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METHODS
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Comparison of Veterinary Nutrition Exam Results After Classroom or Virtual Teaching During the COVID-19 Pandemic at a German University

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Due to the COVID-19 pandemic, university teaching had to be kept up in spite of severe contact restrictions. Virtual teaching of animal nutrition was implemented at the Veterinary Faculty of the Ludwig-Maximilians-Universität (LMU) München, Germany, for both lectures and practical courses. Live online classes were held via Zoom®, and recordings were accessible afterwards. Animal nutrition is taught in the 5th and 6th term of the veterinary studies, followed by an oral state exam about subjects from both terms. In this study, the success of classroom vs. virtual teaching in veterinary animal nutrition was evaluated by comparison of exam results. Two exam cohorts (2019, before the pandemic; 2020, with one term of virtual teaching during the pandemic) were evaluated. The results indicated no significant difference of teaching method on the grades. However, there was a significantly higher probability of students not taking or failing the exam in the 2020 exam cohort, suggesting a general effect of the pandemic on the students. Additionally, two surveys were distributed among the students during summer term 2020 and winter term 2020/21, when virtual teaching due to the pandemic had been implemented for the first time. The survey results provide insights into the students' view of benefits and problems of virtual teaching in animal nutrition at the LMU. The majority was in favor of the live online format for lectures and courses in computed-based ration calculation, whilst feedstuff demonstrations were preferred in classroom setting.

Keywords: didactic methods, online lectures, veterinary education, animal nutrition, veterinary student, online teaching

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INTRODUCTION

The field of animal nutrition is an important part of the veterinary education (Becvarova et al., 2016; Jawad et al., 2020). Students should become adept at providing advice and professional support for livestock and pet owners.

Animal nutrition is a major subject within the veterinary curriculum according to the Ordinance concerning the Certification of Veterinary Surgeons (Verordnung zur Approbation von Tierärztinnen und Tierärzten; TAppV), issued July 26th, 2006 and the Examination and Study Regulations of the Ludwig-Maximilians-Universität (LMU) München, Germany, for the Course

of Studies for Veterinary Medicine (Prüfungs- und Studienordnung der Ludwig-Maximilians-Universität München für den Studiengang Tiermedizin), consolidated version September 29th, 2017. There is an unwritten consensus among the universities in German-speaking countries about the topics covered in veterinary animal nutrition, based on a standard textbook (Kienzle and Kamphues, 2005; Kamphues et al., 2014). In addition, the LMU is accredited by the European Association of Establishments for Veterinary Education (EAEVE), which has defined requirements for competencies in all veterinary disciplines including nutrition.

In the curriculum of the LMU animal nutrition comprises ca. 100 obligatory hours of teaching. It includes lectures and practical lessons in feed evaluation and ration calculation. In addition, elective courses are offered. Animal nutrition is taught during the 3rd year (1st clinical year) of the veterinary program. At the end of the 3rd year, students take an obligatory oral exam.

Due to the COVID-19 pandemic, class room teaching has been severely restricted at all universities in Germany from March 2020 until the end of the present study. Like in other countries, there were many challenges to be faced in university teaching (Mahdy and Sayed, 2022; Simons et al., 2022). Due to the acute change in the curriculum, information about the educational value, the situation of students and the teaching success in animal nutrition at German universities is lacking. Therefore, we report our experience in the implementation of virtual teaching via live online classes held via Zoom®. To complement the description of the teaching situation with the students' experiences, survey results are presented. The results of the present study can help to make decisions about teaching formats in the future.

There are several reports of virtual university teaching, specifically during the COVID-19 pandemic (for example 5,7,8-13). It is clearly stated that the switch to online teaching and the restrictions in on-site teaching have been challenging for teaching staff and students. In most cases, surveys have been used to evaluate the teaching situation. In the present study, we could compare virtual teaching during the COVID-19 pandemic (exam in summer term 2020) with classroom teaching before the pandemic by exam results (exam in summer term 2019). This allows for an objective assessment of teaching success, which renders novel data to consider in planning of the future curriculum.

Before going into detail on the surveys and exam data of this study, we will outline the teaching situation at the LMU as is has been before the COVID-19 pandemic. Then we will describe how we adapted our teaching due to the pandemic.

Pre-COVID Teaching Situation

Supplementary Table 1 shows an overview of the curriculum and the learning objectives in veterinary nutrition at the LMU München. Animal nutrition is taught to students in their 5th and 6th semester of 11 total semesters (winter and summer term).

