

The Impact of Specially Designed Digital Games-Based Learning in Undergraduate Pathology and Medical Education

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• **Context.**—The rapid advances of computer technologies have created a new e-learner generation of “Homozappien” students that think and learn differently. Digital gaming is an effective, fun, active, and encouraging way of learning, providing immediate feedback and measurable process. Within the context of ongoing reforms in medical education, specially designed digital games, a form of active learning, are effective, complementary e-teaching/learning resources.

Objective.—To examine the effectiveness of the use of specially designed digital games for student satisfaction and for measurable academic improvement.

Design.—One hundred fourteen students registered in first-year pathology Medicine 102 had 8 of 16 lecture sessions reviewed in specially designed content-relevant digital games. Performance scores to relevant content sessions were analyzed at midterm and final examinations. Seventy-one students who registered in second-year pathology Medicine 202 were exposed to the games only during the final examination, with the midterm examina-

The revolutionary change of the digital world during the last decades of the 20th century with globalization has changed the way students think and learn, thereby “prompting a need to change traditional lecture based passive learning methodology to an active multisensory experiential learning methodology.”^{1,2} Since the introduction of computers to the common household, the popularity of digital games has skyrocketed to a \$10 billion per year industry.³ Seeking to harness onto this powerful weapon, the British government has recently invested \$350 billion in the British Broadcasting Corporation’s plan to create an entirely new, game-based “digital curriculum”⁴ with the aim of engaging and motivating the modern student. The possibilities for such an educational design are endless, as modern technology has the ability to open new facets of learning that could

serving as an internal matched-control group. Outcome measures included performance at midterm and final examinations. Paired 2-tailed *t* test statistics compared means. A satisfaction survey questionnaire of yes or no responses analyzed student engagement and their perceptions to digital game-based learning.

Results.—Questions relevant to the game-play sessions had the highest success rate in both examinations among 114 first-year students. In the 71 second-year students, the examination scores at the end of the final examination were significantly higher than the scores on the midterm examination. Positive satisfaction survey noted increased student engagement, enhanced personal learning, and reduced student stress.

Conclusions.—Specially constructed digital games-based learning in undergraduate pathology courses showed improved academic performance as measured by examination test scores with increased student satisfaction and engagement.

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have never been imagined even a decade ago. The unique combination of enjoyment, motivation, interactivity, immediate feedback, and engagement/flow offered by digital games provides a sound platform on which learning becomes an anticipated fun event instead of a tedious boring chore. Gaming is an effective teaching strategy for adult learners and games are considered valuable for the acquisition and application of cognitive, affective, and psychomotor knowledge and skills.⁵ Gaming provides the novel opportunity for the learners to contextualize information and to study the consequences of their choices, leading to trial and error exploratory learning. In medical education, active learning tools such as digital games are complementary, e-teaching/learning resources that can greatly expand and enrich the curriculum. Within the specially designed digital game environment, students can learn to deal with the pressures of determining the fate of “virtual patients” through exploration of their various responses and consequences. Though digital games-based learning (DGBL) is spreading rapidly in all educational settings, the literature does not provide clear empirical evidence of its pedagogical benefits.⁶ Although theoretically, digital gaming and education fit together seamlessly, quantitative studies proving the effectiveness of this union are few in the

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published English literature.^{7,8} Though most agree that games can be engaging and instructive as seen in Randel's review of 67 studies during 28 years,⁹ it is often extremely difficult to demonstrate gains in learning that are attributable to the use of the virtual environment of video games, virtual simulations, or digital games. Learning in itself is a truly complex process to assess in a purely quantitative scientific paradigm.¹⁰ This is further compounded by the use of names other than "assessment" used in past efforts of the gaming and simulation community to demonstrate educational effectiveness of their experiential activities in the classrooms of K to 12 students.¹¹ Further, though much is known about games and learning in general, little is known about game attributes that influence and contribute to learning outcomes even though simulation and gaming are used in higher education.^{8,12} This lack of "hard core data" to DGBL is a further deterrent to the acceptance of the use of such active learning tools in higher education. Undergraduate medical education remains quite traditionally bound within its "evidence-based" educational paradigms unlike engineering education with the numerous applications of simulation games.²

