

The "Four-step Approach" for Delivery of the Undergraduate Endodontics Experimental Course

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Abstract

Students' practical skills must be cultivated during undergraduate dental teaching and traditional theoretical examinations do not necessarily evaluate the relevant understanding and the application of knowledge. The current study aimed to produce a template with the potential for wider application for the improvement of practical dental teaching by applying a four-step approach to evaluating progress on an Endodontics course. Practical and theoretical examinations after one year's study via the four-step approach indicated significantly improved practical scores and no difference in theoretical scores compared with students taught by traditional methods. The suitability of the four-step approach, which incorporates continuous assessment and puts emphasis on practical skills, for dental education is discussed.

Keywords: endodontics, continuous assessment, dental education, four-step approach, problem-based learning

1. Introduction

Dentistry is a clinical discipline involving operation, practicality, skill and experience and undergraduate dental education must aid the transition from basic theory to preclinical practice. Laboratory teaching forms a very important part of this process. Students require solid theoretical knowledge, operation skills (Ba-Hattab R, ... Helvacioğlu-Yigit D., 2023), psychological qualities and good doctor-patient communication in order to become competent dentists. The cultivation of students' practical skills has always been a priority for undergraduate dental laboratory teaching (Liu N, Yang DR, ... Ma Z., 2019) (Pang MW, ... Ji P., 2022).

Endodontics covers the common groups of diseases of the dental pulp, including caries, non-carious dental hard tissue disease and periapical disease of the pulp root, about 70% of which cases require hospital treatment. Such diagnoses and treatments must be understood and performed by all dental students (Qiu ZL., 2019). An endodontics course is thus a core part of the undergraduate dental syllabus. Endodontics education in China has usually followed a traditional lecture-based format, followed by practical teaching. However, preclinical education has been updated since 1994 from didactic teaching to Problem-based Learning, Case-reinforced Learning and Innovative technology-based Learning (Wu ZY, & Zhang ZY., 2010) in many universities and Chinese dental schools are adopting similar reforms. However, reforms in dental education are beset by the following hindrances. First, some faculty members are slow to respond to new technologies and equipment and are reluctant to apply new teaching methodologies (Sun WB, Hu QG, ... Zhang H., 2011). Dental school graduates generally lack problem-solving skills and feedback from fifth-grade students indicates a desire to develop their critical thinking and problem-solving skills in addition to gaining theoretical knowledge. Second, assessment usually depends on a theoretical examination, supplemented by practical scores. For example, final examinations at Shenzhen University include a 70% component for the theory examination and 30% for the experimental course (50% of which derives from the core practical course and 50% from a final operation). Stomatology is a practical discipline, requiring extensive practice, which cannot be assessed by theoretical examination. Indeed, students may achieve high scores in the theoretical component by rote learning, which does not reflect clinical competence. Reform of experimental teaching methods is thus vital. The time devoted to experimental courses greatly exceeds that of theoretical teaching and assessment is acknowledged to drive learning (Manogue M, McLoughlin J, ... Christersson C., 2011). Endodontics is a suitable

course component for a trial of experimental course reform, accompanied by continuous assessment to allay student anxiety.

The College of Stomatology in Shenzhen University was founded in 2018 and adopted innovative approaches, such as Problem-based Learning (PBL), Case-reinforced Learning (CRL) and community-based clinical treatment experiences with the support of Sichuan University West China College of Stomatology. The hours devoted to practical courses have been significantly increased and students undergo hand dexterity training in the early stages of undergraduate education (Ling JQ, & Fu Y., 2007). The KaVo dental mannequin, SIMROID robot patient, Moog virtual simulation dentist training machine and NISSIN Fair Grader 100 virtual reality evaluation system have been adopted to facilitate teaching and clinical equipment, such as the Gutta-percha Heating System and root canal motor, are also used. Experimental teaching is facilitated with the support of appropriate equipment by this approach. Practical and theoretical skills of two groups of dental students, one taught by traditional didactic methods and the second by the 4 step approach for the duration of 2 years, were compared.