In the winter term, the subjects started with a lecture on general animal nutrition taught in a lecture hall at the campus in Oberschleissheim. Attendance to the lecture was not monitored. A pdf file of the lecturer's slides was available online to the students enrolled. Average attendance estimated by several lecturers and documented during evaluations was∼60–80 students of an average of 260–280 students in the study year. In addition to the lectures, there were weekly practical courses (see **Supplementary Table 1**) that took place in Oberschleissheim (students divided into four groups with 60–70 students each, course held four consecutive times on the same day). At least two assistants were present to answer any questions. Course attendance was documented by a signature and a maximum of two times absent was allowed. In case of a higher number of missing courses, the student had to provide a medical certificate for the times of absence for this and sit a small oral exam about each missed course topic, otherwise there would be no credit for the course in the respective term. At the end of winter term, there was an oral exam that was obligatory to pass the course and get the credits.

In the summer term, the lectures continued with specific topics from animal nutrition and dietetics in the same setting as in the winter term. There were also courses on ration calculation in the same setting like in the winter term. Students worked on laptop clients to calculate rations via MS EXCEL®. The first course was spent explaining the program MS EXCEL® and the basic functions needed for the rest of the course. A small file for ration calculation was programmed by the students with data on feed stuff nutrient content and energy and nutrient requirements (**Figure 1**). In the following sessions, the students were given a prepared MS EXCEL® file with a template for the specific topic. They had to complete the file by inserting several formulas. Then, either given rations were to be evaluated and improved for the respective case example, or new rations were to be created by the students.

In the 4th course session, a small test of each student's MS EXCEL® skills was done (each student is asked to perform one of the basic operations of the software) in order to monitor successful participation and learning success in the course semester.

After the two terms, there was an oral state exam held in groups of up to five students with one examiner. The students got two questions that had to be answered after a short time of preparation. Besides theoretical questions, a ration evaluation/calculation using MS EXCEL® or the work-up of a case including a sensorial testing of a feed sample were possible tasks in the exam. Grades range from 1 (very good) to 5 (not passed) and were usually averaged from the grades of both questions.

Adaptation of Teaching During the Pandemic

Due to the COVID-19 pandemic, all lectures and courses were switched to the virtual format starting March 2020. The curriculum and the timetables for lectures and courses remained the same. The time table restricted possibilities to try different teaching formats requiring extra time such as virtual lectures for download and self-study and an additional chat after that. Lectures on the same topics as in previous terms were given via Zoom® (Zoom Video Communications, Inc., San Jose, CA,

Worksheet: Ration calculations

A

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		*Contents in ration*						*Contents in feed materials (per kg oS)*					
2	**Feedstuff**	Amt	DM	ME	pcdCP	Ca	P	DM	ME	pcdCP	Ca	P	
3		kg	g	MJ	g	g	g	g	MJ	g	g	g	
4	**Hay**	10	=$B4*H4	=$B4*I4	…	…	…	860	7	50	4	3	
5	**Oats**	3	=$B4*H5		…	…	…	880	10,5	79	1,1	3,1	
6	**Mineral feed**	0,05	…		…	…	…	900			180	25	
7													
8	***Sum***		=sum(C4:C6)	…	…	…	…						
9	***Requirement***			***100***	***360***	***20***	***14***						
10	(BW 600 kg, moderate work)												
11	Ca/P-Ratio		=F8/G8	g/g									
12	Protein/Energy-Ratio		…	g/MJ									
13													

B

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		*Contents in ration*						*Contents in feed materials (per kg oS)*					
2	**Feedstuff**	Amt	DM	ME	pcdCP	Ca	P	DM	ME	pcdCP	Ca	P	
3		kg	g	MJ	g	g	g	g	MJ	g	g	g	
4	**Hay**	10	8600	70	500	40	30	860	7	50	4	3	
5	**Oats**	3	2640	31,5	237	3,3	9,3	880	10,5	79	1,1	3,1	
6	**Mineral feed**	0,05	45,00	0	0	9	1,25	900			180	25	
7													
8	***Sum***		11285	102	737	52,3	40,55						
9	***Requirement***			***100***	***360***	***20***	***14***						
10	(BW 600 kg, moderate work)												
11	Ca/P-Ratio		1,3	g/g									
12	Protein/Energy-Ratio		7,3	g/MJ									
13													

FIGURE 1 | Template for ration calculation for horses in MS EXCEL™ with **(A)** the formulas shown in the cells and **(B)** the finished calculation for an example ration.

USA) meetings in real time with the lecturer as host and at least one assistant as co-host. The lecturers shared their screen with the presentation and students were able to ask questions by using the chat feature or unmuting themselves. During all lectures, students were encouraged to use communication signs to signal their understanding of the teaching content, whether anything should be repeated or if the lecturer should go on faster or slower. The recorded lectures were available online afterwards. The switch to virtual teaching facilitated the invitation of guest lecturers from other universities (Germany and Netherlands) as an inclusion into the regular lecture schedule.