In this context, 2 specially designed content-relevant digital games were created for implementation as complementary learning tools to the first- and second-year students registered in the undergraduate pathology courses at the College of Medicine, University of Saskatchewan, Saskatoon, Canada. The purpose of this study was to examine the effectiveness of the implementation of such specially designed digital games in (1) improving academic performance/learning outcomes, as measured by examination test scores, and (2) examining student satisfaction and perceptions of DGBL.

METHODS

Ethics Approval

This study was approved by the University of Saskatchewan Behavioral Ethics Committee under the "Implementation and Evaluation of Teaching and Learning Strategies in Undergraduate Medical Education."

Digital Games Construction and Student Participation

This project was conducted at the College of Medicine, University of Saskatchewan. A College of Medicine faculty member together with members of a developmental team from Educational Media Access and Production undertook a collaborative project to create specifically designed content-relevant digital games for the pathology courses for students registered in the first and second year of undergraduate medical education. This project was supported by a technology-enhanced learning grant from the provincial government and took approximately 5 months for design and development. Game design principles included gaming strategies of problem solving, strategic thinking, and interpretive analysis with the overall aim of encouraging engagement and motivation to learn in a fun gamelike environment. All games were followed by immediate feedback to the responses, highlighting individual areas of strengths and weaknesses. User-friendly games were focused on time-sensitive task activities, encouraging motivation and goal orientation through rewards, clues, and partial solutions to maintain engagement, progression, and self-direction of

individualized personal learning. These games were designed to be used as complementary e-learning review resources for individual or group play.

The first game, *Path to Success*, places the student in a virtual life or death situation, where the correct responses to multiple choice questions increases both the metered life force and the simulated electrocardiogram (audio and visual tracings) of a patient, whereas incorrect responses (added visual clue "sad face") lower these factors. The challenge offered is to "save" the patient's life force by correctly answering the game questions, which is reflected by the electrocardiogram readings that in turn reflect the player's score. Game strategies for "help" included familiar game options such as Ask an Expert, Poll the Crowd, and 50/50 to guide the player. Each of the help options were designed so that they could be used only once with no added penalty. At the end of the game a printable feedback page informed players of their score with a higher score representing higher winnings and saving the patient. A screen shot image of this game is illustrated in Figure 1.

The second game, *The Path is Right*, is guided by the host Basil Philic and requires students to place wagers on their knowledge, testing them through various question formats including multiple choice, fill in the blank, and extended matching options. Upon the completion of the game, depending on the player's winnings, students were available to purchase "virtual prizes" ranging from a cup of cappuccino or rubber gloves to a fur coat or an exotic vacation. The value of the virtual prizes increased with higher test scores. Images of the action boxes in this game are illustrated in Figure 2, a through e.

Med 102—First-Year Students.—One hundred fourteen students (88 medical, 26 dental) were registered in the pathology course for the first year, Med 102. The pathology course consisted of 16 one-hour in-class "contact" lecture sessions in term II. The digital game *Path to Success* was available for 2 weeks prior to the midterm and final examinations. Eight of the 16 lecture sessions were reviewed in this specially designed content-relevant digital game. The game provided an extended online learning environment and were available to all students via the designated password-protected course Web page. The learning outcomes were assessed by the standard 2-hour multiple choice question midterm and final examinations based on the content addressed within the lecture sessions. Questions used in the game setting were not reused. For the purposes of this study, the performance scores of 10 "test" questions relating directly to the content of the 8 game-reviewed lectures were compared with the remainder of the questions in both examinations. The 10 questions were of comparable level of difficulty and in the same format as the remainder of the examination. They were in no way set apart within the exam papers and were randomly interspersed throughout all questions. This protocol was followed for 2 consecutive cohorts of students during 2 school years (2007–2009).