2. Methods

2.1 Four-step Approach

The four steps are doctor-patient communication, virtual simulation, preclinical simulation exercise and digital evaluation. They were applied to endodontics teaching for 4th-grade dental students. Level 1 (doctor-patient communication) introduced common instruments and their usage. Level 2 (virtual simulation) used the Moog virtual simulation dentist training machine to teach manual dexterity exercises and the KaVo dental mannequin to teach cavity preparation and filling. Level 3 (preclinical simulation exercise) covered skills such as pulp opening and root canal therapy and level 4 (digital evaluation) was performed by the NISSIN Fair Grader 100 virtual reality evaluation system. The four steps with hours of teaching are shown in Table 1.

Table 1. Four-step teaching system

Section	Course content	Hours
Level 1	Commonly used endodontics instruments	4
	Stomatology surgeon surgery type, fulcrum practice	
	SIMROID robot patient training and operation	4
	Doctor-patient communication assessment	2
	Virtual manual dexterity exercises	8
Level 2	Simodont virtual simulator assessment	4
	Plastic teeth class I, II, III, IV, V cavity preparation by hand	12
	Class I, II, III, IV and V cavity preparation on mannequin head	12
	Resin filling	8
	Odontotropy	12
Level 3	Rubber barrier isolation and microscope use	4
	Root canal preparation (step by step, nickel-titanium file for hand, nickel-titanium file for machine)	12
	Root canal filling	14
	Practical skills assessment (preparation and filling of premolar root canals)	4
Level 4	Comprehension exercises	
	NISSIN Fair Grader 100 virtual reality examination and assessment	8

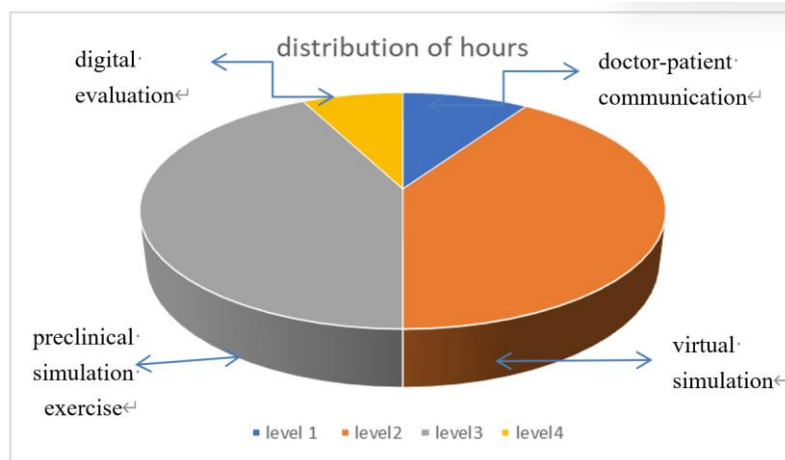


Figure 1. Teaching time devoted to each of the four steps

2.1.1 Step 1: Core Concepts and Assessment

Students who have received didactic endodontics teaching on common dental diseases undertook preclinical training designed to ensure appropriate treatment and communication skills. Students were familiarized with the dental fulcrum and common treatment equipment. The SIMROID robot patient was used for assessment to simulate clinical diagnosis and treatment scenarios. Students were able to take the medical history, make necessary examinations, propose auxiliary examinations and propose a treatment plan. The robot has facial expressions and movements to indicate the degree of comfort and may make verbal responses and turn its head. Fifty common clinical consultation scenarios were input into the system in advance and scores were assessed by examiners. Figures 2 and 3 show the scene editing mode, a sample scenario and the dental robot patient.