Practical lessons in ration calculation (summer term 2020) were done with Microsoft (MS) EXCEL® which was available for the students for free from the university. In the first session, basic MS EXCELTM skills required for ration calculation were taught in the same way as in the classroom. The calculations were demonstrated by the lecturers via screen sharing. Ration calculation was taught similar to before COVID19. The ration calculations of the lecturers as well as those of volunteering students were shared on the screen. Two extra courses were offered to solve individual issues with using MS EXCEL®. These tutorials were attended by approx. 70 students (out of 266 students, who were registered for the practical lessons *per se*).

In winter term 2020/21, the practical lessons on general nutrition (see **Supplementary Table 1**). The lecturer demonstrated all calculation steps for calculation tasks using MS EXCEL®, students were free to use either MS EXCEL® or simply paper und calculator. Students were encouraged to share their screen with the class and discuss their results. The practical lessons on feed stuff were done as lectures. Feed plants and toxic plants were demonstrated in photographs.

To compensate for the lack of direct plant demonstration, students were encouraged to engage in extracurricular tasks in advance (during the summer before their first lectures in veterinary nutrition, by e-mail), e.g., downloading a botanical application such as Flora Incognita® (Technische Universität Ilmenau, Germany) or PlantNet™ (pl@ntNet, supported by Agropolis Foundation, Montpellier, France) and create a virtual herbarium with a number of feed and poisonous plants. They were explicitly requested to take photographs of the plants in different stages of vegetation or health. Creating a traditional herbarium with pressed plants was also an option. As an incentive for participation, a reward such as an extra coaching before the exam in a small group or a book on animal nutrition was conferred for the best herbaria. As an alternative for evaluating several silage samples in the presence courses as usual, students were offered instructions and support for making their own small silage balls according to a method for laboratory tests (Hoedtke and Zeyner, 2011) in a glass jar or a vacuumed plastic bag. In principle, plant material is filled into a small plastic bag, which is closed and vacuumized by a household vacuum sealer. To ensure the necessary anaerobic conditions, a second bag is put over the first one and also vacuumized. A vacuum sealer was available at the Chair of Animal Nutrition and Dietetics, if

required, and students were able to arrange for sealing of their silage packages with the staff. During the pandemic, we did not check for attendance and MS EXCEL® skills in the summer term as before. The students had to sign a statement that they did take part regularly and successfully in the practical trainings. In the winter term 2020/21, we offered a small virtual exam instead of the oral exam that had to be passed at the end of the semester. The students had to answer 24 multiple choice questions in form of an online test in the learning management platform Moodle® (eLeDia GmbH, Berlin, Germany). There was a time limit of 45 min for completion and submission of the answers. The test was passed with at least 60% correct answers, and it was possible to repeat the test three times. It was rather a self-test than an exam, because the students obviously had the possibility to read up the correct answers or ask other students and repeat the test. In this way, during virtual teaching, the responsibility for attending the courses and checking the acquired knowledge before the examination was completely shifted to the students in both semesters.

MATERIALS AND METHODS

The study has been approved by the Ethical Committee of the Faculty of Veterinary Medicine, LMU München (289-21-10-2021).

Comparison of Exam Results

For a valid comparison of exam results, two exam cohorts with the same exam procedure were chosen, where only one cohort had received virtual teaching for one term.

Exam cohort 1 consisted of 238 students sitting the exam in summer 2019. They had received classroom teaching in winter and summer term for both lectures and practical courses in animal nutrition. The oral exam took place in presence.

Exam cohort 2 consisted of 227 students sitting the exam in summer 2020. Their winter term 2019/20 had been classroom teaching ("pre-COVID"), but in summer term 2020, they had received virtual lectures and courses. The oral exams were held in presence just like for exam cohort 1, but under compliance of strict hygiene rules (distance, surgical face masks, open windows).

In both exams, the students had to answer two questions or conduct one EXCEL® based ration calculation. For comparison of the exam results, a table listing question/ration topic, final grade and separate grade for each question was compiled. In addition, it was noted in which term the respective topic had been taught (winter term/summer term/both terms).

Statistical comparison was carried out in SigmaPlot® 14.0 (Systat Software, San Jose, CA, USA). For both exam cohorts, the distribution of grades was calculated. The influence of year (2019 vs. 2020) and term of topic (winter vs. summer) on the separate grades was calculated in a two-way ANOVA using a general linear model ($p < 0.05$). Normality testing was performed with a Shapiro Wilk test. Separate grades from winter and summer terms were compared between the exam cohorts and terms by Mann-Whitney Rank Sum Test ($p < 0.05$).