Med 202—Second-Year Students.—Seventy-one students were registered in the pathology course for the second year, Med 202. Med 202 is a year-long 2-term course. Midterm examination was conducted at the end of the first semester and the final examination was held at the end of the second semester. Each exam was devoted to the assessment of learning relevant to the content addressed



Figure 1. Path to Success screen shot image of an interactive electronic digital game whose goal is to answer multiple choice questions to strengthen the life force of and save a dying patient. The game screen has a life force meter gauge that records the player's progress on the right and the 3 help strategies on the left: Ask An Expert, Poll The Crowd, and 50/50.

in each term and was of equal weight. Students were not exposed to any specially designed, educational digital games in the first semester. For the purposes of the study this served as an internal matched-control group to compare the learning outcome as academic performance scores in the second semester, when students were exposed to the specially designed digital games as mentioned previously. The digital game *Path is Right* was available for all students as a complementary e-teaching/learning resource for 2 weeks prior to the final examination. The difficulty levels of the midterm and final examinations were comparable and the implementation of digital games was the only notable difference to the educational tools used in the course. Performance scores at midterm examinations were compared with those on the final examinations.

Data Compilation

Med 102—First-Year Students.—For the 114 first-year students registered in Med 102, results were tabulated for all questions at the midterm and final examinations during the course of 2 school years (2007–2009). The overall average of the correct response to each question was calculated. The percentile average for all questions, the top 10, and the bottom 10 correct score response were calculated. These 3 groups were compared with each other. The identity of the questions was blinded to the analyst reviewing these performance outcome measures. Ten “test” questions in each exam were directly related to

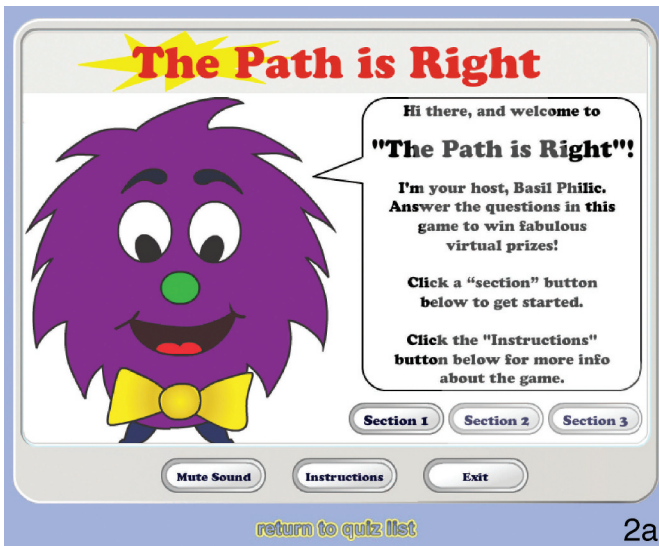
the content played in the digital games. Once the preliminary question response analysis was completed, the identity of the 10 “test” questions was revealed. The “digital games content-related test questions” were then compared with the overall top 10 and bottom 10 score in an attempt to prove or disprove the working hypothesis that DGBL results in improved academic performance.

Med 202—Second-Year Students.—For the 71 second-year medical students registered in Med 202, results including the lowest, highest, and mean for the course were tabulated from the midterm and final examinations. As there had been no exposure to digital games during the first semester, the outcome performance on the midterm examination served as a comparison matched-control, while the outcome performance on the final examination represented the post-digital game-based examination test group. In this way, the beneficial effects of DGBL for student academic success were examined.

A satisfaction survey questionnaire of free written comments and yes or no responses analyzed student engagement and their perceptions of DGBL. This was administered at the end of each examination for each student cohort.