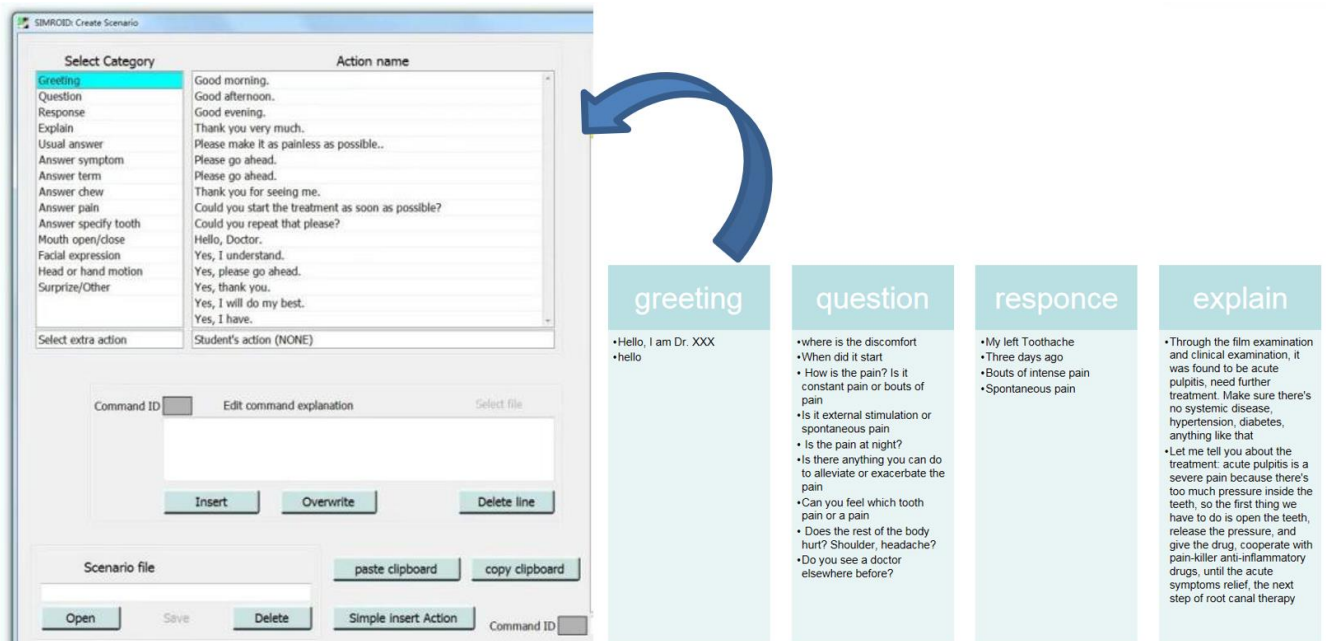


Figure 2. Scenario of editing mode



Figure 3. Teaching with the robot patient

2.1.2 Step 2: Core Concepts and Assessment

Students who have completed the theoretical course and are familiar with the operating position and fulcrum may progress to cavity preparation. Plastic and extracted human teeth have traditionally been used to teach these techniques but extracted teeth without prior work, such as restoration and root canal filling, are in short supply (Leung ALS, Yeung C, ... Chu S., 2021). The Simodont phantom simulator allowed students to practice manual dexterity for cavity preparation on virtual teeth, avoiding the waste of materials or the risk of accidental damage (Yu LH, Lu ZY, & Ren AJ., 2021). Exercises involved removing simulated caries (red) from geometric figures at 5 levels of difficulty, culminating in a square which resembles a class II carie. The assessment took into account the percentage of drilled leeway bottom, drilled leeway sides, drilled container bottom and drilled container sides during a time limit (Fig. 4). Evaluation was achieved by Simodont objective scoring which produced similar results to those from traditional preclinical practice with methacrylate blocks (Rodrigues P, Nicolau F, ... Norte M., 2023).

