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Designing and evaluating an interactive dental educational module to teach freshman dental students

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DESIGNING AND EVALUATING AN INTERACTIVE DENTAL EDUCATIONAL MODULE TO TEACH FRESHMAN DENTAL STUDENTS

by

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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To my parents, for their motivation, constant support and love.
To my wife, who is always there for me.
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CHAPTER I
INTRODUCTION

Demand for qualified dentists has never been higher. Patients are spending more money on elective esthetic dental work, and more people are increasingly living longer, and retaining more of their natural teeth, thus requiring more dental care.

This high demand makes dentistry one of the highest paying professions in the country (1). In addition to the high pay, the perceived lower stress associated with dentistry, as compared to other health care professions, makes it a very desirable profession. This higher demand is reflected in the fact that more students are applying to dental schools, and more dental schools are being established. More dental faculty are required to teach these dentists-to-be, yet the total number of full and part time faculty and the average number of faculty per dental school have been declining for the last two decades (2).

The decline in the number of dental faculty has long been attributed to the higher pay in the private dental sector. The fact that most dental students will graduate with a considerable debt deriving from student loans makes the prospect of working as an underpaid dental educator even less attractive (2). Another challenge to dental education is the generation gap between educators and students; Forty-seven percent of faculty are fifty years of age or older and 19 percent are sixty-one years of age or older (3).

The dental students of today are a much different generation compared to those of years ago. Much has been said about this so called “Generation Y” of computer-savvy individuals, who communicate more through technology than in person. They have been raised on interactive media such as computer games and they have a difficult time taking directions or responding to authority (4).

It is important that in the new generation of computer savvy students, innovative teaching technology be developed to address their needs. Computer simulation modules may help provide the link to repetitive direct patient treatment procedures with immediate feedback that might not be available with more traditional teaching methods.

Although the effectiveness of computer-based learning has been investigated, many educators still resist the idea of using online strategies to replace their lectures. This may be due to tradition or lack of computer skills. In many cases online courses merely reproduce the textbook content on the computer screen, simply post the lectures' PowerPoint® presentations on the internet, or present video demonstrations. This is a clear under-utilization of available technology, which often leaves much to be desired.

Developing innovative and effective computer methodology to teach dental students is a challenge, yet this may be one of the solutions to our pending educational crisis.

Certain Operative Dentistry skill sets, such as bonding procedures, do not require a refined psychomotor skill level as much as a mastery of the concepts. Procedures such as these may lend themselves well to the interactive media style that today's students are so familiar with in a computer module "gaming" format.

Purpose of the Study

The purpose of this study is to answer this question: "Can a computer "game" be as effective as a clinical video in teaching enamel and dentin bonding?"

This study designed and tested a computerized interactive module simulating a dental bonding procedure using a three-component etch and rinse bonding system. The interactive module will monitor the specific placement and sequence of the different components of the systems, including: the timing of rinsing, the placement of the light curing tip and time of polymerization. The student is only advanced to the next step of the procedure if the current step is correctly completed.

This thesis will review different types of learning, from the traditional to the more innovative. It will give an overview of dental education, take a closer look at teacher and learner, and analyze the challenges dental educators face as they try to implement the more innovative strategies. The thesis will also describe and discuss development and testing of the Interactive Dental Educational Module (IDEM).

CHAPTER II
LITERATURE REVIEW

Introduction

Dental education

Although many studies have demonstrated that technologically advanced instructions can be as effective as traditional methods, the curriculum at most dental schools is still based on an outdated model of educational delivery (5). It has long been suggested that didactic presentations (i.e. passive learning) are the least effective teaching methods (6).

What is learned passively is typically not well retained and is commonly not effectively or enthusiastically applied (7). By contrast, active learning is self-reinforcing and more retentive because of the learner's active participation in the educational process (7).

Bloom (6) examined the results of published systematic reviews by searching multiple databases from January 1984 to October 2004, for English language, peer-reviewed meta-analysis and other systematic reviews of Continued Medical Education (CME) programs that alter physician's behavior and/or patient outcomes. Continuing medical education (CME) aims to help physicians keep abreast of advances in patient care. CME also attempts to make physicians accept new more beneficial care, and discontinue use of existing lower-benefit diagnostic and therapeutic interventions.

The goal of Bloom's review was to examine the effectiveness of current CME tools and techniques in changing physician clinical practices and improving patient health outcomes and establishing the spectrum from most to least effective continued medical education (CME) techniques by analyzing data obtained from randomized controlled trials (RCTs).Twenty-six reviews were either formal meta-analysis or other systematic reviews and thus met the inclusion criteria. Interactive techniques (audit/feedback, academic detailing/outreach, and reminders) were found to be the most effective at simultaneously changing physician care and patient outcomes. Clinical practice guidelines and opinion leaders were found to be less effective. Didactic presentations and distributing printed information were found to have little or no beneficial effect in changing physician practice. The authors concluded that even though the most effective CME techniques have been proven (i.e. the interactive techniques), the use of the least effective ones still predominate.

Not everyone agrees that active study methods are more beneficial than passive methods. A study by Ward et al concluded that "the activity or passivity of each study method was secondary to the way in which the students processed the learning." (8). The purpose of Ward's study was to identify the study methods and learning strategies that veterinary students use to study anatomy during their first year of professional school and their effect on students' academic achievements and long-term recall of information. The researchers used questionnaires, classroom observations, and personal interviews to gather data from the students. Multiple methods were used to collect data from the students to minimize bias. The data gathered from these multiple sources was qualitatively analyzed using the phenomenographic method developed at the University of Gothenburg. These qualitative methods described the student's approach to learning as either surface or deep. Deep processors integrate course material with other information they already know, making it personally meaningful. Surface processors are concerned with replicating the knowledge exactly as it had been presented.

Phenomenography which investigates the qualitatively different ways in which people think about something is particularly suited for educational research, because it was developed specifically to address learning approaches from the students' perspective, while assessing their understanding with an expert's sophistication (8). For quantitative measures, the researchers analyzed students' knowledge retention, by examining two sets of anatomy exams on the same topic one year apart.

Deep-processing students who commonly used multiple study methods succeeded more in the class and had better recall. Students who relied on a memorization-heavy surface approach to learning had limited recall and tended to perform poorly in the class. Ward's study (8) concluded that educators can improve long term recall of anatomical information by integrating multiple approaches to a topic and making the connection to prior experiences to make the information relevant and meaningful to students.

An article published in 2006 by the American Dental Education Association (ADEA) Commission on Change and Innovation in Dental Education in the Journal of Dental Education, raised serious questions regarding the current state of dental education. The commission stated that : "…While emerging science, technology, and disease patterns promise to change oral health care significantly the curriculum of most dental schools is still based on an outdated model of educational delivery." (5).

These issues, as raised by the ADEA Commission on Change and Innovation in Dental Education, have led some to question the basis of educational practice and learning in general. Others question the ability of the profession to sustain itself as a learned profession that contributes to the mission of research by creating new knowledge in the university setting. The same ADEA paper quoted Clayton M. Christensen, one of America's most influential business thinker and writer, who described dental education as convoluted, expensive, and often deeply dissatisfying to consumers (9). A more detailed explanation of this description is presented below.

Convoluted: The curricula of dental education have been characterized as overcrowded, complicated and unmanageable. Further, the system is saturated by a culture that supports memorization of factual knowledge over reasoning based on evidence and critical thinking skills (5).

Expensive: The cost of dental education leaves many students with significant debt that limits options upon graduation and thus may influence practice choices (10). This obstacle contributes to the declining ability of the profession to recruit recent graduates into academic careers (5).

Dissatisfying to consumers Passive learning environments fail to challenge students' ability to grow intellectually and to become critical thinkers and lifelong learners (5).

For meaningful curriculum change to occur in dental schools, faculty must go through a process of new skills development that will prepare them to teach differently and to assess students differently than they have before (11).

The need for increasing faculty's knowledge in the advancements of their field is not unique to dentistry. A number of studies of medical school faculty improvement programs found that they were effective at developing teaching skills, building collegial relationships, initiating curriculum changes, and contributing to overall academic advancement. Morahan's survey of U.S. medical schools found that no school had implemented a comprehensive faculty improvement system (12). Moreover, the development of faculty members needs to extend beyond teaching them how to better utilize emerging technology. If the emphasis is solely on technology, it is probable that the outcome will be the creation of an e-version of current curriculum courses with very little change or integration. Rather, faculty development must focus on all of the necessary skills needed to transform the curriculum into an active-learning environment.

To be truly successful, a faculty development plan should be implemented in three stages and should allow faculty sufficient time to assimilate new knowledge and develop new skills. These stages are as follows: 1) focus on changing the culture and understanding the need for change; 2) prepare faculty to teach in the new curriculum; and 3) prepare faculty to assess learning in the new curriculum (11).

Innovations in dental education

All the previously mentioned challenges are forcing dental educators to look for solutions for the current problems facing dental education. Many have turned to technology for answers. Reviewing the literature that evaluates innovative educational tools can be challenging because of inconsistency in reporting and the lack of a unified terminology. Many papers in the literature do not report all the attributes of their tested educational module. This makes it hard to categorize it as being a game or a simulation or something totally different from both.

A review of the literature by Sauve et al concluded that the lack of consensus on the terminology used with regards to games and simulations results in contradictory findings and inconclusive results with regard to learning outcomes (13).

