Using Food to Demonstrate Earth Science Concepts: a Review

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ABSTRACT

This paper categorizes over one hundred print and web resources that use food to demonstrate earth science concepts with the goal of placing these resources in a more usable format for K-12 earth science instructors. Most activities: 1) are found with nearly equal frequency from journals and from the web; 2) feature geologic rather than weather-,water-, or space-related themes; 3) are designed for a primary and middle school audience, but are adaptable to almost any education level, including introductory college classrooms; 4) meet the "Structure of the Earth" middle school National Science Standard; 5) require less than 30 minutes of instructor preparation; 6) cost less than $20 in materials for a class of 25; and 7) are adaptable for variety of group sizes. Outstanding examples of edible earth science include using candy bars to demonstrate weathering concepts, orange peels to mimic plate tectonics, and cookies to demonstrate mining and environmental reclamation. These activities are interesting, promote active learning, facilitate the teaching of the K-12 National Science Standards, and offer opportunities for interdisciplinary education. The main disadvantages of using this approach are safety concerns and, in some cases, extensive preparation.

INTRODUCTION

As earth science instructors, we are encouraged to make subject matter more exciting and understandable, particularly for those with little or no background in science (Rutherford and Ahlgren, 1991; Budiansky, 2001). There have been many attempts to achieve this goal including the use of active learning techniques (Reynolds and Peacock, 1998), cooperative groups (Hodder, 2001), various assessment techniques (Kirchner and Corbett, 1992), and the use of in-class demonstrations. Another way to stimulate an interest in earth science is to take advantage of students' familiarity with food.

Why use edible earth science? Cognitive theorists recognize that in order for learning to occur students need to create new knowledge based on their observations, manipulations, and reflections (Martin, 2000). This theory of learning is called "constructivism." Knowledge is "constructed" when the new concepts being learned are both personally relevant and meaningful to students. Food, which students consume daily, can serve as a reality based analogy to better understand many of the unfamiliar, abstract concepts taught in earth science classes.

The use of edible curricula can appeal to the non-traditional learner. Howard Gardner (1983), in his book "Frames of the Mind: The Theory of Multiple Intelligences," addressed the learning style of non-traditional learners. While acknowledging the importance of the verbal and quantitative modes of instruction and assessment, which today tend to dominate the way students are evaluated, Gardiner proposed that there are several other approaches to learning that can bring out the full potential of student intelligence. These other modes of intelligence are visual/spatial, bodily/kinesthetic, musical, interpersonal, intrapersonal and most recently naturalist (New Horizons for Learning, 2002; Checkley, 1997). An edible curriculum relates to the bodily/kinesthetic learning mode in that activities require students to manipulate and taste food. Visual learners benefit by having the materials for manipulation in view and the interpersonal learner benefits from those edible activities designed for small groups, allowing participants to display leadership and people skills. Edible activities also offer the opportunity on building traditional computational and writing skills.

While the validity of constructivism or multiple intelligences can be debated (Klein, 1997), there is support for the idea that involving students in their own instruction through active learning techniques improves achievement (O' Sullivan and Copper, 2003; Kern, 2000; Hake, 1998). Edible science involves active learning. It is personally relevant (students often get to eat the results of experimentation) and allows students to refine observation and recognition skills. Some edible activities call upon students to make hypotheses (American Geological Institute, 2003), plan and conduct an analysis (Lindstrom, 1996), and use technology and instrumentation to gather data (Holden, 1998; Pankiewicz, 1992).

Another justification for the use of this approach comes from the National Research Council (National Academy of Science, 2002) and National Science Foundation (National Science Foundation, 2002), which call upon instructors to search for more ways in which to meaningfully relate their subject matter to other disciplines. There are many interdisciplinary connections inherent in this approach involving measurement skills, life science, and even language arts. The data from many edible activities may also be entered on spreadsheets where it can be statistically manipulated or displayed through graphs, thus reinforcing math and computer skills.

A final reason to use this approach, specifically for K-12 education, is that many of these activities meet National Science Standards. The National Science Education Standards are part of a document, published by the National Academy Press, that outlines what students should know, understand, and be able to do at various points in their education in order to be scientifically literate (National Academy of Science, 1995).

We provide a review of edible earth science exercises and demonstrations with the goal of making these activities more usable for earth science instructors. In addition to providing references and brief summaries of over one hundred edible earth science activities (Online Appendix), we categorize activities by

