# The Use of Independent, Interactive Media for Education in Dental Morphology

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*Abstract:* Educational researchers have argued for the addition of new technologies to enhance or replace traditional dental education modalities to more effectively engage and appeal to the new generation of dental students. Two- and three-dimensional interactive media technology is now available for implementation into curricula to teach to a next-generation paradigm. The purpose of this study was to analyze the introduction of a unique, online, totally independent learning module for dental morphology instruction, completely replacing the traditional classroom teaching of the topic, and to determine the relationship between its use and parameters depicting success in learning dental morphology. In particular, the authors hypothesized that the novice, preclinical dental student can learn dental morphology independently and efficiently this way. One-third of a 2010–11 first-year class of dental students were given an independent, interactive media module for the instruction of dental morphology. The remaining members of the class experienced the traditional course with classroom lectures. At the end of the module, a written examination and survey were given to both groups. The major findings were that the independent, interactive media module was just as effective as the traditional classroom method for successful dissemination of foundational knowledge in dental morphology; the independent study group performed significantly better on the didactic examination; the online module positively engaged the students; and students preferred the interactive media module but did not regard it as a total replacement for the traditional course.

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Dental students today belong to a new generation. One of the most striking generational differences is that access to and use of technology are simply assumed by today's learners. Researchers in education have found that while earlier generations were introduced to information through print, this new generation takes a digital path.[1] Having grown up with computers, the Internet, online resources, and instantaneous access, this generation of learners has never known life without computers. They are often called the Net Generation, Generation Y, or Generation Me. These students deal with information differently than those in previous generations: they have hypertext minds, and they leap around.[2] They are more visually literate and able to move between the real and virtual instantaneously.[3] For this student generation, a linear thought process is much less common than the ability to piece information together from multiple sources.[1] Researchers who study this generation of students believe they are intuitive visual communicators, able to shift their attention rapidly from one task to another. They are able to respond quickly and expect rapid responses in return.[2] Researchers report these students have little desire to read long texts[4] and are more comfortable in image-rich environments than with text.[1] They have been described as computer-savvy individuals who spend more time playing video games than reading.[5] They have come to expect multimedia, experiential, and interactive learning systems.[6] These students expect interactivity as an important component of instruction, and technology makes it possible to provide them with anytime, anywhere content and interaction. Computer-based instruction has been found to increase the level of interactivity, which appeals to the new generation of students, over that of the traditional lecture.[2]

Computers and technology are increasingly being used in dental education. E-learning is the use of technologies to enhance knowledge and performance. E-learning technologies offer learners control over content, learning sequence, pace of learning, time, and often media, allowing them to tailor their experiences to meet their personal learning objectives.[7] It has become an interactive medium that can be delivered to meet the educational needs of students.

This has been referred to as electronic curriculum or e-curriculum. In dental education, researchers have found a high level of interest among dental educators in e-curriculum[8] and that virtually all North American dental schools have made substantial efforts to provide instructional technology resources to their faculties.[9] Progress has been made in evaluating the structure of current dental education curricula,[10] and educational research supports new methodology focusing on enhancing student learning. The incorporation of e-learning into the dental curriculum has been strongly encouraged by the American Dental Education Association (ADEA) with the specific recommendation "to use information technology to enrich student learning."[8] In 2005, Pyle et al. called for educators to become the change agents to advance and sustain curricular reform and innovation.[11] In a time of curriculum consolidation and change, there is an effort to increase utilization of computer-based and web-based information technology in dental curricula.[12]

When tools of e-learning in dental education were evaluated, a summative report of their benefits and implementation in dental education was issued, concluding that "technology can overcome many of the barriers to learning. Information technology will always remain exciting as it is always changing, and the users, whether dental students, educators, or patients, are like chameleons adapting to the ever-changing landscape."[13] Growing support for and adoption of e-learning in dental education have been reported.[14-19]

A study surveying dental students found they had high expectations for digital learning formats as additional educational resources.[20] Another, more recent study found that dental students viewed e-learning as a right rather than a privilege.[21] Many believe that the addition of innovative online courses into dental curricula will provide asynchronous material and actively engage students. Current examples of dental e-curricula include modules on dental terminology,[22] implantology,[23] oral manifestations of systemic illnesses,[24] geriatric dental care,[25] tobacco cessation,[26] diagnosis and treatment planning,[27,28] clinical simulations depicting many disciplines,[29-40] orthodontics,[41-46] anatomy,[47,48] dental morphology,[49-51] pharmacology,[52] radiology,[53,54] histology,[55] and distance education programs.[56,57] Tan et al.[53] described an e-learning course that totally replaced a face-to-face radiological sciences course and reported no compromise in learning outcomes. A recent study also found interactive e-learning through a dental video game was as good as a passive, noninteractive way of teaching and that the students preferred this method of instruction over conventional lectures.[58] These findings support the idea that students learn equally well by either method and, most times, prefer e-learning. Gadbury-Amyot and Brockman[52] reported a totally online pharmacology course that provided a positive learning experience with enhanced learning outcomes. Recently, Miller et al.[59] found that two online training modules on tobacco and oral health risks and alcohol screening resulted in meaningful improvement in dental students' knowledge of tobacco and alcohol use as well as alcohol screening methods. Additionally, it has been reported that online tests for self-study purposes have been recommended and shown to improve students' motivation.[60] Jackson et al.[61] reported that online self-tests may correlate with effective learning in predoctoral dental education.

The introduction of interactivity in dental education e-learning platforms has been gaining momentum for increasing student engagement and motivation. Recently, Salajan and Mount[62] described the process of developing innovative courses that have online interactive applications, such as the Oral Pathology Virtual Microscope and Virtual Cavity Preparations, to engage online learners. Students' desires for more interactive tools such as 3D graphics, audio, video lectures, and simulation were also reported in that study. Gwozdek et al.[63] presented a framework of strategies for development of online course design, based on models and best practices. Teaching in an online environment requires a specialized educational methodology, technology, and delivery.