Odds ratios were calculated to test the probability of students to sit or pass the exam in the 2019 and 2020 cohort, respectively.

Surveys

During or after virtual lectures or virtual practical courses, we presented polls in Zoom® for the students to vote on. Mostly during summer term 2020, we asked for the students' view of the virtual teaching situation with these polls. For example, we asked whether they would prefer virtual or classroom teaching in the hypothetical situation that the COVID-19 pandemic would end right then. We also asked about students' ability to concentrate in virtual lectures vs. classroom lectures. In addition, we designed small anonymous quizzes on the topic during or at the end of some lectures and courses, which were not graded and evaluated.

In addition, a questionnaire was generated by the Chair of Animal Nutrition and Dietetics (further referred to as "nutrition teaching questionnaire", NTQ) to get more qualitative feedback about virtual teaching in animal nutrition via the online tool SurveyMonkey® (Momentive Europe UC, Dublin, Ireland), open from March 7th−19th 2021 (after the winter term). It contained 24 open-ended questions about learning conditions, such as quality and speed of the WiFi connection, or the environment for learning at home (availability of a room/desk, being able to find a room free of disturbance to study etc.).

The students' office of the Faculty for Veterinary Medicine at the LMU issued a general survey on the virtual teaching of every subject at the faculty (further called "faculty teaching questionnaire", FTQ) during the COVID-pandemic. The FTQ was intended to evaluate the following issues using qualitative and quantitative methods: Technical implementation of the online course and materials provided, students' use of the course, didactic structure and implementation, online teaching vs. face-to-face teaching, students' perception of digital teaching in the subject. The questionnaire was based on an extensive literature research and was validated through an internal peer-review procedure with a group of experienced employees in didactics, medical education, quality assurance and empiric research (Grabbe, 2003; Schulz et al., 2006; Bortz and Döring, 2007; Hirschfeld and Thielsch, 2010; Beran et al., 2012; Shauchenka et al., 2014). The individual themes and items have been established at the faculty for some time and have been applied and evaluated in other internal surveys, so a pre-test was not conducted.

For the evaluation of the animal nutrition courses of the summer term 2020 (6th semester), a link to the FTQ was sent to 253 students via email and for the winter term 2020/21 (5th semester) to 273 students. It was open from January 14th to April 29th 2021 and sought to evaluate summer term 2020 and winter term 2020/21. A reminder for both surveys was sent at the end of February 2021. The analysis was carried out automatically with evasys® (evasys GmbH, Lüneburg, Germany).

The online evaluation included 54 questions divided into five topics:

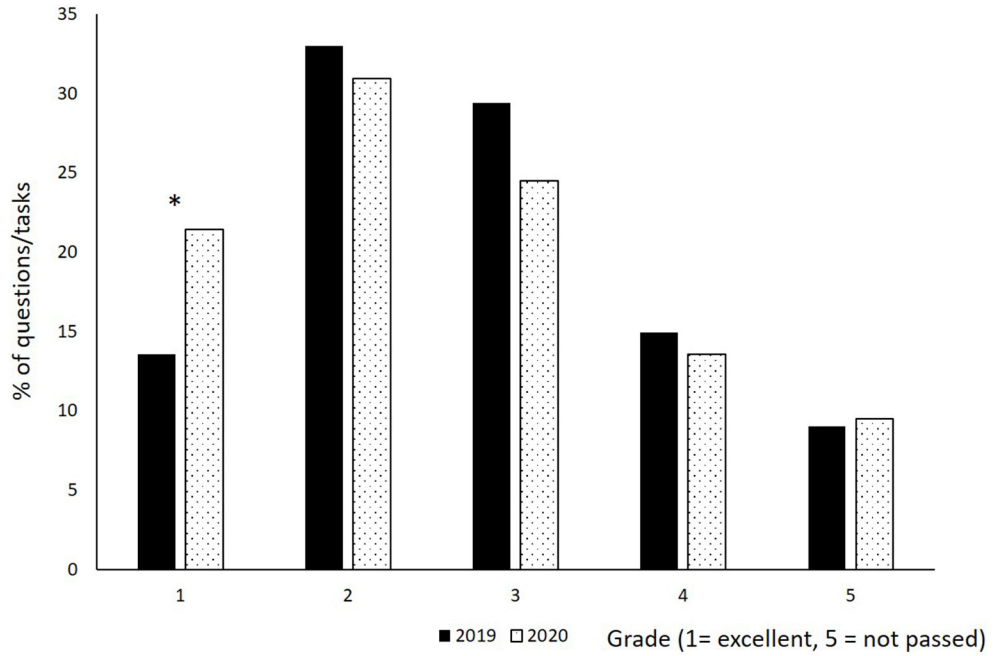

FIGURE 2 | The percentage distribution of exam grades in the state exam in animal nutrition in 2019 after the regular classroom teaching before the pandemic (black columns) and 2020 after the summer term of virtual teaching during the pandemic (white dotted columns). The asterisk (*) marks a significant difference in the odds ratio of a student achieving the respective grade ($p < 0.05$).