Sauve et al tried to establish a distinction between educational games and simulations by defining specific attributes to each. The six attributes that Sauve's paper suggests to encapsulate the concept of educational games are: the presence of a player or players, a conflict, rules that describe the relationships existing between players and the game environment, having a predetermined goal of the game that defines the concept of winning, and its artificial nature (13).

In contrast, Sauve suggests five essential attributes of educational simulations. The simulation needs to have a model of reality that is defined as a system, a dynamic model that allows users to control the reality in order to study it, a simplified model that reproduces the essential characteristics; and a model that has fidelity, accuracy and validity. The fifth attribute relates directly to the learning objectives (13).

Multimedia

A study surveying 204 first and second-year students at Harvard Medical School concluded that "…although live attendance remains the predominant method of viewing lectures, students find video-recorded lectures equally or more valuable." (14)

This study by Cardall et al at Harvard Medical School (14) also noted that talking with a lecturer, asking questions, and hearing questions of classmates which are often cited as benefits of attending a live lecture were not important factors for the surveyed students in attending a live lecture.

The same study at Harvard Medical School (14)also assessed the use of a video-acceleration technology. Video acceleration software allows users to watch recorded lectures at their own speed. The playback speed of the video can be varied from a fraction of the normal speed to two and a half times the original rate, without distortion the pitch of the voice in the video. This feature was cited as very useful by the students in this study. The students thought that having control on the speed on playback saves time by going faster over sections they are familiar with and slower when viewing more difficult concepts.

Romanov et al (15) explored the role of video as a teaching tool, and found that 70% of students watch online educational videos. The study assessed the association between the use of multimedia materials, such as video clips, and collaborative communication tools with learning outcome among medical students.

One hundred and twenty-one third-year medical students attended a course in medical informatics consisting of lectures, small group sessions and eLearning material. The eLearning material contained six learning modules with integrated video clips and collaborative learning tools in WebCT, an online proprietary virtual learning environment system. The course exam measured the learning outcome, mainly testing the searching skills for medical information to support decision-making in clinical settings.

Results showed that approximately two-thirds of students (68.6%) viewed two or more videos. Female students were significantly more active video-watchers. No significant associations were found between video-watching and self-test scores or the time used in eLearning. Video-watchers were more active in WebCT; they loaded more pages and more actively participated in discussion forums. Video-watching was associated with a better course grade.

The study concluded that students who watched video clips were more active in using collaborative e-learning tools and achieved higher course grades (15).

It has been suggested that the more control the learners have on knowledge delivery format, the more they will use that format to study, and the better the educational outcome (16) (14).

A study by Schittek Janda et al. investigated the learning effectiveness of fragmented videos vs. the complete sequential video, in a randomized controlled trial. The study also analyzed the attitudes of the user towards video as a learning aid. Specifically, an instructional video on surgical hand wash was produced. The video was available in two different forms on two separate web pages: one as a sequential video and one fragmented into eight short clips. Twenty-eight dental students in the second semester were randomized into an experimental (n = 15) and a control group (n = 13). The experimental group used the fragmented form of the video and the control group watched the complete one. The use of the videos was logged and the students were videotaped while undertaking a test hand wash. Two independent clinicians analyzed the videos systematically and blindly. The students also completed a written test concerning the learning objectives from the videos as well as an attitude questionnaire.

Results showed the students in the experimental group watched the video significantly longer than the control group. There were no significant differences between the groups with regard to the ratings and scores when performing the hand wash. The experimental group had significantly better results in the written test compared with those of the control group. There was no significant difference between the groups with regard to attitudes towards the use of video for learning, as measured by the Visual Analogue Scales (VAS). Most students in both groups expressed satisfaction with the use of video for learning. The authors concluded that the students demonstrated positive attitudes and acceptable learning outcome from viewing CAL videos as a part of their pre-clinical training. Videos that are part of computer based learning settings would ideally be presented to the students both as a segmented and as a whole video to give the students the option to choose the form of video which suits the individual student's learning style.

Computer aided education

Howerton et al suggested that lectures are still the predominant means of delivering dental instructions (17). The same study found that these lectures are often complemented by handouts, notes, and assigned reading. Popular lecture aids include film or Power Point presentation, overhead transparencies, blackboards, chalkboards, and video presentations. These linear teaching formats make it difficult for students to review and navigate material freely without having to search for specific content. The purpose of Howerton's study was to compare a lecture format to computer-assisted instruction (CAI) using recent hardware and software advances. A pre- and post-test was used to determine student performance and instructional preference. The questions emphasized beam-guiding device construction recognition, radiographic film nomenclature, and film placement in a full series mount. In addition, a post-instruction survey was used to determine student learning preferences.

Seventy-five first-year University of North Carolina (UNC) dental students who were registered for the introductory radiology course were asked to participate. All agreed and were randomly placed in one of three groups (17).

The three groups were: 1) Interactive CD only 2) interactive CD and lecture, and 3) lecture only. The content of the multimedia instruction focused on intraoral radiography. A pre- and post-test was administered to determine if there was a significant difference in gain in knowledge between interactive CD and lecture formats. An evaluation instrument was used to determine if there was a student learning preference between CAI and lecture format. To determine the effectiveness of each of the three interventions, results were analyzed by comparing the median scores for the pre-tests and post-tests for each group using the Wilcoxon signed rank test. The level of significance was set at .05. Analysis of covariance (ANCOVA) was used to determine whether there was a significant difference in learning between the CAI format and the lecture format. No significant difference was found between pre- and post-test outcomes, indicating that similar learning took place regardless of the teaching method used. It is worth mentioning here that the post-test scores were factored in toward the final course grade of the students, which adds a large dose of motivation. The students did, however, express their preference for CAI over lecture format.

Although the effectiveness of Computer Assisted Instruction (CAI) has been shown to be as effective as conventional lectures, the full potential of computers in education has not been utilized, as shown in the study by Lechner. (18) This study showed that more than half the students who evaluated the CAI module were concerned about using it to replace human instruction, although that summative assessment showed that students could attain a desired standard of knowledge if a lecture series was replaced by the CAI program. Students with little or no computer experience found the program to be user-friendly. Most students of the study considered the CAI module to be a useful learning resource (18).

The purpose of Lechner's study was to gather information from students to help guide the refinement of a computer-based program designed to help students learn to design removable partial dentures (RPD). Other goals of the study were to determine: 1) whether students could attain a desired standard of knowledge if a lecture series was replaced by a CAI program; 2) whether students found the program to be a useful learning resource; and 3) whether the program was easy to use, even by students with little or no computer experience.

The research methodology was principally qualitative, but the investigators did not examine the actual difference in outcomes between CAI and more traditional learning, by use of a control group. Instead they exposed all students to the program. They did this for two reasons: first, to maximize the feedback obtained and second, not to deny any group of student's access to this package. Summative empirical evaluation was therefore limited to assessing whether or not the principal goals had been met. Formative evaluation was used as a guide to completion of the program. The evaluation comprised several components, based on questionnaires.

Specifically four series of three questionnaires were administered in designated 10-minute periods at the conclusion of each of three formal 2-hour sessions in a computer laboratory. To monitor progress, students were assigned an anonymous number at the first session and asked to record that number on subsequent questionnaire sheets. Students were asked to record their level of computer literacy, to associate positive or negative words with their experience of the program, and to rate a series of statements regarding use of the program on a scale of 1 to 5 (1= strongly agree, 2=agree, 3=neither agree nor disagree, 4=disagree, 5=strongly disagree) . Open questions were: 'What was the best thing about the session?" "What was the worst thing about the session?" and "How could the program be improved?'. The program had its own 2-minute tutorial and no other demonstration of the program was needed at the first testing site. However, in the second computer laboratory, one of the authors of the program was available to act as a supervisor to respond to questions during the computer sessions and to provide aid to assist with any technical problems that might arise. The researchers also recorded students' questions and observations of their behavior during this time. This observational data became part of the formative evaluation.

It is important to note that students were particularly impressed by aspects of the program that could not be duplicated by a book; the interactive nature of the learning process allowed students to gain the ability to rotate the diagnostic casts. This highlights the need for CAI programs to use the full potential of computer capability, rather than merely replicate a textbook on a screen. Unfortunately most online dental education courses still follow the broadcast paradigm of passive dissemination of knowledge, which does not take into consideration the different learner characteristics (19).

Virtual reality and simulators

The perceived high demand for manual dexterity for dentists has always placed paramount emphasis on teaching psychomotor skills to dental students (20). This important aspect of the dental curriculum is possibly the most demanding on faculty's time and energy. This is why several dental schools nationwide have invested in very expensive virtual reality dental simulators. A study by Jasinevicius (21) evaluated two dental simulation systems: virtual reality versus contemporary non-computer-assisted. The majority of contemporary systems used at dental schools use sophisticated mannequins that can be positioned like patients. The virtual reality system has the added advantage of evaluating students' preparation through the use of computer tracking. Contemporary dental simulation systems were developed to improve dental students' transition from the preclinical laboratory to the clinic. The purpose of this study was to compare the efficacy of a virtual reality computer-assisted simulation system (VR) with a contemporary non-computer-assisted simulation system (CS). The objectives were to determine whether there were differences between the two systems in the quality of dental students' preparations and the amount of faculty instruction time. Students who completed their first year of dental school and had no previous experience preparing teeth were group matched according to their performance in the first-year Dental Anatomy laboratory course and assigned to VR (n=15) or CS (n=13). In the summer, they spent two weeks (approximately 3 hrs/day) executing amalgam and crown preparations on typodont teeth. Short presentations describing the preparations were given to both groups; however, preparation criteria were available on the computer for the VR group, while the CS group received handouts. Both groups could request feedback from faculty, although VR also obtained input from the computer. A log was kept of all student-faculty (S-F) interactions. Analysis of the data indicated significant differences between groups for the following variables: mean number of S-F interactions was sixteen for the VR group versus forty-two for the CS group; and mean time of S-F interactions was 1.9+/-2 minutes versus 4.0+/-3 minutes ($p<0.001$) for VR and CS, respectively. Faculty spent 44.3 hours "interacting" with twenty-eight students, averaging 0.5 hours per VR student and 2.8 hours per CS student. Thus, CS students received five times more instructional time from faculty than did VR students. There were no statistically significant differences in the quality of the preparations. While further study is needed to assess virtual reality technology, this decreased faculty time in instruction could impact the dental curriculum.

