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Assessment of a virtual prosthetic case planning environment for dental education – A multicentric analysis

A. Liebermann[1] | M. Bjelopavlovic[2] | A. Rauch[3] | M. A. Schlenz[4] | K. Erdelt[5]

[1]Department of Prosthetic Dentistry, Center of Dental Medicine, University of Cologne, Cologne, Germany

[2]Department of Prosthetic Dentistry, University Medical Center Mainz, Mainz, Germany

[3]Department of Dental Prosthetics, University Hospital Regensburg, Regensburg, Germany

[4]Department of Prothodontics, Justus Liebig University Giessen, Giessen, Germany

[5]Department of Prosthetic Dentistry, University Hospital, Munich, Germany

Correspondence
M. Bjelopavlovic, Department of Prosthetic Dentistry, University Medical Center Mainz, Augustusplatz 2, 55131 Mainz, Germany.
Email: monika.bjelopavlovic@unimedizin-mainz.de

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Abstract

Objectives: The aim of the present study was the multicentric assessment of the virtual prosthetic case planning environment (VCPE), which relocates patient planning into the virtual space in dental education.

Materials and Methods: The VCPE is separated into two rooms: a virtual entry area where the user can choose between 10 different prosthetic case plans of ascending complexity, and a virtual patient case planning room. In spring term 2022, the use of virtual case planning was voluntarily assessed in four different German dental schools (DSs) from the perspective of both lecturers and students. The assessment was performed afterwards using a questionnaire. Data were analysed using Kolmogorov–Smirnov test, exploratory data analysis, Fisher–Freeman–Halton test, and exact Fisher test. Reliability was assessed with Cronbach Alpha test ($\alpha < 0.05$).

Results: A total of 59 lecturers and 63 students were included. There were 38.5% male, 60.7% female, and 0.8% diverse participants. The mean age of the lecturers was 36.2 ± 9.0 years and of the students 24.3 ± 3.0 years. The VCPE was assessed as good, yet the evaluations between either the DSs or between the lecturers and students were significantly different.

Conclusions: Even though for some assessment criteria significantly different results between the four DS were observed, the majority of participants evaluated the VCPE positively and recommended them for teaching. The virtual reality as a teaching method for teaching prosthetic case planning for the further preparation of the students for the later professional life can be considered as helpful.

KEYWORDS
Dental education, evaluation study, lecturers, multicenter, prosthetic case planning, students, virtual reality

1 | INTRODUCTION

For some decades, digitization has been found its way into all areas of daily life – this trend has also long since arrived in teaching. In some technical but also medical fields, the additional digital teaching capabilities and visualizations have been developed and integrated for quite some time.[1–12] This ongoing trend was accelerated tremendously by the COVID-19 pandemic, as increased creative ideas had to be found to replace conventional face-to-face teaching.[3,13,14] The shift to digital teaching has not only replaced

traditional theoretical teaching methods such as lectures and seminars but has also necessitated increased efforts to facilitate practical elements of medical and dental education. The practical elements had to be drastically restricted almost everywhere, as personal contacts were temporarily reduced or even prohibited, depending on the specific pandemic regulations. Digital teaching formats that medical or dental students could use from home included synchronous or asynchronous online teaching formats (e.g., video communication), computer simulations (to be viewed through, e.g., tablets or smartphones to view), and the wide range of extended reality (XR).[1,2,5–12,15–28]

In addition to augmented reality and mixed reality, virtual reality (VR) in particular has become the focus of creative developments in what is known as XR. The specifications and distinctions of the different XR variants have already been described in the literature.[29] The VR application requires special equipment, which the student may have at home or can be provided by the teaching institute for the courses. This consists of VR glasses with associated hand controllers to interact in the virtual space. There are stationary (without movement in space) or active (with spatial movements) application forms. Students can now use the teaching applications with all-in-one systems in a mobile way, even from home.[24,27,30]

Many medical and dental applications have already been described in the literature, allowing students to practice surgical, anatomical, or communication skills, or enabling the use of enhanced three-dimensional visualization. Medicine even represents the most effective area for VR applications and can be beneficial in planning, training, visualization, and navigation as a teaching method.[31] It is even considered to improve general medical teaching.[13,32]

The great advantage is that the applying student experiences "immersion", a phenomenon of total immersion in a virtual parallel world.[24,27] Meanwhile, the student can fully focus on the teaching content, which can be an intensification of the teaching experience for students and lecturers.[33] The applications have been highlighted as very positive in the medical sector, especially for dental students, as the overwhelming amount of research shows that three-dimensional representation of teaching objects seems to be superior to two-dimensional representation.[34] The learning motivation of the current modern student population also increases significantly compared to learning with conventional teaching methods.[35]

However, a negative aspect of virtual teaching should be mentioned as well. In most assessments of virtual teaching environments, one often reported limitation is the possible occurrence of "cyber sickness". The slight pixelation of the display as well as the interpupillary distance can lead to headaches and dizziness.[36] Therefore, individual persons might evaluate the usefulness of virtual teaching different.

To the best of the authors' knowledge, virtual medical and especially dental applications have been mostly monocentric. Data about the differences in attitudes towards the use of digital teaching tools such as VR glasses in dental teaching is scarce. It is, therefore, still unclear whether there could be dental school-dependent or even age-dependent perceived differences.