At the University of Pennsylvania, an Interactive Media Initiative was initiated with a university-wide call from the Wharton School to study the impact of electronic, interactive media on education. Our study design resulted from this initiative. Our study drew upon the literature showing an increase in e-learning use in dental education, with equivalent or better learning outcomes and high acceptance from students. Our goal was to develop a unique, totally independent, interactive e-learning media module to positively engage dental students and teach foundational knowledge in dental morphology. The proposal was submitted to the Wharton Interactive Media Initiative in 2009, and the project received a Wharton Interactive Media Initiative grant to study the impact of electronic media and training methods on measures of performance at the individual level. The purposes of this study were to determine the rela-

tionship between use of a unique, totally independent, interactive two- and three-dimensional e-learning module and parameters depicting success in learning dental morphology and to measure student perception of the materials' value in the learning experience.

Dental morphology education at the University of Pennsylvania was revised five years ago. It is a two-part process and involves e-learning resources. Dental Morphology, Part 1 occurs early in the predoctoral education (D1, first semester). Preclinical students are introduced to a comprehensive foundational knowledge dental morphology module that is part of a larger preventive and restorative sciences course. In this module, knowledge is tested with a written examination. Dental Morphology, Part 2 occurs in the D1 second semester during the operative dentistry course. More complex aspects of the dentition and comparisons between teeth and arches are covered at this stage. Concurrent with the foundational knowledge presented, there are psychomotor skill components. Students participate in add-on waxing exercises of several teeth in the preclinical laboratory and have small-group discussion/review sessions with study models of the adult dentition. Knowledge is tested with a combination of a written examination, a waxing exercise practical examination, and a tooth identification practical examination.

At the same time, *The 3D Interactive Tooth Atlas,* Version 4 (eHuman, Portola Valley, CA) was added as a major curriculum resource to augment the traditional didactic information. Each student receives this DVD in the beginning of their D1 year as a recommended resource for Dental Morphology, Parts 1 and 2. It is also used in the operative dentistry, endodontics, pedodontics, and radiology courses. This tooth atlas is an interactive dental morphology/anatomy computer program. Students are meant to access the large database of information regarding tooth morphology, view interactive two- and three-dimensional models, take self-paced quizzes at any time, and obtain instant information. This e-learning component of the dental morphology module has been increasing in its popularity and use by the students each year. Currently, this resource is integrated into the curriculum of twenty-three dental schools in North America, fifty-five U.S. dental hygiene programs, and four dental schools abroad.[64] When this program was thoroughly reviewed, the reviewers concluded it "can be extremely valuable as a learning tool."[49] Since this revised method of dental anatomy education was introduced, it has been very successful in meeting the stated objectives, providing essential foundational knowledge related to tooth morphology in a meaningful way by which students are prepared for future applications in subsequent courses and for the National Board Dental Examination (NBDE) Part I.

In this study, we wanted to analyze the introduction of a unique, totally independent, interactive e-learning module meant to positively engage dental students and teach foundational knowledge during Dental Morphology, Part 1. The foundational knowledge would be delivered through the use of online, independent, interactive media only. This new module would totally replace the traditional classroom teaching of the topic. We hypothesized that 1) preclinical dental students can learn dental morphology independently and efficiently, utilizing the two and three-dimensional interactive media outside the traditional classroom and 2) an interactive e-learning package would positively engage the students.

## The e-Learning Module

The newest version of *The 3D Interactive Tooth Atlas,* Version 6.4 (PC- and Mac-compatible) was used for this study. It includes an easily accessible, password-protected, online version that is part of the purchase and registration of the DVD. Online access remedies any previous versions' possible hardware/software incompatibility issues by allowing full use of the program online.

Lecture videos were created with the use of Camtasia, Version 7 (TechSmith, Okemos, MI), a screen recording software program that produces high-quality video presentations and demonstrations in a multitude of formats. It is compatible with PC or Mac. Existing lectures in PowerPoint 2007 (Microsoft Corp., Redmond, WA) were converted into interactive lecture videos. Camtasia has been used by the principal investigator (PI) of the project over the years for several classes in which operative procedure videos were created. Once installed, Camtasia becomes an Add-In within PowerPoint for easy access and use. A simple USB-attached microphone allows clear narration. Pop-up callouts and highlights were easily embedded into the slides during the video editing process. In addition, interactive quizzes were incorporated at desired points during the video, so that students can independently test their knowledge. Importantly, if a student answers a quiz question incorrectly, the interactive quizzes were programmed to take the video back to the cor-

responding informational slide for review, rather than advance the lecture. The final lecture video products were easily downloaded to the school's learning management system course. Quiz results may also be programmed to be reported to the course director or not. For the purpose of this study, the quiz results were not reported to the PI, but the quizzes were intended to let the student gauge his or her own learning progress throughout the module. The lecture videos were created using the same materials presented for the traditional course lectures and the same lecturer, making the content consistent between the study group and control group. The length of the traditional course lectures and the length of the narrated lecture videos were designed to be the same.

The online course management system Blackboard Learning System, Version 9 (Blackboard Inc., Washington, DC) was the university's online course management system at the time of the study. Within Blackboard, a specific dental morphology independent study course was created. Access to the course was password-protected, and only the enrolled students in the study group were given the password. Collaboration and discussion boards were enabled to engage interaction between individuals within the group, as well as between participants and the PI at any time during the module. Lecture videos were downloaded into the course in a format that did not allow them to be copied.

