Novel Card Games for Learning Radiographic Image Quality and Urologic Imaging in Veterinary Medicine

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ABSTRACT

Second-year veterinary students are often challenged by concepts in veterinary radiology, including the fundamentals of image quality and generation of differential lists. Four card games were developed to provide veterinary students with a supplemental means of learning about radiographic image quality and differential diagnoses in urogenital imaging. Students played these games and completed assessments of their subject knowledge before and after playing. The hypothesis was that playing each game would improve students' understanding of the topic area. For each game, students who played the game performed better on the post-test than students who did not play that game (all $p < .01$). For three of the four games, students who played each respective game demonstrated significant improvement in scores between the pre-test and the post-test ($p < .002$). The majority of students expressed that the games were both helpful and enjoyable. Educationally focused games can help students learn classroom and laboratory material. However, game design is important, as the game using the most passive learning process also demonstrated the weakest results. In addition, based on participants' comments, the games were very useful in improving student engagement in the learning process. Thus, use of games in the classroom and laboratory setting seems to benefit the learning process.

Key words: card game, radiology, artifacts, image quality, urogenital game, radiography game

INTRODUCTION

Instruction in radiology is an important part of the veterinary curriculum as most veterinary practitioners use diagnostic imaging on a daily basis. However, it is the author's experience that veterinary students find various facets of their radiology courses to be particularly challenging. Among these challenges are understanding the factors involved in radiographic image quality and generation of appropriate lists of differential diagnoses for various radiographic findings. When trying to improve students' skills in radiographic diagnosis, approaches to teaching including didactic lecturing, case-based laboratory and clinical rounds sessions, and question-and-answer review sessions can be used, but all of these methods have limitations.

Use of gaming in the classroom has been advocated as a possible method for providing students with another means of learning difficult material. Use of educational games and models in the medical and veterinary educational environment has been evaluated in several studies, although these studies have largely examined video games and computer-based models as learning aids for students.[1,2] Various studies have demonstrated that electronic aids can be used to improve technical skills or knowledge,[3–6] while others have found equivalent results in comparisons of electronic and more traditional forms of learning.[7,8] However, positive results from specific studies may be difficult to apply globally, as development of computer software is time-consuming and requires specific expertise. Commercially available software, such as Microsoft PowerPoint, can reduce some of the challenges of software design in creation of games based on quiz-type game show formats such as *Who Wants to Be a Millionaire* and *Jeopardy!*[9–11] Nonetheless, any software-based learning aid will require that the users (the students) own or have access to the appropriate hardware and that they have sufficient expertise to use the hardware and software.

Using board and card games to supplement more traditional means of learning could improve student learning or recall of course material in the same manner as video games, and use of board and card games could also decrease some of the disadvantages of computer-based learning modules, such as long development time, technical expertise required to produce the learning aids, and specific technological requirements to utilize the aids. Investigators have used card and board games as educational aids in various fields, including software engineering, biology, and chemistry.[12–14] However, there are few studies assessing the utility of board and card games as supplemental educational tools in the health sciences professions. Card and board games for use in