Jasinevicius concluded that although students using the contemporary non-computer assisted simulators received five times more instructional times of feedback from the faculty than did the students who used the virtual reality one, there were no statistically significant differences in the quality of the preparations between both groups. We could extrapolate from their findings that the feedback the students received from the computer regarding their progress was as effective as the faculty's feedback.

Although the importance of psychomotor skills for the success of a dentist cannot be over emphasized, several researchers have argued that this is more myth than reality (22). For example, in his review of the literature, Lundergan states that "Studies evaluating manual dexterity have not confirmed a high manual dexterity aptitude for dentists." (22).

Lundergam goes on to stating that "… a finger dexterity score for dentists that fell significantly below the norm for the general population". The researcher also found that first year dental students demonstrated no significantly better tweezers dexterity than the general population taking the Johnson O'Conner Tweezers Dexterity test.

It has been suggested that the dynamic and complex nature of modern dental practice requires such a broad range of skills that digital dexterity contributes only a small increment. However it is still not clear exactly which manual skills are required for a dentist and the balance needed between manual and intellectual skills remains uncertain. Perhaps other characteristics such as interpersonal skills, perceptual or spatial ability, critical thinking, and continuous learning skills are more essential for success and satisfaction in the contemporary practice of dentistry.

Computer games

The notion that computer and video games are only a form of entertainment has seen a shift in recent years (23).

Computer games are a recent addition to the media available for communication in entertainment and education. According to the Entertainment Software Association (ESA) annual report, the sales of video and computer games in the US in 2007 accounted for about USD$ 9.5 billion , and the gaming industry has outgrown its traditional cinema-movie counterpart. The largest consumer groups for those games are adolescents and young adults (24).

Computer and video games are increasingly becoming recognized as a powerful means for learning (23). Trying to study the scientific literature examining “serious games in education” presents many challenges, the biggest of which is a lack of standardization in production value and the lack of a unified definition of the meaning of a “video game” (13).

A study by Timpka et al, exploring how computer game designs can be integrated in the development of interactive health education environments found that playing computer games is mainly motivated by the challenges and competition represented in the game play scripts(25). The same study concluded that interactive health education environments can be improved by implementing challenging game play scripts, as well as spectacular technical features and narratives.

The study by Timpka was based on qualitative analysis of adolescent's experience of playing an action-adventure computer game, using data from in-depth interviews. An interview content guide was constructed based on the available literature on computer games. The guide was designed based on the understanding that it is more important to be invited into the computer game play culture than to use a predefined interview structure. It covered three topic areas with regard to game play: 1-behavior, addressing subtopics ranging from settings to strategies; 2-knowledge, addressing what was regarded as necessary to know for playing computer games and the source for this knowledge; and 3-attitudes and understandings, addressing subtopics ranging from motivational factors for game play to evaluations of game details and design components.

By analyzing the appeal of a popular "non-educational" commercial computer game, Timpka's study highlights important areas educational game developers should take into consideration when designing their game. The study found that the main reason the game was found interesting by the subjects was that the games represented a challenge. Excitement was found in the act of balancing the challenge to finish the game with the stress and frustration faced in demanding game play situations. In other words, the core of the game playing experience was to first create and thereafter master stress and distress.

In a study by Roubidoux (26), an interactive web-based game was developed to teach the concept of breast imaging report interpretation to 4th year medical students taking an elective radiology course. The game was evaluated using student surveys which showed students' preference for this type of education. Although the published paper for this study did not present any statistical analysis of outcomes, and had variable sample sizes, results from the surveys showed that students found the Web site to be worthwhile, convenient, and applicable to other specialties.

A paper by Howell (27) highlights the potential for games for health education to increase the learner's enthusiasm for educational material, which could in turn increase time on task, and lead ultimately to improved performance. Certainly, computer games hold special interest to a generation who has grown up with them, and as such, the games may hold promise as educational tools. It is unclear whether the computer games charm is due to the inherent challenge built into game play, the richness of graphics presented to the user, the opportunity to interact with other users (in web based games and online multiplayer games), the story or context in which the game is contained, or some other feature. Moreover, the availability of immersive environments for entertainment purposes is likely to grow considerably in the next few years, and to have important applications in learning. The report goes on to declare: “Exploiting the inherent motivational aspects of games and simulations for education and training must be based on a sound understanding of which features of these systems are important for learning and why”. The research covered in the same paper (27) states that games can provide players with unlimited opportunities to rehearse skills, receive immediate feedback on performance, obtain and make use of information, experience social support when interacting with other players, and develop the confidence and ability to carry out new skills in their daily lives. The paper goes on to address some of the challenges facing the development of games for health science education. Game engine cost was a major area of concern. In a practice well known in the video game world, several games can be structured on the same game engine originally developed for a game that became very popular. While the use of an existing game engine may ease development of new games, the developers of the new game still have to come up with their own game story, graphic arts and characters, yet the physics of the virtual world in which the game is supposed to occur (i.e. how the characters move and interact within the world, what things to do to win the game…etc.) are based on a game engine already tried and tested. Developing such sophisticated game engines to the standard for current video games is a very complex and time consuming process that costs developers tens of millions of dollars. This is why developers of a new game base their work on existing popular games. The new game developers license the old game's engines for a fee, saving them considerable time.

The licensing fees can represent a very high overhead cost if the games are not developed for mass marketing, as it is the case in health education. Many potential developers of game-based solutions decide it is too costly to attempt, or end up using less capable game engines that result in less effective applications. In addition, to avoid large licensing fees, many developers are forced to give away their games rather than sell them because licensing restrictions of game engines prevent third-parties from repurposing the game for profit without large upfront fees. Since most developers would use the income from game sales to support their research, in the long run this means less money for research.

Another important challenge for games in the health community is the lack of a unified software approach. According to Howell (27), many different investigators have tried to develop unique solutions independently with little communication opportunity to leverage or extend previous work. This makes software development more expensive. It also often means that the software progresses at a slower rate than other fields. Unified platforms and frameworks are needed to enable the community to share efforts and build on other's work.

The gold standard of education has historically been the one-on-one interactive teaching model between teacher and learner. The realities of dental education, with the intense curriculum along with large classrooms and shortage in faculty, often result in passive learning environments that fail to challenge students' ability to grow intellectually and to become lifelong learners and critical thinkers (5). Interactive computer education that provides immediate feedback to the learner and provides real world challenges is a tool that needs to be further investigated and developed.

CHAPTER III
MATERIALS AND METHODS

Overview

Why use a computer game concept to teach the 3-step etch-and-rinse bonding system? Winning at many genres of computer games requires performing repetitive actions in precisely timed sequences.

Achieving clinically acceptable results with a resin bonding system requires the clinician to use various components of the system in a very specific way and in sequence every time. This is similar to winning at a computer game; the user will have to master the correct sequence and the correct timing of the procedure in order to "win".

Mastering using all components of the etch-and-rinse resin bonding system, which is a technique sensitive procedure, depends on executing each step in a correct manner at the correct time. Repeating these steps several times as part of playing the game will make those concepts more memorable to the user.

The objective of this project was to develop and test the acceptability and efficacy of a computer interactive dental educational module (IDEM) in teaching enamel and dentin bonding.

The study was divided into two phases. The first phase involved designing and programming the interactive module. The second phase compared the interactive module to a passive clinical demonstration of the same procedure, by a randomized controlled shear bond strength test as well as a change of didactic knowledge using a pre-test and immediate post-test didactic examination. Feedback was also received from the students on an evaluation attitude questionnaire of IDEM to gather information regarding the student's acceptance of this teaching method.

Research questions

This study will address the following general questions:

1. Do freshman dental students learn the correct concepts and steps of using the three-step etch-and-rinse resin-bonding system by "playing" a computer "game"?
2. Do freshman dental students prefer using a computer interactive module to attending a lecture to learn important dental procedures, such as the three-step etch-and- rinse resin-bonding system?

Phase one: Designing and programming the Interactive Dental Educational Module (IDEM)

The first step in programming a project of this type is to identify the components of the exercise that need to be included in the modules.

These essential components were identified:

1- Phosphoric acid etchant, delivered in a syringe.

