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Title: The Effectiveness of a 3D Virtual Tooth Identification Test as an Assessment Tool for a Dental Anatomy Course

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Data Availability Statement:

Data can be made available by direct request to the corresponding author.

Author Contribution Statement:

ES, EK, VR, HKB contributed to the research design, data analysis, manuscript preparation and manuscript review.

Funding Information:

This project was funded in part by Facebook Technologies; Facebook Reality Labs Policy Programs Team.

Conflict of Interest and Ethics Statement:

The authors declare no completing interests.

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Article type : Original Article

TITLE

The Effectiveness of a 3D Virtual Tooth Identification Test as an Assessment Tool for a Dental Anatomy Course

ABSTRACT

Objectives: The aim of this study was to investigate the effectiveness, efficiency and user satisfaction of a 3D tooth identification test for a dental anatomy course that can be given remotely.

Methods: First-year dental students (n=41) enrolled in a dental anatomy course took both traditional in-person practical and virtual 3D tooth identification tests consisting of 25 test items. The test scores, average test durations, faculty time commitment and user perception were collected and analyzed. Pearson product-moment correlation coefficients ($p<0.05$) were determined for the criterion measures including real tooth identification test scores, comprehensive written examination and overall grade for the course.

Results: The average number of correct answers for the real and 3D virtual tooth identification examination was 21.3 ± 2.65 and 20.7 ± 2.56, respectively. The average test duration for the real and 3D virtual tooth identification test was 25:00 and 21:16 minutes, respectively. There was a positive correlation ($p<0.05$) of the 3D virtual tooth identification test with the real tooth identification test (0.368), comprehensive written examination (0.334) and the overall course grade (0.646). The total faculty time commitment for the real and 3D virtual tooth identification test was 96 and 65 minutes, respectively. The students cited difficulty in manipulating the 3D models.

Conclusion: This study presents evidence that the 3D virtual tooth identification test can be used to assess dental students understanding of dental anatomy effectively and efficiently.

KEYWORDS: Educational Technology, Assessment, Distance Education, Dental Anatomy, Virtual Dental Library

INTRODUCTION

Educators are increasingly questioning how to maximize technology to improve clinical care, education, and research and to effectively integrate these technologies into the dental curriculum.[1,2] Additionally, the 2020 COVID-19 pandemic has had a global impact on social change, highlighting the importance of technology and distance learning for both the educator and student in a time of limited human interactions and social distancing parameters.[3,4,5,6,7] With the progression of distance education incorporated in academic courses, the ongoing global pandemic has placed distance learning in a context that values it more than ever.[5,6,7,8,9]

Distance education primarily occurs across the internet, involving technology-mediated engagement and communication in physical separation of instructors and students.[10,11,12] Much of literature related to online education focus on course design, comparison of online and in-person pedagogical practice, issues of quality and equivalence to traditional education, incentives or disincentives that exist for faculty members, among others.[13] The common goal of existing research is mainly to improve the credit and efficacy of online education modalities or promote faculty utilization of it.[14]

E-learning, a prominent modality to carry out distance learning, is widely implemented in health professional education, across various specialties, educational settings, and training levels.[15] However, reports regarding its usage and effectiveness have ranged broadly.[16] Additionally, assessment of student work and traditional examinations that require physical models or specimens in laboratory settings are a challenge for distance learning.

As a foundational course in the dental curricula, dental anatomy introduces students to the anatomical and morphological characteristics of the human dentition.[17] Student assessment of proficiency in tooth morphology includes the student's ability to identify morphology or identify the tooth number using physical specimens.[17,18,19] Educators are utilizing technological

innovation to teach dental anatomy and shift the course to one that supports distance learning and include technology to facilitate dental education.[20]