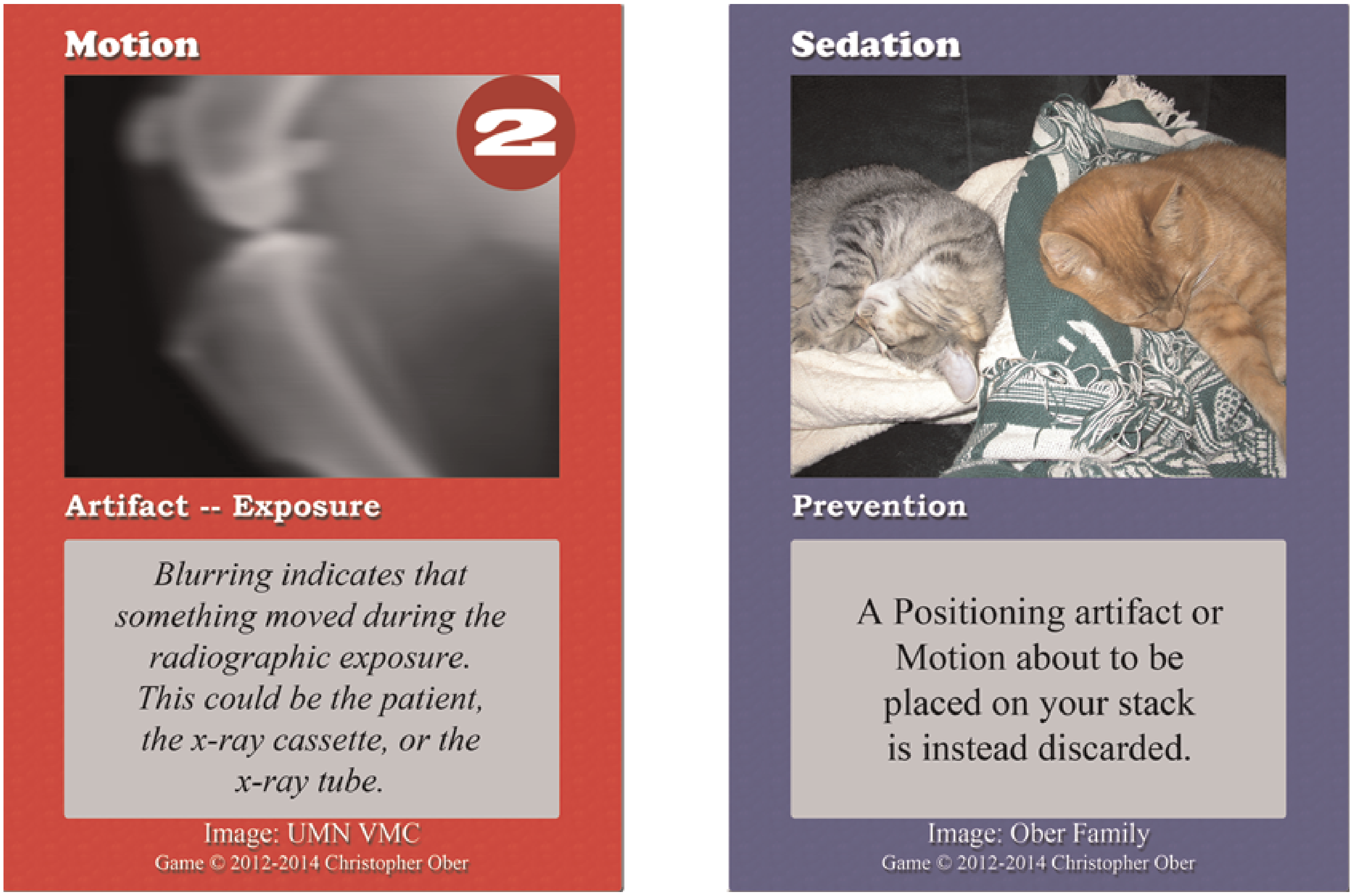

Figure 1: Representative cards from the artifacts game
The card on the left, "Motion," is an artifact card that would be placed in an opponent's play area. The card includes an example image of the artifact as well as a brief description of the cause of the artifact. The card on the right, "Sedation," is a prevention card. As stated in the text on the card, the holder of this card could play it as an opponent was playing either "Motion" or a positioning artifact to prevent that artifact card from being placed in his or her play area.

medical education have been described, but the actual educational benefits of most of these games have not been examined.[15,16] A few card and board games have been demonstrated to improve medical students' test scores immediately after play,[17–20] and participating students generally find educational card and board games to be worthwhile.[3,18,20–22] However, there are no games reported in the field of radiology or in veterinary medical curricula.

The purpose of this study was to assess the utility of card games as an adjunct method for learning the fundamentals of radiographic image quality and differential list generation in a veterinary classroom laboratory environment. The hypotheses were that the card games would improve students' understanding of the concepts covered by the games and that students would find the games to be both enjoyable and useful for their learning.

METHODS

Study Design

The author created four different card games for use in a veterinary class to help teach students various concepts of medical imaging. Two of these games focus on radiographic image quality (artifacts, contrast and blackness), and the other two focus on differential diagnoses for urologic abnormalities (upper urinary tract, lower urinary tract). For each game, participants took a pre-test, played the game, and then took a post-test. The Institutional Review Board of the University of Minnesota granted the study a Category I Exemption for study of an instructional strategy in an educational setting (US federal guidelines 45 CFR Part 46.101[b] category #1).

