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7.3 GAMES FOR THE SCIENCE CLASSROOM

CLASSROOM GAMES FOR TEACHING:

Introduction: Many science educators employ games to stimulate interest, promote teamwork, and review curricula.[12] In this section we will discuss the potential uses of classroom games and provide detailed instructions on a variety of games well suited to the secondary school science classroom.

Team Games as a Review for Tests: Teachers often provide review sessions prior to chapter, unit or final examinations, but such endeavors are often inefficient or ineffective because they do not demand students to use those skills that will be required on the examination. Although review sessions are intended to prepare students for examinations, they are often counter-productive since many students postpone studying until the review session in hope that they can determine what will be on the test prior to beginning their own review. Review sessions that simply tell students what will be on the examination, present information in a repetitive manner, or require little student involvement, are ineffective and should be replaced by *active-learning* events. Active-learning events are student-centered activities that require participation rather than mere observation. Researchers have determined that *active-learning* events, such as classroom games are much more effective in promoting student learning than "passive learning" events such as teacher-centered review sessions. In addition, research illustrates that most students prefer active learning events.[3]

Classroom games may be used prior to the end of a curricular unit to help prepare students for examinations. Rather than delaying study until after a review session, students instead must prepare in advance for the team games. If curricular material used in such games is representative of material on the examination, students will be able to determine areas of deficiency and focus on them when they resume preparation for the examination. As in team sports, conscientious team members can apply a healthy dose of peer pressure to ensure that less motivated students prepare in advance.

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Team Composition: Games are most interesting when teams are relatively equal in ability. Fans can be seen to pour out of baseball stadiums during the 7th inning stretch if there is a wide margin between the teams, but most of these same individuals will stay if the score remains close. In a similar manner, students will lose interest if teams are mis-matched in ability and performance. The loosing team has a tendency to give up, and the winning team a tendency to "slack off". For this reason, it is best to arrange teams so that all have roughly equivalent abilities.

Promoting Teamwork: Students often join team sports, not so much for the physical exercise, but for the camaraderie that develops between team members. A team's performance is based upon the dedication and skill of all its members, and as a result, members tend to encourage one another to excel for the collective good of the team. Unfortunately, there are relatively few team activities within the academic arena. In most schools, students compete against one another for grades or class ranking. In such situations, students are generally less likely to support one another for fear that it might "raise the curve." By contrast, classroom team games promote teamwork, a skill and attitude that are invaluable in family life and the working world.

It is generally best to assign students to teams, appoint team captains and allow team members to develop their own team names based upon the subjects they are studying. For example, if you are studying biology, teams may select creative names such as the *Phosphorylators*, the *Catabolists*, the *Craniums* or the *Active Transporters*.

Games as an Effective Classroom Control Tool: We often think of peer pressure as negative, but it can also be a very positive tool, particularly in the realm of classroom management. Students understand that the performance of a team is dependent upon cooperation and the performance of all of its members. If students are told that the disorderly conduct will adversely affect the score of the entire team, then the more conscientious students will be likely to hold their peers accountable for their actions. For example, if a team loses a point for the disorderly conduct of one of their members, the other members will apply pressure on the offending individual so that they don't suffer further from their behavior. If you use this technique, it may be wise to group teams together for other activities in addition to the games. This will allow team members to keep each other "in line" during the time between games. It is suggested that the instructor use a simple clue to remind students of the policy. For example, you may wish to keep an overhead transparency with team names on it. Whenever there is a discipline problem in the class, simply move the transparency to the overhead and students will understand that you are about to subtract points from any team that is out of order. Students will recognize the clue and quickly encourage their team members to come to order. This student-centered technique of classroom management is generally much more effective than common teacher-centered approaches such as raising one's voice or calling on individuals by name.

Scoring/Ranking: Because of the benefits in classroom management that may accompany the use of games, it is generally a good idea to maintain team composition long enough to build camaraderie and accountability. When team organization remains constant throughout a semester, it is possible to develop leagues (different class periods),

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rankings, All-Star games and "Super Bowls". Ranking can be based upon a win/loss record, and/or the cumulative percent of questions answered correctly. Enthusiasm grows when games are well-developed and executed. This enthusiasm can be shared with others not in the class by holding All-Star and Super Bowl contests between different "leagues" (class periods). Such games can be held during lunch break or after school, and may draw crowds of students from outside your class. Many teachers provide extra credit for members of those teams that win games or championships, but experienced teachers find that the need for extra credit as an enticement to study for such events, diminishes as enthusiasm grows. With time, students may be more motivated by the game than by any extra credit points they might earn by winning the game.

Complete Classroom Participation: Benjamin Franklin said "Trouble springs from idleness, and grievous toil from needless ease." Guard against idleness in your classroom, and design your games so all are actively involved in the learning process. Whenever possible, games should involve the entire class and questions or tasks should rotate among the membership. When this is not feasible, ensure that the observing teams are involved in the learning process by requiring them to take notes, rotating questions between all teams at the same time, or by giving team points for tasks related to the contest.

Question database: Students may be capable of contributing questions for each of the games discussed in this section. You may wish to require that your students submit questions , which you may enter them in a database for future use. It is suggested that you use such questions only for classes other than those in which they were written, and only after you have screened them for accuracy and appropriateness. If you maintain them in a computer database file you may print them out in tabular form so they may be cut up and "drawn from a hat."

Judging: It is important that there be a judge (generally the teacher) who rules on all game activities. The judge should be impartial and accurate, and his or her rulings should stand. Grievances should be dealt with after the game and outside of the class time so as not to distract the teacher and the students from the academic tasks at hand.

