

AN INTERACTIVE GAME APPROACH TO LEARNING IN HISTORICAL GEOLOGY AND PALEONTOLOGY

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ABSTRACT

An interactive game used in conjunction with traditional laboratory work, group discussions, student presentations, and writing exercises, provides an enjoyable and motivating dimension to a university seminar/lab course in Historical Geology and Paleontology. A simple spelling-bee-type game evolves over ten weeks into a room-sized board game based on the geological time scale. The game helps students learn fossil morphology, identification, classification, and paleoecology while illustrating the occurrences of important fossil groups, sea level fluctuations, and orogenic events through time. It also serves as an effective means for evaluating student progress in the laboratory. Although the game content is designed for geology majors in a university setting, the time scale game board can easily be adapted to a secondary school environment.

Keywords: Education - geoscience; education- laboratory; education - precollege; education - testing and evaluation; education - undergraduate; geology; paleontology - general; stratigraphy, historical geology, paleoecology.

INTRODUCTION

For more than 20 years, the Geology Department at Tufts University has taught Historical Geology as an intermediate-level undergraduate mini-course rather than as part of a traditional Physical-Historical introductory sequence. Paleontology has been taught as a stand-alone course or as part of Sedimentology and Stratigraphy. But since half of our Geology and Geological Science majors are now completing second majors in other departments, we have sought ways to combine Historical Geology and Paleontology into a single course.

Since 1995 we have integrated historical topics and a study of the fossil record in a team-taught seminar/lab course in Historical Geology and Paleontology. This one-half credit course (two credit hours) has prerequisites of Physical- and Environmental Geology and typically enrolls 10-12 students. We devote the first of two 1.5 hour weekly meetings to student presentations, group discussions, writing exercises, and graphical presentations of historical concepts, focusing on one chapter in *Evolution of the Earth* by Dott and Prothero (1994). The second class session is a hands-on laboratory study of major fossil groups that are important for understanding the historical development of earth environments and life forms. The interactive game grew out of this laboratory teaching experience.

Our Paleontology laboratories are designed to be self-taught with general guidance and support by the in-

structors. The first half of each lab session involves the study of fossil collections that illustrate and build on homework assigned earlier in the week. Here students apply their home study to the fossil specimens, learning to identify diagnostic parts for classification, attempting to split or lump fossils into realistic groups, and learning to recognize important classes, orders, families, and genera of major phyla. The second half of each lab is an interactive self-test known as "The Game". Each week's game is designed to:

- 1) accelerate and reinforce the learning of fossil morphology, classification, and identification,
- 2) illustrate the occurrences of fossil groups, sea level fluctuations, and tectonic events through geologic time (second half of semester),
- 3) create a high degree of student interaction in the lab,
- 4) provide incentive for home study,
- 5) evaluate student progress in the lab.

We did not set out to design a game that would support our seminar/lab course. Rather, the game grew out of our desire to liven up the labs and address these five goals. It started very simply and was modified and expanded as our students became more interested and involved in the concept. We would not have predicted how well a game would support our course.

PUBLISHED ACCOUNTS OF GEOLOGICAL GAME FORMATS

A mineralogy card game and a board game based on the geologic time scale have been available commercially since 1996 through Ward's Geology catalog (1999). The board game is designed for two to six players and focuses specifically on evolution. It contrasts with our game sequence in several ways. First, we use fossil specimens to promote hands-on learning of paleontology. Our game format changes week to week as more complex rules and new features are added, such as orogenic events and worldwide sea level changes. We also are able to accommodate larger numbers of students and team play with our room-sized, "stand-up" "walk-around" games. Finally, our game sequence is easily adaptable to other fields of specialization in geology.

Using games as a pedagogical tool in geology would seem to be relatively common, but our search of the geological literature yielded very few such examples. Muller (1993) prepared a game specific for an earthquake study module, whereby students analyze "earthquake" data to determine an epicenter. Wright (1972) described a Fortran computer game that deals with natural selection in the

study of speciation and survival concepts. To our knowledge this game has not been revised for Windows or Macintosh platforms.

Many published descriptions of demonstrations and one-time activities - not games - occur in the literature. They are beneficial in communicating concepts and facilitating learning. However, they are a separate type of teaching tool from the interactive, team-oriented games that we present here, which are the framework around which most of the lab work is built.

LABORATORY PREPARATION

We can not overemphasize the importance of student preparation for each laboratory. In order to use the 1.5 hour lab time efficiently, study sheets and reading are assigned earlier in the week that present the factual material and concepts needed to complete the lab. The text *Bringing Fossils to Life* (Prothero, 1998) is a rich source for theoretical and conceptual topics, as well as an overview of the fossil record. In addition, study sheets are used to highlight fossils specific to our labs. It is necessary and required that the students are well-versed in the material on the study sheets by lab time. Knowledge of fossil parts, names, classifications, habitats, time ranges, and other features allows rapid application to the fossil specimens and questions posed in the lab. Without the pre-study, there would not be time during the lab for the interactive game, which also serves as an informal weekly quiz.