Game Design

The artifacts card game utilizes cards that represent several different radiographic artifacts. There are also cards representing preventative and corrective measures that can be used to ameliorate the effects of some of the artifacts (Figure 1). In this game, the player's aim is to have the fewest artifacts in his or her play area and to eliminate other players from the game by forcing his or her opponents to collect artifacts up to a certain point value. Each artifact card includes the name of the artifact, a representative image of the artifact, an artifact creation category (such as grid cut-off or manual processing), and

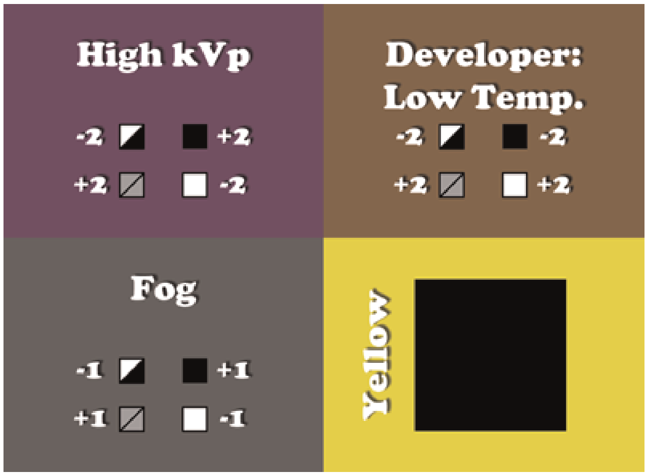

Figure 2: Representative cards from the contrast and blackness game
The cards are placed edge to edge, as in normal game play. The three factor cards have point values correlating with the effects of those factors on contrast and blackness. For example, because increased kVp results in low contrast and increased blackness, the "High kVp" card has a positive value for those conditions and negative values for the opposite conditions (high contrast and decreased blackness). In this case, the Yellow player has placed his or her blackness card adjacent to the three factor cards shown, and currently the blackness card is worth 1 point (the sum of the blackness scores of all orthogonally or diagonally adjacent factor cards).

a point value. Artifacts expected to degrade a radiographic image more severely have higher values; thus, "Pressure Artifact" has a value of 1, and "Overexposure" has a value of 4. Artifact cards also have further explanation text regarding creation of that artifact. Prevention and correction cards are used to eliminate artifact cards from play; many of these can be used to remove only certain classes of artifact (e.g., use of "Automatic Processing" to remove a manual processing artifact). Playing the game consists of players placing artifact cards in their opponents' play areas and using prevention and correction cards to prevent artifact cards from being played in their own play area. The primary educational goal for this game was that students improve their recognition of specific artifacts. Identification of artifact class (mechanism of artifact generation) and means of prevention of the artifacts were considered secondary and less specific aims.

The contrast and blackness game focuses on various factors that affect radiographic contrast and optical density. For the purposes of the game, the term "blackness" has been used instead of "optical density" as the author feels that there is too much opportunity for confusion between the opposing concepts of optical density and radiographic density. The goal in the contrast and blackness game is for players to achieve the highest score by matching general conditions of radiographic quality to factors that produce those states. At the beginning of the game, each player receives four cards representing general states of radiographic quality (high contrast, low contrast, high blackness, low blackness). On each turn of the game, players draw a factor card indicating a condition that influences radiographic contrast and/or blackness (e.g., addition of a grid, increased mAs). Cards are placed on the playing surface edge to edge, in a manner analogous to dominoes. A player receives points when that player's radiographic quality–state card is adjacent to a factor card that produces that state, such as "Increased mAs" adjacent to "Blackness." A participant loses points if his or her radiographic quality–state card is next to a factor card that causes the opposite state, such as "Decreased kVp" adjacent to "Blackness" (Figure 2). Over the course of the game, players must strategically place cards to maximize their own scores and minimize the scores of their opponents. Because each factor card exhibits its own scoring conditions, players are able to learn the interplay among factors and overall quality conditions as they play, without interrupting the flow of play and learning by having to resort to other references.