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SCIENCE JEOPARDY

Internet Resources

- Template for a jeopardy game using the overhead projector
- Template for Jeopardy games using PowerPoint® and a data projector
- Sample Jeopardy files
- Links to Jeopardy resources

Introduction & Purpose: *Science Jeopardy* is a classroom game patterned after the popular television game-show by the same name. In most games, tests, or classroom drills, students are required to provide answers to questions posed by their teachers. In *Science Jeopardy*, however, students create questions to answers provided by teachers. The following example illustrates this difference:

Traditional method: Question first
(Teacher): What biome is found north of the taiga?
(Student): "tundra"

Jeopardy: Answer first
(Teacher):The answer is "tundra"
(Student): "What biome is found north of the taiga?"
(Student): "What cold-weather biome is dominated by grasses?"
(Student): "What biome is found in northern Alaska, Canada, and Russia?"
(Student): "What biome is characterized by permafrost, and short growing seasons?"

Science Jeopardy (figure 1) requires students to generate questions in response to answers, rather than answers in response questions. This technique *discourages the unthinking feedback of rote-memorized "factoids"* and more adequately *assesses comprehension* of the concepts. Teachers and judges should realize that there are generally more than one correct question to an answer as the example above illustrates.

Figure 1 PowerPoint® Jeopardy game board available for download from website. "Ecology for 100 please"

Organization: As with any classroom game, alter the organization and rules to meet the specific needs of your class. The author has found that a team size of 5 works well. Each student should eventually have the opportunity to serve as \team captain. Rotating this position promotes maximum involvement of students in the game.

Rules:

- Beginning: A team is selected to start the game. To lowest ranked team starts first.

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- Selecting Questions: The team captain asks for a particular answer (e.g. "Physics for 300, please"). All teams try to generate a question in response to this answer.
- Time limits: During the first 20 seconds, only the team that made the selection has the opportunity to respond by reading aloud their question.
- Team Captain: The team captain selects an individual to answer the question for the team.
- Scoring: Points are awarded for a well-phrased question that may be answered with the answer given. No points are taken off for incorrect answers, except in "Final Jeopardy". The harder the question, the higher its point value.
- Competing Teams: After 20 seconds have past, other team captains may raise their hands and respond when called upon. If two hands are raised simultaneously, the team that has the lowest score is given priority.
- Selecting Question: The first team with a correct question is given the privilege of choosing the next answer. A team is not allowed the privilege of selecting more than two answers in a row. After that, the lowest scoring team is given that privilege.
- Incorrect Answers: There is no penalty for incorrect questions.
- Terminating Jeopardy and entering Final Jeopardy: Jeopardy can be brought to completion at any time at the discretion of the teacher.: Completion of the first phase leads to *Final Jeopardy*. The teacher announces the category of Fin*al Jeopardy* before point wagers are made.
- Wager Points: In *Final Jeopardy*, each team may wager up to half of their current point total. They must write down their wager on paper before the answer is revealed.
- Final Jeopardy Question. The teacher reads the final jeopardy answer and all teams must write down their questions within the two minutes allotted. Team captains use this time to build consensus and compose the question.
- Final Jeopardy points: If a question is correct, the team receives as many points as wagered, but if the question is incorrect, they lose this number of points.
- Winning: The team with the highest score wins.

Conducting the game: Create a template of answers such as appears in figure 2. The category titles should reflect major subjects within the class you are teaching. For example, if you are teaching a unit in biology on biochemistry, the categories might be: photosynthesis, respiration, metabolism, and kinetics. The template should be prepared on an overhead transparency or on a data file that can be projected using a data projector. If using the overhead, cover the answers with adhesive note paper that can be easily removed when a team selects a particular category and value.

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	BIOLOGY	CHEMISTRY	PHYSICS	EARTH/SPACE SCIENCE
100	Answer: prokaryote *Question: What is a cellular organism that does not posses a definite nucleus?*	Answer: calorie *Question: What is the amount of heat required to raise one gram of water one degree Celsius?*	Answer: E=hf *Question: What is the equation that describes the energy of a photon in terms of the frequency of light?*	Answer: light-year *Question: What is the distance light will travel in a vacuum in one earth-year?*
200	Answer: mutualism *Question: What is the name for a mutually beneficial association between different kinds of organisms?*	Answer: double displacement *Question: What is an ionic reaction in which ion pairs are switched?*	Answer: Capacitance *Question: What is the amount of separated electric charge that can be stored per unit change in electrical potential?*	Answer: Proxima-Centauri *Question: What is the name for the star that is closest to our Sun?*
300	Answer: NADH *Question: What is the reduced from of the coenzyme, nicotinamide adenine dinucleotide?*	Answer: alpha particle *Question: What is a helium nucleus, emitted by some radioactive substances?*	Answer: inverse square law *Question: What law describes the attenuation in radiating forces as a function of distance?*	Answer: Ubmra *Question: What is the part of a shadow or eclipse in which all light is eliminated?*
400	Answer: gibberellic acid *Question:* What are plant hormones that stimulate the growth of stems?	Answer: $1s^2 2s^2 2p^6$ *Question: What is the electron configuration of neon?*	Answer: kg m^2 s^{-2} *Question: What is a unit of energy known as a joule?*	Answer: lateritic soil *Question: What are the leached soils characteristic of the tropics?*
500	Answer: oxidative phosphorylation *Question: What is the process in respiration in which much of the energy in foods is made available to the cell?*	Answer: van der Waals forces *Question: What are relatively weak electric forces that attract neutral molecules to one another in gases and in almost all organic liquids and solids?*	Answer: accelerating anode *Question: What is the electrode in a CRT used to accelerate electrons leaving the cathode?*	Answer: Pulsar *Question: What are cosmic objects that emit extremely regular pulses of radio waves?*

Figure 2 Sample answers and possible correct questions for a Science Jeopardy game.