2- Air/water syringe

3- Primer

4- Adhesive

5- Curing light

Next, the basic concepts the program needs to address were determined to include the following:

1- Obtain proper field isolation with the rubber dam

2- Etching enamel and dentin

   a- Use 37% phosphoric acid to etch the tooth

   b- Extend etchant beyond the margins of the cavity

   c- Etch dentin for a maximum of 20 seconds (over etching dentin constitutes a critical error)

   d- Etch enamel for 20 seconds (over etching enamel does not constitute a critical error)

3- Rinsing

   a- Rinse acid off tooth with water for 30 seconds

   b- Don’t air-blow the acid off the tooth surface

4- Drying

   a- Dry tooth surface with light air pressure

   b- Do not desiccate the tooth by over-drying

5- Primer application

   a- Apply generously to dentin

   b- Replenish primer on micro brush often

   c- Rub primer onto tooth surface for 30 seconds

   d- Gently blow off excess solvent with air syringe

6- Adhesive application

   a- Brush adhesive on tooth surface in thin layer

   b- Do not air-dry too thin.

   c- Light cure for 20 seconds

7- Polymerization

a- Light curing tip should be as close as possible to the tooth surface when curing

b- Light cure adhesive for a minimum of 20 seconds

The above mentioned concepts are the teaching objectives for this exercise and were considered when designing the game.

Main challenges for developing the IDEM program.

Transferring the teaching objectives from paper into an interactive computer program presents many technical challenges. Procedures that look simple and straightforward on paper tend to be very difficult to implement at the computer programming stage. The following are some of the challenges encountered at the programming stage of this research.

Acid etching

Phosphoric acid is typically delivered to the tooth surface and cavity with a syringe that has a blunt tip. The acid is usually an opaque gel (mostly dark blue).

Simulating this material was the easiest of all components since the color is very distinctive, and the material is opaque. A key point when teaching this exercise was teaching the difference between etching enamel and dentin. Enamel can be etched longer, with no effect on its structure or the resultant bond strength.

Etching dentin longer than 20 seconds usually results in lower bond strengths (28). Another important point that was taken into consideration was the surface area of the tooth surface covered with etchant (beyond the cavity margins).

Water

Simulating physical phenomena like liquids and solids interacting (various components of the system acting on the tooth surface) as desired by the teaching objectives requires that the program only work on computers with high end technical specifications and makes the adaptation of the module into other platforms (such as PDAs and smart phones) even more challenging.

It was decided from the beginning that this module would not attempt to improve the physical performance skill level of its user. Rather the program is intended to enable the user to replicate the correct handling of the various components of the 3-step etch-and-rinse system and the correct sequencing of the system. This is why the research team decided to represent the most important concepts of the exercise as components interacting in a two dimensional world.

The other challenge was to be able to differentiate between various components, (air and water) based on the characteristics that can be readily duplicated by this setup. Ideally, it would be best to represent different components by different colors and different phases of the manipulation of the component by a change in the transparency of that component (changing the alpha value). For example, it is very hard to represent the tooth surface being washed by water and then showing a slight drying of the tooth surface.

Water as a transparent substance is visually seen by the light reflected off the water drops and the refraction of light causing the distortion of the surface underneath the water drop. The accurate simulation of water drops on a tooth requires an enormous amount of calculations to render a physically accurate water simulation. Although such an accurate visual simulation of physical phenomena is now possible with 3D programs running on powerful computers, this makes programming the module more time consuming and limits the reach of such a program since all future users will have to utilize a high end computer system. It could be argued that such an accurate (almost realistic) visual representation is not absolutely needed to cover the teaching objectives stated earlier, namely mastering the sequencing and timing of application. The primary researcher assumed that any shortcoming from the inaccurate visual representation could be overcome by more detailed in-game instructions that explained the difference.

Air

Representing air was another challenge. One key component of the three-step etch-and-rinse bonding system is gently drying the tooth surface after adequate washing of the conditioning gel while still leaving the surface damp. Another important step is evaporating the solvent contained in the primer without over blowing the primer. The air syringe used is the same one used for delivering the water stream. Visually representing air is very difficult since clean air is virtually invisible and is only “felt” not “seen”. The clinician in the dental operatory feels how strong the air is blowing when he holds the air/water syringe. The clinical can then assess how hard he should press and how far the tip of the air syringe should be from the tooth surface in order to achieve the desired results; i.e., gently removing excess water from cavity after rinsing, and evaporating solvent after the application of the primer to the tooth surface.

Primer

The primer; a transparent liquid, is delivered by placing a drop from the primer bottle in a dappen dish prior to use and then applying it using a micro brush to the cavity.

Primer is generously applied, and the brush should be dipped in the fluid repeatedly. The proper application of the primer also includes rubbing the primer with the brush in the cavity after placement. The most clinically distinctive feature of the transparent primer is the ethanol smell of the solvent. Since this feature cannot be replicated by a computer simulation. It was decided to use a different color to represent this material to alert the user of the IDEM that this material needed to be handled differently.

Applying the primer was simulated by moving an image of the micro brush onto an image of a dish on screen. This action by the user had the effect of adding a predetermined amount of primer drops to the tip of the brush.

The user was to apply these primer drops to the tooth surface by clicking the left mouse button. Every drop placed on the tooth surface will subtract one from the number of drops on the brush. Once there are no drops left on the brush the user will have to move the brush again over the dish to replenish. The user placed the primer on the tooth for 30 seconds before being instructed to use the air syringe to evaporate excess solvent. Evaporating the solvent in the primer was simulated by increasing transparency (decreasing the alpha value) of the drop when it is hit by an air bullet.

Adhesive

The adhesive is a shiny semi-translucent yellow liquid which is more viscous than the primer. Simulating viscosity was deemed too difficult to reproduce in the module at this time. The same programming procedure used for the primer was used for the adhesive. The user was instructed to apply four coats of adhesive to the tooth surface and then light cure it.

Light curing

At this final step, the program instructed the user to pick up the curing light, place the curing tip as close as possible to the tooth surface and cure for 20 seconds. The curing unit had a timer that started counting only when the light cure tip was exactly positioned over and very close to the preparation. The curing light also had a green indicator light that illuminated when the light cure tip was at the correct position. Although this feature is not present in the real world, it was placed to enhance the message that the adhesive is not properly cured unless the light tip is placed very close to the cavity.

Programming the Interactive Dental Educational Module

Adobe Flash CS3 (Adobe Systems Incorporated, San José, California) was chosen as the platform for programming this interactive dental educational module.

Several factors influenced this decision: The resultant Flash game is readily viewable on almost all computers having a web browser, regardless of the operating system (all versions of Microsoft Windows, Apple operating systems, Linux operating systems). Also many hand-held devices and smart phones support this file format and exporting the game onto these devices could be a future research project. Using Flash makes integrating the game into existing hardware and software setups more cost efficient.

Another reason the Flash format is so popular for developing web content is the compact size of the end product which makes it ideal for internet applications when download speeds are of limited capacity.

High quality photographs were taken using a 10 megapixels digital SLR camera (NIKON D-80-Nikon Corporation, Tokyo, Japan) of all the components of the 3-step etch-and-rinse resin bonding system (Opti Bond FL-Kerr, Orange, CA) which is currently used at The University of Iowa College of Dentistry.

This included photos of the Ultraetch™ syringe, bottles of Opti Bond FL ™ resin primer and resin adhesive, micro brush applicators, and plastic dappen dishes. Photographs were also taken of the air-water syringe, the curing light, and a class V cavity preparation on an anterior tooth.

The images were imported into the Adobe Photoshop CS3 image editing software. All images were edited by digitally removing the background and adjusting the colors if needed. Using digital photographs of the resin bonding system resulted in having the users see and virtually interact with exactly the same products they would be using later for the shear bond strength lab test, and eventually using during their clinical training. The edited photos were then imported into Adobe Flash CS3 developing program, and incorporated into the game. The interactive module was then hand coded from scratch. The game was controlled using a regular computer mouse pointing device, which is the default human interface device (HID) at the time this research was conducted.

The tested program was designed to pace the user through the steps of the bonding system by first telling them about the step and then asking them to perform it on screen before proceeding to the next one. The user had the ability to use the computer mouse to interact with the component by pointing it to the image of the respective component on the computer screen. The user then held down the mouse button to move that component around the screen and interact with the image of the Class V cavity preparation on the tooth. For instance; pointing the mouse HID to the Ultraetch™ syringe and then clicking the mouse button while the mouse pointer is still over the same image, will allow the user to control and move the syringe towards the tooth and pressing the mouse button while over the image of the tooth, will simulate the extrusion of the blue acid etch gel.

Developing the passive clinical demonstration for the control group

A video recording of the three-step etch-and-rinse bonding system clinical procedure was chosen as the passive educational format.

An arch of extracted human teeth was mounted into a Dentiform ™ cast using PVS material. The teeth were isolated with a rubber dam and a Class V cavity was prepared. A proper procedural video recording of the three-step bonding system using the same components that appeared in the interactive module was filmed. The video was edited for clarity and brevity using Final Cut Pro (Apple Computer Inc.). An experienced educator of the course; who is a native English speaker; provided the voice over narration to the video in post production.

Phase two: Testing the interactive module

This module teaches the three-step etch-and-rinse resin bonding system skills to first year dental students. The effectiveness of the interactive module to a passive format (a clinical video demonstration) covering the same topic. Study participants were randomly assigned to the interactive group or the video group. The decision was made to use a video recording of the procedure as the passive format since research has shown that a video is as effective as a lecture (29). A video recording can be edited to precisely cover the same steps of the clinical procedure as the experimental module. Both groups had the same educational objectives. A pre-test and post-test evaluated the change in knowledge for each group.

All first year dental students previously attended a lecture on resin composites as part of their required course work. The students who agreed to be in the study were randomly given an envelope separately containing the pre-test questionnaire, the post-test questionnaire and the attitude questionnaire.