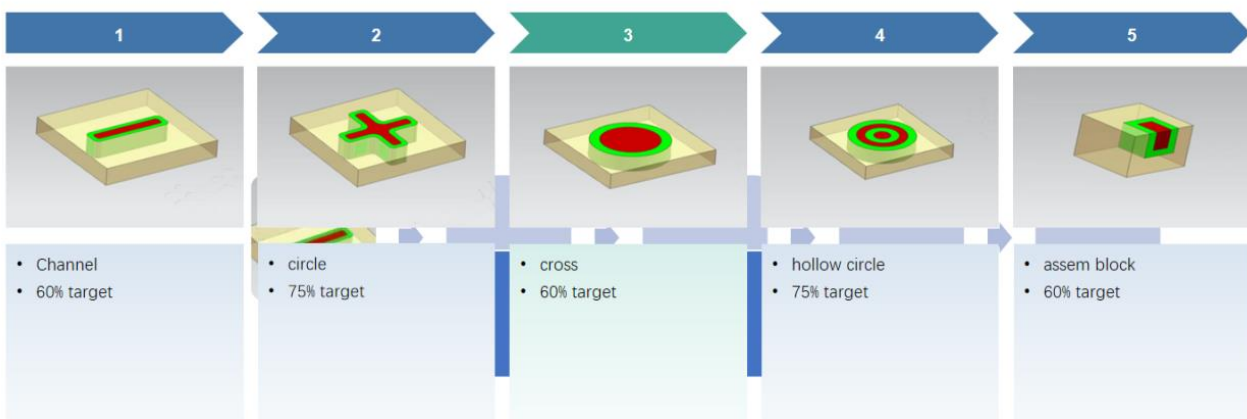


Figure 4. Simodont training blocks of increasing levels of difficulty

2.1.3 Step 3: Core Concepts and Assessment

Class I, II, III, IV and V cavity preparation of plastic or human-extracted front, premolar and molar teeth in the head of a mannequin was performed on an extended time scale to simulate endodontic root canal treatment (Gratton DG, Kwon SR, ... Blanchette D., 2016). Examiners made a visual inspection of the shape and depth of the prepared cavity and a radiographic assessment of obturation and distance of the root filling from the radiographic apex was made. Root canal treatment is an important element of endodontics, although not assessed by the National Dental Licence Examination (NDLE).

2.1.4 Step 4: Core Concepts and Assessment

Cavity preparation assessment is limited by the restriction of the naked eye and the degree of experience with prepared cavities (Zou HR, ... Jin SF., 2016). The NISSIN Fair Grader 100 was used to evaluate Class II cavity

preparation and to give feedback. Class II cavity preparation is assessed as part of the NDLE. Each student prepared a class II cavity using a standardized plastic molar and received an objective evaluation of abutment, outline form, etc. Such assessment avoids subjective feedback bias due to clinical experience (Lugassy D, ... Awad M., 2021). A grading report is shown in Figure 5.

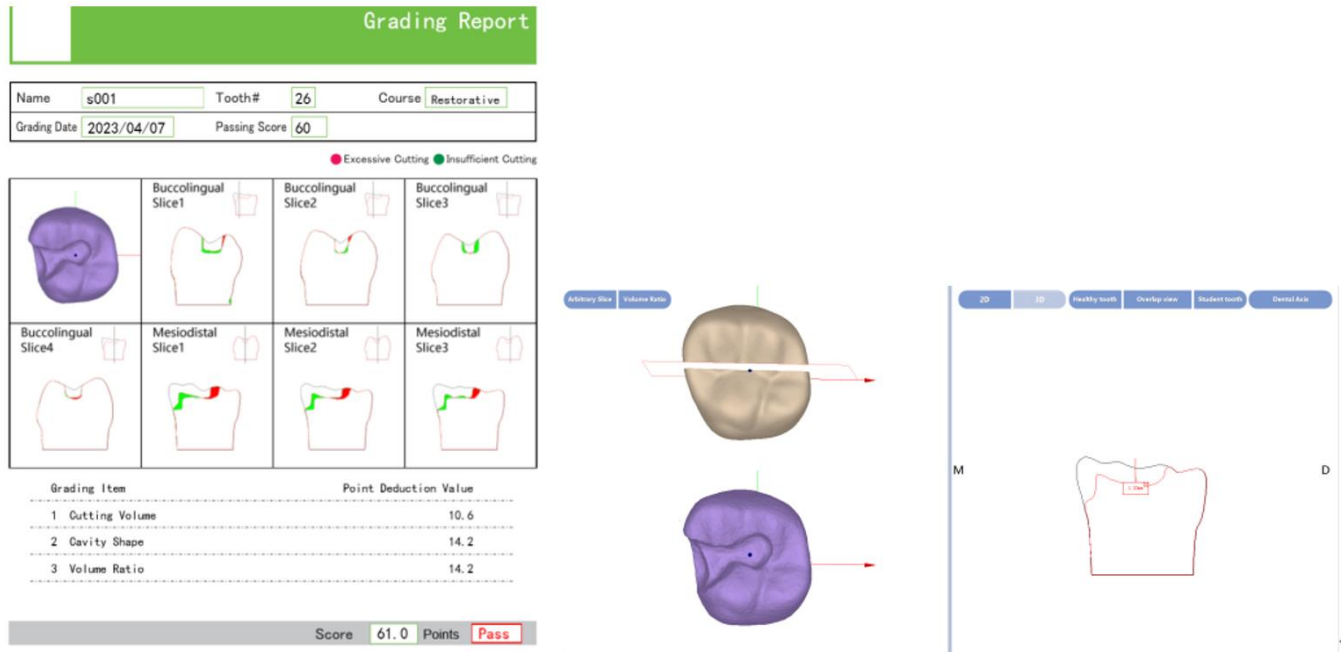


Figure 5. Digital evaluation report of cavity preparation

2.2 Continuous Assessment

Continuous, comprehensive and objective evaluation was performed to stimulate students' interest and enthusiasm and allow optimization of teaching. Assessments were performed after each teaching session and scores were combined to produce final endodontics scores. Continuous assessment aimed to solidify theoretical knowledge and cultivate practical and preclinical competencies to allow a smooth transition from school education to clinical treatment (Yu LH, Lu ZY, & Ren AJ., 2021).