An assessment difference in the delivery and application of virtual teaching opportunities, such as prosthetic case planning, could vary significantly between different dental schools and clinical settings. Most assessments were conducted using questionnaires that had different question formats (e.g., visual analog scale and Likert scale).

Consequently, the aim of the present study was the multicentric assessment of the virtual prosthetic case planning environment (VCPE), which relocates patient cases with all necessary patient information into the virtual space.

The tested hypothesis states that there is no difference of the assessment criteria between the four dental schools analysed and no differences between the results of students and lecturers within each university.

2 | MATERIALS AND METHODS

The multicenter study was approved by ethic committees of the respective dental schools (DS) by referent numbers 21–1104 (DS1), 41/22 (DS2), 2022–16344 (DS3), and 22–2949-103 (DS4). All participating lecturers and students gave their written consent to data collection prior to participation in this study.

2.1 | Virtual case planning environment setup

The VR glasses Oculus Quest 2 All-in-one (Meta Quest, Menlo Park, CA, USA) with 1832×1920 pixels, RAM memory of 6 GB, internal storage capacity of 64 GB and with two corresponding hand controllers were used to apply the case planning app. The programming was done with Unity 2019.1.7f1 software (Unity Technologies, San Francisco, CA, USA). The investigated application is in single-user mode.

The VCPE was separated into two rooms: the virtual entry area (a), where the user can choose between ten different prosthetic cases of ascending complexity (Figures 1 and 2). By increasing the level of difficulty, the students could gradually approach more complex cases avoiding to start directly with a possibly demotivating and too complex case. After selecting the desired patient case, the virtual patient case planning room (b) opens (Figure 3). The entrance area is modelled on the design of a waiting room with a view of the sea. The virtual case planning room is also glass fronted with a view of the sea and is intended to represent a seminar room. In the VCPE, the following information was integrated to the case planning:

1. Anamnesis sheet.
2. Dental and periodontal findings.
3. Radiographs (single tooth radiographs and panoramic radiographs depending on the case)
4. Intraoral photos and lip images.
5. Face scan (three-dimensional patient profile)
6. Situation casts with measuring scales (three-dimensional)

The user could move the situation casts and measurement scales as well as planning planes to visualize the aesthetic measurement of the face scan. All other objects were fixed in the virtual space.

Both students and lecturers were handed out instructions in advance of the application, and a verbal briefing was conducted. Subsequently, the study groups each had 30 minutes to view the various virtual case planning environments. During this time, participants could choose from any of the 10 cases.

2.2 | Assessment

In spring term 2022, the use of virtual case planning seminars was evaluated in four different dental schools from south and middle Germany from the perspective of both lecturers and students at the end of their first clinical course in prosthetic dentistry. The dental schools and lecturers were selected based on their prior experience with digital projects and longstanding successful cooperation in teaching and research. The use of the VR environment was voluntary and offered to all students in the corresponding semester at the respective dental schools for participation. Following the application, participants were given a 23-item questionnaire, which they completed directly after usage. The detailed questionnaire can be found in Table 1. The answers were given in different ways dependent on the questions as either a visual analogue scale (VAS) with marking on a 10 cm line (respectively 0–100%) or (b) a Likert scale.

FIGURE 1 Virtual entry area showing panel board where user can choose between 10 different prosthetic cases of ascending complexity.

2.3 | Data analysis

Data were quantitatively analysed using the statistical program SPSS 28 (IBM, New York, NY, USA). The collected data were verified for normal distribution using Kolmogorov–Smirnov and exploratory data analysis was used to determine the median value, interquartile range (IQR) and minimum/maximum values. The cross-tabulations were tested for significance using the Fisher–Freeman–Halton test, and exact Fisher test. To determine the reliability of the questionnaire, the Cronbach Alpha value was calculated. With a p-value of $<.05$, the test result was considered statistically significant.

3 | RESULTS

The data were not normally distributed in 83.3%, which followed a non-parametric analysis. The Cronbach Alpha value was assessed for the questionnaires with a value of 0.873.

FIGURE 2 Virtual entry area showing a sea view side where user can choose between 10 different prosthetic cases of ascending complexity.