The intent of the upper urinary tract game is to allow students to learn reasonable differential diagnoses for various radiographic appearances of the kidneys. This game contains two types of cards: radiograph cards, representing different renal appearances (such as "Small Kidney" and "Large & Smooth Kidney"), and disease cards, each of which depicts a disease that affects the kidneys. Each radiograph card is worth several points, and each disease card has a rank associated with it. Players aim to collect as many radiograph card points as possible by correctly matching them with disease cards that cause the given renal appearance. During the game, each player holds seven disease cards in his or her hand. Radiograph cards are then revealed on the table. For each radiograph card, every player places one of his or her disease cards face down as a bid for the radiograph card. The winner of the bid is the person who played a valid disease card (one that can cause the given radiographic appearance) that has the highest rank. The winner of the bid keeps the radiograph card, and players bid on the next radiograph card. This game forces players to consider which diseases can cause different radiographic appearances of the kidneys as only a correct match has the opportunity to score points. An answer guide is provided with the game. Players can choose to use this when they are making their bids (when they are first learning the diseases) or only when verifying the winner of disputes (when they have a better understanding).

Similar to the upper urinary tract game, the goal of the lower urinary tract game is for students to understand differential diagnoses for different appearances of the bladder and urethra, both on survey radiographs and during contrast procedures (cystography and urethrography). In this game, there are three types of cards: survey radiograph cards, representing basic roentgen signs that may be seen on survey radiographs (e.g., mineral opacity, large bladder); contrast procedure cards, with signs that may be identified with a cystogram or urethrogram (e.g., intraluminal filling defect); and disease cards, which are specific disease states that can cause the various findings on the other two types of cards. Each card also has an associated point value that is used in scoring at the end of the game. During the game, players attempt to collect cards worth the largest number of cumulative points by matching disease cards to imaging findings; the person with the most points at the end of the game is the winner. Each player has a hand of five disease cards. In each round, two survey radiograph cards and two contrast procedure cards are revealed. The first player for that turn places one of his or her disease cards on the table and states which survey radiograph or contrast procedure card or cards he or she would like to claim with that disease card. If the disease causes all of the claimed appearances, the player moves all of the claimed cards and the disease card into his or her pile of successful claims. If one or more of those claims is incorrect, however, the disease card is discarded, and the survey radiograph and contrast procedure cards remain on the table. Play then passes to the next player. The round ends when all four of the imaging cards on the table have been claimed successfully. A new round begins with a new first player. The game ends when the survey radiograph and contrast procedure card decks have been exhausted. As in the upper urinary tract game, this game requires students to understand which diseases can cause the various imaging findings, as only correct matches will score points. An answer guide is again provided with the game, and the players can decide among themselves whether it will be used during disease card selection or only during claim verification.

Sampling Size and Sampling Method

Opportunity to play the four games was given to all 99 veterinary students enrolled in the second-year Veterinary Medical Imaging class at the University of Minnesota College of Veterinary Medicine during a single semester. Participation in the study was optional.

As a part of the course, each student attends the following laboratory sessions sequentially through the semester: radiographic physics, upper urinary tract, and lower urinary tract. Each lab occurs after all lectures related to the given topic. The artifacts and contrast and blackness games were available during the radiographic physics lab, the upper urinary tract game during the upper urinary tract lab, and the lower urinary tract game during the lower urinary tract lab.

For the purposes of laboratory assignment, there were two collections of games: Physics (the artifacts game and the contrast and blackness game) and Urinary (the upper urinary tract game and the lower urinary tract game). Students were allowed to form groups as they wished; each group consisted of three to six students, and there were a total of 24 groups for each game collection. At the beginning of the radiographic physics lab, each group was randomized to one of the two Physics games, and at the beginning of the upper urinary tract lab, each group was randomized to one of the two Urinary games. Groups remained the same throughout the activities for the given game collection (pre-test, game playing, post-test).

Each participant took a pre-test related to the game or games available to be played that day. Then each group of participants played its assigned game. Immediately after playing the game, each participant took a post-test and a survey regarding their opinions of the game. (Note that, for the Urinary collection of games, the upper urinary tract and lower urinary tract games were played on different days. Thus, on the day "opposite" a group's assigned game day, the participants in that group did not play a game between taking the pre-test and post-test; see Table 1.)