Recently, researchers developed a Virtual Dental Library (VDL) of the human dentition for use in a dental anatomy course using 3 dimensional models (VDL-3D) and virtual reality (VDL-VR).[21,22] VDL-3D can be accessed through computers and mobile devices while VDL-VR can be accessed with virtual reality (VR) head mounted devices and VR software (Arthea.io, Ann Arbor, MI).[21] For VDL-3D, students can spatially view extracted human and ideal resin teeth, prepared resin teeth for operative and prosthodontic restorations, impressions of teeth, and provisional restorations via software accessed on Sketchfab.com (Sketchfab Inc., New York, NY): a commercial platform for publishing immersive and interactive 3D content on the web.[23] Users of VDL-3D are able to customize and visualize their own 3D work on various types of hardware and share the model for showcase, collaboration, and further discussion.[24] Students and faculty members can upload content to expand and customize the library, share with peers, and use the 3D models for virtual assessment tools for a course.[21,25,26]

To address the need for remote assessment of students' knowledge in dental anatomy, a 3D virtual tooth identification test was developed by embedding 3D tooth models from the VDL-3D into an online examination on Canvas (Instructure, Inc., Salt Lake City, UT), an internet-based Learning Management System (LMS) that aids teaching, learning, and student-teacher collaboration.[27] With computer access, students are able to view the 3D models on the display, navigate the mouse to manipulate the models, and type their answers in the provided text box (Figure 1).

When changing the format of an exam (e.g., written test vs. computer-based or virtual test), educators should assess context effects, the validity of the testing method and usability of the new format.[29,30,31] Scores from the modified test should correlate superiorly to the original testing method using the same criterion to support a change in test format.[25,28,31] Additionally, a virtually modified test format should limit test mode effects that lower student scores and offer students a greater capacity to carry out assessment tasks effectively, efficiently, and satisfactorily than the original method.[32,33] While the definition of usability varies across research fields, usability is generally defined as the effectiveness, efficiency and user experience of an educational or assessment tool.[34] Studies demonstrate that optimizing usability and reducing complexity of an e-learning system encourages the adoption of it.[15,35,36] Yet, little has been done

to evaluate the usability of a virtual assessment tool, one that supports distance learning and the specific academic course objectives.

Given the recent increase in demand for distance learning and virtual assessment tools, validated methods that can leverage technology, be remotely accessed, and potentially replace physical testing facilities are needed in the dental curricula. The aims of this study were to investigate the usability in terms of effectiveness, efficiency and user satisfaction of a 3D virtual tooth identification test for a dental anatomy course.

METHODS

The Health Sciences and Behavioral Sciences Institutional Review Board (IRB) at the University of Michgan determined that this research was exempt from IRB oversight (#HUM00157477).

Participants: First-year dental students who were enrolled in a dental anatomy course were recruited for this study. Of the 109 students enrolled in the course, 41 students consented to use their test scores and grades for this study.

Description of the VDL-3D Implementation: All students enrolled in the dental anatomy course were given access to the Virtual Dental Library-3D (VDL-3D) via Sketchfab.com to view and study dental morphology. They were also provided with physical models of ideal resin teeth and extracted human teeth examples.

The 3D virtual tooth identification test was developed by embedding virtual models of 25 extracted human teeth from the VDL-3D into an online examination on the LMS, Canvas (Instructure, Inc., Salt Lake City, UT). The students did not have access to the test items prior to the exam. The 3D virtual tooth identification test was administered two weeks after the traditional real tooth identification exam which consisted of the 25 test items. For the real tooth identification examination, the students were given 1 minute to rotate through each of the 25 stations with the test items and complete a written test form where the tooth number was recorded. The written test forms were collected and scored. Two weeks afterwards, the 3D virtual tooth identification test was administered; students were asked to log into their desktop computers, open an online assessment management system, LockDown Browser (Respondus Inc., Redmond, WA), and access the 3D virtual tooth identification test on Canvas. Students were able to view the 3D models one at a time at their own pace, use the mouse to manipulate

the models, and type their answers in the provided text box. To limit unwarranted collaboration, the order of the test questions were randomly shuffled for each student. Students were given up to 25 minutes to complete and submit the test electronically. The faculty time commitment, including the set-up, break down and grading of both the real and virtual tooth identification tests, was collected. The average test duration for the real and virtual tooth identification examinations were also recorded. Additionally, the number of views for each model in the VDL-3D was recorded during a 4-week duration.