A great deal of time is needed to prepare the study sheets in order to include important information without overwhelming the students. This is particularly true for a course such as ours that covers materials for both Historical Geology and Paleontology. We have found that scanned fossil images are often superior to hand drawn illustrations and can easily be posted on a web site for student reference from their rooms. A sample study sheet can be obtained by contacting the authors.

“THE GAME”

The interactive game is actually a series of nine games that progress from very simple to more complex over the course of the semester. Each game is a standup event around large laboratory tables and is designed to keep participants alert, involved, and interacting with one another.

There are no game components in our first two labs on the “Nuts and Bolts of Classification” and Fossil Preservation, or in our last lab on Microfossils. They will not be discussed in detail. The first game is introduced during the third lab period, which for clarity will be called lab 1. Summaries of all game and scoring rules are included in appendices I and II.

Lab 1 Simple Fossil-Bee - This first lab introduces students to the major characteristics of important phyla. It serves both as an overview for later labs and also as background for seminar discussions on the Cambrian explosion and Paleozoic life. During the first half of the lab,

students study labeled groups of fossils illustrating diagnostic features of the major phyla. The simple game for the second half of the lab begins by dividing the students into two teams. Allowing a minute for teams to decide on a creative course-related team name helps initiate a sense of team spirit. Twenty characteristic fossils from the first half of the lab are lined up along a three meter-long table in random order with one team standing on each side of the table. Large “phylum name” cards are placed on the table for reference during this first part of the game. Individual members from each team take turns identifying the phylum of the next fossil in a “spelling-bee” fashion, placing correctly identified specimens on the appropriate phylum cards. Students must also explain the criteria used to place each fossil in a particular phylum. Teams receive one point for each phylum identified but criteria for choosing the phylum are not scored. Members of the opposing team may challenge the identification and receive the point if the challenge is sustained. If no challenge is made, the first team may correct their colleague’s error to preserve the point. This game moves quickly because the specimens are taken from the first half of the laboratory.

After the first group of fossils is correctly identified, 30 unknown specimens are lined up along the table with the game continuing in spelling-bee format. This time the phylum cards are not available for reference. When all fossils have been identified, the team with the highest score “wins”. Winning team members are first to select their “prizes” from a fresh assortment of donuts, but all participants eventually select a prize. (A donut is particularly well appreciated after our 8:00-9:30 am lab.)

This simple game repeatedly reinforces criteria for major Phyla selection, both visually and verbally. The opportunity for challenges and team corrections focuses every student’s attention on each fossil much more intently than during the earlier self-study laboratory exercises. Teams also provide friendly encouragement or consolation during the game. The public nature of the game and the reliance on the individual performances of team members serve as strong motivation for student preparation in following weeks.

Instructors serve as judges and score keepers during the friendly competition and modify rules when there is a strong consensus to do so. We also have the opportunity to observe each student during the game, which allows for a weekly evaluation of individual achievement and progress. Even though the game serves as an informal means of testing, our students always view it as more of a review than a quiz.

Modifications of the Simple Game - Each week the game is modified and expanded to maintain interest and to provide a sense of anticipation. Teams are changed so that students don’t rely heavily on the same leaders. For labs 2 (arthropods), 3 (brachiopods), and 4 (porifera, bryozoa, and trace fossils) the modifications are modest. (Note: Our order of introducing new phyla is designed to support the weekly seminar discussions of the earth’s historical record; the order does not affect the game.)



Figure 1. Bonus card for the arthropod phylum. Scanned fossil images are printed on heavy-weight, 14x21 cm cards that are color coded by phylum. Fossil parts to be identified are highlighted in red (here the glabella is outlined in white). Fifteen to twenty cards are used for each phylum

Lab 2 Bonus Cards - The rules for game # 2 are similar to those in game 1 with the following changes. Five points are awarded to team "A" if their player correctly identifies a fossil (without team help) and states why it belongs in that classification (phylum, sub-phylum, class, and genus where appropriate). If correct, the person selects an arthropod bonus card (Figure 1) and turns it face-up. Three points are awarded to team A if that same member identifies the fossil illustrated on the bonus card as well as the body parts highlighted in red. If correct, that student continues with the bonus question printed at the bottom of the card. Bonus questions cover a wide range of factual and interpretive topics taken from the study packets and reading. One point is awarded for the correct answer to the bonus question. When finished with the turn, the arthropod card goes to the bottom of the bonus card stack.

Team "B" may challenge any answer. If the challenge wins, Team B earns the points but does not continue with the remaining questions on the card; a successful challenge stops the line of questioning. If team B does not challenge an incorrect answer, members of team A may correct their colleague for credit. Again, the correction ends the line of questioning for that fossil or card. We have tried penalties for incorrect challenges, but they tend to inhibit the lively interactions during the team games.

The next member of team B takes their turn even if they just won points challenging Team A. After all fossils have been identified, the points are tallied for each team. One faculty judge and one score keeper monitor the action (and again provide donut prizes).