Outcome Measures

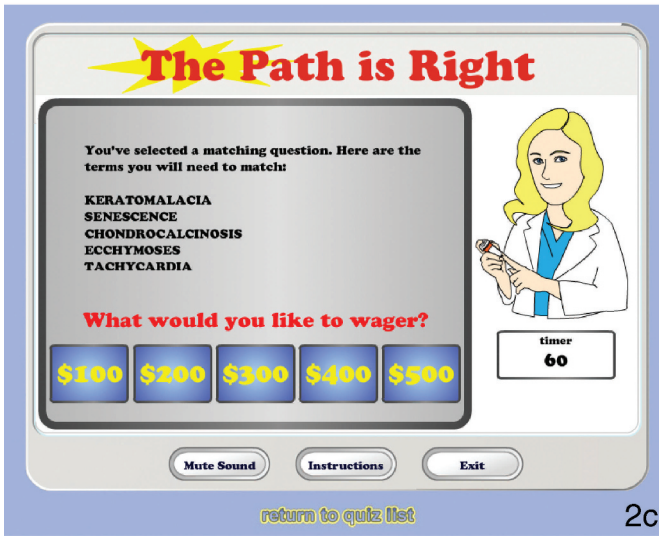
Statistical analyses of the data were analyzed using SPSS 16.0 (SPSS Inc, Chicago, Illinois). Descriptive statistical analysis compared the means of individual test groups through the paired 2-tailed *t* test. Statistical significance was defined as $P \leq .05$ for all measures.



2a



2b



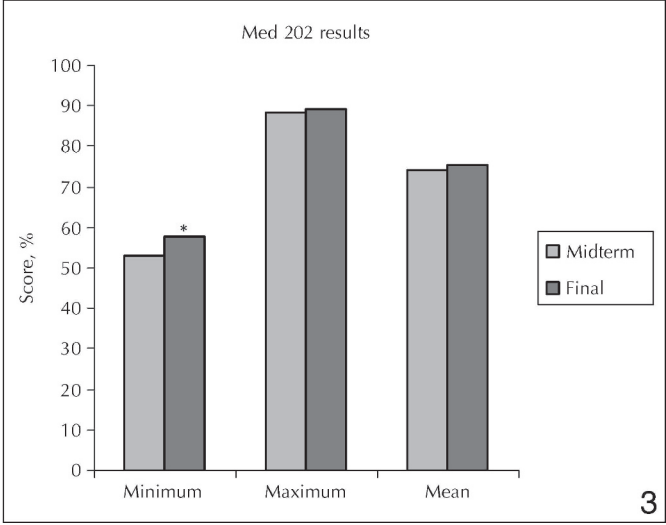
2c



2d



2e



3

Figure 2. The Path is Right images of the action boxes of an interactive electronic digital game with 3 sections. The host Basil Philic (a) guides the players through different challenges and offers constructive feedback with each response (b). The game is based on placing wagers with virtual money (c) with an aim to increase winnings (d) to buy virtual prizes at the end of the game. Each section has 5 options (e) leaving the players in control of their chances of winning at the game. The game design format includes multiple choice, fill in the blank, and extended matching questions.

Figure 3. Second-year medical students registered in Med 202. Midterm examination scores versus final examination scores. This is a visual representation of the minimum, maximum, and mean test scores achieved by 77 second-year medical students on the 70-question multiple choice

First-Year Students Registered in Med 102: The 3 Cohorts of Correct Responses/Examination Questions Studied in the Midterm and Final Examinations During 2 Consecutive School Years (2007–2009)				
Exam & Year	Question Analyzed	All Questions	Top 10 Questions	Bottom 10 Questions
Midterm 2008	Number of questions	50	10	10
	Minimum correct response/question, %	45.74	96.81	45.74
	Maximum correct response/question, %	98.94	98.94	64.89
	Mean correct response/question, %	83.00 ^a	97.98 ^a	57.55 ^a
Final 2008	Number of questions	70	10	10
	Minimum correct response/question, %	3.13	96.88	3.13
	Maximum correct response/question, %	100.00	100.00	55.21
	Mean correct response/question, %	78.62 ^a	98.86 ^a	35.63 ^a
Midterm 2009	Number of questions	52	10	10
	Minimum correct response/question, %	0.88	97.35	0.88
	Maximum correct response/question, %	100.00	100.00	72.57
	Mean correct response/question, %	83.92 ^a	99.03 ^a	57.43 ^a
Final 2009	Number of questions	77	10	10
	Minimum correct response/question, %	5.26	97.37	5.26
	Maximum correct response/question, %	99.12	99.12	51.75
	Mean correct response/question, %	77.89 ^a	98.46 ^a	33.60 ^a

^a Statistically significant difference: $P < .001$.