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SCIENCE TABOO

Internet Resources

- Taboo template for making data cards.
- Sample Taboo files
- Links to dictionary/glossary sites from which you may gather ideas for Taboo terms.
- Game timers (freeware and shareware for timing turns)

Introduction and purpose: The term "taboo" is of Polynesian origin and was introduced into the English language by the English explorer Captain James Cook after visiting the Pacific island of Tonga in 1771. Cook noticed that the Polynesians had many rules, based upon ritualistic distinctions that prohibited certain actions. For example, it was "taboo" (forbidden) to touch chiefs or members of other high social classes, or travel in certain areas of the forest. Taboo® is a game introduced by Milton Bradley® in which players must describe a particular term without using a few taboo (forbidden) words. For example, a player may have to describe the term "gravity" with out mentioning "earth", "apple", "Newton", "attraction", or "fall". If his or her team guesses "gravity" within the allotted time, the team scores.

Science Taboo is a classroom game based upon this Milton Bradley® game. It is designed to test student understanding of scientific concepts. A member of a team draws a card such as one of those that appear below. He or she must explain the bold term at the top without using any of the five taboo terms that appear below it. For example, if the student drew the card "telescope", he or she would have to explain this term in such a way that team-mates would be able to guess it, but without the benefit of the five taboo terms: "star", "astronomer", "observatory"," planet" or "look". This game tests the ability to *explain science concepts in one's own words*. For example, in traditional settings a student can explain that mitochondria are the "powerhouses" of the cell without even knowing what a "powerhouse" is, but in Taboo they can not rely upon the definitions of others, but must convey concepts in their own terms. If , for example, a student is able to explain "mitochondria" to his or her teammates without using "powerhouse" or other taboo terms, then he or she probably has a good understanding of what mitochondria are and what they do.

Sample cards: Figure 3 illustrates some cards that may be used in a game of Science Taboo. The target word is in bold while the taboo terms appear below it in normal font.

(1) Telescope
♦ star
♦ observatory
♦ astronomer
♦ planet
♦ look

(2) Photosynthesis
♦ light
♦ leaves
♦ chlorophyll
♦ green
♦ sunlight

(3) Mitochondria
♦ organelle
♦ powerhouse
♦ cell
♦ ATP
♦ respiration

(4) Convection
♦ heat
♦ rise
♦ cold
♦ dense
♦ sink

Figure 3 Sample cards for Science Taboo. The target terms are in bold font, and the taboo terms are in standard font.

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Sample explanations: The following are sample explanations that students may use to explain the term without using the taboo terms.

1. *Telescope*: This instrument is used to observe distant cosmic objects.
2. *Photosynthesis*: A biochemical process in plants that produce sugars using atmospheric carbon dioxide.
3. *Mitochondria*: This microscopic structure is used to transform chemical energy from sugar molecules into a readily usable energy form.
4. *Convection*: This is a process in which thermal energy is transferred by the movement of a heated fluid.

Rules for Science Taboo

- Teams: Split the class into two or more teams.
- Game play and refereeing: The starting team chooses one student from their team to explain the target term listed at the top of the game card. The student cannot use any of the taboo words listed below this term. The student has one minute to explain as many target terms as his or her team can guess. A referee from the opposite team is chosen to monitor this student to ensure none of the taboo words are used. If any of the taboo words are used, the referee immediately sounds a buzzer , and the remainder of the turn is forfeited. After the one minute turn has expired, the student who has served as referee draws a new term and must explain it to his or her team while a new referee from the other team comes forward to observe. Students serve as referees immediately prior to explaining terms of their own.
- Correct Answer: Team members shout answers in response to the clues given by their representative. The teacher awards points whenever a correct answer is given and immediately gives the team representative a new card unless the one minute turn has expired. No points are given if a team guesses a term after the one minute buzzer. You can download computer-based timers from our website.
- Goal of Game: The goal of the game is to guess as many terms as possible without using any taboo terms.
- Scoring. Three points for a correct term and zero points and loss of turn for using taboo words. One point is subtracted for each term forfeited. The team with the most points at the end of the game wins.
- Passing a term: The student explaining the term has the option to forfeit the word and proceed to the next term. For each term forfeited, one point is deducted from the team's total score. This discourages the passing of difficult terms while encouraging greater thought in the development of explanations.
- Illegal techniques: The student explaining the terms can not say "sounds like" or use physical movements to explain the term. If such actions are used, the team's turn is forfeited.

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SCIENCE BINGO

Internet Resources

- Templates for using Science Bingo on classroom computers
- Sample Science Bingo files
- Science Bingo template for use with an overhead projector

Introduction and Purpose: In secondary school science classrooms, students are asked to memorize large quantities of new terms, many of which are abstract and difficult to understand. To assess student understanding, teachers often ask students to define required terms. Unfortunately, students may be able to memorize definitions and repeat them on tests or quizzes, but have no real understanding of their meaning of significance. To ensure that students truly understand definitions, we encourage teachers to employ Science Bingo or some similar assessment that tests for understanding rather than mere memorization. Unlike the popular Bingo game, *Science Bingo* is based upon skill and understanding rather than chance.

Rules:

- Playing board: Students are given a blank five cell by five cell grid and a list of vocabulary terms.
- Filling the Grid: Students fill in the grid using the terms, using only one term per square and no repeated terms. As in the example that follows, the teacher may chose to have more than 25 terms, providing an element of choice and greater variation between student playing cards.
- Definitions: The teacher gives the number of the clue followed by the definition. For example, if the first term to be identified is "*cellulose*", the teacher should say, "Number One: A complex polysaccharide that is the basic structural component of plant cell walls."
- Identifying terms: When students hear a definition and associate it with a term on the grid, they put the clue number in the appropriate cell.
- Winning: Students yell "Bingo!" when they have identified 5 terms in a row, column, or diagonal line. The teacher must look at the student card to ensure that the numbers associated with the terms in their "Bingo" row or column match the numbers of the definitions read. It is generally wise to continue playing until at least four or five students have finished.