1. Overall assessment: 1 question, grades from one (very good) to six (insufficient)
2. Technical implementation and the framework conditions (provided documents, internet connection, etc.): nine questions, multiple-choice
3. Courses (course process and structure, the teaching methods, and the use of the e-learning opportunities, etc.): 16 questions, five multiple-choice, 11 questions using a Liekter scale, some of the questions with free text options
4. eLearning in this subject area (comparison between virtual teaching and teaching in presence, implementation of e-learning, desirable online teaching methods, etc.): 26 questions, 19 questions using a Likert scale, five free text questions and two multiple-choice
5. Conclusion (wishes, suggestions, improvements): two free text questions.

The Likert scale ranged from "fully correct" to "not correct at all". Cronbach's alpha was used to assess the reliability of the scales and the internal consistency of the subscale "questions about the course" and "e-learning". The internal consistency is satisfying, with Cronbach's alpha for both = 0.84.

For the qualitative analysis, the students answers in the free text fields of the NTQ were thematically analyzed by at least two proficient lecturers in animal nutrition and categorized into praise, criticism, wishes and suggestions for improvement and to further specify multiple choice answers (in the free text field "other") (Braun and Clarke, 2006).

RESULTS

Exam Results

In the winter term 2018/19, 253 students were admitted to the nutrition course according to their credits. In winter term 2019/2020, 269 students were admitted to the nutrition course. In the summer term, it was 260 vs. 266 students in 2019 vs. 2020, respectively. The credit rules were the same, however, some allowances were made in the summer term 2020 because of the pandemic. The number of students sitting the exam for the first time was 238 in exam cohort 2019 and 227 in exam cohort 2020. Fifteen vs. 42 students did not sit the exam (exam cohorts 2019 vs. 2020). The odds ratio that a student would not sit the exam in 2020 compared to 2019 was 2.936 ($p < 0.001$).

Twenty-eight students did not pass the exam in 2020, vs. 23 in 2019. The percentage of students who did not sit or not pass the exam was 15% in exam cohort 2019 and 26% in exam cohort 2020. The odds ratio that a student would pass the exam was 1.85 in 2019 compared to 2020 ($p = 0.009$).

The final grade data were not normally distributed in both exam cohorts (Shapiro-Wilk normality testing failed). Though there was no significant difference between the final grades of both exam cohorts ($p = 0.179$), there was a shift in the percentage of "good" and "bad" grades (**Figure 2**).

Neither in exam cohort 2019 nor exam cohort 2020 was there a significant difference in the separate grades between topics from winter or summer term ($p = 0.470$; $p = 0.463$).

TABLE 1 | Distribution of separate grades per topic from the exam cohorts 2019 and 2020, grouped according to the term in which the topic had been taught (summer vs. winter term).

	Mean	SD	Median	Skewness	Kurtosis	K-S Prob.
Exam cohort 2019						
Winter term topic ($n = 188$)	2.91	1.19	3.00	0.28	−0.80	<0.001
Summer term topic ($n = 156$)	2.82	1.08	3.00	0.40	−0.58	<0.001
Exam cohort 2020						
Winter term topic ($n = 190$)	2.70	1.20	2.50	0.53	−0.63	<0.001
Summer term topic ($n = 158$)	2.72	1.22	2.75	0.32	−0.80	<0.001

SD, standard deviation; K-S Pro., probability according to Kolmogorov-Smirnov Test.

TABLE 2 | Influencing factors on separate grades in the oral exam in animal nutrition.

Source of variation	DF	SS	MS	F	*p*
Term	1	0.035	0.035	0.025	0.875
Exam cohort	1	5.767	5.767	4.173	<0.05
Term × exam cohort	1	1.131	1.131	0.819	0.366

DF, degrees of freedom; SS, sum of squares; MS, mean square.
Factor "term" means the term in which the topic had been taught; factor "exam cohort" defined as exam in summer term 2019 after classroom teaching vs. summer term 2020 after classroom teaching in winter and virtual teaching in summer term.

In both exam cohorts, the separate grades did not display normal distribution. The parameters of distribution differed between the exam cohorts of 2019 and 2020 (see **Table 1**). The separate grades from winter term topics were significantly better in the exam cohort 2020 ($p < 0.05$), while they did not differ between the exam cohorts for summer term topics ($p = 0.393$).