Data Analysis: All 109 students enrolled in the dental anatomy course were given the opportunity to complete an anonymous survey (Qualtrics, Seattle, WA, USA) on their preferences and perceptions of the virtual testing method. On the survey, students were asked if they strongly agreed, agreed, were neutral, disagreed, or strongly disagreed with statements on their perceptions of their performance on the virtual test and their preference for either the real or the virtual test. They also were asked on their perceptions of the accuracy of the virtual test to assess their knowledge in dental anatomy and the ability to identify teeth using virtual models. Students were asked whether they liked or disliked using the VDL. Another survey question asked students to rank four different response choices to complete the statement, "I prefer to use _____ to view the 3D models in the virtual dental library." The response choices included mobile device, Oculus Go VR headset, computer, and no preference. An open-ended question followed each of the survey questions for any comments and suggestions for the students to elaborate on their responses.

Descriptive statistics were used to compare the average test scores and standard deviation of the real and 3D virtual tooth identification tests. Pearson product-moment correlation coefficients ($p<0.05$) were computed for the 3D virtual tooth identification test, a real tooth identification test consisting of 25 questions, a 2nd tooth identification test consisting of 50 questions, a comprehensive written examination and the final grade that the student received for the course.

RESULTS

The average number of correct responses for the real and 3D virtual tooth identification examination was 21.3 ± 2.65 and 20.7 ± 2.56, respectively. The average test duration for the real and 3D virtual tooth identification test was 25:00 and 21:16 minutes, respectively. There was a positive correlation ($p<0.05$) of the 3D virtual tooth identification test with the real tooth

identification test (0.368), comprehensive final written examination (0.334) and the overall grade (0.646) the student earned for the dental anatomy course (Table 1). The real tooth identification exam significantly correlated positively with another tooth identification exam consisting of 50 items while the virtual tooth identification exam did not. The real tooth identification examination scores did not correlate significantly with the comprehensive written examination.

When faculty time commitment was evaluated for conducting the assessment for the real and the 3D virtual tooth identification examinations, the set-up of the real tooth examination was 33 minutes while the 3D virtual tooth identification test was 62 minutes. However, there was an additional 65 minutes required for the real tooth identification test for breakdown of the test stations (15 minutes), grading the written test forms (41 minutes) and organization of the test forms (9 minutes), making the overall faculty time commitment for conducting the real and 3D virtual tooth identification tests to 98 and 65 minutes, respectively. When usage of the VDL-3D is evaluated, there were a total of 5,175 views of the contents in the Virtual Dental Library over a 4-week period during the time of the dental anatomy course (Table 2).

The response rates for each survey question ranged from 75-83% (Table 3). The majority of the students either strongly agreed (46%) or agreed (20%) that they felt they performed better on the tooth identification exam using real teeth as compared to the virtual teeth. Students strongly disagreed (52%) or disagreed (22%) with the statement “I prefer the virtual tooth ID test over the real tooth ID test”. They also strongly disagreed (25%) or disagreed (22%) that using virtual teeth accurately tested their knowledge in dental anatomy. Students strongly disagreed (21%) or disagreed (29%) that the virtual teeth accurately tests their ability to identify the teeth. Overall, the students preferred using computers to view the 3D models in the VDL over other devices such as mobile phones or VR headsets. When the students were asked to comment on what they liked about the VDL, they cited convenience, access to many examples, enhanced visualization and cool technology. When they were asked about what they disliked about the VDL, student were mostly concerned regarding the inability to manipulate, rotate and orient the teeth easily.

DISCUSSION

Technology has been used in dental education to support preclinical and clinical teaching, share educational content and methods and build a learner-centered information infrastructure.[20]

When choosing the type of technology to incorporate into a curriculum, decisions should be driven by educational goals and evidence-based integration of the technology.[37] With the recent increase of distance education incorporated in academic courses due to the ongoing global pandemic, more research is needed that validates virtual tools that assess student learning and encourages adoption of the tool. This study evaluated the effectiveness, efficiency and user satisfaction of a 3D virtual tooth identification test for a dental anatomy course.

The tooth identification test is traditionally used in the dental curricula as an assessment tool that evaluates a student's cognitive skills in dental morphology.[26] Instructors utilize extracted human teeth to administer the tooth identification test in a large room so students can rotate through the stations and identify the tooth number or anatomical structure. Over the years, examiners rely on this method of testing despite limitations including inefficiency in faculty set-up, inconsistent morphologies across human teeth with an additional decrease in availability, and an unfair sentiment from students regarding the staged testing structure.[25,26,28] Concerns arise when teeth are accidentally dropped and broken or tooth markings are altered, wherein the test must be paused and alternate test items are used.