The envelope also contained a random number that assigned the student to be part of either the control group or the experimental group. All students were asked to answer the pre-test questionnaire and hand it to a member of the research team before going to their assigned group.

Students in the control group went to the simulation clinic where they watched the clinical video of the procedure. Each student watched the video on an individual monitor. Students in the experimental group used the computers available in the student's operative clinics. At the time of this study, the student's operative clinics area was the only location in the college with the most number of computers in one area, 38 in total.

Students in the control group watched the video of the clinical procedure twice. After the students finished watching the video, they were asked to answer the post-test questionnaire before starting the practical part of the experiment. The experimental group had supervised access to the website with the interactive module. They used the module until they decided they were ready to take the post-test. They were instructed to take the post-test out of the envelope and answer the questions before proceeding to the simulation clinic to perform the shear bond strength test.

Students in both groups performed a practical bond strength test in the lab using the three-step etch-and-rinse system previously taught as part of this research using either a passive or an active method to bond prepared teeth samples, and test the shear bond strength using the Ultradent jig (Ultradent Products, Inc., South Jordan, Utah)..Statistical comparisons were made between the two study groups.

Population studied

A total of eighty first year dental students from The University of Iowa College of Dentistry (2008/2009 academic year) attending the introductory course to Operative Dentistry as part of their dental curriculum, were asked to participate in this study before they started their clinical training.

The students were randomly assigned into two equal groups: a control group that was exposed to the passive learning model (the clinical video), and an experimental group that was exposed to the computer module as an interactive learning model. Other than a lecture, the students had no previous exposure to the three-step etch-and-rinse resin-bonding system during their Operative Dentistry introductory course. They also had no practical experience bonding or handling resin composites.

IRB Approval

Prior to the study, an application for conducting this study was completed and sent to the Iowa Human Subjects Office. Approval was obtained from the IRB office.

The research envelope

Envelopes were prepared for all eighty participants of this experiment. Each envelope had a random number printed on it which assigned the students to be part of the control group or part of the experimental group. The envelopes contained the IRB consent form, the pretest questionnaire, the post test questionnaire and the IDEM evaluation questionnaire.

All students were asked to answer the pre-test questionnaire and return it to a member of the research team before going to their assigned group. The envelopes containing the post test questionnaire and the IDEM evaluation questionnaire were not to be opened and completed until after the teaching session.

Group formation

A total of eighty first year dental students participated in this study. This was the total number of dental students enrolled in the first year at the College of Dentistry in the University of Iowa at the time of the study.

The students were told that their participation in this research and answering the tests would not have any effect on their grades.

Students that agreed to be part of this study were first given the informed consent form as required by the IRB before being assigned randomly to either the group watching the video (the control group) or the group using the computer module (the case group).

The control group

The students in the control group were asked to take their research envelope and proceed to the simulation clinic after finishing the pre-test.

The simulation clinic is set up so that each student has a separate monitor in front of him/her to watch clinical demonstrations. The clinical video showing the application of the three-step etch-and-rinse resin bonding system was shown to the students twice using the above mentioned setup. After the students finished viewing the video they were asked to answer the post-test questions and then put them back in the envelope before performing the shear bond strength test.

The experimental group

The students of this group were instructed to go to the sophomore clinic after they are finished with their pre-test. At the time of conducting this research the sophomore clinic was the only place with thirty-eight computers in one area. Members of the research team were present to help with any technical difficulties. Computer use was supervised to assure accuracy of the tests (i.e. prevent cheating). The students had a short explanation of how to use the games functions, an in-game help function was also available with a click of a mouse button. The students used the game for up to 30 minutes before they answered the post-test.

Evaluation

Students' knowledge retention was measured through written and practical examinations. The written examinations included an immediate pre-test and an immediate post-test. The practical examination was a shear bond strength test.

The questionnaire

The questionnaire is presented in the appendix and the following are some remarks regarding some of the questions.

On further analysis of the questions, it becomes clear that some questions asked the same thing in different ways. For example, question 4 and question 8 ask about the dampness of dentin following acid etching and prior to using the primer. Question 2 and question 9 ask about the light curing component of the bonding system. Question 5 and 6 ask about proper application of the primer.

Due to the limited scope of the experiment, and its practical nature, the research team had a very limited variety of didactic questions to include in the questionnaire.

The shear bond strength test

Immediately following the post-test, students of both the experimental and the control group performed a shear bond strength test as part of their original course work in the introduction to operative dentistry. This exercise required to use the 3-step resin-bonding system to attach a button of composite to a prepared tooth sample.

The strength of the bond of composite to dentin was then measured using a shear bond strength machine.

Statistical methods

The nonparametric Wilcoxon Rank Sum (Mann-Whitney) procedure was used to compare the two groups with respect to the pre-test scores, the post-test scores, the difference between the two scores (Post – Pre) representing the gain in score, and the outcome of shear bond strength testing. The Wilcoxon Signed Rank test for paired data was used to assess whether post-test scores changed significantly relative to pre-test scores within each group. Group comparisons of correct vs. incorrect responses to individual questions were assessed using Fisher's exact test. The level of significance was specified to be 0.05.

Hypotheses

The main hypotheses for the study are presented below in the form of null hypotheses:

1. There is no difference in knowledge gained between using an interactive dental educational module (IDEM) compared to watching a video recording of the clinical procedure when teaching first-year dental students the three-step resin bonding system.
2. There is no difference in clinical skills gained between using an interactive dental educational module (IDEM) compared to watching a video recording of the clinical procedure when teaching first-year dental students the three-step resin bonding system.
3. There will be no difference in preference in learning the three-step resin bonding system by a lecture or by the interactive dental educational module.

The secondary hypotheses for the study are presented below:

1. The mean results of the practical examination on shear bond strength test will be the same for the group who used the interactive module and the group who watched the clinical video.
2. The mean score of the change in knowledge will be the same between the group who used the interactive module and the group who watched the clinical video.

Figure 1. Screen shot of acid etch application in IDEM

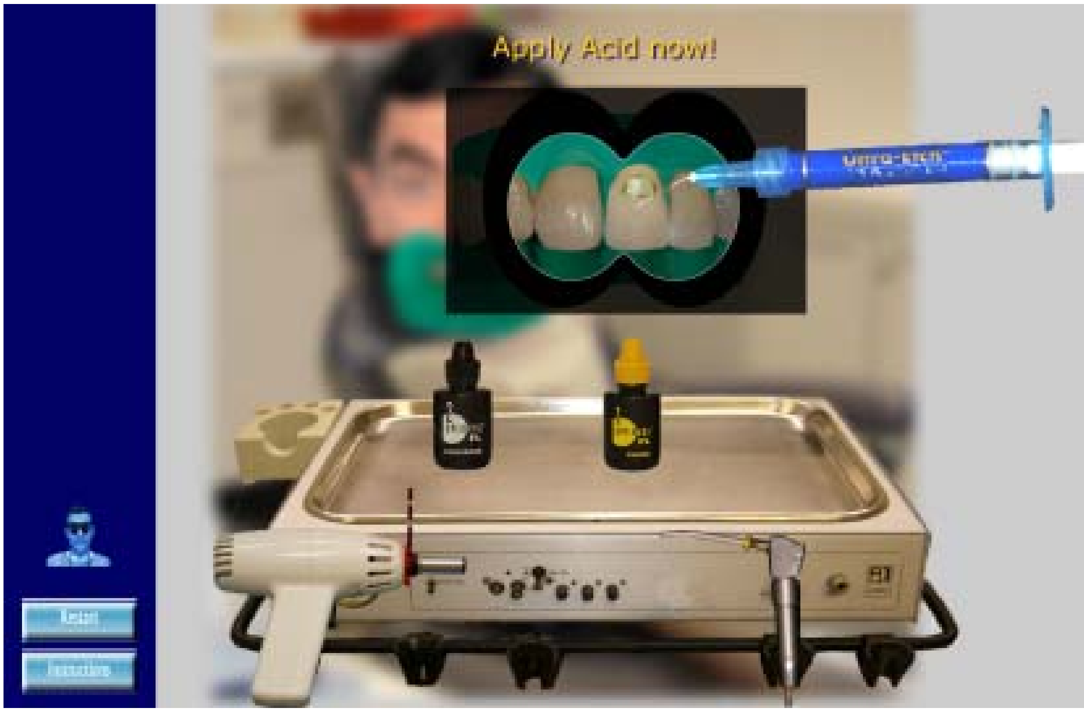


Figure 2. Screen shot of air syringe in IDEM

Operational definitions

1. Students: first year dental students at the College of Dentistry, University Of Iowa.
2. Conventional lecture: traditional lecture given by a lecturer to the students, usually as a passive Power Point presentation.
3. Interactive dental educational module (IDEM): the program developed to teach the three-step resin bonding system in a game format.
4. Immediate pre-test: Test given to the students immediately before starting the experiment.
5. Immediate post-test: Test given to the students immediately after finishing either the passive of active educational module.
6. Simulation clinic: The clinical lab where dental students perform dental exercises on mannequin heads and pre-clinical wax ups.
7. Shear bond strength test: A practical test where students use a resin bonding system to attach a composite button to a flat dentin surface of an extracted human tooth and a testing machine measures the force needed to break the button off of the tooth. This is an indication of the effectiveness of the bond

CHAPTER IV
RESULTS

Introduction

The findings of this study are presented in this chapter in five sections. The first section covers the study population. The second section presents information on the two questionnaires given to both groups of the study. The results of the pre and post-tests are given in section three. The fourth section presents the results of the evaluation questionnaire given to the experimental group which used the interactive dental educational module (IDEM). The fifth section compares the dental students' shear bond strength test results. Results of the study are considered to be statistically significant at the 0.05 level of significance (P-value ≤ 0.05).