There was no significant influence of the term in which an exam topic had been taught (factor "term") on the separate grades ($p = 0.875$), but the exam cohort (factor "exam cohort") did have a significant influence ($p < 0.05$; **Table 2**). The factors "term" and "exam cohort" did not interact ($p = 0.366$).

Attendance and Participation

Attendance of virtual lectures was considerably higher than attendance of classroom taught lectures (130–180 vs. 60–80 attendees). The situation was different for obligatory ration calculation courses: During classroom teaching, participation in the course was strictly controlled and enforced throughout the whole term as described above (2 times of absence allowed without consequence). This resulted in an attendance of more than 200 students per course in total. In summer term 2020, we offered two repetitions of the same virtual course on 1 day. Attendance of virtual courses was not enforced, as described above. It has to be considered that some students did attend both repetitions of one course topic in order to improve their understanding of the subject. Therefore, we cannot give a precise estimate as to the number of students who did not take part at all. It was, however, clear to see that not all enrolled students did take part in all courses. About 70 people took part in the virtual extra coaching in MS EXCEL®. In a Zoom® poll after the first coaching session (47 participants), most students found the MS EXCEL® coaching moderately helpful (53%) to very helpful (45%). The self-evaluation of their MS EXCEL® skills showed that more students felt "very secure" after the coaching (28%) than before (2%).

The majority (usually more than 90%) of attendees answered spontaneous survey questions on learning progress during the lectures or courses. These possibilities for self-evaluation got a lot of positive feedback from the students. There were always numerous reactions such as checkmarks or crosses when we asked about the adequacy of the speed or the necessity for repetitions and additional explanations. Students asked many questions via chat or by unmuting themselves. A direct comparison of the number of questions on the same topics during classroom or virtual teaching was not possible. It was, however, more difficult to keep to the time allotted for the lectures during virtual teaching because of numerous questions. Especially during the summer term 2020, when we started virtual teaching, many students expressed their gratitude that we helped them to continue studying after each lecture.

Before the guest lecture on intensive care nutrition that was held in English, 35% of the 162 students taking part in a Zoom poll said the language would be no problem at all and further 55% were positive that they would manage. After the guest lecture, the majority of 115 participating students answered that they understood the language "very well" (52%) or "well" (27%) and only 1% were completely lost.

The self-study with software applications for plant identification resulted in 46 virtual herbaria being submitted to the Chair of Animal Nutrition and Dietetics. Twenty-six of them had more than 60% of the plants we asked the students to find. **Supplementary Figures 1–4** show a few examples of plant photographs and even of a traditional herbarium. By contrast, only three students made their own silage (**Supplementary Figure 5**). The results were discussed in context with the virtual practical lesson on silage. Pictures of feed plants and toxic plants from the herbaria were included in the respective course presentation slides, appreciating the photographer(s) by name. In this way, we could add images of the plants to the course presentation, compensating for the lack of live demonstration of plants and samples.

Surveys

Ninety-three students responded to the NTQ. The numbers of responses in the FTQ was sorted according to term and lesion: There were 80 responses for the lecture in animal nutrition in the winter term 2020/21, 75 responses for the practical course in animal nutrition in the winter term 2020/21, 66 responses for the lecture in animal nutrition in summer term 2020 and 65 answers regarding the practical course in animal nutrition in summer term 2020.

The overall student evaluation of the virtual teaching in veterinary nutrition in the FTQ on a 1–6 Likert scale was 1.5

(range 1–5 with 1 meaning very well-satisfied and 5 meaning not at all satisfied).

According to the results of the FTQ, the technical implementation of virtual teaching at the veterinary faculty of the LMU worked well for 87.5% of respondents, worked in part for 10.9% and not at all for 1.6%. Problems were mainly related to WiFi connection and hardware.