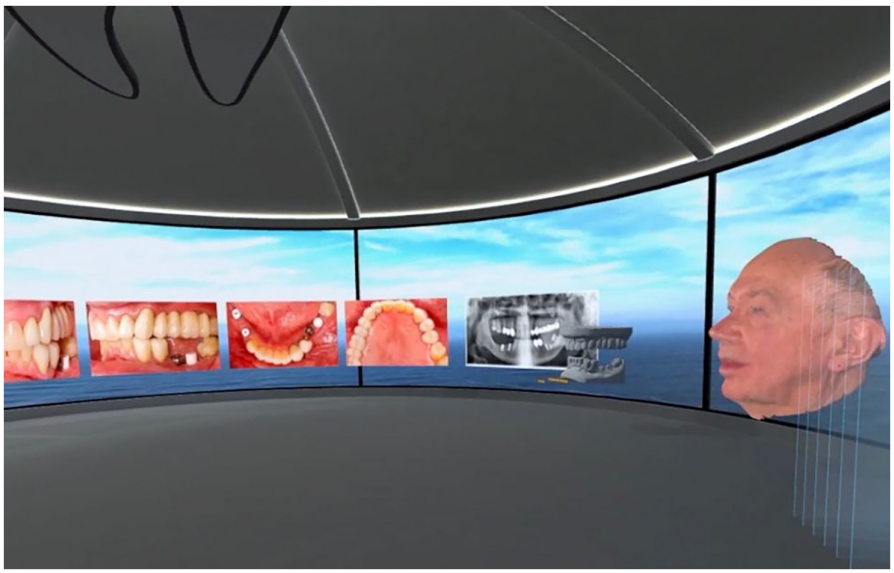

FIGURE 3 Virtual case planning environment with following information integrated: (1) Radiographs (panoramic radiographs), (2) Intraoral photos, (3) Face scan (three-dimensional patient profile), and (4) situation casts with measuring scales (three-dimensional) as case example.

A total of 122 participants were included in the multicentric analysis that consisted of 59 lecturers (DS1: 15; DS2: 17; DS3: 10 and DS4:17) and 63 students (DS1: 18; DS2: 16; DS3: 10 and DS4:19).

Detailed results can be found in Table 1.

3.1 | Evaluations of lecturers

The mean age of the lecturers was 36.2 ± 9.0 (median: 34.0, IQR: 10.0) years. Differences regarding the age of the lecturers could be analysed between the DS ($p = .002$). DS2 showed a higher age compared to all other three DSs ($p \geq .013$). Otherwise, no other differences in age could be observed between the other DSs ($p \geq .318$). There were no differences in terms of gender ($p \geq .187$). In DS1, 46.7% were male, 46.7% were female, and 6.7% were of divers gender. In DS2, 29.4% were male and 70.6% were female. In addition, in DS3, 40.0% were male and 60.0% were female, and in DS4, 52.9% were male and 47.1% were female. Overall, 42.4% were male, 55.9% female, and 1.7% divers gender.

In terms of professional qualifications, in DS1 53.3% reported no further qualification to study dentistry, 13.3% were also dental technicians, 20.0% had a master's degree, and 13.3% were specialists. In DS2, 35.5 of the lecturers reported having no further qualification, 11.8% were also dental technicians, 23.5% had advanced orthodontic training, 23.5% had a master's degree, and 5.9% were specialists. In DS3, 70.0% reported no other qualifications, 10% had a specialist, and 20.0% had other qualifications. In DS4, 41.2% reported having no additional qualifications, 11.8% were also dental technicians, 5.9% were dental assistants, 5.9% had a master's degree, 11.8% were specialists, and 23.5% had other qualifications.

3.2 | Evaluations of students

The mean age of the participating students was reported as 24.3 ± 3.0 (median: 24.0; IQR:10.0) years. There was no difference in the age of the students among the four DS ($p = .087$). There were no differences in gender ($p \geq .363$). In DS1, 33.3% were male and 66.7% were female. In DS2, 18.8% were male and 81.3% were female. In addition, in DS3, 50.0% were male and 50.0% were female, and in DS4, 42.1% were male and 57.9% were female. Overall, 34.9% were male and 65.1% were female.

In terms of additional education available, in DS1, 72.2% reported having no additional education, 16.7% were dental technicians, and 11.1% had already completed medical school. In DS2, 87.5% had no additional education, 6.3% were dental technicians, and 6.3% were dental assistants. In DS3, 80.0% had no further education and 20.0% had already completed medical school. In DS4, 78.9% reported having no further professional qualifications, 10.5% were dental technicians, 5.3% were dental assistants, and 5.3% had already completed medical school.

3.3 | Comparison of lecturers among the four dental schools

When the individual responses to the lecturers' questions were compared between the DS, no differences were observed for question 1 ($p = .617$), question 4 ($p = .073$), question 13 ($p \geq .053$), question 14 ($p \geq .064$), question 15 ($p = .100$), question 16 ($p = .065$), question 19 ($p = .138$), question 21 ($p = .110$), question 22 ($p \geq .103$) and question 23 ($p = .401$). For question 2 ($p = .030$–$.464$), question 3 ($p = .033$), question 5 ($p < .001$), question 6 ($p < .001$), question 7 ($p < .001$), question 8 ($p = .003$), question 9 ($p = .002$), question 10 ($p = .004$), question 11 ($p < .001$), question 12 ($p = .001$–$.621$), question 17 ($p = .005$), question 18 ($p = .022$), and question 20 ($p = .001$) differences were found, which can be seen in detail in Table 1.

3.4 | Comparison of students among the four dental schools

Significant differences ($p = .007$) could only be analysed between the DSs when answering question 1. For this question, the students of DS1 were willing to pay a significantly higher purchase

TABLE 1 Detailed information (single questions/answer possibilities) of assessment questionnaire used with all results of both lecturers and students using median/number (%), minimum (Min), maximum (Max), interquartile range of all four dental schools (DS1–4) included.