Study population

The 80 study participants were first year dental students at The University of Iowa. The age range was between 21 years and 39 with mean age of 23 years. The group consisted of 31 females and 49 males.

Students were randomly divided into two groups. By randomization, the control group (Group I) was to have 42 students and the experimental group (Group II) was to have 38. The reason for this disparity was the limited number of available computers to simultaneously run the experiment.

At the time of the experiment, one student from the experimental group accidentally went with the control group instead of his designated group, resulting in the experimental group being reduced to 37 students. For this reason, the student was re-assigned from Group II to Group I. resulting in 43 students in this group.

Due to IRB requirements, participation in this experiment was voluntary and anonymous. At the onset of the experiment, the students were assured that no personal identification information was collected, and participation in this experiment had no effect on course grade.

One student from the control group did not return the immediate pre-test questionnaire, and another student from the same group, did not return the immediate post-test questionnaire to the research team. This resulted in both students being eliminated from the study and final analysis. As a result, the study ended with 41 students in Group I and 37 students in Group II.

Questionnaires

Following the scheduled lecture on resin bonding, the pre-test questionnaire was administered to all students who agreed to be in this study. The same ten questions used in the immediate pre-test were also used in the immediate post-test questionnaires. The questions were in the multiple choice format with only one possible correct answer for each question.

Analysis of pre- and post-test scores

The nonparametric Wilcoxon Rank Sum (Wilcoxon-Mann-Whitney) procedure was used to compare the responses of the two study groups for the total score based on the ten questions on the pre-test and then on the post-test questionnaires. These results are based on the 78 subjects (41 control subjects and 37 IDEM), after exclusions due to non-response as mentioned previously.

The data provided no evidence of any differences in prior knowledge, as measured by the pre-test total score ($p=0.81$), with a median score of 7 in the control group and 6 in the IDEM group. Similarly the two groups did not appear to differ with respect to post-test total scores ($p=0.27$); both groups had a median post-test score of 8. Comparison of the distribution of the difference score (total post-test score minus total pre-test score) also yielded no evidence of group differences ($p=0.13$).

Individual questions.

In consideration of individual pre-test questions, there was no evidence of a difference between the two groups ($p>0.05$ in all instances, Fisher's exact test); however, there was a somewhat suggestive difference ($p=0.0642$, Fisher's exact test) for pre-test Question 4. In this case, somewhat more of the IDEM group (19/37 or 51.4%) answered correctly than did those in the control group (12/41 or 29.3%). In contrast, the data provided evidence ($p=0.0011$, Fisher's exact test) that the control group was more likely to answer post-test question 4 correctly (32/41 or 78.1%) than were the members of the IDEM group (15/37 or 40.5%). No other group comparisons were significant ($p>0.05$) for any of the other post-test questions, although the results for post-test question 8 were somewhat suggestive ($p=0.075$, Fisher's exact test), with 24/41 (58.5%) controls answering correctly and 14/37 (37.8%) of the IDEM group subjects answering correctly).

IDEM evaluation questionnaire

Only students in the experimental group were given an evaluation questionnaire to collect feedback on their experience with the module. Two of the 37 students in this group returned the questionnaires to the research team unanswered, and were not included in these analyses.

The questionnaire consisted of nine Likert items questions, with one out of five possible responses.

The possible responses are as follows:

1. Strongly disagree.
2. Disagree.
3. Neutral neither disagree nor agree.
4. Agree.
5. Strongly agree.

In addition to the nine Likert scale questions that evaluated the students' experience with IDEM, two questions were asked to collect data regarding the relationship between the students and video game playing and types of popular technology the students use on a regular basis. The students were also encouraged to provide written feedback in their own words regarding the experiment or the tested module. Students were asked to write down the features they liked the least, including anything they would like to be changed in the final version of the module.

The nine Likert scaled items of the questionnaire are listed Appendix B. Results for the first nine items on the questionnaires are given in table 3.

Responses tended to be very favorable to the use of the interactive module, with most falling in the Agree zone of the Likert scale. The question that generated the most negative feedback with a shift in responses towards the Disagree zone was question 9 which called for the complete replacement of the lecture with a computer interactive module. This question got a large 11.43% of Strongly Disagree response from the students. In comparison, none of the other eight questions got any responses in the Strongly Disagree zone of the Likert scale.

The response to question 10 addressed the video game playing pattern of the dental students in this experiment. This showed that most dental students (65.71%) like to play video games in some capacity.

Question 11 gauged dental students' use of popular technology. Data gathered from this question show that most students use laptops and cell phones on a regular basis (94.29% and 85.71 % respectively). It became clear however, that not many students are using smart phones or hand held PC at this time (31.43% and 8.57% respectively). This is an important fact in guiding the future path of IDEM development.

Shear bond strength testing

The shear bond strength testing exercise was conducted immediately following the post-test questionnaire for both groups as part of their original course work.

It is worth mentioning that even though this exercise is part of the curriculum it is not graded, and the results do not count towards the final score of the course.

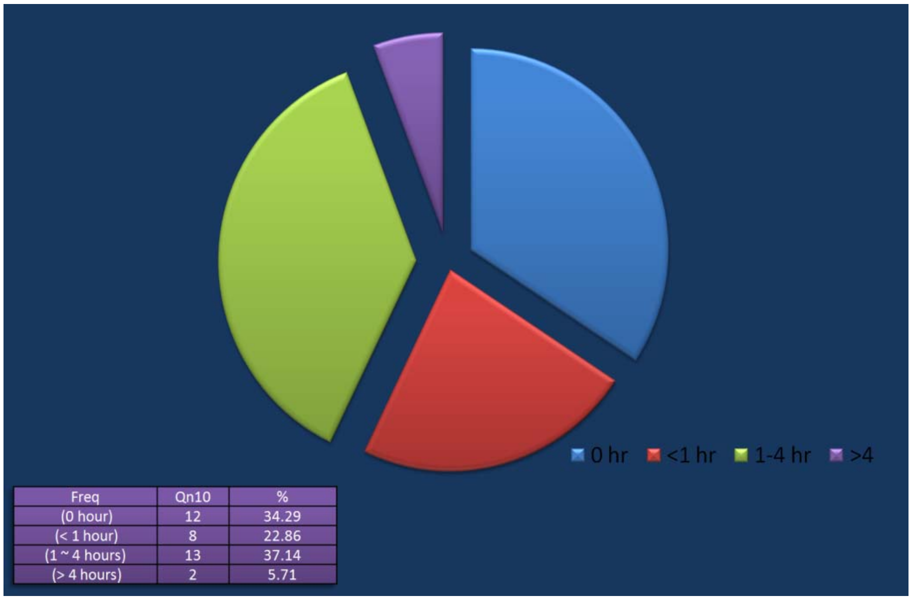
For this practical exercise, students were asked to bond a composite resin stub to a flattened tooth surface. The shear bond strength was measured for each specimen in Megapascals (MPa) by using a shear bond tester. The highest score recorded was 37.20 MPa. Forty-two results out of 43 were recorded for Group I and 36 results out of 37 were recorded for Group II. The results from the two students who were previously eliminated due to non-response were not included in the final analysis of the shear bond strength, resulting in the final control group sample size of 41.

The nonparametric Wilcoxon Rank Sum test was used to compare the results of the Shear Bond Strength Testing between the two study groups.

There was no evidence that the distribution of shear bond strength measures from the practicum differed for the two groups ($p=0.97$), with a median SBS of 12.8 in controls and 12.9 in the IDEM group.

The issue of whether to include shear bond strength (SBS) values of zero was raised since one occurred among each of the intervention groups. The conclusions; however, remained unchanged if these observations were omitted and the data re-analyzed, with no evidence of group differences in the distribution of SBS ($p=0.95$, Wilcoxon Rank Sum test)

Figure 3. Amount of time dental students play video games



Freq	Qn10	%
(0 hour)	12	34.29
(< 1 hour)	8	22.86
(1 ~ 4 hours)	13	37.14
(> 4 hours)	2	5.71

Table 1. Descriptive statistics for entire study sample

Group	N	Variable	Mean	Standard deviation	Min	Median	Max
Experimental	37	Pre-test	6.49	1.50	4.0	4.0	10.0
		Post-test	8.03	1.38	4.0	0.0	10.0
		Post-test	1.54	1.54	-2.0	2.0	4.0
		Shear Bond strength Test (MPa)	13.41	9.20	0.0	2.0	37.2
Control	41	Pre-test	6.27	1.48	3.0	6.0	9.0
		Post-test	8.34	1.46	4.0	8.0	10.0
		Change (Gain in Score)	2.07	1.74	-3.0	2.0	7.0
		Shear Bond strength Test (MPa)	13.45	13.45	0.0	12.6	35.6

Table 2. Results of the IDEM questionnaire

Question		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Missing
1	**N=** **%=**	24 68.57%	11 31.43%	0	0	0	2
2	**N=** **%=**	21 60%	13 37.14%	1 2.86%	0	0	2
3	**N=** **%=**	16 45.71%	17 48.57%	2 5.71%	0	0	2
4	**N=** **%=**	9 25.71%	17 48.57%	8 22.86%	1 2.86%	0	2
5	**N=** **%=**	16 45.71%	17 48.57%	2 5.71%	0	0	2
6	**N=** **%=**	11 31.43%	17 48.57%	5 14.29%	2 5.71%	0	2
7	**N=** **%=**	15 42.86%	12 34.29%	8 22.86%	0	0	2
8	**N=** **%=**	17 48.57%	13 37.14%	5 14.29%	0	0	2
9	**N=** **%=**	3 8.57%	6 17.14%	11 31.43%	11 31.43%	4 11.43%	2