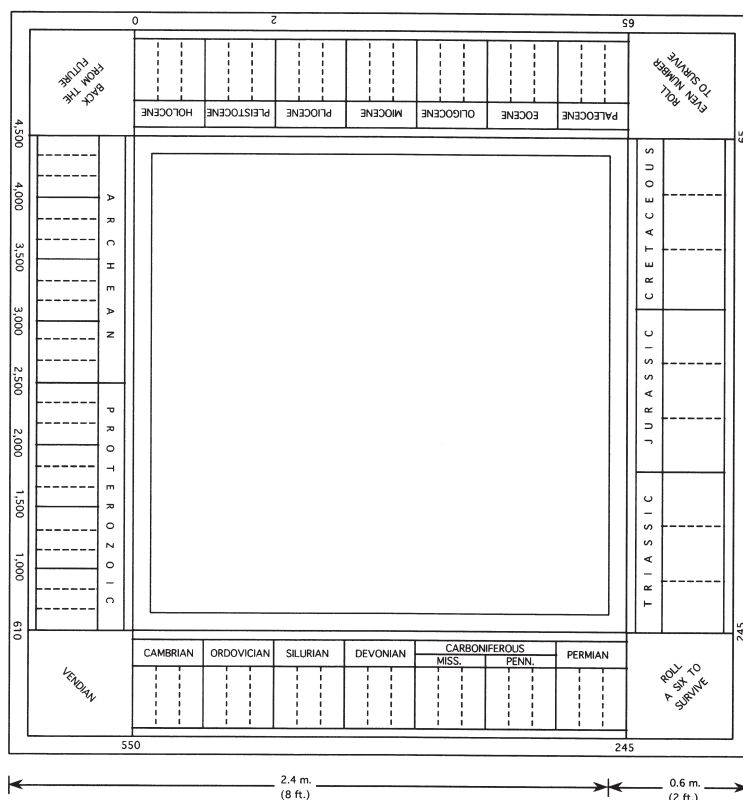


Figure 2. Game board based on the geologic time scale is painted with standard U.S. Geological Survey colors.

Lab 3 Cumulative Unknowns - Rules for the brachiopod game (#3) build on the previous week. This time all game fossils are unknowns, with two thirds of them brachiopods and one third arthropods from the previous week. Two or three "haven't had" fossils are included to be identified by phylum, as in lab 1. A second set of brachiopod cards is used for bonus questions each time a brachiopod is correctly identified. Arthropod cards continue to provide bonus questions for arthropod fossils.

Lab 4 Roll of the Die - Game rules for the combined lab on porifera, bryozoa, and trace fossils are almost identical to those outlined above. In addition, there is a third set of cards with illustrations of and questions about the new fossils for this week. To add a bit of variety, an over-sized die is used to select the next fossil along the line to be identified. For example, if the first student rolls a 3, s/he identifies the third fossil in line on the table. When the turn is over, the fossil is removed from the table. If the student on the opposing team next rolls a 4, s/he identifies the fossil four places further along the line (the seventh fossil). When the roll of the die takes a student beyond the end of the row of fossils, the count continues back at the start of the line of fossils. This pattern is repeated until all fossils have been identified and removed from the table. Using the roll of the die to choose the next fossil helps focus attention on the fossil "in play" by discouraging other players from silently analyzing the next fossil in line.



Figure 3. Game board in action. Each of the 80 specimen trays contains a fossil and a card containing questions with answers on the back.

Lab 5 Teams of Two - After four weeks of team play, attention ebbs while other students are identifying the fossil at hand. To re-involve all students in every identification and bonus question decision, the remaining games are played with pairs of students (one group of three is needed with an odd number of students). Fossils are lined up around the perimeter of a large lab table and students in each pair alternately roll a large die to select the next fossil to be identified. Student pairs move around the table at different rates depending on the roll, and often pass other groups. If too many people are clustered at one part of the table, students are allowed to reverse directions for one or two turns until the impasse clears. Members of the pair take turns identifying fossil unknowns that are displayed in individual specimen trays along with a bonus question card. Important body parts of some fossil unknowns are marked and must also be identified. When a student correctly identifies the fossil and the labeled parts, s/he may then attempt the bonus question. Answers on the back sides of bonus cards decrease the need for arbitration by the instructors. Fossils are not removed after identification but remain to be later identified by the other member of the pair and by members of other student groups. When the die roll brings a player to a fossil s/he successfully identified earlier in the game, that player skips forward to the next unidentified fossil.

In addition to the new fossils for the week (cnidaria), unknowns include examples from all previous labs. Some unknowns are changed each week, but many important fossil types repeat. Fossils and bonus questions repeated from week to week are strongly reinforced. Greater familiarity with the fossils also facilitates the more complex game play in the following weeks.