Number question	Question/Statement	Answer possibility	Dental school (DS)	Median/ Number (%)	IQR	Min	Max	Median/ Number (%)	IQR	Min	Max
				Lecturers				Students			
1	How much money would you invest in the equipment to use virtual case planning?	VAS (0 Euro to 2000 Euro)	DS1	$1000.0^{A,a}$	1066.7	155.6	2000.0	$1000.0^{A,b}$	1111.1	288.9	2000.0
			DS2	$933.3^{A,a}$	755.6	155.6	2000.0	$777.8^{A,a}$	711.1	66.7	1555.6
			DS3	$888.9^{A,a}$	777.8	88.9	1600.0	$666.7^{A,a}$	244.4	222.2	1711.1
			DS4	$1000.0^{B,a}$	700.0	533.3	1666.7	$500.0^{A,a}$	333.3	100.0	1533.3
2	I understand the planning of a prosthetic patient case	1. Highly much better through learning in the virtual space than through a conventional seminar	DS1	$26.7^{A,b}$	–	–	–	$11.1^{A,a}$	–	–	–
			DS2	$0.0^{A,a}$				$0.0^{A,a}$			
			DS3	$0.0^{A,a,b}$				$0.0^{A,a}$			
			DS4	$5.9^{Aa,b}$				$0.0^{A,a}$			
		2. Much better through learning in the virtual space than through a conventional seminar	DS1	$33.3^{A,a,b}$				$38.9^{A,b}$			
			DS2	$6.7^{A,a}$				$6.3^{A,a}$			
			DS3	$30.0^{A,a,b}$				$20.0^{A,a,b}$			
			DS4	$47.1^{A,b}$				$57.9^{A,b}$			
		3. Equally well through learning in the virtual than through a conventional seminar	DS1	$40.0^{A,a}$				$50.0^{A,a}$			
			DS2	$33.3^{A,a}$				$62.5^{A,a}$			
			DS3	$60.0^{A,a}$				$50.0^{A,a}$			
			DS4	$47.1^{A,a}$				$26.3^{A,a}$			
		4. Much better through learning by means of conventional seminar	DS1	$0.0^{A,a}$				$0.0^{A,a}$			
			DS2	$60.0^{A,b}$				$25.0^{A,a}$			
			DS3	$10.0^{A,a}$				$30.0^{A,a}$			
			DS4	$0.0^{A,a}$				$15.8^{A,a}$			
		5. Highly much better by learning by means of conventional seminar	DS1	$0.0^{A,a}$				$0.0^{A,a}$			
			DS2	$0.0^{A,a}$				$6.3^{A,a}$			
			DS3	$0.0^{A,a}$				$0.0^{A,a}$			
			DS4	$0.0^{A,a}$				$0.0^{A,a}$			
3	How do you assess the innovation potential of virtual prosthetic case planning?	VAS (not at all innovative to very innovative)	DS1	$100.0^{B,b}$	18.9	50.0	100.0	$88.9^{A,a}$	21.7	30.0	100.0
			DS2	$85.6^{A,a}$	17.8	50.0	97.8	$78.9^{A,a}$	24.7	50.0	100.0
			DS3	$83.9^{A,a}$	36.9	58.9	100.0	$79.4^{A,a}$	24.4	63.3	100.0
			DS4	$86.7^{A,a}$	17.5	55.0	100.0	$76.7^{A,a}$	23.3	53.3	96.7
4	How do you assess the innovation potential of virtual case planning for other dental specialties (e.g. surgery, orthodontics)?	VAS (not at all innovative to very innovative)	DS1	$95.6^{A,a}$	25.6	50.0	100.0	$84.4^{A,a}$	21.4	27.8	100.0
			DS2	$85.6^{A,a}$	25.0	15.6	96.7	$86.7^{A,a}$	16.1	65.6	100.0
			DS3	$82.2^{A,a}$	34.2	55.6	100.0	$84.4^{A,a}$	20.3	63.3	100.0
			DS4	$90.0^{A,a}$	15.8	56.7	100.0	$80.0^{A,a}$	25.0	56.7	100.0
5	What is your general assessment of the assessability of virtually represented patient objects?	VAS (very poorly assessable to very well assessable)	DS1	$91.1^{B,b}$	17.8	72.2	100.0	$60.0^{A,a}$	30.3	26.7	88.9
			DS2	$54.4^{A,a}$	30.0	5.6	96.7	$52.2^{A,a}$	11.4	24.4	95.6
			DS3	$46.7^{A,a}$	39.4	24.4	82.2	$67.8^{A,a}$	38.1	35.6	94.4
			DS4	$76.7^{B,b}$	23.3	40.0	100.0	$61.7^{A,a}$	23.3	31.7	95.0

(Continues)

TABLE 1 (Continued)