Course materials including syllabus, course objectives, individual lecture outlines, learning objectives with referenced sections of the tooth atlas, and worksheets were made available to the study group through Blackboard. The Kilgore B-3 305 (Kilgore, Inc., Coldwater, MI) model of adult human dentition was given to each student.

# Methods

This was a prospective study conducted in 2010. The research proposal was approved by the University of Pennsylvania's Institutional Review Board. To test hypothesis 1, the 2010 D1 class (N=120 students) were involved their first semester during their Dental Morphology, Part 1 course, a module within a larger preventive and restorative dentistry parent course. After an informational recruitment session, informed consent was obtained from 118 volunteers who wished to participate in the study (98.3 percent of the D1 class). A blind, randomly selected group of 30 percent of the students was selected to participate (N=35). The study group was known as the +Independent, Interactive Digital Media group (+IIDM). The remaining 70 percent of students (N=85) signed an informed consent to become the control group, known as the -Independent, Interactive Digital Media group (-IIDM). The groups were balanced on the basis of gender and age distribution.

The -IIDM students experienced the current, traditional, lecture-based dental morphology course module. They were given the course syllabus handout and *The 3D Interactive Tooth Atlas* DVD as a primary resource to be used in conjunction with the lecture materials. Use of the tooth atlas was not mandated or monitored, but its use was very strongly recommended. The Kilgore B-3 305 study model of human dentition was another traditional resource provided and expected to be brought to the lectures. The -IIDM group attended the four traditional lectures (6.5 hours of lectures plus time for questions; eight hours total). Lecture topics included tooth development, terminology, nomenclature, anatomical landmarks, and distinguishing characteristics of each tooth. Each lecture topic had printed specific outlines and objectives given at the time of the lecture. This group was advised to take notes during the lectures. Students were given blank individual tooth summary table worksheets to be completed during the lecture during the note-taking process. The course syllabus, lecture outlines and objectives, and worksheets were identical to the study group's e-versions. Each lecture outline advised students to access specific sections of *The 3D Interactive Tooth Atlas* DVD on their computer or online to augment the lectures. The students were advised to access the tooth atlas for a suggested minimum of eight to ten hours during the module. Members of the -IIDM group were given online (Blackboard) access to PDF lecture handouts created with Adobe Acrobat 9 Pro (Adobe Systems Inc., San Jose, CA) before each lecture, as this was established course protocol. Finally, summary quizzes for each tooth, designed to test students' knowledge on key characteristics, were available to the students online (Blackboard) but were not mandated.

The +IIDM group was given the independent, interactive study materials for the Dental Morphology, Part 1 course module, as previously described. The material content was identical to that presented to the -IIDM group, differing only in the avenue of delivery. This group signed a document outlining copyright protocol of the lecture videos with specification not to share the materials with anyone outside of the group. The group did not attend any

traditional classroom lectures during the module, but were instructed to spend at least one to two hours on each online, narrated, interactive lecture video. There was a private, seminar room with Internet access and sufficient power for laptops reserved during the traditional lecture times as an option for interested students to view the lecture videos at the same time. This was offered as an option, if anyone wished to be in synchrony with the rest of the class. No faculty intervention was provided. Use of this time was not mandated, and students could access online lecture videos at any time. It was suggested that students take notes while viewing the lectures, fill out the individual tooth summary table worksheets, and take the interactive quizzes within each lecture. The students were also advised to access *The 3D Interactive Tooth Atlas* DVD on their computer or online and to complete selected sections corresponding to the lectures for a suggested total of eight to ten hours.

At the end of the module, a written examination testing relevant didactic knowledge was given to all the students. The examination was compiled of subtle variations on multiple-choice questions from several years of previous dental morphology sections of the NBDE Part I. These tests and questions were originally validated. No access to this course's previous tests was made available. The +IIDM group was given the date and time to meet to take the examination together with the -IIDM group. The examination consisted of twenty-seven multiple-choice questions with three more difficult questions designated as extra credit bonus points of equal value. There was a potential, if all the answers given were correct, to achieve a score of 111 with the extra credit points included. Each exam was identified only by student number and was graded by Scantron. The outcome of this examination was categorized as pass/fail and not numerically tabulated into the overall parent preventive and restorative sciences final course grade. This was to avoid any conflict between participation and nonparticipation in the study and final grade outcome for the parent course. Re-examination, when necessary, was given prior to study group subject identification and during the remaining time of the parent course. Data reports of the examination grades for both groups were tabulated, evaluated, and compared only after the course ended. To test hypothesis 1, the primary outcome measured was performance on the written examination.

To test hypothesis 2, two investigator-developed questionnaires were the primary data collection methods. At the conclusion of the written examination, the questionnaires (which were both attached to the examination) were completed by the +IIDM and -IIDM students. The students were instructed to anonymously fill out the questionnaire that pertained to them, separate it from the exam, and turn it in separately. The questionnaires were developed by the primary investigator, based on the hypotheses to be explored, and were reviewed by other faculty members to rule out ambiguity and for comments. The +IIDM questionnaire measuring student perceptions of this method of teaching and utilization of the technology sought answers to questions regarding amount of time spent online viewing lecture videos and interactive quizzes; amount of time the tooth atlas was utilized; and perceived value of the interactive media. The -IIDM questionnaire primarily sought answers regarding utilization of the tooth atlas program, online quizzes, and perceptions of the strongly recommended online resources. The surveys were completed anonymously, and Scantron answer forms were used to enable tabulation of data. Survey data were tabulated and evaluated for each group.

IBM SPSS, Version 19 (IBM, Armonk, NY) statistical software package for Windows was used to analyze the data. Summary frequency tables (mean, standard deviation, and variance) were generated to describe the examination outcomes. The Wilcoxon-Mann-Whitney test was applied to assess mean differences between the groups. A non-parametric 0.95 confidence interval was set, and a p-value of $\leq 0.05$ was considered significant.

