Games in an Introductory Soil Science Course: A Novel Approach for Increasing Student Involvement with Course Material

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ABSTRACT

An optional 1-credit recitation course was developed to supplement a traditionally taught 4-credit lecture-plus-laboratory course in soil science at Oregon State University. Popular, competitive games that would be familiar to students were revised to be "soils-based" and were employed in the recitation class. These games were seen as a potential means to use knowledge in an atypical fashion while at the same time generating enthusiasm for the subject. Evaluation of two terms of games implementation showed that these activities increased both student enthusiasm and, potentially, course performance. A greater percentage of students in the games-oriented recitation reported high enthusiasm for the subject matter than did those in the lecture course (92 vs. 80.5%). Although most students commented favorably on the approach, some did not like the competitive aspect and fast pace. Moreover, those who took the optional recitation scored significantly higher (7.5%) on the final exam for the co-requisite lecture course than those who did not take the optional recitation despite the fact that the overall mean GPA of the two groups was similar ($p = 0.30$). Whether or not the grade increase is specifically due to the use of games or to the additional hour in the classroom was not evaluated. Rather, the purpose of this paper is to present the idea of games as a meaningful complement to more traditional classroom methods, even at the college level.

SCIENCE EDUCATION is being called to task. The need for employees with critical thinking skills is going up, and the number of "science literate" citizens is not keeping pace (AAAS, 1989; Pew Charitable Trusts, 1998; Twigg, 1994). One answer, it seems, lies in "active learning," which is as much an environment as a myriad of techniques (Johnson and Malinowski, 2001/2002). Techniques such as group work (Bull and Clausen, 2000; Klionsky, 2001/2002), investigative activities (Udovic et al., 2002), focused questioning (Klionsky, 1999), and even email communication (Marbach-Ad and Sokolove, 2001/2002) are being used in college science classrooms and early results appear promising (Ebert-May et al., 1997; Haskett, 2001; Lawson et al., 2001/2002; Udovic et al., 2002).

One of the challenges facing faculty who teach large, information-rich classes is to stimulate enthusiasm for the subject material. I teach a traditional introductory soil science course with three lectures plus a 3-hour laboratory each week. The course is required for majors in forestry, horticulture, rangeland resources, and crop and soil science, as well as for some options within the interdisciplinary majors of natural resources and environmental science, and typically has 70 to 100 students per term. I also teach a companion optional recitation course, in which I use various active learning techniques to increase enthusiasm and enhance student performance in the co-requisite lecture course. My focus is on enthusiasm in addition to performance because, as pointed out by Druger (1998), "Our job as teachers is to help students learn. Part of this mission is to teach students to want to learn." I expected student satisfaction to be high in the optional course because (i) it is not required, and (ii) it is based on active participation rather than passive learning. Further, I predicted that those students who took the 1-credit optional recitation course would achieve higher exam scores in the traditional lecture course than those who did not. In this paper I will focus on the use of games as a potential means to enhance enthusiasm and improve performance. Games were played roughly every other week; during alternate weeks we reviewed homework assignments, worked additional quantitative problems, or discussed answers to exam questions.

EXAMPLES AND METHODS

Although "games" and "critical thinking" might not sound like they belong in the same sentence, any activity that encourages students to apply information in an unfamiliar context does much toward furthering real knowledge, and from that, critical thinking can arise. Familiar games with content revised to be "soils-based" allow students to apply knowledge in an unusual fashion while at the same time generating enthusiasm for the subject. Games developed or adapted included New Horizons, Jeopardy, and Pictionary (Table 1 and 2). The examples below worked well for a 50-minute class period, and material needed for game preparation was essentially free.

New Horizons

New Horizons can be played in teams or as individuals and works well early in the term when soil horizonation is covered, although the concept could be applied to other topics. This game in and of itself will likely not last an entire class period, so it is good paired with some time spent going over upcoming homework, or some other activity (e.g., I did this the first week of class, when we needed to spend time going over course policies, taking attendance, and so on).

Preparation. Cards are made with real and imaginary master soil horizon labels, and these are placed into a hat. Another group of cards is made with real and imaginary soil subscripts, which are placed into another hat.

Game Rules. A student picks a card from each of the two separate hats. The student is asked whether the two can be put together to make a meaningful profile, and if so, to describe that profile and relate where it might be found. For example, a student may select *B* and *i*. If the game is played in teams,

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Table 1. Characteristics of the games used in *CSS 306: Problem Solving: Soil Science Applications*, at Oregon State University.