Number question	Question/Statement	Answer possibility	Dental school (DS)	Median/ Number (%)	IQR	Min	Max	Median/ Number (%)	IQR	Min	Max
				Lecturers				Students			
6	Does the communication and interaction capability lead to improved understanding of the virtual patient case?	VAS (no better understanding at all to completely better understanding)	DS1	$90.0^{A,c}$	21.1	50.0	100.0	$74.4^{A,a}$	41.9	46.7	100.0
			DS2	$50.0^{B,a}$	25.6	5.6	82.2	$58.9^{A,a}$	29.7	26.7	86.7
			DS3	$60.6^{A,a}$	23.6	24.4	73.3	$66.1^{A,a}$	38.9	3.3	97.8
			DS4	$70.0^{A,b}$	24.2	35.0	95.0	$60.0^{A,a}$	25.0	11.7	100.0
7	Does individual interaction with hand controllers lead to improved understanding of the virtual patient case?	VAS (no better understanding at all to completely better understanding)	DS1	$91.1^{A,c}$	24.0	50.0	100.0	$84.4^{A,a}$	41.7	24.4	100.0
			DS2	$42.2^{B,a}$	27.2	0.0	91.1	$55.0^{A,a}$	24.2	26.7	97.8
			DS3	$45.0^{A,a}$	46.1	0.0	100.0	$60.6^{A,a}$	31.4	2.2	100.0
			DS4	$75.0^{A,b}$	28.3	50.0	91.7	$61.7^{A,a}$	31.7	30.0	100.0
8	Does the additional information on the patient information walls (e.g., x-rays, medical history sheet, findings) lead to an improved understanding of the virtual patient case?	VAS (no better understanding at all to completely better understanding)	DS1	$94.4^{A,b}$	14.4	73.3	100.0	$93.9^{A,a}$	15.8	38.9	100.0
			DS2	$57.8^{A,a}$	39.4	0.0	97.8	$68.9^{A,a}$	36.9	3.3	97.8
			DS3	$56.7^{A,a}$	29.2	50.0	100.0	$75.6^{A,a}$	46.7	12.2	100.0
			DS4	$83.3^{A,b}$	15.8	26.7	100.0	$81.7^{A,a}$	21.7	50.0	100.0
9	How do you find your way around the virtual space?	VAS (very poor to very good)	DS1	$94.4^{A,c}$	20.0	57.8	100.0	$93.9^{A,a}$	18.1	22.2	100.0
			DS2	$57.8^{A,a}$	55.0	1.1	96.7	$83.9^{A,a}$	43.3	40.0	100.0
			DS3	$90.0^{A,bc}$	38.3	52.2	100.0	$75.0^{A,a}$	34.4	41.1	100.0
			DS4	$75.0^{A,ab}$	35.0	35.0	100.0	$88.3^{A,a}$	33.3	25.0	100.0
10	In your opinion, how well did the use of virtual case planning work from a technical standpoint?	VAS (very poor to very good)	DS1	$97.8^{A,b}$	23.3	57.8	100.0	$85.0^{A,a}$	26.7	31.1	100.0
			DS2	$73.3^{A,a}$	41.1	10.0	97.8	$77.8^{A,a}$	36.4	50.0	100.0
			DS3	$86.7^{A,ab}$	45.8	11.1	100.0	$75.0^{A,a}$	36.9	50.0	100.0
			DS4	$73.3^{A,a}$	24.2	41.7	95.0	$91.7^{A,a}$	25.0	40.0	100.0
11	How well do you think the use of virtual case planning has worked with the quality provided?	VAS (very poor to very good)	DS1	$93.3^{B,b}$	20.0	57.8	100.0	$73.9^{A,a}$	35.0	37.8	100.0
			DS2	$57.8^{A,a}$	38.9	10.0	96.7	$56.7^{A,a}$	37.8	28.9	100.0
			DS3	$48.3^{A,a}$	66.9	8.9	90.0	$71.7^{A,a}$	41.4	50.0	94.4
			DS4	$73.3^{A,b}$	25.0	31.7	100.0	$80.0^{A,a}$	23.3	31.7	100.0
12	How did you feel about the object size of the models in the virtual planning environment?	1. Too small	DS1	$0.0^{A,a}$	–	–	–	$0.0^{A,a}$	–	–	–
			DS2	$11.8^{A,a}$				$0.0^{A,a}$			
			DS3	$0.0^{A,a}$				$0.0^{A,a}$			
			DS4	$5.9^{A,a}$				$5.3^{A,a}$			
		2. Optimal	DS1	$93.3^{A,b}$				$61.1^{A,a}$			
			DS2	$47.1^{A,a}$				$68.8^{A,a}$			
			DS3	$30.0^{A,a}$				$50.0^{A,a}$			
			DS4	$70.6^{A,a,b}$				$42.1^{A,a}$			
		3. Too big	DS1	$6.7^{A,a}$				$38.9^{A,a}$			
			DS2	$100.0^{A,b,c}$				$31.3^{A,a}$			
			DS3	$70.0^{A,b}$				$50.0^{A,a}$			
			DS4	$23.5^{A,a,c}$				$52.6^{A,a}$			

TABLE 1 (Continued)

