüdtke, 2018).

3 | RESULTS

The compilation of the first virtual patient started in July 2016 as a pilot case and was first released and extensively evaluated with students of

the 7th semester in February 2017. The assignment was an ovulation timing and pregnancy diagnosis with suspected luteal insufficiency.

The two additional virtual patients addressed pyometra and benign prostatic hyperplasia and were added to the module of reproduction in February 2018.

3.1 | Case-based survey

3.1.1 | Didactic use of media

For the survey of the pilot case, students of the 7th semester in the winter semester 2016/2017 ($n = 156$) answered questions regarding the didactic use of media on a response scale consisting of items of the Likert type (1 = very useless to 6 = very useful).

Significantly more than 90% of the students found the following media type useful: video lectures (99% [95%–100%]), hands-on videos (97% [93%–100%]), animations (99% [95%–100%]) glossary (98% [94%–100%]), textual feedback (98% [93%–100%]) and the visual feedback (100% [96%–100%]). The lowest usefulness was reported for the support contact button with a percentage of negative answers of 28% (Figure 4).

3.1.2 | Usability

Usability was analysed for the pilot case, respectively, the entire module in the winter semesters 2016/2017, 2017/2018 and 2018/2019. The survey consisted of five items focussing on comprehensibility, structure, availability of necessary information and the presence of clear tasks and aims with a response-scale consisting of items of the Likert type (1 = strongly disagree to

6 = strongly agree). The total number of students in the three semesters was 479.

Significantly more than 90% of the students agreed on a high usability in all five items. Most of the students chose strongly agree. The internal reliability of the scale usability with five items was also high with Cronbach's alpha at $\alpha = .87$ (Figure 5). The level of difficulty of the implemented exercises was also evaluated with a response scale consisting of items of the Likert type (1 = far too easy to 5 = far too difficult). On this scale, more than 88% of the students agreed on exactly the right degree of difficulty.

3.2 | Concept-based survey

3.2.1 | Self-assessed learning outcome

The survey of the self-assessed learning outcome consisted of 26 statements and was examined in the 7th semester with the complete reproduction module in the winter semesters 2017/2018 and 2018/2019 ($n = 323$). With respect to the 26 specific statements on three categories of Bloom's Taxonomy for learning objects, most of the students agreed on reaching a high level of the self-assessed learning outcome in each category with the new reproduction module. The individual questions can be found in the Appendix S3.

The highest learning outcome, with a 95% proportion of positive responses, was recorded in the 'Knowledge' category. The categories 'understanding' and 'application' had a percentage of positive responses of over 80%. To analyse the reliability, Cronbach's alpha was calculated for all three categories of the self-assessed learning outcome and it exceeded $\alpha = .81$ for all three aspects (Figure 6).