Name of game	Preparation time†	Applicable period	Positive aspects	Limitations or caution
New horizons	15 minutes	After soil horizons are introduced	Relaxes the atmosphere, prepares students to work in small groups	Content-specific, only interesting for 15-20 minutes
Jeopardy	2 hours	Just prior to an exam	Great means to review for exams, reminds students of the breadth of material covered	Some students do not like the competitive or fast- paced nature of the game
Pictionary	15 minutes	Near the end of the term	Everyone participated equally; time pressure to "think" not as high as in Jeopardy	Students must have a reasonable knowledge base of subject matter vocabulary before this is most useful

† Time required for the author (preparation of materials only).

the team members can help the individual who selected the cards. Very early in the term, I recommend not keeping score—rather, making it a group effort. Questioning from the instructor throughout the game will enhance learning beyond just memorizing the horizon labels. For example, "*Bi* does not exist, you are correct. Can you describe what it would look like if it did exist? What properties would it have? What is a real horizon that has properties as similar as possible to those you describe?"

Jeopardy

We played Jeopardy before each of the three exams as a means to review. This requires the largest up-front investment, but once the answer–question pairs are created, they can be re-used for other terms/semesters. Table 2 provides an example set of soils-based question–answer pairs for a round of this game. The pairs are not perfect but are designed to stimulate classroom discussion.

Preparation and Supplies. The game requires chalk or transparencies and appropriate pens, musical instruments, or a variety of noise-makers (e.g., a cow bell, a tambourine, a triangle, clackers, a shaker, etc.), and a list of five questions and answers falling into each of five categories (e.g., soil horizons, factors of soil formation, physical properties). Five question–answer pairs per category, ranked from easiest to most difficult, take about 50 minutes to complete. Note that forming the material into the appropriate pattern can be challenging, and sometimes it is tempting to sacrifice accuracy, so checking the pairs with colleagues is advisable. If you plan to provide the pairs to the students in written form, perhaps a disclaimer is appropriate, noting that these are meant to reinforce concepts rather than being correct "to the letter of the law."

Game Rules. The instructor writes the categories and points (100–500) in columns on the board. Students are asked to form 4- to 5-person teams, to pick a team name, a sound or an instrument (so you can distinguish which team "buzzed in"

Table 2. An example set of question–answer pairs for Soils Jeopardy.

1. Laboratory
   - Q1: What is the Munsell color book?
   - A1: This is a tool used to standardize people's perception of color.
   - Q2: What is loam?
   - A2: A soil composed of a balanced mixture of sand, silt, and clay is generally referred to as this.
   - Q3: What is the clay content?
   - A3: The length of ribbon a soil forms tells you this about the soil.
   - Q4: What is organic matter?
   - A4: Dark colors (low values and chromas) most likely indicate the presence of this.
   - Q5: What are redox features?
   - A5: Iron and manganese concentrations known as concretions or nodules are examples of this.
2. Soil Horizons
   - Q1: What are the O, A, E, B, and C horizons and the R layer?
   - A1: The six master horizons are named with these letters.
   - Q2: What is argillic?
   - A2: This subsurface diagnostic horizon is commonly associated with a Bt horizon.
   - Q3: What is a forest?
   - A3: This vegetative community often is associated with well-drained soils that have O horizons.
   - Q4: What is an E horizon?
   - A4: Bh and Bs horizons are most likely to be found immediately beneath this horizon.
   - Q5: What is saprolite? Or, What is a Cr horizon?
   - A5: This material appears to be soft, weathered rock, and it can be dug with a spade.
3. Factors of Soil Formation
   - Q1: What are climate, organisms, relief, parent material, and time?
   - A1: These are the factors of soil formation.
   - Q2: What is parent material?
   - A2: Glacial till, alluvium, and granitic residuum are examples of this factor of soil formation.
   - Q3: What is topography (aspect, slope)?
   - A3: Soils are wetter at the bottom of a hill than in the middle portion of a hill mainly because of the effect of this factor.
   - Q4: What is vegetation (organisms, biota)?
   - A4: At any given location, Mollisols and Alfisols are distinguished due to this factor.
   - Q5: What is climate?
   - A5: The presence or absence of a near-surface Bk horizon is primarily due to this factor of soil formation.
4. Processes of Soil Formation and the Soil Profile
   - Q1: What is physical weathering?
   - A1: Exfoliation is an example of this.
   - Q2: What is hydration?
   - A2: The chemical weathering process whereby water is added to the structure of a mineral is known as this.
   - Q3: What is hydrolysis?
   - A3: This chemical weathering process splits water molecules.
   - Q4: What is translocation?
   - A4: The movement of materials from one location to another in the soil profile is known as this.
   - Q5: What is Eluviation? (leaching)
   - A5: This process is associated with an E horizon.
5. Soil Taxonomy
   - Q1: What is a Xeralf?
   - A1: This soil is an Alfisol formed under a Mediterranean climate regime.
   - Q2: What is an Aquoll?
   - A2: This is a grassland soil formed in a very wet climate.
   - Q3: What is Ochric?
   - A3: This epipedon (surface diagnostic horizon) is either too light in color or too shallow to meet the conditions necessary for the other common epipedons.
   - Q4: What are Oxisols and Gelisols?
   - A4: These are the only two soil orders not found in Oregon.
   - Q5: What is Great Group?
   - A5: A Calciustert is classified at this taxonomic level.