# Results

Detailed results are shown in the figures and tables. The first set of analyses evaluated and compared the learning outcomes through the didactic examination results.

## Didactic Examination

Educational outcome results are presented in Figure 1 and Table 1. None of the +IIDM students failed the examination compared to 5 percent of the -IIDM students. Frequency and distribution characteristics are shown in Table 1. The grade distribution of the +IIDM group showed a mean of 95.4 versus a mean of 88.1 for the -IIDM group. A significant difference in the scores for +IIDM and -IIDM conditions was validated ($z=-2.838$, $p=0.005$). The second set of analyses evaluated and compared the responses to the questionnaires.

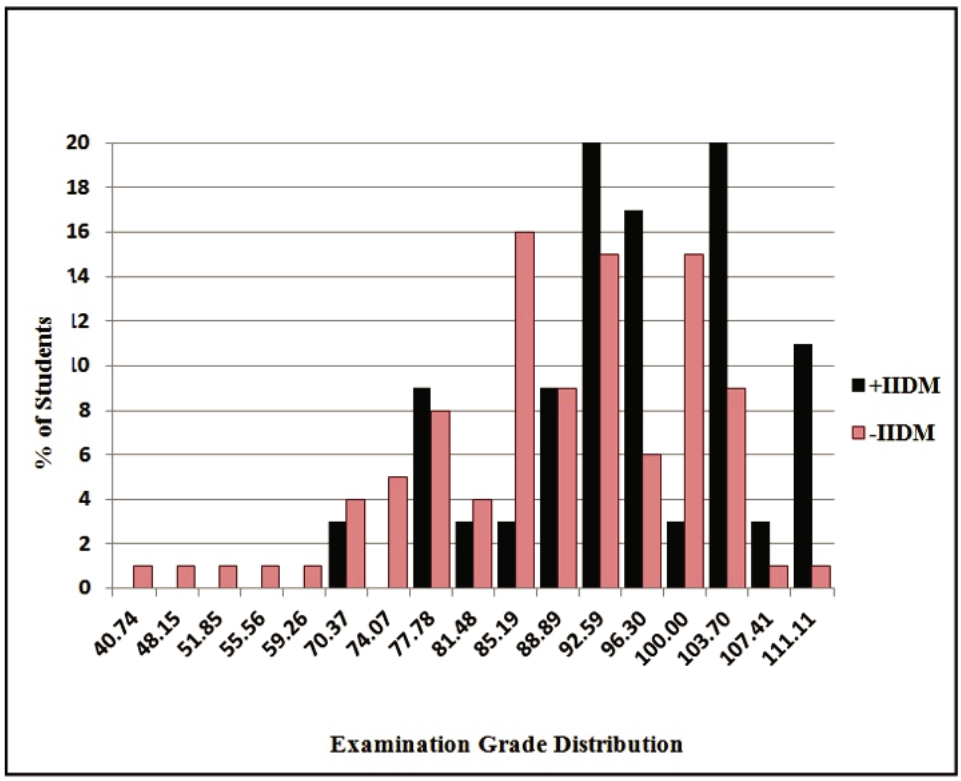


**Figure 1. Examination performance frequency distribution**

**Table 1. Examination descriptive characteristics and statistical comparisons**

| Group | N | Gender M/F | Max | Min | Mean | Standard Error of Mean | Failures (%) | SD | p-value |
|---|---|---|---|---|---|---|---|---|---|
| +IIDM | 35 | 54%/46% | 111.1 | 70.3 | 95.4 | 1.76 | 0 | 10.4 | 0.005* |
| -IIDM | 85 | 54%/46% | 111.1 | 40.7 | 88.1 | 1.45 | 5.8% | 13.4 | |

*Significant difference

## +IIDM Questionnaire

These results are shown in Table 2. One hundred percent of the group completed the post-study survey, and 100 percent of the group accessed the online materials, as expected, since that was their only avenue of foundational knowledge delivery. In addition, 100 percent viewed each lecture video for the one to hours hours mandated, if not more, and 100 percent reported using an increased playback speed of 1.5x to 2x the original speed of the lecture videos the majority of the viewing time. All (100 percent) reported they practiced the interactive quizzes embedded into the lecture videos. *The 3D Interactive Tooth Atlas* was accessed by 100 percent of the group, but 70 percent used this resource less than the suggested eight to ten hours. Despite this, 69.8 percent of the group strongly agreed or agreed that the tooth atlas was a helpful resource. Of the group, 80.1 percent strongly agreed or agreed that the independent, interactive media module was an effective way to learn the topic of dental morphology; 93.8 percent strongly agreed or agreed that the interactive media helped them learn the topic better; and 81.8 percent strongly agreed or agreed that the interactive quizzes within the video lecture helped them understand the presented materials better.