RESULTS

First-Year Medical Students, Med 102 (2007–2009)

There were 114 first-year students enrolled in Med 102 during the study periods (2007–2009). Complete data were available for all students for 2 school years. The midterm examination for 2007–2008 had 50 questions, whereas the midterm examination for 2008–2009 had 52 questions. Similarly, the final examination for 2007–2008 had 70 questions, whereas the final examination for 2008–2009 had 77 questions. All questions were of comparable mixed levels of difficulty in both examinations. The Table shows the correct responses per question in the 4 student cohorts for each examination. The performance scores to the examination question cohorts studied were divided into 3 categories: all questions, top 10 questions, and bottom 10 questions. Consistently, the top 10 correct responses in the 4 examinations represented the “test” questions related to the digital game-based content. In each cohort, the maximum, minimum, and mean of correct response score per question were analyzed.

Statistical analysis using the paired 2-tailed t test showed statistically significant differences: $P < .001$ between the comparison of the means of the correct response scores of all questions and the top 10 questions. All questions and the bottom 10 questions were also statistically significant at $P < .001$ (Table). These trends were consistently observed in all 4 examinations—midterm and final examinations for 2008 and 2009. The analyst reviewing these outcome measures had no knowledge of the content-specific identity of the questions. Review of the examination questions revealed the top 10 questions were identical to the “test questions” that were specifically randomly inserted into the examination reflecting learning outcomes of the digital games content sessions. This trend was consistently observed in both years and in both examinations of each year, suggesting DGBL enhances overall academic performance as measured by examination test scores.

Second-Year Medical Students, Med 202 (2008–2009)

There were 77 second-year medical students enrolled in Med 202 during the study period. Complete data were available for all students. The midterm and final examinations each had 70 multiple choice questions. The outcome performance (the aggregated percentile score at the midterm) ranged from 53.06% to 88.50% with a mean of 74.31%, whereas the final examination results ranged from 57.84% to 89.22% with a mean of 75.52%. Though the means and the highest scores remained similar, the lowest score shifted from 53.06% on midterm examination to 57.84% on final examination (post-digital game based outcome). This increased positive upward shift was statistically significant at $P = .04$ (Figure 3).

Student Satisfaction Survey

Both digital games were received with positive feedback on the satisfaction questionnaire administered at the end of each examination for both the first- and the second-year student cohorts. All students visited the game site at least once with 42% recording multiple hits. One hundred percent of students perceived the games to be both (1) a useful preexam review tool and (2) an enhancer of their personal learning. Figure 4 is an aggregated response chart to the survey questionnaire administered. A total of 92.31% of students found the games to be an effective learning tool, whereas 92.31% found the DGBL to be fun and relaxing; 76.92% of the students also found the DGBL styles a powerful stress reliever. Students played the games individually (69.23%) and in groups (38.46%). In their freestyle comments, prominent themes noted were that the games (1) offered the opportunity to “reinforce concepts and terminology,” (2) aided students to “feel more confident about [their] knowledge,” and (3) helped students to “recognize areas of weakness.” Students also appreciated the prizes, though virtual, as these motivated them to try for better prizes, relating to higher scores in a repeat game. There were also requests that expressed a

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portion of their midterm and final examinations. A statistically significant increase (*) is evident between the minimum percentages of the class performance outcomes at the midterm and the final examination. Comparison of the maximum and mean test scores showed no statistically significant difference. Statistical significance of $P = .04$ is indicated by an asterisk (*).