Sample card: Figure 4 is a sample card showing how a student might mark the card in response to the definitions read by the teacher. Each student selects any 25 of the following 30 words and writes one word in each of the 25 boxes. This sample shows that a "Bingo" was achieved in the third row after reading the eighteenth definition.

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Defitintions

The teacher reads the number and the defition. the student associates it with the appropriate terms on the card

1	torr	a unit of pressure equal to 1 mg Hg
2	taiga	boreal forest, subarctic coniferous forest
3	gizzard	chamber of bird digestive tract specialized for grinding food
4	diamond	colorless form of carbon with extremely high density
5	diode	used as a rectifier in electrical circuits
6	dielectric	electric insulator; a nonconductor of direct electric current
7	endothermic	energy consuming process
8	zygote	fertilized egg
9	glycogen	glucose monomer that stores energy in animals
10	homozygous	having two copies of the same allele of a given gene
11	synapse	junction between two neurons
12	absolute zero	theoretical temperature at which there is an absence of heat
13	mesoderm	the middle of the three primary germ layers of an embryo
14	precession	slow gyration of the rotation axis of a spinning body
15	vector	animal that transmits a pathogen
16	enzyme	organic catalyst for biochemical reactions
17	electron	particle with resting mass of 9 x 10-31 kg
18	cellulose	polysaccharide that is the main building material for plants

Note that Bingo has been reached by the reading of the 18th definition

19	*anode*	*positive electrode*
20	*impulse*	*product of force and the time interval over which it acts*
21	*impedance*	*ratio of effective voltage to effective current in an ac circuit*
22	*halite*	*rock salt, mined extensively throughout the world*
23	*olfaction*	*sense of smell*
24	*monocot*	*subclass of angiosperms characterized by parallel venation*
25	*commensalism*	*symbiosis in which one benefits and the other is unharmed*
26	*energy*	*the capacity for doing work*

absolute zero **12**	anode	ductility	gizzard **3**	joule
homo-zygous **10**	impulse	taiga **2**	energy	diamond **4**
cellulose **18**	glycogen **9**	diode **5**	mesoderm **13**	torr **1**
		Bingo		
codon	electron **17**	halite	monocot	zygote **8**
vector **15**	ampere	dielectric **6**	enzyme **16**	synapse **11**

Possible Terms

Student fills in blank table with 25 words of his or her choice from this list. Download templates from the website.

bsolute zero
allotrope
ampere
anode
cellulose
codon
commensalism
diamond
dielectric
diode
ductility
electron
endothermic
energy
enzyme
gizzard
glycogen
halite
homozygous
impedance
impulse
joule
mesoderm
monocot
olfaction
precession
synapse
taiga
torr
zygote

Figure 4 Sample Science Bingo game. Templates are available for download on the web.

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SCIENCE PICTONARY:

Internet Resources

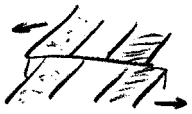
- Templates for using on the classroom computer
- Sample Pictionary files
- Game timers (freeware and shareware for timing turns)

Introduction and Purpose: It has been said that "a picture is worth a thousand words", and yet many educators do not take full advantage of diagrams and drawings in their instruction. Winn and Holiday[4] summarized the benefits of using diagrams in instruction as follows: "(1) diagrams help learners because they direct attention to important information, replacing critical verbal information with graphic devices such as lines and arrows; (2) diagrams help low-verbal learners overcome some of their difficulty with language by providing information in a form they can handle more easily; (3) through the use of normal left-right, top-bottom layout, arrows and other graphic devices, diagrams can teach sequences of events effectively; [and] (4) the addition of study questions to diagrams helps learners by directing their attention to critical information." Students, as well as teachers, need to develop the skill of diagramming concepts rather than simply copying those developed by others.

Science Pictionary is patterned after the popular party game invented by Pictionary Incorporated® in which team members need to communicate concepts and terms only through drawings that do not use standard letters, numbers, or other common symbols. A student generally has a good understanding of a concept by the time they can diagram it a way that others can recognize and/or understand the concept without the use of written or spoken words. This game is designed to encourage students Figure 6 illustrates some sample science Pictionary drawings and the terms they describe.

greenhouse effect

atherosclerosis



strike-slip fault

osmosis

Figure 5 Sample Science Pictionary drawings

Rules:

- The class is divided into teams and captains are assigned or elected.
- The team captain determines the sequence in which students from his or her team will go to the blackboard, whiteboard or overhead projector.
- When a student comes up to the overhead or blackboard, he or she is given a term which must be represented in diagrammatic or pictorial form.
- The student may not say anything, make any gestures, nor draw any letters or common symbols, other than arrows.
- As the student draws, his or her team members shout out terms they think the diagram represents.

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- If they are correct, their team is awarded a number of points equivalent to the number of seconds elapsed since the student began.
- If the student's team has not guessed the term correctly after 60 seconds they get 60 points and the other team(s) is given 10 seconds to guess the term. If the second team is correct, 15 points are subtracted from their score.
- A student may pass a difficult term for a 10 second (10 point) penalty.
- The instructor determines an appropriate number of questions for the game.
- The team with the fewest points (least time to communicate concepts through drawing) at the end of the game wins.