Number question	Question/Statement	Answer possibility	Dental school (DS)	Median/ Number (%) Lecturers	IQR	Min	Max	Median/ Number (%) Students	IQR	Min	Max
13	How did you feel about the object size of the face scan with the auxiliary layers in the virtual planning environment?	1. Too small	DS1	0.0[A,a]	–	–	–	0.0[A,a]	–	–	–
			DS2	0.0[A,a]				0.0[A,a]			
			DS3	0.0[A,a]				0.0[A,a]			
			DS4	5.9[A,a]				0.0[A,a]			
		2. Optimal	DS1	66.7[A,a]				44.4[A,a]			
			DS2	41.2[A,a]				43.8[A,a]			
			DS3	30.0[A,a]				60.0[A,a]			
			DS4	70.6[A,a]				47.4[A,a]			
		3. Too big	DS1	33.3[A,a]				55.6[A,a]			
			DS2	100.0[A,a]				56.3[A,a]			
			DS3	70.0[A,a]				40.0[A,a]			
			DS4	23.5[A,a]				52.6[A,a]			
14	How did you feel about the object size of the patient information walls in the virtual planning environment?	1. Too small	DS1	0.0[A,a]	–	–	–	0.0[A,a]	–	–	–
			DS2	5.9[A,a]				0.0[A,a]			
			DS3	10.0[A,a]				0.0[A,a]			
			DS4	23.5[A,a]				5.3[A,a]			
		2. Optimal	DS1	93.3[A,a]				88.9[A,a]			
			DS2	70.6[A,a]				81.3[A,a]			
			DS3	50.0[A,a]				50.0[A,a]			
			DS4	58.8[A,a]				78.9[A,a]			
		3. Too big	DS1	6.7[A,a]				11.1[A,a]			
			DS2	23.5[A,a]				18.8[A,a]			
			DS3	40.0[A,a]				50.0[A,a]			
			DS4	17.6[A,a]				15.8[A,a]			
15	How intuitive do you consider the handling of the VR equipment to be?	VAS (not at all intuitive to very intuitive)	DS1	85.6[A,a]	34.4	33.3	100.0	83.9[A,a]	40.6	11.1	100.0
			DS2	53.3[A,a]	38.9	7.8	100.0	69.4[A,a]	38.6	37.8	100.0
			DS3	76.1[A,a]	30.6	41.1	100.0	70.6[A,a]	22.2	40.0	97.8
			DS4	68.3[A,a]	30.8	30.0	100.0	78.3[A,a]	35.0	40.0	100.0
16	Have you had any health problems (e.g., nausea, dizziness, eye pain) after prolonged use?	1. Yes	DS1	20.0[A,a]	–	–	–	44.4[A,a]	–	–	–
			DS2	52.9[A,a]				56.3[A,a]			
			DS3	70.0[A,a]				50.0[A,a]			
			DS4	53.3[A,a]				15.8[A,a]			
		2. No	DS1	80.0[A,a]				55.6[A,a]			
			DS2	47.1[A,a]				43.8[A,a]			
			DS3	30.0[A,a]				50.0[A,a]			
			DS4	46.7[A,a]				84.2[A,a]			

(Continued)

TABLE 1 (Continued)

Number question	Question/Statement	Answer possibility	Dental school (DS)	Median/ Number (%) Lecturers	IQR	Min	Max	Median/ Number (%) Students	IQR	Min	Max
17	Would you recommend virtual case planning to others?	1. Yes	DS1	$100.0^{A,b}$	–	–	–	$100.0^{A,b}$	–	–	–
			DS2	$70.6^{A,a}$				$68.8^{A,a}$			
			DS3	$100.0^{A,a,b}$				$70.0^{A,a}$			
			DS4	$100.0^{A,a,b}$				$94.7^{A,a,b}$			
		2. No	DS1	$0.0^{A,a}$				$0.0^{A,a}$			
			DS2	$29.4^{A,b}$				$31.3^{A,b}$			
			DS3	$0.0^{A,a,b}$				$30.0^{A,b}$			
			DS4	$0.0^{A,a,b}$				$5.3^{A,a,b}$			
18	Would you like to continue using virtual case planning in the clinical section?	1. Yes	DS1	$93.3^{A,a,b}$				$94.1^{A,a}$			
			DS2	$70.6^{A,a}$				$62.5^{A,a}$			
			DS3	$100.0^{A,a,b}$				$70.0^{A,a}$			
			DS4	$100.0^{A,b}$				$84.2^{A,a}$			
		2. No	DS1	$6.7^{A,a,b}$				$5.9^{A,a}$			
			DS2	$29.4^{A,b}$				$37.5^{A,a}$			
			DS3	$0.0^{A,a,b}$				$30.0^{A,a}$			
			DS4	$0.0^{A,a}$				$15.8^{A,a}$			
19	Would you like to use virtual case planning at an earlier stage of dental school?	1. Yes	DS1	$86.7^{A,a}$	–	–	–	$83.3^{A,a}$	–	–	–
			DS2	$58.8^{A,a}$				$62.5^{A,a}$			
			DS3	$90.0^{A,a}$				$60.0^{A,a}$			
			DS4	$88.2^{A,a}$				$78.9^{A,a}$			
		2. No	DS1	$13.3^{A,a}$				$16.7^{A,a}$			
			DS2	$41.2^{A,a}$				$37.6^{A,a}$			
			DS3	$10.0^{A,a}$				$40.0^{A,a}$			
			DS4	$11.8^{A,a}$				$21.1^{A,a}$			
20	How did you find the display quality of the prosthetic VR planning environment?	VAS (not good at all to very good)	DS1	$91.1^{B,b}$	28.9	44.4	100.0	$67.8^{A,a}$	30.6	16.7	100.0
			DS2	$54.4^{A,a}$	37.2	25.6	100.0	$68.9^{A,a}$	40.8	31.1	100.0
			DS3	$61.1^{A,a}$	42.8	21.1	84.4	$57.2^{A,a}$	28.1	50.0	94.4
			DS4	$76.7^{A,b}$	24.2	50.0	100.0	$75.0^{A,a}$	36.7	26.7	100.0
21	Did the VR learning environment allow you to focus on the content better than traditional learning methods?	1. Yes	DS1	$66.7^{A,a}$	–	–	–	$50.0^{A,a}$	–	–	–
			DS2	$23.5^{A,a}$				$18.8^{A,a}$			
			DS3	$50.0^{A,a}$				$40.0^{A,a}$			
			DS4	$43.8^{A,a}$				$47.4^{A,a}$			
		2. No	DS1	$33.3^{A,a}$				$50.0^{A,a}$			
			DS2	$76.5^{A,a}$				$81.3^{A,a}$			
			DS3	$50.0^{A,a}$				$60.0^{A,a}$			
			DS4	$56.3^{A,a}$				$52.6^{A,a}$			