first), and a team "ringer," who will signal that the team is ready. After deciding which team goes first, the lead team picks the category and point value, then the instructor reads the *answer*, and the team ringer "buzzes in" when team members think they know the *question*. For example, for the category Soil Horizons, an answer might be, "Bh and Bs horizons are mostly likely found in soils of this order." (Question is, "What are Spodosols?"; see Table 2 for further examples.) The team that questioned correctly gets the points and selects the new category and level (e.g., clay mineralogy for 300 points). I found it helpful to cross the points off the appropriate column on the board when selected to keep track of answers that are still available. The team with the most points at the end wins (I give stickers to winning team members). One caution with this game is that it is easy for a group to become dependent on a single team member, who has already started to study for the upcoming exam (or kept up with the course material). Other team members can then feel left out, intimidated, or "feel slow." If there is only one such member in the class, the instructor can ask that student to help keep score or read the answers (leading this game is almost a two-person job). If one group is much better prepared or faster than other groups, I often handicap that group, by blatantly ignoring their "buzz." This must be used with caution, but I have found other groups find it amusing, and if not continued for too long, the winning team will not get angry (unless they lose the lead).

Pictionary

We played Pictionary near the end of the term; it is quite straightforward and little preparation time is needed.

Preparation and Supplies. Make or buy slips of paper or cardboard that are big enough for a single word (3 by 5 index cards are great, but the recycle bin and a paper cutter work fine). Gather a large stack of scratch paper.

Game Rules. Students were given four slips of paper (or index cards) and asked to write a term or concept from the course on each. The instructor should do so as well because many "entries" will not work (do not tell students first what you will do with these words). All entries are collected and placed in a hat. Students are asked to form teams of 4 to 5 students each, and to select the person who will go first. Each team is given a stack of scratch paper. A representative of each team (the "drawer") comes to the hat, one person selects a card, then all drawers decide if it is a term that is possible to illustrate (e.g., *regolith* is easy, but *volumetric water content* is more difficult). Drawers then return to their respective groups, and on a signal from the instructor, each drawer tries to sketch something that will cause team members to guess the appropriate term. Points are assigned to the winning team, and a new drawer for each team comes to the hat. The process continues until time is up or all words are used. We played for 50 minutes and no one appeared ready to quit. Of all the games, this game probably got the most people thinking because there was no obvious advantage inferred to those who had studied prior to class. Further, some terms required actively linking the term to familiar objects or related (but more easily drawn) terms from class (e.g., *wilting point* was illustrated by a student who showed evaporation from a lake, then evapotranspiration from a plant, and finally a plant wilting).

Table 3. Student evaluations of selected aspects of the recitation course compared with all courses taught by the Department of Crop and Soil Science. Mean scores for Fall 2002 and Winter 2003 terms combined.

	Recitation course taught by author†		All courses taught by Crop and Soil Science Dep.	
Evaluation question	Score‡	*n*	Score	*n*
The instructor stimulated enthusiasm for the subject matter of the course	3.92	25	3.61	648
The instructor encouraged me to think for myself	3.79	24	3.60	641
Overall course rating	3.85	NA§	3.59	NA

† TAs taught additional recitation sections. Those scores are not included here.
‡ Score based on 0 (poor or strongly disagree) to 4 (excellent or strongly agree).
§ Not available.