Data Collection

After randomization of the groups of participants, each participant received one packet containing the pre-test, post-test, and survey. Pre-test questions in a packet were different from the post-test questions in that packet. During each lab session, two possible packet variants were available; the only difference between the two packet types was that the pre-test questions in one packet variant were used as the post-test questions in the other variant (Table 1). Use of different questions between the pre- and post-tests for a given packet prevents students from simply studying for known questions as they play. The use of two different packets and crossover design between pre- and post-test sets of questions removes the possibility that apparent improvement or worsening of scores is because one set of questions is easier than the other. During distribution of packets, when there was an even number of students in a group, equal numbers of the two packets were given to that group. When there was an odd number of students, the packet type with a greater number was assigned on an alternating basis.

Data Analysis

Data were analyzed with commercially available statistical software (JMP 11.0.0, 2013, SAS Institute, Cary, NC). Means and standard deviations were calculated for all pre-test and post-test results for all groups. For each game, a two-tailed paired *t*-test was used to compare pre-test results to post-test results for each packet type. One-way ANOVA procedures were also performed to compare pre-test means among the four groups (packets A and B for those who played a given game, packets A and B for those who did not) and to compare post-test means among the same four groups. When the ANOVA demonstrated significant differences, differences between pairs were assessed with the Tukey–Kramer HSD experimentwise test. Statistical significance for all analyses, defined as the probability of the null hypothesis (e.g., no difference) being true, was set at less than 5% ($p < .05$).

RESULTS

Ninety-eight students participated in the Physics portion of the study (the artifacts game and the contrast and blackness game). Ninety-six students participated in the Urinary portion of the study (the upper urinary tract and lower urinary tract games). All students present in each lab session chose to participate in the study; students who did not participate in a part of the study were absent from the respective laboratory sessions. Groups generally spent approximately 45 to 60 minutes of each 3-hour lab

Table 1: The sequence of events and subdivision of groups playing card games in veterinary medical imaging laboratories

Randomize groups for Physics grouping				
Physics lab	Artifacts game groups		Contrast and blackness game groups	
	Packet A Pre-test 1 Play artifacts game Post-test 2	Packet B Pre-test 2 Play artifacts game Post-test 1	Packet A Pre-test 1 Play C&B game Post-test 2	Packet B Pre-test 2 Play C&B game Post-test 1
Re-randomize groups for Urinary grouping				
Upper urinary lab	Upper urinary tract game groups		Lower urinary tract game groups	
	Packet A Pre-test 3 Play upper urinary game Post-test 4	Packet B Pre-test 4 Play upper urinary game Post-test 3	Packet A Pre-test 3 Post-test 4	Packet B Pre-test 4 Post-test 3
Lower urinary lab	Upper urinary tract game groups		Lower urinary tract game groups	
	Packet A Pre-test 5 Post-test 6	Packet B Pre-test 6 Post-test 5	Packet A Pre-test 5 Play lower urinary game Post-test 6	Packet B Pre-test 6 Play lower urinary game Post-test 5

Note: C&B = contrast and blackness
Events closer to the top of the chart occurred before those closer to the bottom of the chart. Each column represents a set of play groups; each group stayed within its assigned column except during the re-randomization event. Sets of questions (pre-test or post-test) with the same Arabic numeral contain the same questions.

session playing each game and taking the associated pre-test and post-test.

When evaluating responses to artifacts questions, participants who played the artifacts game scored higher on the post-test than those in the respective control groups regardless of testing packet (both $p < 0.01$; see Table 2). Students who played the artifacts game and received test packet B scored higher on the post-test than they did on the pre-test ($p < .001$), but those who received test packet A showed no difference in performance between pre-test and post-test ($p = .21$). Students in the control group (those who played the contrast and blackness game) exhibited no differences in scores between pre-test and post-test ($p = .63$ for packet A, $p = .07$ for packet B). On the pre-tests, participants in artifacts group B scored significantly lower than those in artifacts group A ($p < .001$) and control group A ($p < .001$). Participants in control group B scored lower than those in artifacts group A ($p = .03$).

In regard to contrast and blackness questions, students who played the contrast and blackness game scored higher on the post-test than they did on the pre-test regardless of test packet ($p < .001$ for both subgroups), and participants who played the contrast and blackness game scored higher on the post-test than those in the respective control groups for both test packets (both $p < .001$). Students in the control group (those who played the artifacts game) exhibited no differences in scores between pre-test and post-test (both $p > .45$). There were no differences in scores among pre-tests ($p = .89$).