Each individual has a score card kept by the other member of the pair. Students earn three points for correctly identifying the fossil and any marked body parts, and one point for the bonus question. Any answer may be challenged by the other member of the pair. If the chal-

lenger is correct s/he receives the score for that question. The game ends as the lab period draws to a close. The instructors call time, and collect score cards to determine which team wins (and gets first pick of the donuts). Final rankings are based on the total scores for all members of the group. This equalizes scores for individuals who must work in groups of three and who do not have time to answer as many questions during the game.

Geologic Time Scale Game-Board - A three meter-square (10 ft.-square) geologic time scale is used for the game board in the remaining labs 6-9 (Figures 2, 3). Our prototype is drawn and air-brushed on twelve foam-board panels which take brilliant colors and are easy to handle and store. Standard U.S. Geological Survey colors accentuate each of the time periods and epochs. The game board could also be painted on four 2.4 m. x 0.6 m. (8 ft. x 2 ft.) plywood or press-board panels that would be more durable and much quicker to assemble. A less expensive alternative would be to construct the game from poster-board and colored paper. The board is set up around the perimeter of a three meter-square table cluster. The choice of four equal sides to represent Precambrian, Paleozoic, Mesozoic, and Cenozoic times allows more fossils to be displayed on the recent geological eras than a true-scale representation of time. Our prototype game board uses equal-sized time periods and epochs, each divided into three equal game spaces by dotted lines. Time-proportional dimensions could easily be substituted. During the seminar class meetings, we develop an illustrated, true-scale timeline along an entire wall of the lab, which avoids misconceptions based on the game board proportions of geologic time.

Although the objectives and rules for the remaining games change, they are all based upon fossil identification and the occurrences of life forms through geologic time. Where possible, fossils are placed on the game board time scale during periods appropriate to their occurrence in the

Blast from the Past Hexapod Hotel

A.

CAMBRIAN	ORDOVICIAN	SILURIAN	DEVONIAN	MISS.
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Cephalopod Delicacy Revolution on Earth

B.

CAMBRIAN	ORDOVICIAN	SILURIAN	DEVONIAN	MISS.
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Figure 4A. Riddles and puns as seen on the student work sheet (a highly reduced version of the game board).

Figure 4B. Answers to riddles and puns are written on strips of cardboard and concealed under rows of specimen boxes along the game board. This view is drawn as if the fossils and specimen trays were transparent. Students landing on a space identify the fossil and answer bonus questions contained in that specimen tray. If they answer all parts correctly, they can lift the specimen tray and record the hidden letters on their answer sheet.

geologic record. Fossils used in these games include unknowns from previous labs, along with additional specimens from the new phylum of the week. All unknowns are displayed in individual sample trays with appropriate bonus questions and hidden answers. Approximately 15 minutes are needed to set up the game board and distribute the fossil trays before the beginning of each lab.

Lab 6 Riddles and Puns - The goal of Game 6 (mollusca lab) is to solve a series of riddles and puns related to major historical and paleontological events along the time scale (Figure 4A). The puns and riddle answers are located under the sample trays on the game board (Figure 4B). Students again work in pairs and move around the game according to the roll of a die. When a fossil is correctly identified (phylum, class, order, family, genus where appropriate) and the bonus question is answered, members of the pair are allowed to record the letters found under the specimen tray. These letters provide partial answers to one or more historical riddles and puns. Students record the letters on a 28 cm (11")-square diagram of the game board with appropriate blanks for the hidden letters. The more success students have with the fossils and bonus questions, the more parts of the puns and riddle answers are revealed.

Our riddle answers require 61 fossil trays to cover all of the letter groupings. With this large number of unknowns, the game is most successful if there is at least one hour for identification and the majority of the unknowns

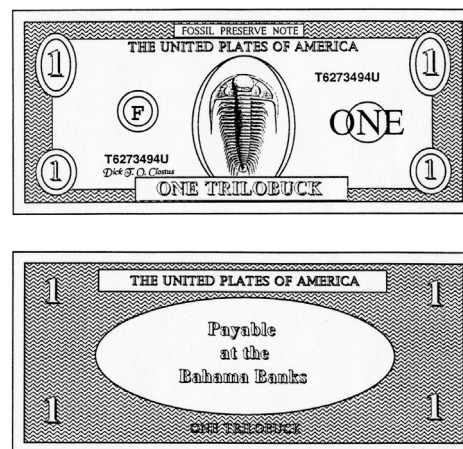


Figure 5. Trilobuck currency minted specifically for our department carries the Tufts University Geology Department phone number as well as an image of a locally occurring trilobite.

have been used in previous games (excluding the "fossils of the week"). For this one lab we also suggest that students do not re-identify fossils previously identified by their partner. This allows students to solve more than half of the riddles during the lab. At the conclusion of the game, the game board answer sheets are collected to measure student progress and also to preserve some of the riddles for the next year's class.

Lab 7 Trilobucks and Extinctions - For our echinoderm lab game and all remaining games, correctly identifying a fossil and its designated parts earns a player one "trilobuck" (Figure 5) from the generous supply placed along the edges of the game board. Correct answers allow the student to try the bonus question, which also is worth one trilobuck. The number of bucks in a player's "wallet" (a legal envelope) at the end of the lab is a rough measure of his/her success in that lab.