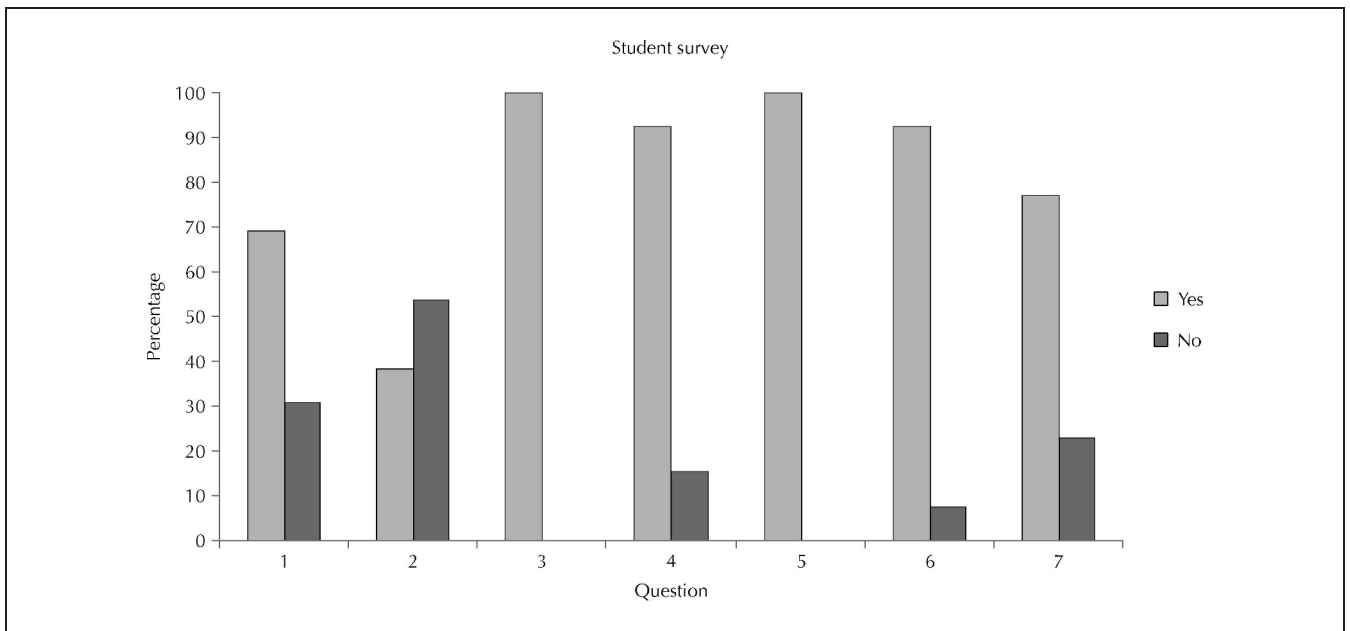


Figure 4. Student satisfaction survey. This figure is a quantitative graphic representation of the collated data to the aggregated responses obtained from the specifically designed student satisfaction survey. The survey encouraged freestyle written feedback and included a simple yes/no response to the following questions: (1) Did you prefer to play the games individually? (2) Did you prefer to play the games in groups? (3) Were the games a useful preexam tool? (4) Were the games an effective learning tool? (5) Did the games enhance your personal learning? (6) Were the games fun and relaxing? (7) Did the games aid in relieving your stress?

wish for the creation of similar digital games for future lessons and reviews.

COMMENT

The face of postsecondary education is changing with the postmodern generation wanting fun with power in their own hands through the uninhibited use of technology.¹³ The potential of using digital games as a complementary active learning educational resource remains relatively unexplored in higher education settings such as undergraduate medical education. It is well established through a large body of research that incorporation of active learning strategies improves learning with understanding.^{14,15} Active learning techniques, such as the construction of verbal and visual metaphors and creating concept maps, have been incorporated within the lecture contact classroom delivery of pathology education at the College of Medicine and met with generally positive results.^{16,17} The ongoing competition for curricular hours resulting in reduced contact hours often results in the lack of review sessions with students not being adequately prepared for exams. The use of games as active learning techniques “to encourage students to review materials during the life of a course and engage them in review” has a positive impact on exam performance and feedback from students derived from a questionnaire has been reported by Massey et al¹⁸ in kinesiology. This study explored the impact of extending the learning environment with specially designed digital games for such review sessions in undergraduate medical education.