In assessment of the upper urinary tract questions, students who played the upper urinary tract game scored higher on the post-test than they did on the pre-test regardless of test packet ($p < .002$ for both subgroups; see Table 3). For both packets, participants who played the upper urinary tract game scored higher on the post-test than those in the respective control groups ($p < .001$ for packet A, $p = .006$ for packet B). Students in the control group (those who played the lower urinary tract game) exhibited no differences in scores between pre-test and post-test (both $p > .50$). There were no differences in scores among pre-tests ($p = .08$).

In regard to lower urinary tract questions, participants who played the lower urinary tract game scored higher on the post-test than those in the respective control groups ($p < .001$ for packet A, $p = .006$ for packet B). Students who played the lower urinary tract game scored higher on the post-test than they did on the pre-test regardless of test packet ($p < .001$ for both subgroups). Students in the control group (those who played the upper urinary tract game) exhibited no differences in scores between pre-test and post-test (both $p > .60$). There were no differences in scores among pre-tests ($p = .33$).

Table 2: Mean ± standard deviation values of pre-test and post-test scores for students playing either the artifacts game or the contrast and blackness game

	Artifacts questions		Contrast and blackness questions	
	Pre-test	Post-test	Pre-test	Post-test
Game group A	3.56 ± 0.87	3.80 ± 0.91	4.67 ± 1.83	8.12 ± 1.75
Game group B	2.44 ± 1.04	4.20 ± 0.76	4.68 ± 1.13	8.00 ± 1.48
Control group A	3.17 ± 0.96	3.04 ± 1.20	4.92 ± 1.50	5.04 ± 1.88
Control group B	2.95 ± 0.95	3.36 ± 1.00	4.96 ± 1.93	5.28 ± 1.95

Note: "Game group" represents participants who played the game related to the questions in the given column; "control groups" played the opposite game. A and B designate which packet the group received.

Table 3: Mean ± standard deviation values of pre-test and post-test scores for students playing either the upper urinary tract game or the lower urinary tract game

	Upper urinary questions		Lower urinary questions	
	Pre-test	Post-test	Pre-test	Post-test
Game group A	3.54 ± 1.18	4.50 ± 0.93	3.52 ± 1.38	5.10 ± 0.98
Game group B	3.00 ± 1.02	4.27 ± 1.08	3.19 ± 1.33	4.85 ± 0.82
Control group A	2.83 ± 0.82	2.92 ± 1.32	3.42 ± 1.22	3.42 ± 0.84
Control group B	3.28 ± 0.94	3.40 ± 0.91	3.90 ± 1.37	4.05 ± 1.28

Note: "Game group" represents participants who played the game related to the questions in the given column; "control groups" played the opposite game. A and B designate which packet the group received.

When responding to survey questions for each game, most students stated that they enjoyed the games (from a low of 87.5% for the artifacts game to a high of 100% for the upper urinary tract game). Most students also felt that their knowledge of the respective subjects improved (from a low of 81.2% for the artifacts game to a high of 92.3% for the upper urinary tract game). The majority of the participants indicated that they felt playing the games was a worthwhile activity (from a low of 85.4% for the artifacts game to a high of 100% for the upper urinary tract game).

DISCUSSION

The results of this study indicate that use of card games in a classroom laboratory setting can help improve student understanding of veterinary medical imaging. With respect to all four games, students who played a given game performed better on questions related to that topic than did students who did not play that game. In addition, students who played three of the four games demonstrated clear improvement in their understanding of the respective topics relative to pre-test performances. This improvement is similar to results in several previous studies involving educational board or card games.[17–20]

The purpose in creating the four card games used in this study was not to replace conventional means of teaching and learning. Rather, the games were intended to target specific competencies within the radiology course and to supplement students' learning opportunities. It has been demonstrated that most first-year medical students prefer to have information presented to them in multiple formats,[23] and there is a wide range of preferred learning styles among veterinary students[24]; thus, adding educational games to more conventional teaching methods such as didactic lecturing and case-based study may help many students learn the material. In addition, student motivation to study is also important, and the novelty and competitive setting of games could lead students to become more engaged in the learning process.[15] Indeed, the overwhelmingly positive responses from the participants indicate that students appreciate this form of learning as an addition to their more conventional studies.