TABLE 1 (Continued)

Number question	Question/Statement	Answer possibility	Dental school (DS)	Median/ Number (%)	IQR	Min	Max	Median/ Number (%)	IQR	Min	Max
				Lecturers				Students			
22	Did you experience any technical malfunctions or problems?	1. Yes	DS1	$0.0^{A,a}$	–	–	–	$0.0^{A,a}$	–	–	–
			DS2	$0.0^{A,a}$				$6.3^{A,a}$			
			DS3	$0.0^{A,a}$				$20.0^{A,a}$			
			DS4	$23.5^{A,a}$				$5.6^{A,a}$			
		2. No	DS1	$100.0^{A,a}$				$100.0^{A,a}$			
			DS2	$100.0^{A,a}$				$93.8^{A,a}$			
			DS3	$100.0^{A,a}$				$80.0^{A,a}$			
			DS4	$76.5^{A,a}$				$94.4^{A,a}$			
23	How did you use the virtual environment during virtual case planning?	1. Stationary	DS1	$46.7^{A,a}$	–	–	–	$88.9^{A,b}$	–	–	–
			DS2	$52.9^{A,a}$				$31.3^{A,a}$			
			DS3	$22.2^{A,a}$				$40.0^{A,a}$			
			DS4	$33.1^{A,a}$				$47.4^{A,a}$			
		2. Space movement	DS1	$53.3^{A,a}$				$11.1^{A,a}$			
			DS2	$47.1^{A,a}$				$68.8^{A,b}$			
			DS3	$77.8^{A,a}$				$60.0^{A,b}$			
			DS4	$68.8^{A,a}$				$52.6^{A,b}$			

Note: Uppercase supercript letters indicate significant differences between lecturer and student answers within one DS. Lowercase supercript letters indicate significant differences between lecturer as well as student answers between the different DSs.

price for the VR equipment with the mean value of 1000 Euros than the students of DS4 with the mean value of 500 Euros ($p = .001$). In addition, significant differences could be analysed in question 2 ($p = .007–.413$), question 17 ($p = .008$) and question 23 ($p = .003$). All other questions showed no differences in student ratings between the DS ($p \geq .115$). Detailed results can be found in Table 1.

3.5 | Comparison between lecturers and students within each dental schools

Within DS1, there were significant differences between the answers of lecturers and students for questions 5 ($p < .001$), question 11 ($p = .033$), and question 20 ($p = .012$), where the answers of lecturers turned out better than those of students. For all other questions, no differences could be analysed ($p \geq .178$).

Within DS2, differences were found for question 6 ($p = .023$) and question 7 ($p = .002$), where students gave better ratings than lecturers. Furthermore, no significant differences could be measured ($p \geq .136$).

Within DS3, no significant differences between lecturers and students could be analysed for any question ($p \geq .089$).

Within DS4, significant differences could be analysed for questions 1 ($p < .001$) and 5 ($p = .012$), with lecturers giving higher or, respectively, better ratings. No differences were found for other questions ($p \geq .057$).

4 | DISCUSSION

The tested hypothesis of the multicentric assessment of the VCPE stated that there is no difference of the assessment criteria between the four DSs and no differences between the results of students and lecturers within each DS. The tested hypotheses could be rejected in the present study, since significant differences in the results could be analysed in all areas within the DS between lecturers or between students and likewise between lecturers and students. These will be discussed in more detail in the following sections.

When considering the acquisition costs that lecturers and students would be willing to pay for the VR equipment, the willingness of lecturers tended to be higher than that of students, for DS4 even significantly. This is certainly due to the level of financial resources available to the participants. The values of 500 Euros, which were given in other assessments in the literature for students, agree with the results obtained here.[29,37]

Prosthetic case planning is a vital component in dental education. The ability to virtually practice on a variety of patients can increase knowledge and enhance the routines of students to plan clinical cases. If surgical procedures are practiced and navigated virtually, VR use could even lead to improved patient safety.[24] This was also considered positively in the present study. In the data obtained, it became obvious that the lecturers and students rate practicing in the virtual cases as good and intuitive (question 15) and that a majority would also recommend it to others (question 17). In addition, all of them consider the innovative potential of the assessed virtual prosthetic case planning and further application areas to be high (question 3 and 4). The lecturers and students would like to continue using the virtual case planning environments in the clinical undergraduate courses (question 18) and they agreed it would be beneficial to already use it in the preclinical study phase (question 19).