For the past 20 years cognitive scientists^{7,19} have believed that computers could be an effective learning tool of paramount importance in the evolution of learning/education. A recent study has shown that the complexity of the required learning in popular video games far exceeds that of the most formal educational

activities, yet, because of the incorporation of fantastical elements, the motivation and the engagement of the gamer eases this task. Interactive digital tools such as video games are a powerful media and the development of “serious games” in different perspectives is challenging educators to rethink the role of information, tools, and aesthetics in a digital age.^{11,12,19} Digital games effortlessly and seamlessly integrate vital concepts necessary for learning within safe, virtual, mystical worlds. The exploration of multiple learning theories within the framework of multiple intelligences²⁰ also supports the widely accepted hypothesis that digital games can engage, motivate, and enhance learning. Skills essential for medical education, including problem solving, trial and error learning, and parallel attention are all core elements of many popular digital games. These features are enhanced and embellished through true-to-life or magical environments, contextual situations, and in-the-moment active participation, which are all aimed at creating increased engagement and motivation.

Results from the Med 102 cohort of first-year medical students during 2 years demonstrate that knowledge gained and reinforced while actively engaged in digital gaming has enhanced academic performance in comparison with information learned through passive reading reviews. Unlike textbook reading, digital gaming involves one’s eyes, ears, touch, and mind, allowing students to enrich their knowledge implicitly through the 3 primary senses and therefore appealing to diverse visual, auditory, and kinesthetic student learners. In this context, digital games offer an opportunity to root information in context rather than as individual chunks of “siloes” information.¹⁹ Correct response scores on the examinations related to the content of the digital games were in all cases the 10 most successfully answered questions. The examination consisted of higher order level of questions aimed at

testing comprehension, application, and analysis. This reinforces our working hypothesis that the ability to contextually think and reason is augmented by game play. Further, despite the occurrence of such high-level learning, student surveys expressed no concern about the difficulty of the game or the tediousness of learning these new, necessary, useful skills translating as improved academic performance. This is in accordance with the findings of Goodman et al²¹ that "educational material can be conveyed successfully and in an appealing manner via video game play" as intrinsic motivation leads to positive learning experiences.

Academic performance outcomes for the second-year medical students were also consistent with trends reported in the literature. In our study, the exam results on the midterm in Med 202 for the second-year medical students ranged from 53.06% to 88.50% with a mean of 74.31%, whereas the final examination results ranged from 57.84% to 89.22% with a mean of 75.52%. These results indicate that the range of marks is elevated, especially for students at the lower end of the scale. The change in the lowest scores achieved (from 53.06% to 57.84%) was statistically significant ($P = .04$), indicating weaker students benefited more from this e-teaching/learning resource. This is consistent with the literature's suggestion that digital gaming is most effective on students with less self-motivation and lower grades.³ Marc Prensky⁴ outlines 3 types of students: (1) the self-motivated student who wants to do well and will succeed regardless of the teaching strategies used, (2) students who recognize the benefits of knowledge and will push themselves to overcome obstacles to reach this end, and (3) students who "tune out" the professors. The large shift resulting in the elevation of the marks in the bottom percentages of the class demonstrates that through digital gaming students who otherwise show little enthusiasm for school are perhaps enticed to learn implicitly through a fun activity. This distinction is important to note, as not all students will be affected similarly by the implementation of digital games.²² Such technology, therefore, should not be a replacement for a good teacher, rather it can be used as an additional e-teaching/learning resource for professors to complement, enrich, and provide an extended student learning environment.