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SCIENCE BOWL

Internet Resources

- Links to "Science Bowl" sites
- Game timers (freeware and shareware for timing turns)
- Links to College Bowl and High School Bowl
- Spreadsheet template for ranking

Introduction: Since 1953 the College Bowl Company, Inc. has been producing *College Bowl* as a live event for television and radio. More recently, the company introduced *High School Bowl* and international versions of *College Bowl*. The company has received an Emmy, as well as Congressional and Presidential Citations for their efforts in promoting academics through the popular media. On our website you will find links to the College Bowl Company where you can read official rules and learn how your school may participate in state or national competition. In addition, you will find links to other competitions such as the U.S. Department of Energy's Science Bowl . We encourage you to visit these sites to get additional ideas and see sample questions. In this book we offer a modified version of this popular academic game. If executed well, this game can be used to stimulate learning and enthusiasm for the subject while promoting class spirit. Science Bowl has been enthusiastically received by students from basic to Advanced Placement courses. The instructor plays the role of a game show host and sports announcer, emceeing the game and building enthusiasm through "play by play" analysis. This activity assesses *knowledge and comprehension of scientific facts,* and may be used prior to examinations so students have basic facts before they encounter higher order questions on the examinations.

Rules:

Team size: This game can be conducted with teams of any size, depending upon the needs and the time available. If you have an entire class period, you may wish to have numerous small teams and run three or four games. If, however, you have less than a half hour, it is perhaps better to split the class in two and conduct just one game. It is suggested that you keep team composition the same for at least a semester to allow for the development of team discipline and rivalry.

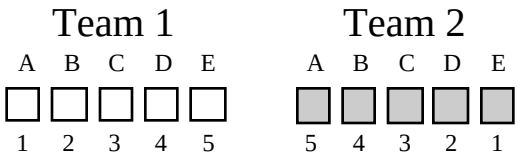

Figure 6 When working with small teams, give each student a number and a letter such that no two people have the same coordinates. Note that a question posed to "As" will produce a different match than one posed to "1's:.

Assigning teams: When assigning students to teams, keep in mind that games are much more interesting to watch and play if the teams are well-matched, and therefore make teams as equal as possible. Each member should be assigned a number and a letter as shown in figure 6. Please note that the numbering and lettering are done in such a manner so that no two students have the same coordinates. Figure 7 illustrates how to arrange students in larger groups so that you can better match scores to keep the games more competitive. Students loose heart or motivation if teams are excessively mismatched, and this type of student arrangement will allow you to keep the scores closer. For example, if team 1 is behind, the teacher might ask questions of As, favoring team 1. By contrast, if

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Team 2 is behind, the teacher might ask questions of 3s, thereby favoring team 2. Do not disclose the logic in your seating arrangement to students.

- Questions: *Designated Questions (one point)* When the teacher calls "C", only those students with a C designation can answer. Similarly, when the instructor calls "threes" only those with a designation of 3 can answer. Sometimes two or more sets can be identified, such as "Ones and D's". If no one answers the question in the allotted time (generally 10 seconds), you can open it up to other combinations. Students will remain alert if there is always a chance of their number or letter being called. *Toss-Up Questions*: (one point) These questions can be answered by any team member. *Team Questions* : (three points) The time limit should be tripled (30 seconds) for these questions because they require consultation. They are more difficult or multi-part questions and must be answered by the team captain or his or her designee after consensus has been reached.

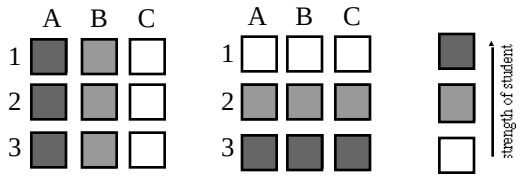

Figure 7 Coordinates for students allow the teacher greater flexibility when asking questions and can help him or her prevent "runaway" games.

- Scoring: The first eligible student to raise their hand or press the buzzer after the question has been asked must answer the question. If the student raises his or her hand before the question has been completed, they must answer immediately, without the benefit of whatever else might have been said. If they are correct, their team scores and the teacher poses another question. If they are incorrect, the other team is given five seconds to respond. There are no penalties for wrong answers. If you raise your hand or hit the buzzer when it is not your turn, it will be an automatic forfeit of your right to answer the question, and the other team will then have the opportunity to answer the question unopposed.
- Ranking: Teams will be ranked on the basis of two crucial criteria. The first, and most important, is their win/loss record. If two teams have identical win/loss records, however, their rankings will then be based upon the total percentage of points that their team has earned throughout the year. To obtain this value, divide the points earned by the team in all of its games by the sum of points earned by that team and the teams it played during this period. The win/loss record is the most important, but if two teams have the same win-loss record, they shall be ranked on the total percentage of the points earned.
- Special Awards: Although this game is designed as a team sport, you may wish to record individual scores for each game and award most valuable player MVP) status with extra credit points for those students who have played exceptionally well.
- Special Games: If you have multiple sections of a class, you may wish to hold "All Star" or "Super Bowl" games in which you pit the best students or team from one class versus the best students or team from another. These games can be held at lunch break or after school. When held in a public place like the

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gymnasium or quad, such games may prove to be good for public relations, building interest in your class among future students.

SCIENCE BASEBALL

Internet Resources

- Transparency master for use in the classroom
- Links to related resources

Introduction: Although classes generally display a wide range of abilities, most teachers do not have the tools to individualize instruction, assessment or games to meet the specific needs of their students. Students of all ability levels are asked to perform the same tasks and are assessed on the same instruments. Science baseball, unlike most of the other games mentioned in this chapter, allows students the freedom to select the level of difficulty of the question asked, thereby providing a degree of individualization. Students will be enthusiastic if the teacher is enthusiastic. A teacher who comes to class in umpire's shirt, calls out scores like a baseball announcer, decorates the room with baseball photographs, and has teams make their own pennants, is likely to have much greater success than a teacher who does none of the above. Enthusiasm is contagious, but so is apathy.