**Table 2. +IIDM survey results**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | True | False | | | |
| 1. | I accessed the online lecture videos. | 100% | 0 | | | |
| 2. | I utilized the 3D Interactive Tooth Atlas as a resource to learn the material. | 100% | 0 | | | |
| 3. | I utilized the interactive embedded online quizzes. | 100% | 0 | | | |
| | | 1-2 Hours | 2-4 Hours | 4-6 Hours | More Than 6 Hours | |
| 4. | How long did you view each narrated lecture video? | 42.5% | 45.5% | 9% | 3% | |
| | | Normal Speed | 1.5x Speed | 2x Speed | 4x Speed | |
| 5. | For the most part, at what playback speed did you view the narrated lecture videos? | 0 | 64.5% | 34.5% | 0 | |
| | | 8-10 Hours | 6-8 Hours | 4-6 Hours | Less Than 4 Hours | Night Before Exam or Less Than 2 Hours |
| 6. | In total, how long did you utilize the 3D Interactive Tooth Atlas? | 30% | 30% | 33.3% | 6.7% | 0 |
| | If you answered *Night before exam or less than 2 hours,* please comment as to why on the back of the scantron. | | | N/A | | |
| | | The Incisor Lecture | The Canine Lecture | The Premolar Lecture | The Molar Lecture | |
| 7. | If you answered *true* to question 3, please indicate which lecture(s) you used the online corresponding quizzes for. | 100% | 100% | 100% | 100% | |
| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 8. | I believe the 3D Interactive Tooth Atlas was a helpful resource. | 24.2% | 45.6% | 24.2% | 3% | 3% |
| 9. | I believe the interactive media module was an effective way to learn the topic of dental morphology. | 47.7% | 33.4% | 13.3% | 3.3% | 3.3% |
| 10. | I believe the interactive media helped me learn the topic of dental morphology better. | 66.6% | 27.2% | 3.6% | 3.6% | 0 |
| 11. | I believe the interactive quizzes within the video lecture helped me understand the presented materials better. | 51.5% | 30.3% | 15.2% | 3% | 0 |
| 12. | I would have preferred the traditional classroom-based lecture format instead to learn dental morphology. | 6.7% | 6.7% | 23.3% | 40% | 23.3% |
| | If you answered *agree* or *strongly agree* to question 12, please comment as to why on the back of the scantron. | | | | | |
| 13. | I think the independent, interactive media e-learning module should totally replace the traditional classroom-based format. | 30% | 26.7% | 13.3% | 23.3% | 6.7% |

When asked if they would have preferred the traditional classroom-based lectures instead, the majority (63.3 percent) strongly disagreed or disagreed with the statement. Of the remaining 36.7 percent, students who responded they would prefer the traditional classroom method were asked to state why they felt that way. Nineteen students (54 percent of the entire +IIDM group) responded to this question. All of the students who preferred the traditional classroom method (N=5) responded, as well as all of the students who chose neutral as their answer (N=8) and even some students (N=6) who favored the independent, interactive module. The most common answer given was that students preferred some direct, face-to-face interaction with faculty members (N=17). A small number of students (N=2) felt the independent module took too much of their time to complete. Finally, when the +IIDM group was asked if the independent, interactive module should completely replace the traditional classroom based format, 56.7 percent said it should.

## -IIDM Questionnaire

These results are shown in Table 3. All (100 percent) of the group completed the post-study questionnaire regarding online material utilization, and all (100 percent) accessed online materials in Blackboard to print lecture handouts or take practice quizzes. The majority of the group took each of the posted online quizzes, but quiz use decreased as the course progressed. *The 3D Interactive Tooth Atlas* was utilized by 67 percent of the group, while 33 percent did not install the DVD or access this resource online at all. None of the group accessed the program for the suggested eight to ten hours, and 20 percent accessed it the night before the exam or for less than two hours. If students answered they accessed the material the night before the examination or for less than two hours, they were prompted to comment why. One hundred percent of the applicable respondents (N=39) answered this question, reporting three different reasons: time constraints (N=32), too much information in the tooth atlas (N=5), and computer

**Table 3. -IIDM survey results**

| | | | | | | |
|---|---|---|---|---|---|---|
| | | True | False | | | |
| 1. | I accessed the online materials (to print lecture handouts or take the practice quizzes). | 100% | 0 | | | |
| 2. | I utilized the 3D Interactive Tooth Atlas as a resource to learn the material. | 67% | 33% | | | |
| | | 8-10 Hours | 6-8 Hours | 4-6 Hours | Less Than 4 H ours | Night Before Exam or Less Than 2 Hours |
| 3. | If you answered *true* to question 2, how long did you utilize the 3D Interactive Tooth Atlas? | 0 | 38.3% | 23% | 19.7% | 20% |
| | If you utilized the 3D Interactive Tooth Atlas the *Night before exam or less than 2 hours*, please comment as to why on the back of the scantron. | | | | | |
| | | True | False | | | |
| 4. | I utilized the interactive embedded online quizzes. | 76% | 24% | | | |
| | | The Incisor Lecture | The Canine Lecture | The Premolar Lecture | The Molar Lecture | |
| 5. | If you answered *true* to question 4, please indicate which lecture(s) you used the online corresponding quizzes for. | 83% | 78.6% | 77.2% | 62.2% | |
| | | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
| 6. | I believe the 3D Interactive Tooth Atlas was a helpful resource. | 22.4% | 41.2% | 21.2% | 8.2% | 7% |

or software issues (N=2). Finally, the majority of the -IIDM group (63.6 percent) thought *The 3D Interactive Tooth Atlas* was a valuable resource, despite the fact that one-third of them had not used it at all.

# Discussion

The use of e-learning, specifically interactive media is a departure from the traditional, linear lecture format. Traditional lectures are acknowledged to have low levels of interactivity. In a recent study of a modified curriculum using e-learning as a component for dental morphology instruction, Obrez et al.[65] concluded that when given appropriate structural supports, students are more capable of learning through independent study than previously acknowledged in traditional lecture courses. An effort was made in our study to design independent, interactive methods to engage the new learner dental student and promote greater learning satisfaction over the lecture-only format. This study's approach, to our knowledge, was the first attempt to implement an independent dental morphology e-learning module, totally out of the classroom, utilizing novel, interactive content resources in addition to *The Interactive 3D Tooth Atlas,* a frequently used dental morphology software program.