Continuous assessment scores from the 4-step curriculum account for 70% of the final mark with the remaining 30% from the final exam which focused on learning attitude, pre-class preparation, course completion and other performances (Fig. 6).

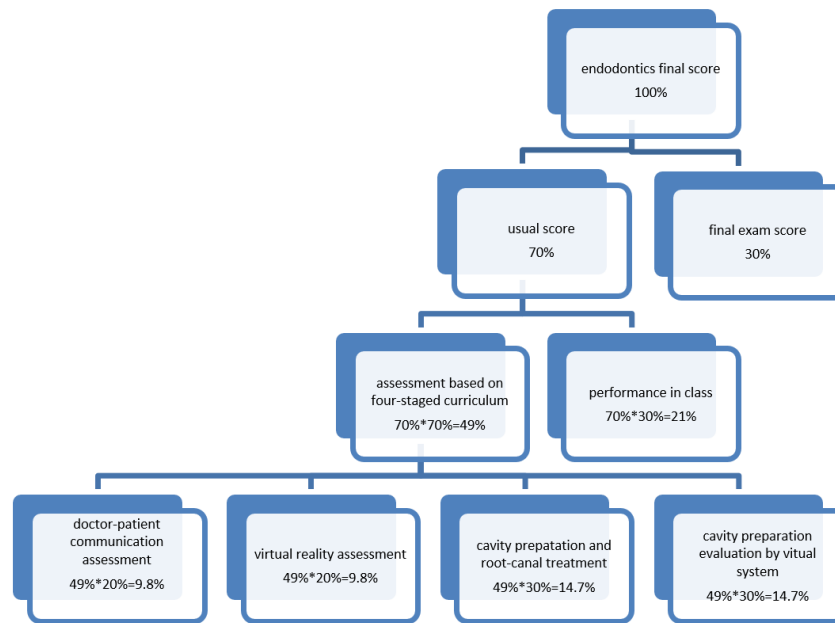


Figure 6. Assessment design

The 18-week course comprised lectures and clinical simulation with doctor-patient communication assessment in week 2, virtual simulation assessment in week 4, subsequent and entry preclinical skills assessment in week 17 and digital evaluation in week 18. Class performance was assessed 6 times. The assessment schedule is shown in Figure 7.

week 1	week 2	week 3	week 4	week 5	week 6	week 7	week 8	week 9	week 10	week 11	week 12	week 13	week 14	week 15	week 16	week 17	week 18	final examination	
★			★			★			★			★			★				
doctor-patient communication assessment																			
			virtual reality assessment																
				cavity preparation and root-canal treatment assessment															
																cavity preparation evaluation by virtual system			

Figure 7. Assessment schedule

★ routine performance of experimental courses

3. Results

The 4-step course has been offered for the past 2 years. Current 4th-grade students (Group A, n=30) underwent traditional evaluation with 30% of the final score derived from class results and 70% from the final examination. The next intake of students (Group B, n=32) followed the four-step teaching system and evaluation. Assessment scores for the two groups were compared by paired t-test (Table 3). No difference was found in assessment scores for the theoretical component but scores for Group A were significantly lower than for Group B for the experimental component.

Table 2. Assessment of dental pulp theory and experimental courses for Group A and Group B

Group	Theory score (%)	Experimental score (%)
A (n=30)	76.516±6.490	84.065±1.769
B (n=32)	78.065±5.698	87.290±4.133
t	-1.043	-4.251
p	0.305	<0.01

A survey was conducted among Group B to collate student opinions regarding the new curriculum and evaluation system (Table 3). 85.6% of students found the four-step experimental teaching method helpful for endodontics learning and 92.5% felt it stimulated their interest in learning. Most students found the cavity preparation, root canal treatment skills and digital evaluation skill assessments the most helpful and these skills are fundamental to endodontics. An additional 23.7% of students found doctor-patient communication assessment the most helpful, indicating increased interest in this facet among Chinese students. 100% of students found the digital evaluation of cavity preparation helpful. This mode of assessment was accepted by most students.