The majority of students (85%) described their learning conditions as satisfactory in the NTQ. There were, however, some students who admitted that the place to learn had been their bed at first or commented that they would study "just where [they found] a place". Some students had trouble with a noisy environment. Someone admitted to locking himself into their room to avoid being disturbed by their family. Other reasons given for a better work atmosphere at home were "saving of travel time, travel costs, energy and stress". These results were consistent between the FTQ and the NTQ. After the first few nutrition lectures in summer term 2020, we asked whether the students would like to return to the classroom or prefer virtual lectures if the pandemic would not exist in a Zoom® poll. The response was that 66% voted in favor of the virtual lectures. We got similar results when we asked about the ability to concentrate: a majority of two third of the participating students voted that they could concentrate better during virtual lectures than during lectures at the university. Only a minority of <10% had difficulties and the remaining students did not feel a difference in their concentration between virtual and classroom lectures. The results obtained by the faculty were similar in this regard: In the FTQ, more than half of the students (55.6%) ticked "very true" or "true" for better ability to concentrate in the virtual lectures. Even for the virtual teaching of ration calculation in MS EXCEL®, more than half of the students chose virtual training over class-room teaching in the NTQ. The FTQ asked how much of the content of the ration calculation training should be taught virtually after the pandemic. Fifty percent of the respondents wanted more than half of the content to be taught virtually, and 33% wanted more than 90% to be taught virtually after the pandemic. However, many respondents of the FTQ commented that the practical feed stuff demonstrations should be held in presence, if possible. The students found it very positive that lecture recordings were available: "Knowing that lectures are recorded and available to you permanently and around the clock is nice." In the NTQ, many students commented that they preferred virtual teaching because they did not have to commute to the different locations of the university (especially since Oberschleissheim is in the outskirts of Munich with most of the veterinary campus being in the city center). On the other hand, some students admitted that they had problems with self-motivation and self-discipline and were not able to structure their days sensibly during the pandemic. In addition, students stated that "staring permanently at a screen is very tiring".

DISCUSSION

This retrospective study on the teaching situation of animal nutrition in the veterinary curriculum at the LMU compares classroom teaching before the COVID-19 pandemic with the complete virtual teaching at the beginning of the pandemic in 2020.

As an objective measure for teaching success, the comparison of exam results was used. The exam results of the cohorts in 2019 and 2020 can be compared because the exam procedure (oral and in presence at the institute) was identical. The hygiene rules that applied in 2020, like wearing masks and keeping distance from each other, did not alter the exam process in a fundamental way. In exam cohort 2020, there was no difference between the grades achieved in topics taught virtually vs. grades in topics taught in the classroom (summer vs. winter term), which shows clearly that there was little difference in learning success between classroom and virtual teaching for a majority of students. The changes in the distribution of the exam grades with more "good" and more "bad" grades (**Figure 2**) was not linked to virtual teaching, i.e., topics from winter term 2019/20 vs. topics from summer term 2020. Presumably, the general situation during the pandemic contributed to the differences between the exam results from 2019 vs. 2020. The absence of many leisure activities such as cultural events, parties or team sport may increase the time available for exam preparation. Moreover, students' jobs such as working in the gastronomy were paused due to stores, restaurants and event locations closing at least temporarily. In addition, some other subjects of the veterinary curriculum were not taught in real time but with material for self-study, allowing more flexibility. Another point may be that clinical subjects are more difficult to teach virtually than the subjects of our virtual summer term. Consequently, the attraction of the more clinical subjects may decrease in comparison to nutrition. It is possible that the students put more effort into subjects more compatible with virtual teaching than into other subjects. Given the point that not only good grades but also bad grades and the percentage of students not sitting or passing the exam increased, it is important to discuss possible reasons for the problems at the lower end of the grade scale. In this context, studies on mental health of students during the pandemic from many different countries come to mind. Unequivocally, these studies show serious effects of the pandemic situation on mental health of students including depression and increased anxiety (Jawad et al., 2020; Mahdy, 2020; Wang et al., 2020; Chaturvedi et al., 2021). Especially in medical study subjects, students are under high pressure and the pandemic might have increased this state by cancellation of practical training, inability to meet study groups and financial problems due to loss of part-time jobs (Jawad et al., 2020). In the present study the shift of responsibility for course attendance and learning success toward the students may also have contributed to the problem, because the external pressure was reduced. Several students admitted to lacking self-discipline and motivation. In the meantime, our routine and skills with virtual teaching has increased, and as the latest addition we are now able to check on participation and learning success, which we are confident will reduce this type of problems in the future.

On the other hand, the attitude of the faculty toward the credits necessary for the course was a bit more relaxed during the onset of the pandemic. Some students were admitted to the course in spite of having not passed the previous exams completely. It is quite likely that this practice also contributed

to the higher number of students who did not sit the animal nutrition exam in summer term 2020. A survey from the USA (Trivedi et al., 2021) found that due to inability for work experience and practical opportunities, some students were reluctant to apply for veterinary college. Our observation that more students did not sit the animal nutrition exam in 2020 may have had similar reasons, when some students might have been delayed in the general progress of their studies. However, we do not have actual data on the reasons for this observation.

The virtual teaching methods applied in animal nutrition at the LMU München were met with good acceptance by the students. As mentioned by other authors (Albrahim, 2020), a high level of preparation (Bao, 2020) and a certain level of technologic skill (Mishra et al., 2020) by the teaching staff is necessary.