The game board is again covered with fossil unknowns arranged on appropriate parts of the time scale, three trays for each time period. The mechanics of die rolling, working in pairs, and moving around the board are similar to game 6 except that the cardboard riddles are not on the game board. The cumulative nature of the game leads to more unknowns than will fit on the Phanerozoic times. As a result, we use open spaces in the Precambrian for review fossils with bonus questions about their actual occurrence in the geologic record.

To add interest, students landing directly on a corner representing the end of the Paleozoic or Mesozoic Era must roll their die to see if they will survive that mass extinction. For the Cretaceous-Tertiary boundary, an even number must be rolled to survive the approximate 50% extinction rate at that time. Players must roll until they survive. In the case of the Permo-Triassic boundary, a "six" must be rolled to survive, simulating an extinction rate of about 84%. Using a 10- or 12-sided die would more realistically represent the Permo-Triassic extinction chances but would take too long to roll the survival num-



Figure 6. Icons representing orogenic periods and sequence/sea level curves are cut from two inch-thick rigid foam insulation using a bandsaw. Our orogenic periods are painted purple and the sequence/sea level curves alternate between light and dark blue.

ber. Each unsuccessful roll requires the forfeit of one trilobuck, with the amount lost noted on the student's wallet. Students quickly become wary of approaching these extinctions on the game board.

LAB 8 OROGENIES AND SEA LEVELS

The final two lab games incorporate orogenic events and interregional sequences defined by sea level changes that have been discussed during the seminar class meetings. Game 8 (chordata lab) continues as in week 7, but with the opportunity to earn additional trilobucks by identifying foam models (icons) representing orogenic periods and sequence/sea level curves, such as the Sauk, Tippecanoe, Kaskaskia, etc. (Figure 6). At the start of the game, these icons are placed name-side down next to the appropriate time periods on the game board. Successful identification of a fossil, its parts, and the bonus question are worth one trilobuck each and qualify a student to name the orogeny and sea level-sequence overlapping that time period. One trilobuck is earned for correctly identifying the orogeny or interregional sequence/sea level curve associated with that time. Thus, four trilobucks may be earned for any one fossil station. As an added incentive, an extra buck is awarded if all four parts of the question are answered correctly. This allows the use of five-trilobuck bills, which decrease the number of "ones" needed to play the game.

One week prior to this lab, an illustration is distributed to students showing the positions of sea level curves and orogenies as they appear along the geological time scale. This helps summarize material discussed over the entire semester and also helps students anticipate how orogenies and sea level curves will wrap around the corners of the game board.

Lab 9 The Final Game - For the final game (plant kingdom lab), students are divided into two teams, one representing the "Mountains" (orogenic events) and the other the "Seas" (sea level curves). Students work in pairs, one member from each of the two teams. The game begins



Figure 7. A member of the "Sea" team places a name card next to a sequence/sea level curve after correctly identifying the: 1) fossil in that tray; 2) bonus question; 3) sequence/sea level (icon here is face-down); and 4) orogenic event (none occur at this game position). When student name cards have been placed next to each end of an icon, that icon is "set up" (tipped-up) into the vertical position. Here, name cards occur next to (in line with) the ends of the "set up" Caledonian-Acadian orogenic icon and the "set up" Tippecanoe icon (name behind right end of this icon not visible). Note the over-sized die and trilobucks along the game board.

with all foam models laying face down along time-appropriate sides of the game board. The goal for each team is to "set up" their team's face-down models through correctly identifying fossils and answering bonus questions along the length of the models. Models in the starting and upright positions can be seen in Figures 3 and 7.

Game rules are identical to game 8 up through earning five trilobucks for correctly answering all questions about a fossil, the orogenic event, and the sea level sequence. Each time this is accomplished, the student places a team card on that game space next to their icon (Figure 7). For example, a person on the Sea team answering all questions correctly would place their team card next to the face-down foam model of the sea level curve. Only one Sea card can be played in any one game space. When the Sea team has name cards next to both ends of a sea level curve segment, the foam model is raised to the vertical position with much fanfare. We found that it took too long to require name cards next to every space along a model. Once a sea level segment is raised into position, exposing the sea level sequence name, members of the opposing Mountain team landing next to any part of this icon must pay two trilobucks to the Sea team member for each incorrect answer at that station. On the other hand, they earn two trilobucks from the board for each correct answer.

Similarly, if a person from the Mountain team correctly answers all four questions at a station, they may put their team card on that board space next to the face-down mountain icon. When Mountain cards are at both ends of an orogenic event, the mountain range icon is raised to the

vertical position. Sea players landing next to the vertical mountain symbol earn two bucks for each correct answer and pay two bucks to the Mountain team for each incorrect answer.