E-learning can present multiple ways for students to acquire, learn, and review information. A substantial number of studies from many areas of higher education regarding the use of e-learning have found that instructors can expect students' performance to be equivalent to what is typically achieved by classroom lectures,[66-69] with no compromise in the learning outcome.[53] Bogacki et al., in particular, found that e-learning strategies using computer-animated graphics to teach human dental morphology have been statistically equivalent to the lecture method.[70] Our study found that the +IIDM group performed better in the examination with a statistically significant increase in knowledge outcome, rather than an equivalent one. These results suggest that the independent, interactive e-learning module did have a positive effect on learning outcomes and support the finding from another study.[52] One possible explanation may be that the embedded self-study, interactive quizzes within the lecture video helped students understand the material better—a finding from a previous study.[61] Our findings agree.

Previous studies regarding learning outcomes of e-learning have produced persistent findings of at least equivalent outcomes when compared to traditional lecture methods. Our study not only tested learning outcomes, but also explored the students'

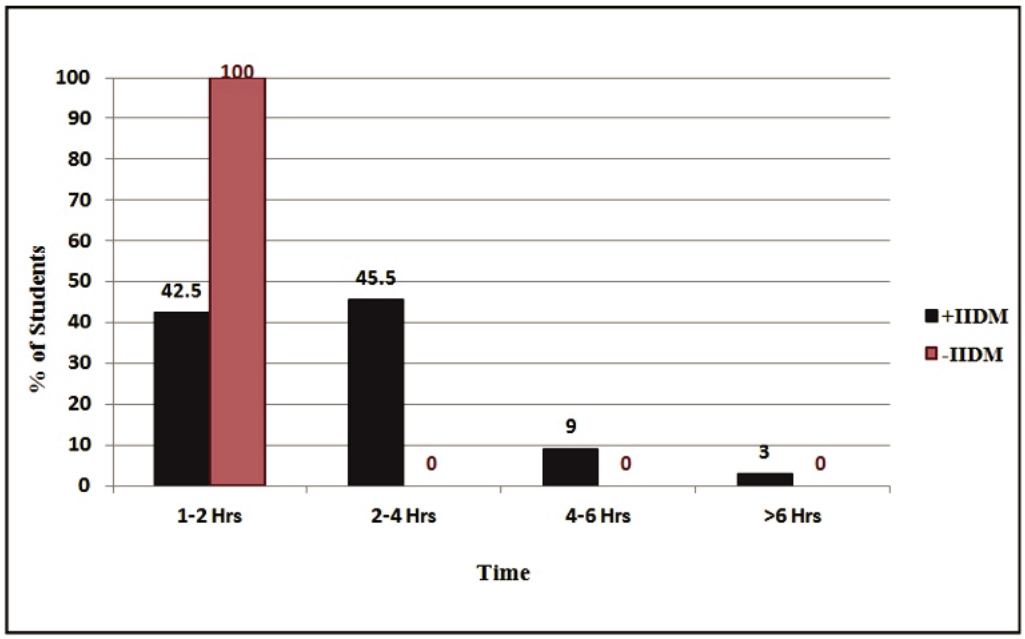


**Figure 2. Reported time spent in each lecture segment**

perception of value for the new e-learning module, as well as the students' use of each specific e-learning component. We found that 100 percent of the +IIDM group accessed the e-learning components as expected, since this was their only avenue of information delivery and the incentive was high. None of the group spent less than the suggested minimum time for viewing each lecture and taking the interactive quizzes. Interestingly, 57.5 percent of the group reported they spent more time (between two and six hours) viewing each lecture video than the suggested amount. All traditional classroom lectures were approximately one to one and one-half hours and no more. The lecture videos were timed to match the corresponding traditional lecture; then, twelve additional quiz questions were interspersed within each video lecture. The majority of the +IIDM group spent more time per lecture video than the maximum time per lecture for the -IIDM group (Figure 2). We speculate that the +IIDM students spent the extra time engaging in the interactive quizzes and reviewing information throughout the lecture videos. This speculation may be supported by the fact that all of the +IIDM group reported they viewed the lecture videos at increased speeds of between 1.5x and 2x, yet they still spent more time within each lecture video than its actual timed video length. Allen and Katz also found this "speed listening" pattern in a study comparing use of podcasts versus lecture transcript as learning aids for dental students.[71]

Neuhaus et al.[72] concluded that nonobligatory online tests for self-study may help to improve student motivation. In our study, it did not seem to matter whether the quizzes were obligatory (+IIDM) or not (-IIDM) since student motivation to use the quizzes was found for both groups. The quiz questions for the +IIDM were obligatory since they were embedded in the lecture. Still, 84.8 percent of the group found them helpful in learning the material better, and this group spent more time on the quizzes. The -IIDM group had the same quiz questions available to them on Blackboard, and 76 percent were motivated to use them and found them useful (Table 3 and Figure 3).

Besides increased student motivation and perceived usefulness related to the online quizzes, our findings also suggest that the impact of the quizzes may have been different between the groups. Although the questions were the same, the delivery of the quizzes was different, and the level of interactivity was greater for the +IIDM group. This may possibly explain why this group performed significantly better on the examination. The dissimilarity in the +IIDM quiz delivery and interactivity is explained by the different format in which these quizzes were