Prosthetic case planning is a routine part of everyday dental practice and is also part of the students' final examination. A more advanced opportunity to get an insight into many different cases of varying complexity can be a benefit before facing dental examinations in the dental practice after graduation. However, it must be noted that virtual teaching is currently only an add-on to conventional teaching. Question 2 showed that many lecturers and students consider conventional learning important with regard to case planning and do not necessarily benefit from learning in the virtual space. Lecturers of DS2 and students of DS2 and DS3 even considered the learning comprehension to be significantly better through the conventional textbook. Virtual teaching could represent a higher impact in other areas where the three-dimensional approach plays a more essential role. In the coming years, however, this form of teaching could become more common as the quality of the resolution and technical components continues to improve (question 11). The COVID-19 pandemic and the shift to digital teaching formats have gained considerable momentum in recent years.

The possibility of interactions with the virtual objects was rated rather mixed with regard to the resulting better understanding (questions 6–8). The size of the objects regarding the face scan (question 13) was predominantly optimal for the DSs or assessed as too large by the lecturers and students. The size of the patient information, on the other hand, was rated slightly better by size (question 14).

The answers according to the use of the virtual case planning environment must be considered critically. Since most users apply it in smaller rooms, the inpatient application should have a higher value. In question 23, the application is rather equally distributed. This probably stems in the difficulty of conceptualization, as one can also interact in the stationary application. However, the spatial use enables to walk in the virtual environment without “real” obstacles and without teleportation.

When examining the results, it is apparent that DS1 assessed the VCPE significantly better compared to the other three dental schools (D2–D4). Additionally, in some questions, the four different dental schools exhibited considerably different evaluations. This can be explained by the fact that DS1 is the developer of the VCPE. There, the lecturers and students were strongly involved in the development and test phase from the beginning, so that individual components such as object sizes are based on their earlier assessment. Therefore, the handling of the technical components is more familiar. Furthermore, it is noticeable that the results of the lecturers of DS2 tend to be lower than those of the other three DSs. Since

this DS had a somewhat higher average age of the lecturers, this could have led to technically more critical results. However, regardless of DS1 as developer, all other DS had no experience with virtual teaching before, it seems surprising that there were significant differences in the evaluations. Though, the DS with individual scientific consensus might have an impact on the perception towards VCPE. In addition to the age of the lecturers, this could also be due to the different levels of anchored digital teaching content. However, this point certainly seems to be attenuated after the Corona pandemic than before the pandemic, as all dental schools were forced to convert to digital teaching. Differences could have been even more pronounced before the pandemic.

As in most assessments of virtual teaching environments, one limitation was the occurrence of health problems (question 16). The slight pixelation of the display can lead to headaches and dizziness, the so-called "cyber sickness".[36] In most cases, the interpupillary distance and the fit of the VR glasses might not be optimally adjusted in advance, which can cause the quantitatively mentioned problem.

Another limitation or adverse effect could be that all 10 different patient cases were available. This could have led to a certain bias as the consideration of complex cases might led to a more negative evaluation.

Crawford et al. reported on a multi-user VR environment and were able to demonstrate the great potential of using VR applications already in the preclinical section of dental school. This environment was composed of a classroom and a treatment room in which virtual instruction could be delivered.[14] Another limitation of the present multicenter study is the difficulty in comparing it to other virtual teaching environments, since these are usually programmed very differently, cover different subject areas, and the assessment consists of very differently designed questionnaires.

Virtual teaching environments in single-user mode have the problem that no feedback or important interaction with the lecturers is possible. A further development of the present virtual case planning environment has already been developed for conducting virtual seminars. However, this was not part of the multicentric assessment and therefore represents a limitation within the multicentric approach. A multicentric analysis in multi-user mode would be desirable.

5 | CONCLUSION

Even though for some assessment criteria significantly different results between the four DS were observed, the majority of participants evaluated the virtual prosthetic case planning environment positively and recommended them for teaching. Furthermore, differences in the perception between lecturers and students could be detected. Improved technology could reduce the problems of technical handling and possible cyber sickness. Virtual reality as a teaching method for teaching prosthetic case planning for further preparation of students for later professional life and final state examinations can be seen as helpful. Since virtual teaching yielded significantly different evaluations by the users, the virtual reality might be an add-on to conventional teaching. Training of the lecturers and/or users might be helpful to improve acceptance for application of VR in teaching.

AUTHOR CONTRIBUTIONS

Conceptualization: A.L., M.B., A.R., M.S., and K.E.; Methodology: A.L., and K.E.; Software: K.E.; Formal Analysis: A.L. and K.E.; Investigation: A.L., M.B., A.R., and M.S.; Writing – Original Draft Preparation: A.L. and K.E.; Writing – Review & Editing: A.L., M.B., A.R., and M.S.; Visualization: K.E.; Supervision: A.L.; Project Administration: A.L.; All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data of questionnaires are covered in the presented huge table. Excel sheet can be sent on request at any time.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all subjects involved in the study.

ORCID

M. Bjelopavlovic https://orcid.org/0000-0003-1478-1680

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