Table 3. Descriptive statistics of shear bond strength by group

Group	N	Variable	Mean	Standard deviation	Median	Minimum	Maximum
Experimental	37	Shear Bond Strength Test (MPa)	13.41	9.20	12.9	0.0	37.2
Control	41	Bond Strength Test (MPa)	13.45	9.14	12.6	0.0	35.6

Table 4. Descriptive statistics of shear bond strength by group after exclusion of zero SBS results

Group	N	Variable	Mean	Standard deviation	Median	Minimum	Maximum
Experimental	36	Shear Bond Strength Test (MPa)	13.78	9.04	13.20	0.5	37.2
Control	40	Shear Bond Strength Test (MPa)	13.79	8.99	12.80	1.1	35.6

Table 5. Dental students' use of technology

Freq	Laptop	Cell	Smartphone	Handheld	IPod MP3	Videogame
0 (No)	2 5.71%	5 14.29%	24 68.57%	32 91.43%	7 20%	27 77.14%
1 (Yes)	94.29%	30 85.71%	11 31.43%	3 8.57%	28 80%	8 22.86%
Missing	**2**	**2**	**2**	**2**	**2**	**2**

CHAPTER V
DISCUSSION

This study compared clinical knowledge of first year dental students receiving two different educational approaches. A conventional video demonstration was compared to a computer interactive module teaching the three-step etch-and-rinse bonding system.

To the best of our knowledge, this was the first attempt to evaluate the efficacy of an interactive module to teach dental students the three-step resin bonding system.

Unlike studies that assessed the impact of computer simulators on the psychomotor skills of students (21) (30) (31), our study was designed from the beginning to test clinical procedures that require mastering sequencing and handling concepts rather than a refined psychomotor skill.

Educational software should be evaluated for many important technical criteria, including the quality of the end-user interface, which affects user's perception of the product, the level of engagement, which is the motivation to work with the medium and the interactivity and customization of the software which allows users to configure them to meet individual needs (32).

The full technical evaluation of any software, including educational software, is very time and money intensive. This explains why evaluation of dental and medical educational software is reported in the literature as either quantitative or qualitative (33). Although some papers report both (17)(34), most only report qualitative evaluations(18)(26) .

Experts in educational software evaluation have argued that conducting randomized trials to compare a test group that is using a computer-based module to a control group that is using a traditional module is a flawed endeavor (32)(35)(36).

The research question whether a computer based educational module results in better learning outcomes does not usually separate between two important confounding effects. The effects of the educational media and the effect of the educational method confound each other (36). Our research tried to address this by delivering the passive educational format as a clinical video recording viewed on a computer screen instead of a live demonstration.

Limitations in the computer program

Many published papers on computer simulators and games do not report all the attributes of their tested educational module. This makes it hard to categorize it as being a game, a simulation or something totally different from both (13). This also makes the comparison between our module and theirs more difficult. Also, the lack of any standard platform for designing educational programs for the medical or dental field means that every new project will have to start by using different programming and designing tools which the research team arbitrary chooses.

In a study by Roubidoux (26), the authors rationalize the use of Java Script programming language instead of Flash authoring suite, claiming that Flash is more complex. The limited interactivity of the game in Roubidoux’s study might justify their use of Java Script instead of Flash. The interactivity in their game is limited to choosing questions and then appropriate answers with the program providing feedback on the correct answer. There is no animation or video in Roubidoux’s module. This is very different from the interactivity in Howerton's study that reported using a multimedia authoring tool (Macromedia Director 8) in addition to various image and video editing programs to design their module. Lechner (37) reported using Quicktime VR to present the 3D dental model used in their tested educational module, yet there is no mention of the authoring tool that was used to incorporate the 3D video into the educational module itself.

Other studies reviewed fail to mention what authoring tools they used to create their educational modules (16) (34) and what experience they had designing them.

From our experience designing our interactive module, there is very limited literature either in the form of textbooks or online resources that deal with the challenges of designing and programming a dental educational module in Flash. The only available resources at the time of this experiment were general programming books that did not address the specific requirements of an educational module (38)(39)(40)(41)(42). This lack of technical references on common areas of difficulties translated into more time and effort being spent solving design and programming issues.

Our module, like Howerton's interactive intra-oral radiology module (17), compared an interactive module to a passive one (a lecture).

When analyzing the pre-test and post-test results for the interactive and the passive groups, Howerton found no difference in knowledge gained between the groups. Like our study they also received favorable feedback from the students regarding their program.

The post-test was administered to all students (the passive and interactive groups) two weeks after the final lecture. It is worth mentioning, that the post-test scores in Howerton's study were factored in towards the final course grades, which is a powerful motivation to study from whatever available source. Howerton's study could not account for all contamination effects between study groups, and since the interactive CD was with the students at all times, it is possible that students shared lecture notes and CDs before the "scored" post-test.

Like Lechner's interactive multimedia RPD teaching program (37), our program was intended to be used before more conventional teaching of the subject. In our case, the module is intended to be used before working on extracted natural teeth, and ultimately before working on a natural tooth in a patient's mouth.

However, unlike Lechner's module which guided students by a series of questions through the process of selecting the best design for a case from a predetermined set, our module allowed the students an interaction with the components they will use in real life, with the exact sequencing and timing involved.

Lechner's study did not examine the actual difference in outcomes between the interactive module and more traditional RPD design learning model. They relied instead on evaluation questionnaires for feedback from users, which were mostly positive (37).

One of the very few teaching tools in the medical literature that could truly be called a computer game was the interactive web-based breast imaging game for medical students by Roubidoux et al (26) . The game was both interactive and competitive. It was designed as a quiz-show with points gained for each correct answer. The game also had a competitive element, where two students could play against each other, or chose a "cyber-player" to compete against.

The version of the IDEM we tested in this study lacked a challenging or competitive game-play script which is the biggest motivation to play computer games (25). This is an important feature to consider in future releases of the module.

The Roubidoux study did not compare the educational efficacy of the game to a traditional teaching method. Instead, it evaluated the feedback from students who used the game, which was mostly positive.

Roubidoux's study stresses the importance of the content and the format when creating a computer teaching tool, because development is expensive. Merely reproducing material from textbook onto a web site adds little teaching value other than easier accessibility of the information (26). The study also mentions the advantage of having the teaching tool on a website instead of a CD, which makes it easier and cheaper to update and to distribute to students. The interactive module tested in this study can be considered a pre-release beta version rather than the finished program. Due to time and budget limitations the program tested in this study had several unpolished areas, especially in applying the air syringe.

The version tested for this research had no distance gauge for air syringe, to ascertain the importance of leaving the dentin moist after etching the cavity. This meant that students had no feedback from the program when they overdried the tooth surface. On the contrary, the program only advanced the user to the next step after the white chalky appearance of enamel was achieved.

This could possibly explain the results obtained from analyzing questions 4 from the post-test. Question 4 asks about the condition of dentin following etching and before applying the primer to the cavity. There was a somewhat suggestive difference ($p=0.0642$, Fisher's exact test) for pre-test Question 4. In this case, somewhat more of the IDEM group (19/37 or 51.4%) answered correctly than did those in the control group (12/41 or 29.3%). In contrast, the data provided evidence ($p=0.0011$, Fisher's exact test) that the control group was more likely to answer post-test question 4 correctly (32/41 or 78.1%) than were the members of the IDEM group (15/37 or 40.5%). No other group comparisons were significant ($p>0.05$) for any of the other post-test questions, although the results for post-test question 8 were somewhat suggestive ($p=0.075$, Fisher's exact test), with 24/41 (58.5%) controls answering correctly and 14/37 (37.8%) of the IDEM group subjects answering correctly). This is an interesting finding, since question 4 and 8 virtually ask the same thing.

There are many different philosophies regarding how to handle dentin after the tooth has been etched. The area of controversy is how to remove excess water after washing off the acid.

Research has established that over drying of dentin results in higher percentage of marginal openings in Class V resin composite fillings (43).The same research did not find a superior way of drying dentin following the application of acid etch to the cavity(43). The lack of a consensus in the literature regarding how to dry dentin is reflected in the different ways this procedure is being taught to the students by different faculty. Some educators in the Operative Dentistry Department reject the use of air as a drying mechanism, and instead advocate blotting away excess water with a cotton pellet. Others advocate the use of light air pressure to remove excess water, with the need to use a damp cotton pellet to moisten dentin again.

It was hard to include all these philosophies into the interactive portion of the program at the time of this study due to time constraints, but all these areas were addressed in the instructions and prompts of the tested interactive module (IDEM). It is however important to include some sort of rewetting mechanism in future releases of IDEM to highlight this important concept to the students.

Limitations in testing the educational computer module

We were unable to find a validated evaluation instrument in the literature to measure dental student's attitude towards interactive educational modules. This meant that we had to develop our own instrument. Due to the limited window of opportunity to run our experiment we were unable to evaluate our questionnaire for reliability (reproducibility of measurements) or validity (how well it measures the variables of interest) before administering it.