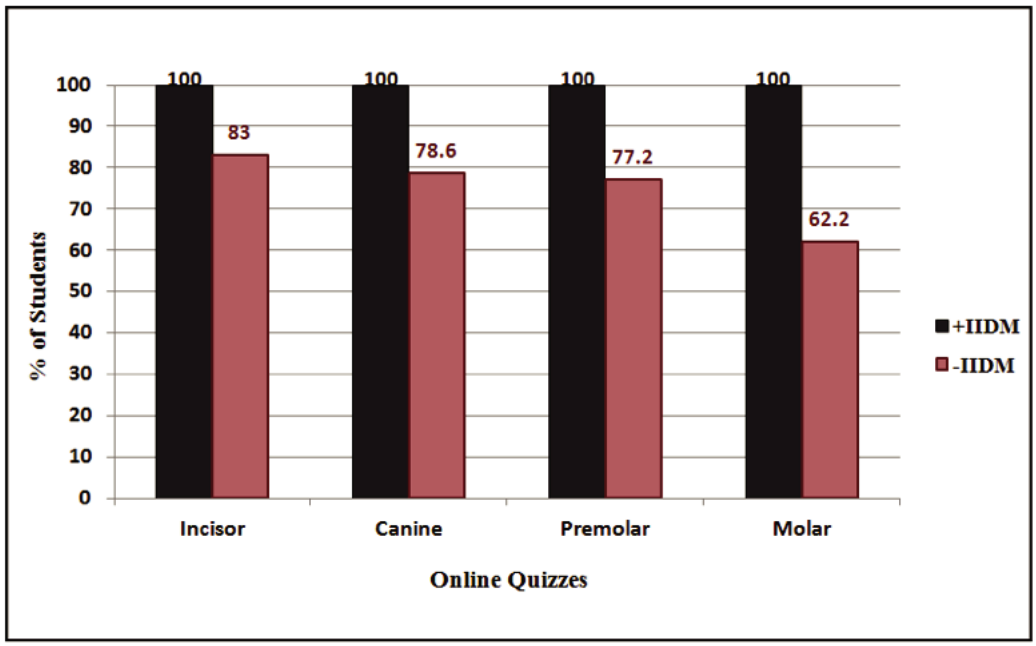


**Figure 3. Online quiz interaction**

created. During the lecture video editing and production phase with the Camtasia program, the +IIDM quizzes were designed to force the correct answer to each question in order to proceed through the video lecture. If a quiz question was answered incorrectly, rather than continuation of the lecture video, the user was forced back to the slide position in the video where the correct information was delivered. The mandated format for correct answers increased interactivity. This may be the reason more of the +IIDM group believed these interactive quizzes helped them understand the presented materials better. Since the quizzes formatted this way in the lecture videos made the +IIDM students validate knowledge acquisition, we could speculate that this is why so many felt the embedded quizzes were beneficial. It may also explain the increased learning outcome displayed by this group.

Comparison of *The 3D Interactive Tooth Atlas* usage is shown in Figure 4. All of the +IIDM students used this resource, as it was mandated. The majority used the resource more than six hours, but only a minority accessed the program for the suggested eight to ten hours. Like the +IIDM group, the majority of the -IIDM group accessed the tooth atlas, but for less time (six hours or less) than the +IIDM. None of the -IIDM group accessed the program for the suggested eight to ten hours. This underutilization is consistent with studies that report e-learning resources commonly were not used extensively by the students although they were made readily available.[51,73] Wright and Hendricson, in particular, found that use of *The 3D Interactive Tooth Atlas* increased only when incentives were introduced.[51] These authors speculated that preclinical dental students, not yet oriented to patient care, may not appreciate the relevance of this resource in planning or implementing patient treatment or that these students perceived the information provided to exceed what was needed to do well on examinations in the dental anatomy course. In our study, students who reported they underutilized this resource were questioned for the reason. While these findings suggest that some students felt the resource contained more information than they needed, the majority of the responses were that the decreased utilization was related more to students' individual time management skills. This finding offers another possible reason for students' underutilization of e-learning resources.

The majority of both groups used *The 3D Interactive Tooth Atlas* less than the suggested amount of time, but they still believed it was a helpful resource (Table 4). The findings from the -IIDM group are interesting. The majority of this group believed this