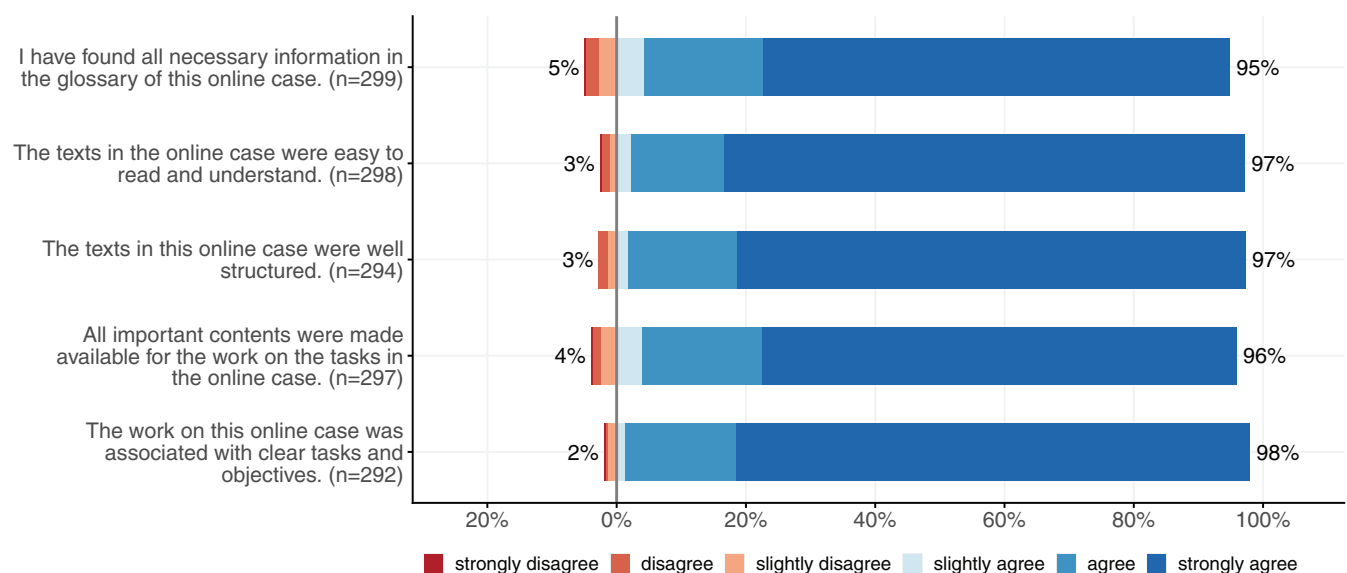


FIGURE 5 Diverging stacked bar charts showing results of the case-related usability in the pilot case in the winter semester 2016/2017 and for the complete reproduction module in the winter semesters 2017/2018 and 2018/2019, demonstrating the negative and positive proportions of five items ($n = 479$). See Table S2 for exact numbers

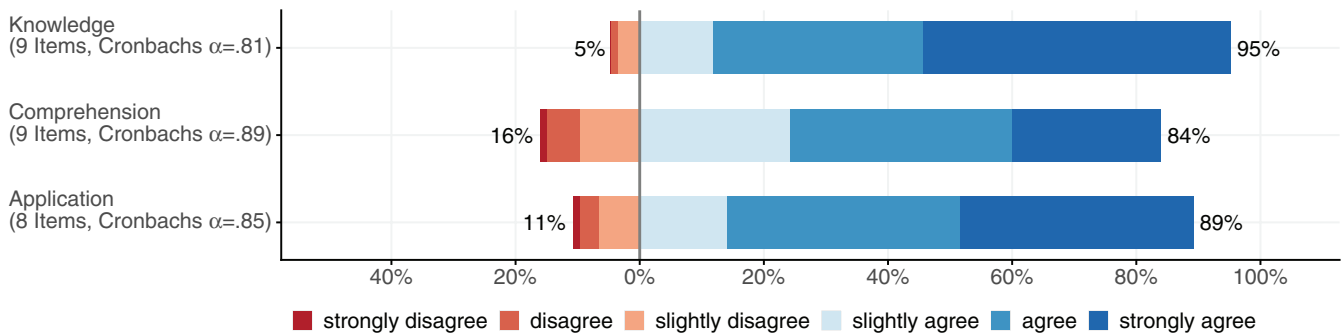


FIGURE 6 Diverging stacked bar charts showing results of self-assessed learning outcome in the categories knowledge, comprehension, application in semesters 2017/2018 and 2018/2019 in the reproduction module ($n = 323$). For the questions of each category see Appendix S3

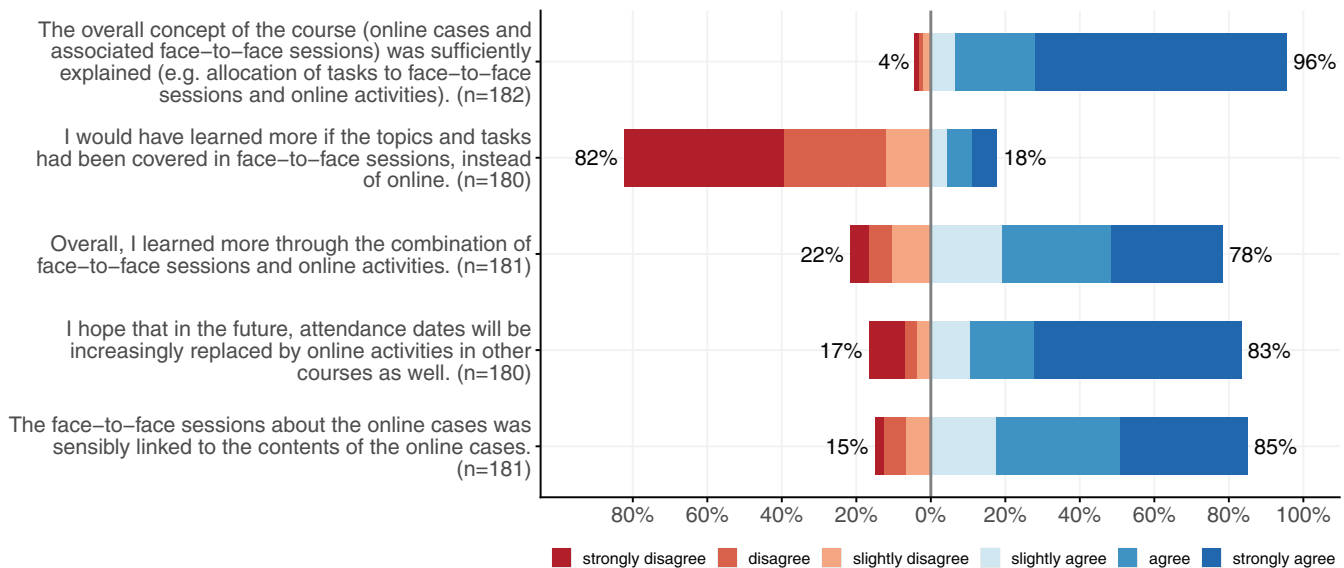


FIGURE 7 Diverging stacked bar charts showing results of blended learning concept consisting of five items in semesters 2017/2018 and 2018/2019 ($n = 323$). See Table S4 for exact numbers