Table 3. Questionnaire responses

number	content	Proportion (%)	
1	Was the four-stepped experimental teaching method helpful for your endodontics course learning?	Very helpful	85.6
		same	12.1
		unhelpful	2.3
2	Did the course stimulate interest in active learning?	Very helpful	92.5
		same	7.5
		unhelpful	0.0
3	Which skill assessment was the most helpful?	Doctor-patient communication	23.7
		Virtual simulation	15.2
		Cavity preparation and root canal treatment skills	31.0
		Digital evaluation	30.1
4	Was digital evaluation objective and helpful for skill mastery?	Very helpful	100.0
		same	0.0
		unhelpful	0.0
5	Does the proportion of continuous assessment need to be adjusted?	Increase the proportion	83.4
		remain unchanged	4.5
		Reduce the proportion	8.1

4. Discussion

Two year's observation of the 4 step teaching approach allows some conclusions to be drawn regarding forms of assessment. Traditional summative assessment, where final exams account for the majority of the overall score, rely on the student assimilating a large amount of theoretical core knowledge (Ferris H, & O'Flynn D., 2015). By contrast, formative assessment is a continuous process aimed at instructing the learning process by giving frequent feedback to students. Formative assessment is more suitable for dental education. In the case of the endodontics course, the assimilation of basic knowledge must be accompanied by the cultivation of preclinical skills and the latter is facilitated by frequent opportunities to practice skills, correct mistakes and form habits. The 4 step approach, incorporating evaluation of progress, was designed to cater to the specific requirements of dental education. Students' learning was multi-channel and evaluation multi-angle to stimulate an awareness of the individual's strengths and

weaknesses and to promote practical skills and problem-solving. The course enabled students to think within a clinical context and facilitated dentist-patient interactions.

Contemporary students are more willing to question and challenge grades and intelligent teaching equipment may address this need by making assessment reliable and objective. The "virtual simulation + model evaluation" system (Su XL, Zhou HJ, ... Liu L., 2022) allows students to receive an objective evaluation from their first introduction to cavity preparation through to the comprehensive assessment of the entire course. The combination of intelligent equipment with teacher-led scoring avoids the influence of personal habits, clinical experience and other factors on feedback. Doctor-patient communication was a novel addition to the assessment using the SIMROID robot patient. Such teaching equips students for interpreting patients' problems and may help to avoid doctor-patient disputes caused by poor communication in clinical practice (Shi Q, Du XJ, ... Xu JY., 2022).

Virtual evaluation systems have been recently introduced into Chinese dental schools, facilitating self-assessment and eliminating subjective influences. This system is especially valuable for dental schools such as that of Shenzhen University which is newly formed and lacks the full complement of faculty members. The assistance of the virtual evaluation system frees up the time of staff members to focus on those students most in need of guidance (Renne WG, ... McGill ST., 2013). The evaluation system also allows the extensive practice required by students in caries skills for competition in "The Guanghua Cup" and "The South China Cup". The approach does not replace the gold standard of cavity preparation but is a valuable addition to the international teaching process (Zhou Y, Zhang SH, & Zhao Shenzhen., 2021). The benefits of a comprehensive and unbiased assessment include increased enthusiasm of students for learning, reduced staff scoring burden and improved student skills in operation and competition.

The 4 step approach to teaching and assessment is at an exploratory stage and requires further refinement to fully meet the teacher and student needs (Ruan M, Liu JN, ... Ji T., 2021). Some students voiced their disapproval of the relatively high-frequency assessment, which they felt disrupted their learning and increased their burden. In addition, some teachers require more time to adjust and equipment costs are high due to the involvement of intelligent devices on a larger scale. Staff training and allowance of time for student adaptation are expected to address these issues.

Long-term feedback from internship supervisors is required for continuous improvement to allow the 4 step teaching method to be more widely used in endodontics and other dental preclinical curricula.

5. Conclusions

The 4 step teaching and evaluation approach significantly improved student performance in the experimental component of the endodontics course. The approach is suitable for degree courses with substantial practical content leading to professional competency, such as dentistry. The use of simulated surgical teaching using virtual reality and robot patients is expected to be more widely adopted.

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