Rules:

- Question database: Develop a set of questions and categorize them in four groups (singles, doubles, triples and home runs) according to difficulty.
- Recording play: Download the baseball diamond graphic from the website (figure 8) and project it from a data projector or make a transparency of it in your printer and project it from an overhead projector. Alternatively, you may draw a diamond on the board.
- Line-ups: Split your class in two teams and determine a "line-up" sequence for each or appoint team captains and allow them to determine the line-ups for their teams. Each student "comes to bat" according to his or her position in the lineup, and may select a random question from one of the four groups (singles are easiest and home runs are most difficult).
- Scoring If the student answers the question correctly, then the instructor writes his or her initials on the appropriate base. Each wrong answer is an out and each team is allowed three outs before their opponents come to bat. The game is

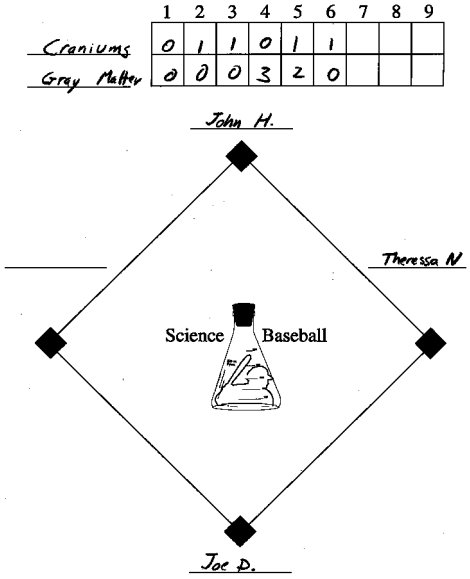

Figure 8 Science Baseball template. "Four to five in the top of the seventh."

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scored like baseball, with points given for each “runner” who crosses home plate. You can play as many innings as time permits.

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WHAT IN THE WORLD?

Internet Resources

- Links to numerous graphic databases of scientific images
- Sample "What in the World?" game in PowerPoint®
- Fair use laws for graphics

Introduction: Science instruction generally involves numerous diagrams and pictures, and teachers often assess their students' understanding of such graphic information. For example, students in an anatomy class may be asked to label all of the organs illustrated on a given diagram. Unfortunately, such tests are often more an indicator of a student's ability to memorize a particular graphic than they are an indicator of the student's understanding of the principles or structures involved. For example, a student may be able to accurately label all of the bones of a body on a blank diagram identical to the one in the textbook from which he or she studied, but unable to identify them in a picture taken from a different text.

Students need to learn to identify salient features in the objects studied so that they can develop a general understanding that will allow them to recognize and identify the same objects in different settings. For example, a student who truly understands the anatomy of the femur will not only be able to identify it on a the diagram from which he studied, but also from photos taken from different angles and diagrams drawn from different perspectives. In addition, he will be able to locate the bone on himself, or identify it from a model when blindfolded.

It is the teacher's responsibility to stress the significant features of the objects studied, and provide a rich learning environment in which the student will be exposed to examples from a variety of sources. "What in the World?" is a game that requires students to identify familiar objects in unfamiliar views, and thereby assesses their ability to *generalize, transfer, and extrapolate (figure 9).*

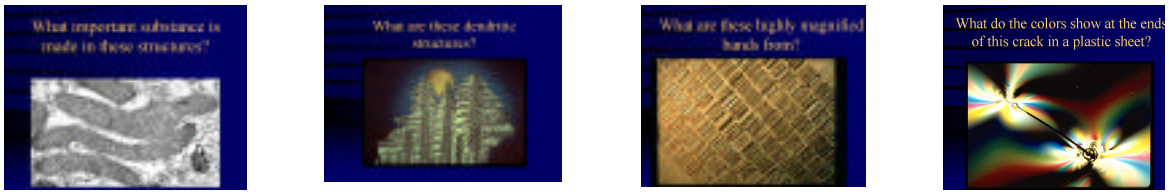

Figure 9 Sample questions from "Where in the World?" game.

Select a series of images of objects related to your lesson using the graphic databases and graphic search engines linked from the website. To encourage the development of transference skills (the ability to recognize similar features in dissimilar environments) select images that portray the objects of interest from new perspectives. For example, if your textbook illustrates chloroplasts diagrammatically, then obtain images of chloroplasts taken with a scanning or transmission electron microscope. In order to identify such novel images of familiar objects, the student must be able to differentiate between relevant and irrelevant information. Although the diagram in the book may show the chloroplast as a green structure, the micrograph from a transmission electron microscope will display it in black and white. The student must recognize that color is not a key feature in this situation because transmission electron microscopes use electrons, rather than light, to create images. Similarly, the diagram in the text may

present the chloroplast in a three dimensional manner, while the micrograph shows only a thin section through the center of the organelle. The student must therefore look for distinctive features such as the grana stacks that will appear in both a diagram and a micrograph.

This game can also be used to develop extrapolation skills, the ability to get the "big picture" from small pictures. Using the internet search engines and databases listed on the website, select some large graphics of things that students have studied. Using a graphic editing program, select a close up view of just a portion of the image and incorporate this into your game file. For example, if you have been studying fruit flies, select just the compound eye of the fly and see if students can extrapolate from this to identify its source.

Building a graphic database: Locate and download images to your personal computer and reference their sources as outlined on the website. Copy and paste these graphics in an appropriate sequence into a word processor file or a presentation manager file (e.g. PowerPoint®). More specific instructions and sample files may be found on the website.