Though the relationship between learning and digital gaming has been theoretically examined at great length for the past 20 years and students' preference for digital gaming is becoming increasingly clear, "literature does not provide clear empirical evidence of its pedagogical benefits."⁶ As curriculums and textbooks continue to expand while classroom hours remain stagnant, an alternative form of learning is required. Digital gaming offers professors and students the opportunity for an extended learning environment with an emphasis on student-controlled learning. Multiple advantages of using games as a learning tool have been described in gerontology, geriatrics, and aging-related courses.²³ In the current world of instantaneous information, globalization, and interconnectedness, with constant visual, auditory, and kinesthetic stimulation, traditional teaching approaches do not satisfy all students. Students demand a more multisensory experiential learning methodology with challenges and feedback through "just-in-time" learning styles. Listening to the voice of a professor or staring at a page in a textbook can often result in

unmotivated students losing sight of the importance and relevance of the presented materials. Yet, just the simple use of technology to provide the excitement, entertainment, and constant engagement of the multidimensional virtual world alone will not entice learning in students who are otherwise accustomed to its overwhelming presence. Integration and relevant harnessing of this technology, therefore, is the key for creating a successful educational intervention.²⁴

Assessing effectiveness of teaching programs and educational interventions often entails using Kirkpatrick's 4-level model²⁵: level 1 evaluation-reactions, level 2 evaluation-learning, level 3 evaluation-transfer, and level 4 evaluation-results. Students' positive perceptions (level 1) to the satisfaction survey questionnaire of the digital games enhancing their personal learning and being a useful learning tool further supports the effectiveness of this educational resource. Although these positive reactions to this learning experience are not the sole determinant of learning and are subjective, they play a key role in assessing student engagement that enhances active learning, which encourages learning with understanding. Yet, such a survey data collection tool has the inherent limitations of subjectivity, that is, self-report bias.

Assessing gains in learning (level 2) moves beyond learner satisfaction and attempts to assess whether students have advanced in skills, knowledge, or attitudes as a direct result of the educational intervention. Measurement at this level is more difficult and laborious as seen in our study, as it would be ethically unfair to exclude any student from the use of additional educational resources. It is for this reason that the study design has the control factor as the different lecture sessions in MED 102 and time as midterm versus final examination in MED 202. Despite this, it is still difficult to attribute the enhanced learning outcome of increased academic performance as seen in our study to have occurred solely as a result of the educational intervention of using specially designed digital games. These are the recognized limitations of our study.

In summary, digital games provide a bridge over the continually growing gap between classical education and the e-world, tethering the infinite possibilities of technology and loosening the hold on education to create a compromise where both student and professor can interact and communicate. Emerging technology has placed a wedge between "digital native" students and "digital immigrant" professors. As learning is the central function of all education, active learning tools such as digital games are complementary e-teaching/learning resources that can reduce the gap between the digital native students and the digital immigrant professors providing a more effective, engaging, expanded, student learning environment. Yet "teachers cannot be expected to embrace digital games as a tool for learning unless they have a sound understanding of the game as well as its limitations, and are confident in their ability to use games effectively to enhance learning."²⁶ Thus, the ultimate success of digital games as a medium for learning will depend on their adoption and implementation by teachers.

CONCLUSIONS

This study provides insight that specially designed content-relevant digital games can (1) be used as an additional, e-teaching/learning resource for the teaching

of pathology in undergraduate medical education; (2) improve academic performance on examination test scores; (3) increase student engagement, promote student satisfaction, and reduce student stress; and (4) foster an improved, facilitated, fun, nonthreatening, extended student learning environment. Digital games offer the new generation of teachers an opportunity to mix rich traditional approaches with an authentic modern style, providing dual, traditional and contemporary student-learner experiences.

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Plan now to submit abstracts and case studies for the College of American Pathologists (CAP) 2011 meeting, which will be held September 11th through the 14th in Grapevine, Texas. Submissions for the CAP '11 Abstract Program will be accepted from:

Monday, January 31, 2011 through Friday, April 1, 2011.

Accepted submissions will appear in the September 2011 issue of the *Archives of Pathology & Laboratory Medicine*. Visit the ARCHIVES Web site at www.archivesofpathology.org and also the CAP '11 Web site at www.cap.org/cap11 for additional abstract program information as it becomes available.