Attendance and interaction in our real-time virtual lectures and courses were high, even though the recordings were available for view after the session. This suggests that the students appreciated the possibility to ask questions. The possibility to offer consultation and answer questions has also been found highly appreciated in other studies concerning online teaching (Bao, 2020), and online learning is known to enhance interaction and feedback in classes (Jawad et al., 2020). The increased interaction of students with the lecturer may be due to the higher number of attendees in lectures. Another likely reason is that shy students may find it easier to participate via chat than face-to-face in the classroom.

To study completely from home, a good internet connection and adequate hardware was necessary for the students. In some rural parts of Germany, the quality of the internet connection may be less reliable, which might pose a problem especially for students who have moved back with their families away from the university towns. In a survey among first-year veterinary students in India, e-learning was found to be more useful for students from families with a better socio-economic status (Das et al., 2021). Computer hardware and software needs to be available to participate in online education. In the present study, no socio-economic and demographic data was recorded. However, only $<$15% of the students reported internet problems in the NTQ. On the contrary, the possibility to attend the lectures and courses without the commute to the campus site in Oberschleissheim was seen as an advantage by many students in the NTQ. This saves time, effort and cost. In addition, the possibility to watch the recordings again as exam preparation may offer the advantage to listen and understand at an individual speed (Mishra et al., 2020).

In the animal nutrition curriculum, the only topic that could not be transferred into the virtual format without problems was the practical demonstration of feed stuffs. This was not surprising, because important sensorial qualities like smell and touch are lacking during virtual teaching. Handling of feed stuff samples during presence courses could not be replaced successfully by showing more pictures in the lectures and courses. Similar results were obtained in a global survey on online teaching of veterinary anatomy during the COVID-19 pandemic (Mahdy and Ewaida, 2021), where it became clear that online teaching was a good temporary solution, but practical sessions cannot be replaced in the long run. The implementation of virtual reality or augmented reality technologies, as described for vocational education and training (Torres and Vandeweyer, 2021), might offer possibilities in the future. It is, however, not possible to convey the full sensorial impression of a feed sample, with touch and smell, via such technologies. Teaching in presence for small student groups has proven advantageous (Simons et al., 2022), but is limited by staff and time contingent. At the university in Munich, the high number of students per semester ($>$200) makes it hard to implement practical classes in small groups.

On the other hand, the creation of herbaria that was suggested as a way to get in touch with the feed plants was implemented only by 16% of the students in winter term 2020/21. Presumably, the reason for the relatively low response to this task was students being busy with studying for other exams when the call was distributed. It is still possible that students who did not submit an herbarium tried to collect plants and/or identify them via the recommended apps, and thus engaged in the topic without reporting it to us. Tools for students to engage in the class topics at home were found useful in a survey across Northern American universities during the pandemic (Simons et al., 2022). It seems beneficial to keep up some of the newly adopted tools or teaching formats, even when the main curriculum can return back on-site.

CONCLUSION

Looking back on the terms since the onset of the COVID-19 pandemic, we can state that animal nutrition is a topic that can be taught virtual for the most part. The exam results showed that teaching success between classroom and virtual teaching was comparable, while there seems to have been a general effect of the pandemic on students' performance. Live lectures and courses were well-attended and received a lot of interaction with the lecturer. However, the practical demonstration of feed stuff samples should be held in presence, if possible.

LIMITATIONS OF THE STUDY

The study results were obtained at a single university in Munich, Germany, so that a possible regional or national bias must be considered. The situation at the onset of the COVID-19 pandemic shortly before the start of summer term 2020 was similar in all German universities. However, the challenge of virtual teaching was met with different solutions in different universities on a national and international level (Bao, 2020; Mishra et al., 2020; Simons et al., 2022). In this study, we report on live online lectures and courses in animal nutrition, while other universities/departments may have used pre-recorded online classes or teaching videos only. This will change the possibility of interaction between students and teaching staff, likely leading to differences in perception of virtual teaching and learning success.

Demographic data on the student population of veterinary science at the LMU was not obtained in the present study due to the German data protection legislation. Thus, we cannot investigate potential effects of personal factors such as age, gender, social background on the perception of virtual teaching during the pandemic. Without detailed demographic data, it can only be stated that the student population of veterinary medicine in their 5th and 6th term at the LMU are >90% female and in their mid-twenties. This may limit the results to a certain population type. Students with the ability to learn in a self-reliant way may have been more successful during complete virtual terms. There are many intrinsic and external factors influencing learning success. Given the relevant data, this would certainly be an interesting angle to follow up on.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

LB, CP, SH, BD, CK, and EK: methods. VA, CP, and LB: surveys. EK, CP, and VA: data curation. CP, EK, and LB: manuscript writing. LB, CP, VA, SH, BD, CK, and EK: review and editing. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fanim.2022.878657/full#supplementary-material

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