If you do not have a computer data projector, or are unable to make overhead transparencies, you may wish to make a set of slides using 35 mm slide film. You do not need to be a great photographer to develop a good slide collection. You do, however, have to have access to a good source of photographs. There are many excellent sources of photographs including such journals as *National Geographic*, *Natural History*, and *Audubon* as well as many photographic works such as anatomy or botanical atlases. While you may photograph a single copy of an image for your own use, you may not duplicate or sell your collection due to copyright laws. Give proper credit to the photographers and publishers of the works your photograph.

To produce a 35 mm slide collection, it is necessary to have a camera which has macro capabilities. Some cameras come equipped with macro lenses which will focus to within 10 cm of the object being photographed. If you do not have such a lens, but you do have a single lens reflex camera, you have a variety of options at your disposal including bellows, close-up rings, close up filters, or macro lenses. Close-up filters generally are sold in sets of 3. By using different combinations on the front of the lens, you will be able to focus quite close to the picture you are photographing. Close-up rings are hollow tubes which are placed behind the lens in such a way that they allow you to focus substantially closer. Bellows are also placed behind the lens, and but provide for a continuous "zoom" so that you may create a wide variety of field sizes. A slow (e.g. ASA 100), low grain film gives excellent results if you have good lighting and a steady camera. If camera motion is a potential problem, or lighting conditions are not very good, use a faster film such as ASA 400 or higher. Take pictures outside where light intensity is high. Make certain that there is no glare in the viewfinder when focusing the lens. If there is glare in the viewfinder it will also appear on your slide! Hold down the pages of the book that you are copying from so that the entire image is flat. Do not shoot pictures at less than 1/60th of a second or slight camera motion may blur your pictures. Although a tripod is desirable, it is possible to gain sufficient stability by resting your arms upon the seats of two opposing chairs. Focus your lens in such a way that the image fills the entire screen. Some digital cameras have macro capability, allowing you to make a digital file that will be much more versatile than film.

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Rules:

- Teams: Divide the class into two or more teams and assign a team captain to each. The team captain will be responsible for building consensus among team members when they are asked to identify features of a novel image.
- Team conferences: Present the images using the data projector or overhead. Ask the first team in the lineup to identify specific features illustrated. Provide a set amount of time for the team members to share their ideas and build consensus. The team captain must build consensus among his or her team and then appoint a member to answer the question on behalf of the team.
- Scoring: If the team gets the answer right, they score one point and the next team in line is given the opportunity to answer a new question. If the team is incorrect, the next team is given the same question, thereby ensuring that all teams will pay attention, even when they are not "at bat." After giving each team an equal number of questions, the highest scoring team will be considered the winner.

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TWENTY-ONE QUESTIONS

Internet Resources

- Template for Twenty-one Questions or a Dichotomous Keys
- Sample dichotomous keys

Introduction: A dichotomous key (figure 10) is a tool for classifying organisms, rocks, or other natural items. The key asks dichotomous questions -- questions in which there are only two possible responses. After answering a series of dichotomous questions and following the appropriate directions, the object is "keyed out" or classified. Figure 11 illustrates a simplified dichotomous key used for identifying a few common beans used in cooking.

A. Bean elliptical or oblong	Go to B
B. Bean has dark pigments	Go to C
C. Bean color is solid	Go to D
C. Bean color is mottled	**Pinto bean**
D. Bean is black	**Black bean**
D. Bean is reddish-brown	**Kidney bean**
B. Bean is white	**White northern**
A. Bean is round	**Garbanzo bean**

Figure 10 A simple dichotomous key for classifying beans used in cooking

Taxonomists classify organisms according to common characteristics. Figure 11 illustrates the classification of the magnolia, a broadleaf tree common to the southeastern United States. Each level in the classification can be reached by asking a set of specific questions in a similar fashion to that illustrated above. It should be noted that the word endings (see underlined portions) are generally associated with the level of classification. For example, Rosaceae can only refer to a family because of the "*aceae*" ending.

Classifications (plant kingdom)	Classification of *Magnolia grandiflora*, a tree common in the Southeastern United States
Kingdom	Plantae--includes all plants
Division	Magnoliophyta--flowering plants
Class	Magnoliopsida--dicots
Subclass	Magnoliidae--subclass for Magnolia-like plants
Order	Magnoliales--order for Magnolia-like plants
Family	Magnoliaceae--family for Magnolia-like plants
Genus	Magnolia--genus that includes all
Species	Magnolia grandiflora--specific epithet

Figure 11 Classification of Magnolia grandiflora

Classification is extremely important in science, and yet not all classification schemes are equally valuable. A popular folk game named "Twenty-One Questions" can provide an

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excellent introduction to the concept of dichotomous keying and *illustrate the importance of asking good questions in a logical fashion* when developing a *taxonomic key.*

Rules:

- Target: The teacher thinks of a relevant item (e.g. a specific concept, plant, animal, rock, etc.).
- Questioning: Students try to determine what the teacher is thinking about by asking him "yes" or "no" questions. Since every question must be answered with a "yes" or "no", students are effectively classifying the mystery item using a dichotomous key. Many students will try to circumvent the keying process and immediately guess a specific item. Each time they do this, they waste a question, and since only 21 questions are allowed, they decrease their chances of determining the unknown
- Developing a dichotomous key: With time, students should learn that dichotomous keys work best when each question divides the remaining domain into two approximately equal sub-domains. If each question splits the remaining domain exactly in half, then the number of items that can be keyed out will increase as a power of 2. One dichotomous question can key out two items (2^1), two questions can key out 4 items (2^2), three questions can key out 8 items (2^3), and so on. Theoretically, one can key out 2^{21} items (2,097,152) with twenty-one dichotomous questions. In reality, the number is much smaller because it is difficult to divide the remaining domains exactly in half. None-the-less, the process shows how the dichotomous key is a powerful tool for classifying a large set of objects.