The primary focus of the artifacts game was recognition of radiographic artifacts, and techniques to prevent artifacts represented a secondary emphasis of the game. This topic area was chosen for creation of a game because students often have difficulty differentiating various artifacts (such as pressure artifacts and static electricity). In addition, the author's institution routinely receives referred radiographs for interpretation that exhibit several artifacts that go unrecognized and uncorrected by those practices, indicating that many veterinary practitioners may be inadequately trained in recognition and correction of imaging artifacts. In this game, each artifact card features an image of its stated artifact, which provides students with continued exposure to examples of these artifacts as they play the game. Thus, as students play, continued exposure to these images should allow them to become more familiar with the represented artifacts and to improve their ability to recognize the artifacts. This phenomenon is common in players of commercially available games, such as collectible card games, where players are ultimately able to recognize cards by their artwork and do not need to read the card's name or effects once they have recognized the card.[25] In addition, successful play in the artifacts game requires students to identify means of preventing various artifacts. Thus, this game involves several levels of the revised Bloom's Taxonomy[26]: remembering (artifact recognition), understanding (artifact classification), and applying (use of correct preventions for artifacts).

The contrast and blackness game was developed because the author has found that students often struggle to remember and understand the complex interplay among different technical factors and how alterations of those factors result in changes to radiographic appearance and quality. Because most practicing veterinarians do not work directly with radiologic technologists or veterinary technicians with broad radiographic experience, understanding these concepts is critical for a veterinary practitioner as these practitioners will be responsible for quality control. Levels of the revised Bloom's taxonomy[26] encompassed by the contrast and blackness game include remembering (students must recall the effects of specific factors), understanding (factors are classified into groups), and analyzing (organization of factors by effects and evaluating positive and negative effects to achieve a desired outcome).

Both the upper and the lower urinary tract games lead students to consider various differential diagnoses for given radiographic appearances of the kidneys and lower urinary tract, respectively. While generation of an adequate list of differential diagnoses is only one component of image interpretation, it is historically a weakness of many students at the author's institution. It is also a critical part of the interpretative process, as the differential list will help guide the diagnostic or therapeutic plan. Cognitive processes in the revised Bloom's taxonomy[26] used by students playing the two urinary tract games include remembering (recall of pathophysiologic processes), understanding (classification of radiographic patterns and diseases), analyzing (attributing different patterns to disease processes), and evaluating (defending the placement of a given disease card with a specific pattern card).

Although all of the games relate to veterinary medical imaging, it should be noted that two different topic areas were covered by the games. Two of the games related to radiologic physics and image quality, while the other two focused on the more clinically based activity of differential list generation. The fact that games in both of these broad topic areas resulted in improvement in student scores suggests that benefits of games are not necessarily confined to certain subjects, but may be applicable to a wide variety of topics and settings.

The game relating to radiographic artifacts exhibited the weakest results. This may be because it provided a more passive learning situation than the other games did. Although pertinent images of artifacts were present on the cards, the game could be played without focusing attention on those images. This is in contrast to the other three games, in which understanding of the respective educational concepts was required for successful in-game decision making.

A further factor potentially confounding the results from the artifacts game is that the two tests may not have been of equal difficulty. Pre-test scores from both the test and the control groups who had packet B were lower than those who had packet A. Thus, the lack of score differences between pre-test and post-test for game-players with packet A may partially be due to a post-test that was harder than the pre-test. Likewise, some of the improvement identified in the game-playing group with packet B may have been because their post-test was actually easier than their pre-test.

Nonetheless, while the artifacts game did not demonstrate the same positive results as the other games, it should be noted that this game was not detrimental to the students' learning as evaluated with objective measures; it simply did not improve outcomes compared to the conventional case-based laboratory methods.

Additional prospective evaluation will be necessary to determine whether card games remain beneficial to learning in the longer term. Because each student evaluation was performed on the same day as the respective game was played, this study only assesses short-term memory and understanding of the material. Longer-term assessment would be required to examine any potential benefits of games on extended understanding.

CONCLUSION

The results of this study demonstrate that using card games as a supplement to conventional materials is associated with improved understanding of imaging concepts by veterinary students. In addition, veterinary students enjoyed and found value in this method of learning. Thus, continued use of these games in the classroom setting is justified.

CONFLICT OF INTEREST

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