Effectiveness of an assessment tool such as a tooth identification test is measured by comparing user performance of a measure (i.e., speed, errors, number of steps taken, whether the task was completed within a time limit, etc.) to a predefined level.[38] In testing different technologies for efficiency, researchers oftentimes collect data on task completion times and task completion accuracy to assess which software demonstrates greater efficiency by the users.[39] The study results show that the students were as effective in identifying the teeth using both the virtual and physical specimens as demonstrated by the comparable average test scores. There also was significant positive correlation of the virtual 3D tooth identification test to other criterion measures used in the course such as the real tooth identification test, comprehensive written examination and the overall grade that the student earned for the course suggesting that the 3D virtual tooth identification test was a valid assessment. Moreover, the study results demonstrate that the 3D virtual tooth identification exam was more efficient than the real tooth identification exam using physical specimens when evaluating faculty time commitment to conduct and grade the exam and the shorter time it took for the students to complete the exam. The need for a large facility to conduct the examination using real teeth was also eliminated.

There has been other technology-based assessment tools have been developed to test students' cognitive skills in dentistry.[40] Similar to this study, Kim-Berman et al. found that there was a significant positive correlation among tooth identification test scores using physical examples of extracted teeth, a virtual test using augmented reality, comprehensive written examination and overall performance of students in a dental anatomy course.[25] However, the authors noted limitations to physical manipulation and visualization, suggesting further development of the augmented reality application and improvements in user experience.[25] For this study, although the students performed as well on the virtual test compared to the real practical exam, the students preferred the practical examination using real teeth and felt that the virtual test did not accurately test their ability to identify teeth nor evaluate their knowledge in dental anatomy. The students cited difficulty in manipulating the 3D models in the virtual examination indicating a possible need for further improvement in the user interface of the 3D virtual tooth identification test. It also appears that the students used the VDL as a resource to study dental anatomy during the course duration. One student comment illustrates the overall response to user satisfaction toward the virtual tooth identification exam and the VDL; "I don't think that there should be a virtual tooth ID exam in the future. The exam seems irrelevant to what we have to work on as dentists, which are real teeth that exist within the patient's oral cavity. I do believe, however, that it is an asset to have a virtual teeth library so that it can build on our knowledge of tooth morphology and anatomy." This exemplar statement and over 5,000 views of the virtual 3D models in the VDL during the 4-week period of the course indicate that the students may be willing to adopt and use the Virtual Dental Library as part of their dental education. Additionally, as digital technology and digital planning of clinical cases are emphasized and increased in the dental curricula as well as improvements in the manipulation features of the program, first year dental student attitudes on incorporating 3D models as part of assessments and relevancy to dentistry may change.

One of the limitations of this study is in recruitment of students to participate. Although the students were assured that all student data would be de-identified, there were some hesitation for students to consent to use their grades for study purposes. Methods of increasing recruitment of study participants should be considered in future studies.

CONCLUSION

Compared to the traditional method of using real teeth for a practical examination, the virtual 3D tooth identification test demonstrated similar effectiveness and greater efficiency to assess students' knowledge in dental anatomy. However, students preferred the traditional testing method, many citing difficulties in manipulating the 3D models. Despite the lack of positive user satisfaction, this study presents evidence that the Virtual Dental Library-3D is a viable educational tool in a dental anatomy course and that the 3D virtual tooth identification test may be utilized to assess dental students remotely.

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Table 1: Results of Pearson product-moment correlation coefficients for the real tooth identification test, 3 dimensional (3D) virtual tooth identification test, 2nd real tooth identification tests, final written examination consisting of 40 Multiple Choice Question (MCQ), and student's overall grade for the dental anatomy course.