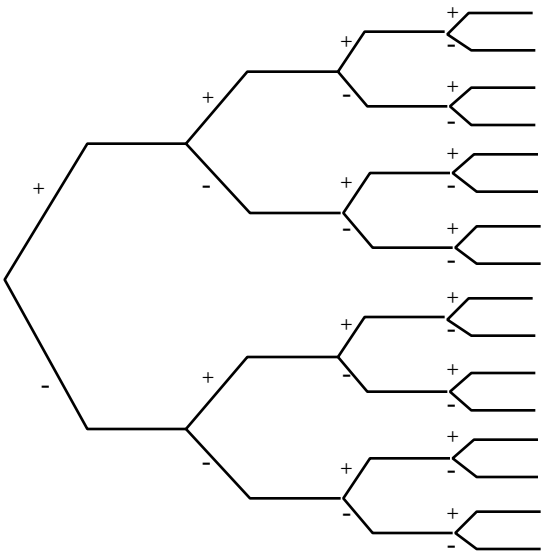

Figure 12 Dichotomous key (Decision tree) . Download original from website. Write the characteristic on the horizontal line A positive (+) symbol indicates that the object has that characteristic A negative (-) symbol indicates that the object being keyed does not have that characteristic

- Playing with multiple teams: You may wish to break the class down into different teams and give each an identical series of terms to solve through the questioning process. Separate the groups sufficiently so they will not be able to hear the questioning process of the other groups. Select knowledgeable and impartial individuals to serve as "answer men" and appoint one to work with each team. The team members should write down each question and its answer. The team that is able to solve the puzzle with the lowest average number of questions is the winner.

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Hands-on taxonomy activity: Once students have learned the value of asking the right questions and sequencing them in a logical fashion, give them opportunity to develop their own taxonomic scheme for a set of miscellaneous objects, such as hardware (assorted nails, washers, bolts, nuts, cotter pins, dowels, tacks, etc.) Give each group a jar containing the same assortment of items and ask them to develop a logical classification scheme. Provide each team with a dichotomous decision tree such as that illustrated in figure 12.

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COMPUTER GAMES & SIMULATIONS

Internet Resources

- Computer simulation freeware and shareware
- Computer games for the science classroom

On our website you will find links to numerous software programs that can be used as games in the science classroom. We will introduce a couple here and illustrate how they can be used to develop specific reasoning skills fundamental to an understanding of science.

Games: There are a numerous excellent computer games that can be used in the science classroom to introduce or reinforce scientific principles. Go to the website to access software vendors or to download relevant freeware or shareware. Many of these programs can be used in a single computer classroom provided you have a large monitor or data projector and divide the students into teams.

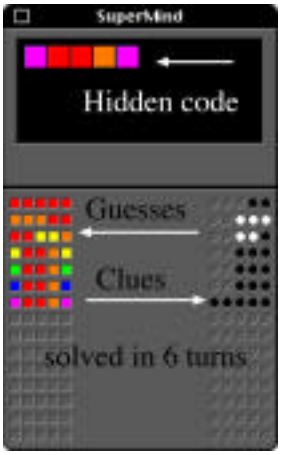

Figure 13 Games like Mastermind (Supermind) can introduce students to "black box" experiments

Many computer games have relevance to the science classroom even though they may not deal directly with science content. For example, there are many logic games that can be used to introduce scientific reasoning. One such game available from the website is "Mastermind" (figure 13) , a computer game copied from the popular Milton Bradley board game by the same name. The object in Mastermind is to guess a hidden sequence of four or more colors that have been selected by your opponent (the computer in this case). Each time you guess a particular sequence of colors, the computer returns pegs. Each white peg indicates that your guess includes a correct color in an incorrect location, and each black peg indicates that your guess includes a correct color in a correct location. The position of the white and black pegs is not related to the actual position of the colors, however. Mastermind provides a great *introduction to "black box" science* in which scientists must use probes to measure the object to be studied, and can only look at the response of the probes since the object is too small or too difficult to be seen. For example, Ernest Rutherford determined the basic structure of the atom through a classic *"black box"* experiment in which he shot alpha particles at a thin sheet of gold foil. Although he could not see the atoms in the foil, he concluded that they must be made primarily of space since most of the alpha particles went straight through the opaque foil, while only a small percentage were reflected or deflected by the sub-atomic particles within the foil. In the same way, students playing a strategy game like Mastermind must work with probes to determine a code that they are not allowed to see. The black and white pegs returned by their opponent (computer) play the role of the deflected or reflected alpha particles, giving evidence of the hidden code or structure, and allowing the experimenter (student) to *draw inferences about the unseen*. In addition, many times a student will have to discard a previous hypothesis (sequence of pegs) because it does not

fit the new data, just as a scientist must discard previously respected hypotheses that don't fit recently acquired data.

Simulations: A simulation is the imitative representation of the functioning of one system or process by means of the functioning of another. A variety of computer-based simulations that represent real-world processes can be used as classroom games provided you have a data projector or access to a computer laboratory. On our website you will find such freeware or shareware simulations available for download.

An extremely popular group of simulations deal with projectile motion in which opponents try to bombard each other by manipulating the initial angle and force given to the projectile. In these games, each scenario presents different terrain and wind features, forcing students to adjust their initial angle and force. After downloading and installing one of the projectile simulation programs, divide the class into two teams, assigning one student from each to be the field general. The field general must build consensus among team members before he or she enters the parameters into the computer. As time progresses, teams will become better at estimating. Although most teams start out changing both variables at once, with time they learn that it is better to change only one variable at a time so that they can see its effect in isolation from the other variable. In so doing, they learn a basic principal of scientific investigation…. *to determine the influence of an independent variable on a dependent variable, you must change only one independent variable at a time.*

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