3.2.2 | Blended learning concept

The survey of the blended learning concept consisted of five items and was examined in the 7th semester with several modules in the winter semesters 2017/2018 and 2018/2019 ($n = 323$). Results showed that significantly more than 70% of students were satisfied with the new concept and its implementation, preferred the blended learning over in-class lectures and hoped for expansion of the concept. The second statement holds an opposite significance as to revise the student's awareness. A blended learning subscale was not calculated, as the items covered many different dimensions (Figure 7).

4 | DISCUSSION

The interdisciplinary lectures at the Freie Universität Berlin in 2014 were evaluated as being suboptimal and have not been based on a coherent course concept. Apart from that, the requirements for

clinical veterinary training in general regarding animal welfare have changed.

Therefore, the task was not only to successfully create a consistent course concept that fulfilled the teaching requirements but also to implement virtual patients in a blended learning format.

For this reason, an extensive course concept was developed. In addition, we assessed the acceptance of this format by students and evaluated whether virtual patients were suitable for teaching interdisciplinary lectures in a mandatory blended learning format.

According to the evaluation results, students found video lectures, hands-on videos, animations and the glossary very useful, which showed that students appreciate this kind of supporting media for virtual patients. The videos and glossary not only give background information to a patient, but also support understanding contexts and applying knowledge to relevant situations. The lowest number of votes and lowest rating concerning usefulness was given to the button for support. The lowest rating can presumably be explained by the fact, that the button was not needed or used very often. This can also be the reason for the few votes as well. Students

sometimes contacted the project team directly via E-Mail for mainly technical related problems.

The usability of the three cases was graded as very high concerning the comprehensibility, structure, availability of necessary information, the presence of clear tasks and aims and the difficulty of the exercises. In this context, the usability of case-based learning modules is essential for a good acceptance of virtual patients in education.

When students were asked to assess their learning outcome (Figure 6), the first category (knowledge) of Bloom's Taxonomy received the highest agreements. Knowledge means remembering facts and is considered being the lowest category. It may be concluded that the presented teaching concepts mainly focus on knowledge acquisition. However, also the second (comprehension) and even the third category (application) received agreements of more than 80%. These categories are regarded as relatively high concerning the level of understanding and application. It was our aim to enhance autonomous and active learning on higher levels with this format of education. Although there were higher categories of learning integrated in the cases, we only evaluated the first three categories. A survey of higher dimensions such as analysis, synthesis and evaluation in Bloom's Taxonomy is difficult for students to answer objectively. Also, students already know this kind of survey of the first three categories from other surveys implemented at the department of veterinary medicine at Freie Universität Berlin. As there were no examinations scheduled in the interdisciplinary lectures, the self-assessed learning outcome offered a practicable alternative for an overview of the students learning success.

In terms of a spiral curriculum, the information learned in this project will be revised and enhanced during the clinical year. In future studies, it should be assessed if teaching on virtual patients will support the learning outcome of real-life clinical patients learning.

The blended learning concept received a high acceptance and over 80% of the students support an extension of the concept to other courses. This concept was implemented to give students more flexibility as well as face-to-face discussions on a higher level.

Results show that teaching reproduction with virtual patients is well accepted by students for interdisciplinary lectures in the 7th semester. Students especially preferred videos such as lectures, hands-on videos and animations as well as a glossary for background information to successfully and autonomously work on a virtual case. The assessment of the self-assessed learning outcome provided positive results in each of the three categories. This shows that the students confirm to have learned the relevant content of knowledge for each case of the implemented reproduction module, which could be interpreted as an effect of the good acceptance of this format. However, these results reflect subjective ratings and further objective assessment should be considered.

Based on these positive results concerning the implementation of virtual patients in a blended learning concept, the combination of virtual patients with simulators in skills laboratories and the possibilities of refining and reducing animal experiments in veterinary education thereby are of future interest.

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CONFLICT OF INTEREST

None of the authors have any conflict of interest to declare.

AUTHOR CONTRIBUTIONS

MD, LV, VD, CH, SB designed the study. LV and MLW planned and submitted the request for the animal experiments. LV, VD, CH, PH, SA and SH carried out the study. LV, AB, SA and MLW drafted the paper. LV and AB analysed the data. All authors discussed the results and contributed to the final manuscript.

DATA AVAILABILITY STATEMENT

For privacy reasons, the raw data cannot be shared.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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