Grading

Grades for the recitation course were based on participation (attendance-based unless there was obvious lack of participation, either 0 or 5 points weekly) and on the homework. The homework assignments were given to all students in the lecture class, but were only *required* of those students taking the recitation. All students were informed multiple times that doing the homework assignments would be good preparation for the exams. An answer key to each homework assignment was posted for *all* students after recitation students turned in their assignments (five assignments, each worth 10 points).

RESULTS AND DISCUSSION

Results of the games experiment were assessed via three mechanisms: (i) instructor observation of the level of participation and enthusiasm, (ii) a student questionnaire, filled out at the end of the term, and (iii) comparison of the mean score on the final exam for the two populations: those who attended recitation, and those who did not.

Although not all games worked equally well, most students got involved and actively participated. In fact, there were several sessions in which students were not ready to leave at the end of the class period—a pleasant change from the all too common shuffling of papers 5 minutes before the end of lecture.

Student questionnaires indicated that 94% of the students who took the recitation course in which games were played were glad they did so. Overall instructor rating on the University-wide evaluation form was 3.85 out of 4.0 for the two terms offered thus far, and 3.92 for enthusiasm (Table 3). Although only 22% of respondents thought games were the most meaningful thing done in the course (working through problems on the board received roughly 75% of the "votes"), 74% said they thought the games helped them learn the material, and 75% (not all the same students) said that the games increased their enthusiasm for the course and the subject matter. On the negative side, about 12% of respondents hated games (Table 4). However, another 12% said the thing they would do to improve the course would be to add more games. One aspect of the games that needs improvement is a means to assure that dominant personalities do not always get priority; structuring game scoring so that each group member contributes should help meet this goal.

The third means to evaluate the effectiveness of games to increase learning was via comparison of the mean score on the

final exam for the two populations: those who took the optional recitation course, and those who did not. The final exam was chosen for the analysis because it is comprehensive and is structured to assess the ability of students to apply the information learned throughout the term to unfamiliar problems. A two-tailed *t*-test of population means (S-Plus statistical software) indicated that students who took the companion recitation course performed significantly better on the final exam than did those students who did not take the recitation (81.4 ± 0.2 vs. 75.8 ± 0.2, respectively; $p = 0.0097$). For all data combined (both terms), it is estimated that taking recitation would give between 1.4 and 9.7 more points on the final exam (95% confidence interval).

It is possible that the mere fact that students who took the optional course were exposed to the material in a formal setting for an additional hour per week explains their higher grade on the final exam. In order to evaluate this hypothesis, recitation sections with and without games could be implemented. However, because maintaining instructor enthusiasm is also critical to promoting student learning, I decided to implement games in all the recitation sections. Thus, I cannot directly evaluate the impact of games themselves on student performance. It is also possible that the students who took the optional course are more motivated and thus "better" students than those who did not take the optional course. The mean overall cumulative GPA for the students who took the recitation was not significantly different from that of students who did not take the recitation ($p = 0.62$), so this is unlikely. Whatever the reason for higher test scores, the fact remains that students rated their enthusiasm for the subject higher when they took the course with games included. I suggest that at the very least, games do not hurt performance and they may improve performance.

Table 4. Selected quotes from student questionnaires regarding the use of games in the classroom.

Positive comments:
"They [the games] made you want to go to class because you would learn something and have social interaction…"
"Playing games was very helpful…it helped us be creative in our thinking."
"I learned a lot of new ideas from these games. It also helped me get to know other people in the class."
"My enthusiasm for the subject increased because we applied everything to games."
"Playing games helped me to think on my feet…"
Negative comments:
"I didn't like the games that much, they seemed like an inefficient use of time."
"I hated Pictionary, because I had to get up in front of class."
"They [the games] did make me think about soils, but the pace was too fast."
"…I don't learn that way. Hard facts or nothin'."
"…the competitiveness just made me feel stupid. Feeling bad is not conducive to learning."

CONCLUSIONS

Games were used in an optional recitation course as a means to inspire student enthusiasm for the course and the subject. Based on the initial two terms, games appear to be a meaningful instrument to enhance both enthusiasm and ability to apply knowledge in an unfamiliar context. The number and variety of games that could be adapted to any particular subject matter is nearly limitless. However, thoughtful application is necessary to encourage those students who feel pressure under competitive situations, with scoring that requires participation by all group members.

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