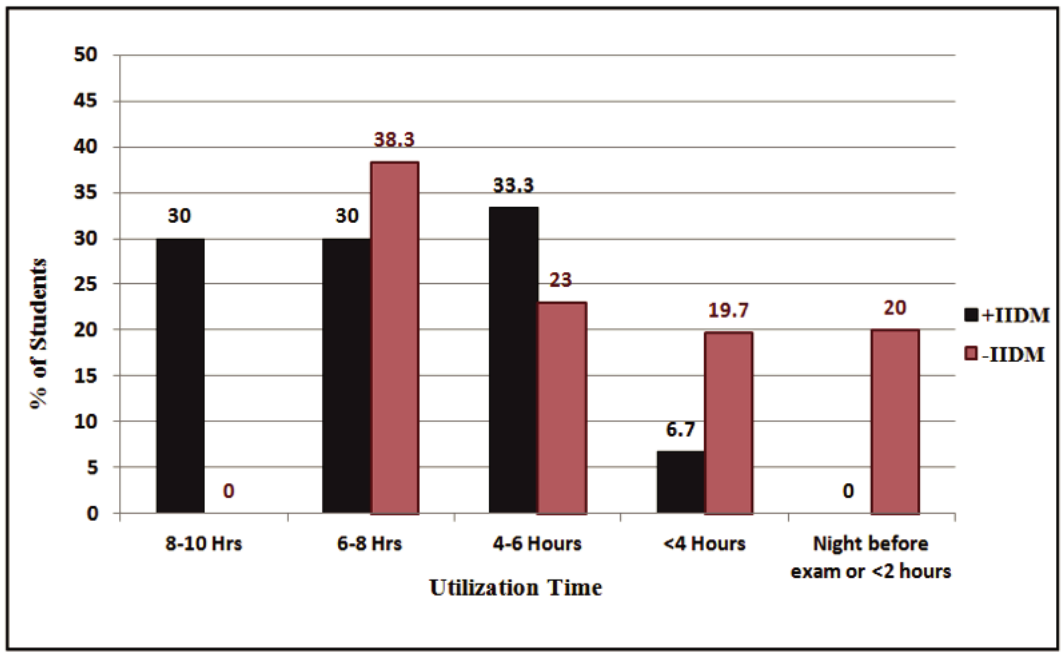


**Figure 4. Utilization of *The 3D Interactive Tooth Atlas***

**Table 4. Perceived value of *The 3D Interactive Tooth Atlas*: +IIDM vs. -IIDM**

| | Strongly Agree | | Agree | | Neutral | | Disagree | | Strongly Disagree | |
|---|---|---|---|---|---|---|---|---|---|---|
| | +IIDM | -IIDM | +IIDM | -IIDM | +IIDM | -IIDM | +IIDM | -IIDM | +IIDM | -IIDM |
| 1. I believe the 3D Interactive Tooth Atlas was a helpful resource. | 24.2% | 22.4% | 45.6% | 41.2% | 24.2% | 21.2% | 3.0% | 8.2% | 3.0% | 7.0% |

resource was valuable despite the fact they used the resource less than the +IIDM group, with one-third not accessing it at all. These findings suggest that even preclinical students value this resource. This result was similar to that in another study in which students placed a high value on an e-learning module using 3-D imaging to learn dental morphology.[74] It was also consistent with the finding in another study that current dental students value online interactive tools such as 3D graphics.[62] It is worth recalling that the most cited reason why the -IIDM respondents in our study had not used this resource related to time constraints. Our study may further suggest that perhaps the underutilization itself may be a reason why students report placing less value on this e-learning resource. It can be speculated that, if students were not able to access the program, they may be likely to answer they did not believe it was valuable.

The majority of the +IIDM students believed the independent, online delivery of information was an effective way for them to learn the topic of dental morphology and that it helped them learn it better. The responses showed a high rate of acceptance of the independent, interactive learning module components to teach dental morphology and a preference for this format over traditional classroom-based lectures. Although the majority of this group also believed this independent module should replace the traditional classroom-based course, almost one-third of the group did not. Interaction with faculty members face-to-face was still desired by these students. This finding is consistent with recent studies[21,50,52] concluding that new learners value technology as a learning resource, but they want to have technology augment the classroom experience and not totally replace it. The results suggest that the +IIDM students, although viewing the e-learning module as a beneficial tool for learning dental morphology, still want some sort of classroom interaction as well. Direct interaction with a faculty member at some level was still preferred. This combination is referred to as "blended learning," in which e-learning is combined with traditional classroom learning. Blended learning has been recently described as the latest approach in e-learning that may best meet the new learner's needs.[23,50,51,54]

A possible limitation of our study is that the study group +IIDM was small (N=35). The size was limited by the decision to make optional seminar room space available. Although the online course was designed as an asynchronous delivery method, it was felt that an optional seminar room was needed to provide online lecture video viewing at the same time as the traditional lecture time to accommodate students who have concerns regarding time management. Although the subject group was considered small, it is of equivalent size to or larger than most of the groups in comparable studies, and we deemed it sufficient. Another possible limitation of our study could be selection bias in spite of the blind, random selection process. It is possible that only early adopters of technology and those most comfortable with this learning style volunteered for the study. This could have influenced the experience and perceptions of the teaching modality. Although this is a possibility, it can be argued that given 98.3 percent of the class volunteered to participate (118 of 120 students), an accurate cross-section of the group would have been represented, thus negating the chance of selection bias.

An additional limitation of our study to consider is the possible crossover of information from the +IIDM group to the control group. This was prevented as much as possible by utilizing a password-protected site to view the materials, posting the lecture videos in a way that was not downloadable, adding a copyright clause in the beginning of each lecture video prohibiting reproduction or sharing material, and having the participants sign a contract not to share material with the control group. An additional possible limitation, found in any kind of social science research in which subjects are not blinded to their participation, is the heightened potential for the Hawthorne effect to influence the experimental

group's performance.[75] The Hawthorne effect suggests that subjects are liable to modify their behavior when they know they are part of an experiment. This potential bias is unavoidable, and investigators must take it into account when results are analyzed and discussed. Finally, experts have argued that evaluation studies that compare the performance of learners exposed to e-learning or with those using a traditional approach are problematic because exam performance is often a weak indicator of competence.[18] Careful consideration was given to the steps set forth and described by Schleyer et al.[18] during the design of this study, and the outcome measurement tool (written exam) was a compilation of multiple previously validated tests.

# Conclusions

The results of this study revealed that an independent, interactive e-learning module for dental morphology was successful in the delivery of foundational knowledge for the topic, with statistically significant enhanced performance on the didactic examination. The interactive content positively engaged new generation dental students. The interactive module was recognized as a valuable learning resource and was preferred over the classroom, but not necessarily seen as a total replacement for a traditional course. Thoughtful integration of e-learning into the curriculum is required and may be best if combined with some classroom activities or seminars to address the students' desire for faculty interaction. The interactive e-learning materials were better utilized when mandated and were underutilized when they were a recommended reference. When used, there was a tendency to value the resource more.

Based upon these findings, this independent, interactive e-learning module has become a permanent addition to the Dental Morphology, Part 1 course at this university, and other courses are now using video lectures with embedded, interactive quizzes. This study has relevance in that it may influence future pedagogical methods in dental education. New education philosophy embraces engaging the student and implementing independent learning. The learning outcomes of this interactive, independent learning module suggest that students can benefit from this method of foundational knowledge delivery. It further validates students' preference for blended learning methods to meet their education needs. More studies on the impact of interactive e-learning in dental education, as well as development of new e-learning strategies for the new learner, are necessary to continue to increase dental educators' knowledge and use of these media.


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