The questionnaires

The IDEM evaluation questionnaire was developed to assess student's opinion on using the interactive module, and to gather some data from the students regarding their use of technology and the amount of time they would play computer games.

Our attempt at gathering some demographic data was unsuccessful. Only 5% of the students filled out the question that asked for the gender of the respondent. Due to the complete anonymity in which the study was conducted, no gender information was gathered in any other way, and thus possible effects of this factor could not be assessed.

Most of the responses to the IDEM evaluation questionnaire were favorable. Most students preferred being taught the three-step resin bonding system by a computer module rather than a lecture. Due to the lack of a cross-over design, the experimental group was not exposed to the clinical video demonstration the control group had. We were therefore unable to assess whether the students would prefer a video or an interactive module to be taught the 3-step resin bonding system. No evaluation questionnaire was administered to the control group to assess their preference for a clinical video. The researchers considered the clinical video to be part of the "traditional" passive teaching module.

The biggest negative response (42.86% either disagree or strongly disagree) from the students was to question number nine of the evaluation questionnaire. This question asked whether the students believed that the IDEM should completely replace a lecture in teaching the three-step resin bonding system. Actually, it can be argued that this is actually a low negative response from the students to the software, since 57.14% either wanted the IDEM to replace the lecture or didn't care if it was replaced (31.43% were neutral).

Regarding the relationship between dental students and video game playing, our questionnaire found that 65.71% of dental students play video games in some capacity (between less than one hour and more than four hours per week). This is very close to data reported by the Entertainment Software Association (ESA), which found that 65% of American households play computer or video games (44).

The ESA also reports that 38% of homes in America have a video game console, which is higher than what our study found. Only 22.86% of the students reported using video game consoles. Another interesting finding was the low use of handheld personal data assistants (PDA) by dental students (8.57%). This is much lower than the 45% to 85% reported in the literature for physicians and medical residents (45).

Sample size

The sample size and eventually the effect size we were able to detect are limited by the number of first year dental students agreeing to participate in the study. Examining the literature shows that our cohort of eighty student was larger than many similar published studies (17)(37)(26).

Shear bond strength test comparison

Due to restructuring of the introductory Operative course at the time of conducting this experiment, the students in this study had no previous clinical exposure to either the resin bonding system or the resin composite itself. This meant that students had challenges executing the shear bond strength test due to difficulties in handling the resin composite.

Some of the problems the students faced at the time of running this experiment were packing the composite into the well of the Ultra Dent jig (Ultradent Products, Inc., South Jordan, Utah) without leaving either a void between the prepared tooth surface and the composite, or having too much material placed in the well, which required breaking the composite button when taking the tooth sample out of the Ultra Dent Jig. Both of these cases resulted in a failed specimen, or a recorded shear bond strength of zero.

Placing resin composite and preparing the samples for the shear bond strength test were not part of our experiment; hence we never addressed that issue in either the video clip or the interactive module. We also assumed that failed samples were probably due to wrong handling of the resin rather than the adhesive. This is why we decided to also assess the results after omission of those values.

Bond strength to dentin depends on many factors in addition to proper handling of the bonding system and the resin composite. The proper preparation of the dentin sample by the researchers also plays a role. We rationalized that since distribution of the samples was randomized, an omitted variable bias would have been accounted for.

The pre-test and the post-test questions

Test questions have traditionally played an important role in evaluating the results of student learning. And although some have argued that this is not the best method to evaluate educational media (35)(32), we found the use of a pre-test and post-test questionnaire the most feasible to evaluate our IDEM.

One of the biggest limitations of this research was using questions that had no previous validity or reliability established.

The lack of a delayed post-test to assess the long term retention of knowledge is another limitation of our study. Comparing the results one week following the experiment would have been a more realistic test.

The only question that had a statistically significant difference between the two tested modules was question four, with suggestive results for question eight, which was directed at similar knowledge content. These two questions asked about the state of dentin following acid etching the cavity and prior to applying the primer. In both instances, the control group had a better score at post-test than the IDEM group. As noted previously, although the importance of leaving the dentin damp after acid etching was stated in the on-screen prompts and instruction, this feature was not an interactive part of the tested version of the educational module. It is interesting to note that this argument does not hold true when analyzing the results of question ten. Question ten asks about the distance of the light tip from the cavity. This was addressed in several ways in the interactive module game play. First, the timer of the light cure unit only counted when the tip was very close to the cavity preparation and second, a green LED was added to the light cure gun in the module that only lit when the curing tip was in the right position. This feature does not exist on light cure units in real life, and was added to the module to stress this important feature to the students. Our research found no statistically significant difference between the two groups on this question. It is our opinion that the wording of the questions themselves had an effect on the results. Some students expressed their confusion with the wording in question eight and thought it wasn't clear, others pointed out the interchangeable use of acid-etch and conditioner in the questionnaire. Some students said this was the first time they knew that acid-etch was also called a conditioner.

CHAPTER VI
CONCLUSION

Although our research method failed to find a statistically significant difference between the interactive module and the video recording, the feedback from the students was very encouraging. Further improvement is needed to make the IDEM a stand-alone module that is both fun and informative to use. Adding scoring and competition elements to the module will make it more challenging. Allowing the students the opportunity to perform the procedure in different ways, by choosing any component of the bonding system, even out of order, and then providing feedback at the end of the procedure will make IDEM more enjoyable and useful. Some students may have said it best in their comments that, "I learn best from my own mistakes."

APPENDIX A

QUESTIONS USED FOR THE IMMEDIATE PRE-TEST AND THE IMMEDIATE POST-TEST

QUESTIONS USED FOR THE PRE-TEST AND IMMEDIATE POST-TEST QUESTIONNAIRES

Please answer the following questions in reference to the procedure using the three-step etch-and-rinse resin bonding system:

1- The correct sequence of application of the components of this system is:

a- Acid etch-Primer-Adhesive.

b- Primer-Adhesive- Acid etch

c- Primer- Acid etch -Adhesive

2- When using the 3-step etch and rinse bonding system which of the following components is **light cured**?

a- Acid etch

b- Conditioner

c- Primer

d- None is light cured

3- The ideal times for **etching enamel** and **dentin** are:

a- 30 seconds Enamel, 5 seconds Dentin.

b- 15 seconds Enamel, 30 seconds Dentin.

c- 20 seconds Enamel, 15 seconds Dentin.

d- 60 seconds Enamel, 30 seconds Dentin.

4- When applying the **primer** on the **conditioned dentin**, the dentin surface should be:

a- Wet

b- Damp

c- Dry

5- Following the application of a **primer** , air should be blown on the surface to:

a- Produce a dry surface

b- Produce a very thin layer of the primer

c- Remove the solvent from the primer

d- Remove the water from the tooth

6- Which component of the three-step etch-and-rinse bonding system should be applied as several coats and then gently blown with air to evaporate the solvent?

a- The primer

b- The acid etch

c- The adhesive

d- None of the above

7- When a conditioner is applied to the tooth, which structure is it applied to first?

a- Enamel

b- Dentin

c- It is applied to both simultaneously

8- After rinsing the conditioner from dentin we should remove water from the cavity to the extent that the surface should be:

a- Wet

b- Damp

c- Dry

9- After applying the resin adhesive to the preparation, the dentist should.

a- Air dry to evaporate the solvent.

b- Reapply several coats and rub them in by agitating the brush.

c- Light cure.

10- When using a curing light to polymerize a component of this system, the tip of the light should ideally be:

a- As close as possible to the tooth surface.

b- Far enough so the light will shine on the whole surface simultaneously.

c- The light intensity is strong enough that the distance doesn't really matter.

1-a, 2-d, 3-c, 4-b, 5-c, 6-a, 7-a, 8-b, 9-c, 10-a

APPENDIX B

QUESTIONNAIRE TO EVALUATE THE INTERACTIVE DENTAL EDUCATIONAL MODULE (IDEM)

Please answer the following questions by selecting and circling the most appropriate answer from the list.

Possible answers are: Strongly Agree (SA), Agree (A), Neutral (N), Disagree (D), and Strongly Disagree (SD)

1. The instructions and prompts were clear and self explanatory
   SA-A-N-D-SD
2. I enjoyed using the Interactive Dental Educational Module (IDEM)
   SA-A-N-D-SD
3. Using IDEM helped me understand the proper way of using the 3-steps bonding system
   SA-A-N-D-SD
4. IDEM helped me identify my strengths and weaknesses in understanding the 3-steps bonding system.
   SA-A-N-D-SD
5. Using IDEM helped me maintain interest in the topic
   SA-A-N-D-SD
6. After using IDEM I feel more confident for the upcoming practical shear bond strength testing exercise
   SA-A-N-D-SD
7. I consider using IDEM more informative than attending a conventional lecture
   SA-A-N-D-SD
8. I prefer being taught the 3-step etch-and-rinse system using IDEM rather than a lecture
   SA-A-N-D-SD
9. I believe that IDEM should completely replace a lecture in teaching the 3-step etch-and-rinse bonding system.
   SA-A-N-D-SD

10. Given the chance, how many hours per week would you play video games (either on a PC or a console) :

a. 0
b. Less than one hour
c. One hour to four hours.
d. More than four hours

11. Which of the following devices do you use/ would like to use on a regular basis (circle all that apply)

a. Laptop
b. Cell phone (only for phone calls and text messages)
c. Smart phone (e.g. Blackberry, iPhone, HTC, etc.)
d. Hand held PC/ PDA
e. iPod/mp3 player
f. Video game console (PLAYSTATION, X-BOX, Wii, etc.)

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