Sea team members should continue to place team cards in empty spaces next to sea level icons even after they have been "uplifted". One measure of a winning team at the end of the game is to determine which one has the most team cards next to their icons. In our game, cards next to the Kaskaskia sea level curve are ignored because there are 11 more board spaces next to sea level icons than occur next to mountain ranges. A second measure of winning is to total all trilobucks earned by each team during the game. Trilobucks lost due to extinctions are included in the team totals, but trilobucks lost due to incorrect answers are not counted.

Although we go through the motions of determining a winning team and allow it first choice from the donut prizes, there are no losers in the game. All students find the game an enjoyable means of learning and reinforcing lab and discussion materials.

DISCUSSION

Our game sequence works exceptionally well with groups of junior and senior students in a university setting. This may be, in part, because the game is the vehicle that facilitates learning rather than the focus of the lab. The game so effectively disguises the reinforcement of fossil identification and historical events that students are disappointed when the lab period ends. We also find that students are intrigued by the evolving format of the game and often enter the lab asking what new twists will be added to the game that week. The close relationship of game materials (fossils, orogenic events, sea level fluctuation, and geologic time) with the readings, discussions, and writing exercises reinforces the overall goals of the seminar course. Three disadvantages to employing a game sequence should be noted: 1. A great time investment is required to prepare the home study guides and game materials. 2. The game requires a significant amount of time in the lab in order to provide significant reinforcement of the newly introduced fossils and the review fossils from previous weeks. 3. Achievement is in public view, which could prove embarrassing for a student with significantly lower ability. This might be avoided by extra outside study.

The level of participation, motivation, and interest in the games and thus the lab work is so high and clearly driven by the games, that we are not willing to try a semester-long experiment without the game format as a control. The dramatic difference in student interaction and interest between our first fossil preservation lab and the following labs ending in interactive games (that serve as informal quizzes) is strong enough evidence for us to continue with this format.

EVALUATION OF GAME EFFECTIVENESS

Although Paleontology and Historical Geology have been taught for over two decades at Tufts, it is only since 1989

that these courses have been formally consolidated into a single half-credit course. This course has been taught six times, in alternating years. For the first three offerings, visiting faculty taught it in a traditional lecture and laboratory format. The last three times, we have presented the course in the seminar and lab game format.

In order to evaluate whether our new incarnation of the course has led to enhanced learning, we have compared the results of course evaluations by students from the "pre-game era" with those enrolled in the game format labs. The course evaluation is a standard form used by every department and for every course at Tufts. Six of the evaluation questions are relevant to our comparison. The questions address how effective the various components of a course are to understanding course material, overall ratings of the course and lab, and how much was learned compared to other courses at Tufts. Table 1 summarizes the overall ratings for the course taught in the traditional way from 1989 to 1993 and for the course taught in the seminar and game format since 1995. The highest possible score is 5.

In every category, students rated the game-format course significantly higher than the traditional-format course. There is clearly positive support from the students for the more interactive approach provided by the game. The numbers of evaluations are modest (28 students for the game-format course, and 19 for the traditional-format course). Yet the uniformly higher ratings given to our new method are strong evidence that this is a very effective teaching tool.

OTHER GAME POSSIBILITIES

There are unlimited modifications that can be made to the game we have described. Just changing the fossils, fossil parts, and bonus questions can transform an easy game into an extremely difficult one, or a factual game into a highly interpretive one. Models of important geologic events (Permian reefs, Silurian salt, initiation of the San Andreas Fault) could be displayed at appropriate times along the game board, each affecting some aspect of the moves. Each student could move a fossil "piece" to show position on the board. As that fossil moved through different times and geological environments, it would have to react to the environments or predators that commonly occurred during those times. The game board corner spaces or specific time periods could contain cards of chance that players must draw when landing on that position. Each of these cards could contain questions or consequences relevant to the fossil involved. A large outline map of North America (or the world) could be set in the empty space at the middle of the game with geologic features keyed to different parts of the game board. Global tectonic reconstructions of the closing of the Iapetus Ocean and the opening of the Atlantic could be distributed around the inside edges of the board and keyed to the game moves. Alternately, the entire game could be built around the development of geological structures and tectonic events through time. Stratigraphic columns from well-known regions could be drawn to scale along the sides of the board

Course Evaluation Criteria	1989-93 Avg.	1995-99 Avg.
Overall evaluation of section or lab	3.0	4.9
Applicability of lab/discussion material to course	3.8	4.9
Contribution of lab/discussion to your understanding of course	3.5	4.8
Overall organization of the course	3.1	4.7
Overall rating of course	3.2	4.8
Compared to other course at Tufts, I learned ____ than usual	3.8	4.5

Table 1. Summary of course evaluation ratings for the Paleontology/Historical Geology course, comparing the traditional teaching style (1989-93) and the game format laboratories (1995-1999). For the first five questions, students select ratings ranging from 5 = excellent to 1 = poor. For the last question (comparing amount learned in the course) choices range from 5 = much more to 1 = much less.

and tied to game play in a stratigraphy-centered game. Students might also learn from helping to create the game. The only limiting factor is that complex rules and logistics decrease the amount of time students spend dealing with the course materials.