Correlations (n=41)	**Real tooth ID test (25 models)**	**3D virtual tooth ID test (25 models)**	**2nd real tooth ID test (50 models)**	**Final Written Exam (40 MCQ)**	**Overall Grade**
Real tooth ID test (25 items)	1	0.368*	0.318*	0.079	0.662**
3D virtual tooth ID test (25 items)	0.368*	1	0.224	0.334*	0.646**
2nd real tooth ID test (50 items)	0.318*	0.224	1	0.182	0.562**
Final Written Exam (40 MCQ's)	0.079	0.334*	0.182	1	0.671**
Overall Grade	0.662**	0.646**	0.562**	0.671**	1

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

Table 2: The number of total views of 3 dimensional models by tooth type from Virtual Dental Library (VDL-3D) during a 4 week period.

Models	Number of Views
Molars (8 models)	1,704
Premolars (8 models)	1,341
Incisors (8 models)	1,261
Canines (4 models)	712
Dental arches (2 models)	157
Total	5,175

Table 3: Responses to survey questions (n=109) regarding user perception of the 3D virtual tooth identification test and illustrative comments.

	Survey Question	Question response rate	Response*	Example Statements
Q1	"I think I did better on the tooth ID exam using real teeth as compared to virtual teeth."	83%	SA: 46% A: 20% N: 17% D: 13% SD: 4%	"Though I performed very well on the real tooth ID I feel that I did not do as well on the virtual one since I was unable to rotate the teeth the way I wanted to and I was unable to get an idea of the true size of the tooth on the virtual platform."
				"I felt that the VR teeth were better representatives of normal tooth anatomy than the real teeth. However, it was difficult to manipulate the virtual teeth so time became an issue."
Q2	"I prefer to use _____ to view the 3D models in the virtual dental library." Please rank the following response choices (most preferred at top as 1)	75%	1: Computer 2: Mobile 3: VR 4: No Pref.	"I thought it was easiest to turn the teeth on a mobile device using a touch screen. Using a computer mouse, the teeth did not turn as smoothly for me. Using the Oculus Go (VR headset) made it the most difficult for me to turn the teeth, as I do not have experience using virtual reality and had some trouble getting used to the program."
				"Computer. This device is the most practical for what we might see in the real dental field."
Q3	"I prefer the virtual tooth ID test over the real tooth ID test."	83%	SA: 0% A: 6% N: 9% D: 33% SD: 52%	"A real tooth ID provides the ability to see a real tooth…One is able to touch the tooth, rotate as they desire, and can see certain structures more distinctly than using a virtual tooth."

				“I found using the virtual allowed me to see some landmarks better than the real, but I found it easier to orientate myself using real teeth.”
Q4	"Using virtual teeth accurately tests my dental anatomy knowledge on a test."	83%	SA: 3% A: 17% N: 32% D: 22% SD: 26%	“I do not see why we need to do a virtual tooth ID and a real tooth ID test. I will likely never use virtual teeth in practice.”
				“To understand a basic idea of visualizing teeth, virtual tests are good for that.”
Q5	"Using virtual teeth accurately tests my ability to identify teeth on a test."	82%	SA: 2% A: 26% N: 21% D: 29% SD: 21%	“Using virtual teeth for studying purposes is beneficial for convenience and since they are actual scanned teeth, you know the anatomy is correct. Again, however, the images during the test were hard to control orientation and did not move freely.”
				“Using virtual teeth did not accurately test my ability to identify teeth on a test. It was difficult to manipulate the virtual models, which made it challenging to identify the teeth.”
Q6	“Please describe what you LIKED about using the virtual dental library”	83%	n/a	“I loved that we could study the teeth anywhere at anytime without the hassle of trying to swap teeth with our classmates. Also, people who are not dentists, or affiliated with dentistry sometimes find it gross that you are studying from real teeth and touching them. So having the virtual bank of teeth was awesome, I was able to see many examples of each tooth and that is

				key in seeing the typical features."
Q7	"Please describe what you DISLIKED about using the virtual dental library"	83%	n/a	"It was hard to manipulate and turn the teeth to be able to view all surfaces."

*SA=Strongly Agree; A=Agree, N=Neutral, D=Disagree, SD=Strongly Disagree

Figure 1: Sample test question using 3D virtual tooth identification test on a web-based learning management system. User can manipulate the 3D model with a computer mouse and type the answer in the text box.