SECONDARY SCHOOL APPLICATIONS

Although our game requires a detailed knowledge of fossils and historical events, the geologic time scale game board easily can be adapted to a secondary school program. Such a game could include the appearances of major groups of plants and animals in the geologic record (fish, land plants, trees, insects, etc.) as well as major extinctions and plate tectonic events (K-T boundary, break-up of Pangea, etc.). Other well known geological events could also be incorporated into the game, such as the development of the sedimentary layers in the Grand Canyon, Pleistocene glaciation, or highlights of local geologic events. Developing the game in stages over several weeks keeps the course materials from being overwhelmed by the game logistics and rules.

CONCLUSIONS

Adopting a game component as part of a course in Historical Geology and Paleontology heightens interest and motivation, facilitates learning, and increases student enjoyment of the course. The game sequence, with new and progressively more complex rules each week, adds an element of anticipation, action, and camaraderie to the lab study, seminar discussions, student presentations and writing exercises that comprise the rest of the course. In addition, the game serves as an informal but effective means of evaluating progress with the laboratory and discussion materials. Such a game format could be applied to a wide variety of disciplines, and modified for other age groups.

Descriptions of games in courses, in which there are clearly defined rules and some conclusion with a "winner" or "winning team", are rare in the geological literature. Many accounts of demonstrations and class activities are available, and are valuable dimensions of any course, especially in a lab. However, the game format provides an unusual dimension that our students relish, perhaps in part because they are so much in control of the outcomes of the lab exercises. If they have prepared well for the lab, they and their team will excel in the game, and ultimately, in the course.

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REFERENCES

- Dott, R.H., and Prothero, D.R., 1994, Evolution of the Earth (5th edition): New York, McGraw-Hill, 569 p.
- Muller, E., 1993 Whose fault is it?: The Science Teacher, v. 60, p. 28-33.
- Prothero, D.R., 1998, Bringing Fossils to Life; An Introduction to Paleobiology: New York, McGraw-Hill, 457 p.
- Ward's Geology, 1999, Cinnabar: A Card Game of Rocks and Minerals and Evolution: Geologic Time Chart Game: Rochester, NY, Catalog p. 170 and 183.
- Wright, R.C., 1972, Evoll - A computer based natural selection game: Journal of Geological Education, v. 20, p. 75-77.

Appendix I

Summary of Game Rules

	Games each rule is applied								
	1	2	3	4	5	6	7	8	9
Rules initiated during game #1 "Simple Fossil Bee" (major phyla)									
-students divide into two teams	*	*	*	*					*
-teams line up on each side of long table	*	*	*	*					
-teams alternate identifying phylum of next fossil in row along table	*	*	*	*					
-members of teams take turns in "spelling-bee" format	*	*	*	*					
-faculty serve as judge/referee and score keeper	*	*	*	*					
-large phylum cards on table as aids during first half of game	*								
-students explain criteria for identifying phylum	*								
Rules initiated during game #2 "Bonus Cards" (arthropoda)									
-teams alternate identifying applicable phylum, sub-phylum, class, genus		*	*	*					
-player explains key feature(s) needed to identify fossil		*	*	*	*	*	*	*	*
-correct identification allows student to select bonus card		*	*	*					
-identification of bonus fossil and labeled parts allows try at bonus question		*	*	*					
-successful challenge or incorrect answer ends players turn		*	*	*	*	*	*	*	*
-two or three "haven't had" fossils need only be identified by phylum		*	*	*	*				
Rules initiated during game #3 "Cumulative Unknowns" (brachiopoda)									
-2/3 of unknowns are fossils from current lab, 1/3 come from previous weeks			*	*					
-new set of bonus cards added to game for fossils studied that week			*	*					
-bonus cards for brachiopods used after identification of brachiopod fossil and arthropod bonus cards after identification of arthropod fossil, etc.			*	*					
Rules initiated during game #4 "Roll of the Die" (porifera, bryozoa, trace fossils)									
-large die used to select next fossil for identification				*	*	*	*	*	*
-fossil removed from table after being identified				*					
Rules initiated during game #5 "Teams of Two" (cnidaria)									
-game played with pairs of students (one group of three if an odd number in class)					*	*	*	*	*
-students in each pair alternate identifying fossils placed around perimeter of large lab table					*				
-student pairs move counterclockwise around table unless overcrowding requires one or more groups to take a turn in reverse direction					*	*	*	*	*
-fossils with marked body parts set in trays with small bonus question card					*	*	*	*	*
-fossil classification, body parts, and bonus answers on back of bonus question card					*	*	*	*	*
-correct identification of fossil and marked body parts allows try at bonus question					*	*	*	*	*
-fossil trays remain in same place on table throughout game					*	*	*	*	*
-each player keeps scorecard for other member of the pair					*				
-players bypass fossils they successfully identified earlier in the lab					*	*	*	*	*
-but players identify fossils identified by the other team member earlier in the lab					*		*	*	*
Rules initiated during game #6 "Riddles and Puns" (mollusca)									
-game played on 3-meter square geological time scale game board						*	*	*	*
-students work as team of two attempting to solve riddles and puns on the game board						*			
-solutions to riddles and puns hidden beneath fossil trays on game board						*			
-correctly identifying fossil, marked body parts, and bonus question allow both members of a team to lift tray and record letters concealed beneath tray						*			
-each student carries game board answer sheet for recording letters and solving riddles						*			
-if one member of the team lands on a fossil previously identified by the other member, the fossil is bypassed and the next unidentified fossil (for that team) is chosen						*			
-game board answer sheets collected at end of lab to record student success and to preserve answers						*			
Rules initiated during game #7 "Trilobucks and Extinctions" (echinodermata)									
-where possible, fossils placed on game board in time-appropriate positions							*	*	*
-some review fossil unknowns placed on Precambrian board spaces							*	*	*
-students earn trilobucks for correct identifications and bonus answers							*	*	*
-students landing directly on game board corners that represent mass extinctions must roll a "6" (end of Paleozoic) or an even number (end of Mesozoic) in order to "survive"							*	*	*
-one trilobuck lost for each unsuccessful roll							*	*	*
-trilobucks lost at mass extinctions noted on outside of student's "wallet" (legal envelope) so total number of correct identifications may later be calculated							*	*	*

Appendix I (cont'd)
Summary of Game Rules

	<u>Games each rule is applied</u>								
	1	2	3	4	5	6	7	8	9
Rules initiated during game #8 "Orogenies and Sea Levels" (chordata) (one week prior to this lab, handout distributed showing positions of orogenic periods and sequence/ sea level icons as they appear on geological time scale game board)									
-during game, foam icons of orogenic events and sequence/sea level curves placed face down (so name not visible) on time-appropriate game board positions								*	*
-correct identification of fossil and marked body parts allows try at bonus question								*	*
-correct answer to bonus question allows naming orogenic event and/or sequence/sea level occurring at that game board position for additional trilobucks								*	*
Rules initiated during game #9 "The Final Game" (plant kingdom)									
-students divide into two teams ("Mountains" and "Seas")									*
-two students (one from each team) move around the game board together, alternating rolls of the die									*
-player correctly answering all questions at one board position places name card next to his/her team icon in that game board position									*
-only one "Seas" name card placed next to sequence/sea level icon in any one game space									*
-only one "Mountain" name card placed next to orogenic icon in any one game space									*
-when a "Seas" team name card next to both ends of a sea level curve segment, icon "set up" or raised into the vertical position so name can be read									*
-when "Mountain" team name card next to both ends of a orogenic icon, icon "set up" or raised into the vertical position so name can be read									*
-when a player lands on board position with opposing team icon "set up", each correct answer worth two trilobucks, each incorrect answer costs two trilobucks (paid to opposing player)									*

APPENDIX II

Scoring Guidelines for Game Sequence

Game #1

one point for each phylum identified correctly
 no points for criteria for phylum - although student must state why fossil belongs to the particular phylum
 opposing team may challenge an answer and receive the point if correct. no penalty for incorrect challenges.
 if no challenge from opposing team, the player's team members may correct their player to save the point.

Game #2,3,4

five points for correct identification of fossil and criteria for classification
 three points for correct identification of fossil and marked parts seen on bonus card
 one point for correctly answering bonus question
 opposing team may challenge an answer and receive points if correct.
 if no challenge from opposing team, the player's team members may correct their player to earn the points.

Game #5

three points for correct identification of fossil and marked body parts
 one point for correctly answering bonus question
 opposing player may challenge an answer and receive points if correct

Game #6

point system not used during this game
 letters recorded on student game sheets at end of lab indicate student success at identification and bonus questions

Game #7

one trilobuck earned for identifying both the fossil and the marked body parts
 one trilobuck earned for correctly answering the bonus question
 second member of pair may challenge any answer and receive trilobucks for corrected answer
 one trilobuck lost for each unsuccessful die roll when trying to survive a mass extinction

Game #8

one trilobuck earned for identifying both the fossil and the marked body parts
 one trilobuck earned for correctly answering the bonus question
 one trilobuck earned for correctly identifying orogenic period occurring at that fossil position
 one trilobuck earned for correctly identifying sequence/sea level at that fossil position
 one extra trilobuck earned if all four parts of player's turn answered correctly
 second member of pair may challenge any answer and receive trilobucks for corrected answer
 one trilobuck lost for each unsuccessful die roll when trying to survive a mass extinction

Game #9

all scoring rules of game #8 apply until a game space contains a "set up" icon for one or both teams
 when an opposing team icon is set up next to a player's game space, each correct answer earns two trilobucks from the board and
 incorrect answers cost two trilobucks (payable to the opponent)
 total number of name cards next to icons for each team at end of game gives rough measure of winning
 name cards next to Kaskaskia sea level curve ignored because 11 more game spaces next to sea level icons
 total number of trilobucks earned by each team (including those lost to extinctions) another measure of success