Item	Classification	Comments
Origin	Print or Web	Search for “Print” resources was conducted with “Geobase,” “GeoWeb,” “ArticleFirst,” and “Education Select,” WilsonSelect,” “Eric” library databases Search for “Web” resources was conducted with “DLESE” (NSF-supported Digital Libraries for Earth Systems Education) and “Google,” and “Askeric” Search terms to discover activities were “edible earth science,” “edible geology,” “edible science lesson plans,” “edible weather,” “edible space science,” “edible water science,” and “edible science” “food and geology” “food and earth science” in conjunction with “lesson plans,” “learning activities,” “science activities,” “education,” “curricula,“ “K-12 education,“ “food analog,“ “education,“ “science instruction,“ “hands on science,“ “science education,“ and “science instruction“
Subject Area	Geology, Water Science (which included Oceanography), Weather, and Space Science	The newest category of earth science, “cryology,” was subsumed under geology section.
Education Level and National Standards	Elementary (K-5) Middle (6-8) High School (9-12)	Elementary National Standard : Properties of Earth Materials, Objects in the Sky, and Changes in the Earth and Sky Middle School National Standards: Structure of the Earth System, Earth’s History, and Earth in the Solar System High School National Standards: Energy in the Earth System, Geochemical Cycles, Origin and Evolution of the Earth System, and Origin and Evolution of the Universe
Preparation Time	“Low” (<15 minutes), “Moderate” (15-30 minutes), And “High” (> 30 minutes).	This category included setup and cleanup time.
Cost	“Low” (<$10), “Moderate” ($10-$20) and “High” (>$20)	Cost based on estimates for supplying an entire class of 25 students, either individually, in small groups, or as a class demonstration. Costs would be higher if basic laboratory materials were not available.
Number of Students for Which the Experiment was Designed	“Individuals,” “Small Groups/Pairs,” or “Class Demonstration”	Group size had an effect on the cost category above and was factored into the analysis.

Table 1. Summary of the procedures used to meet our objectives.

1) print or world wide web origin,
2) subject,
3) education level,
4) National Science Standard (appropriate only for K-12 instruction),
5) time and cost associated with implementing these activities, and
6) whether these activities are best carried out by individuals, pairs/small groups, or class demonstration.

METHODS

We gathered and summarized print and web based resources that use food to teach earth science concepts. Activities were differentiated into categories based on what was either stated or inferred from each article. Time and cost constraints prevented us from field testing all activities. Also, in regard to cost and preparation involving each activity, it was assumed that standard laboratory items like balances, rulers, hot plates, and magnifying glasses were available to students. Table 1 summarizes the procedure used to meet our objectives.

Analysis - Classification by origin and subject area - During the data gathering phase of the study, we discovered that solely using search terms like “edible earth science” or “food and geology” yielded few useful articles. We were more successful when we broadened our search to include these terms in conjunction with terms like “science activities,” “education,” “curricula,” “K-12 education,” and “food analog.” The complete list of search terms is found in Table 1.

During the data gathering phase of the study, we also found many interesting and useful math, physical science, and life science activities. If these activities had some conceptual connection to earth science, then such an activity was classified within the earth sciences. An example was “Snap Crackle Jump” (MadSci Network, 1997a). Here students use Rice Krispies© Cereal, a wool sweater and Plexiglass© to demonstrate static electricity. Static electricity is generally thought of as a physics concept, but it can also be adapted for use in an earth science lesson on lighting and weather. Many of the activities relating to weather and water science are interdisciplinary in nature and could fit equally well under physical or earth science. Edible activities relating to color (AskEric, 1994; MadSci Network, 1997b), are further examples of activities that could be taught in either discipline.

Based on our search criteria, we discovered 109 edible resources relating to earth science with 54 discovered on the web and 55 found in journals, books, or magazines. Note that almost half of all activities were found on-line pointing to the growing trend for

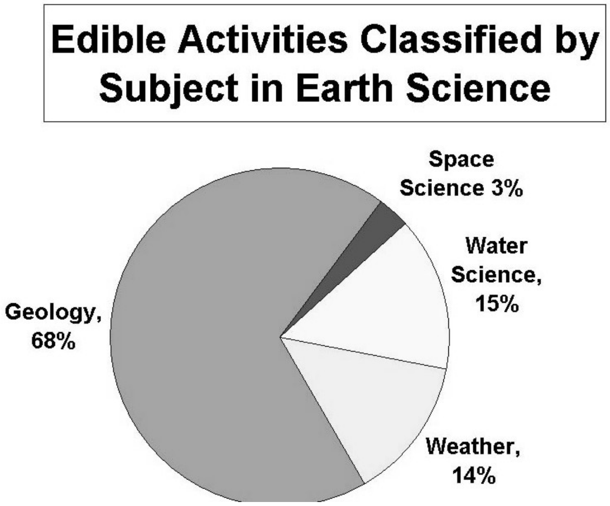
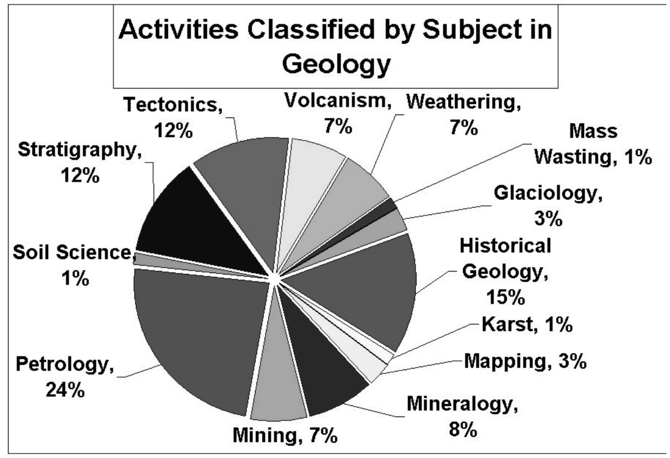


Figure 1.



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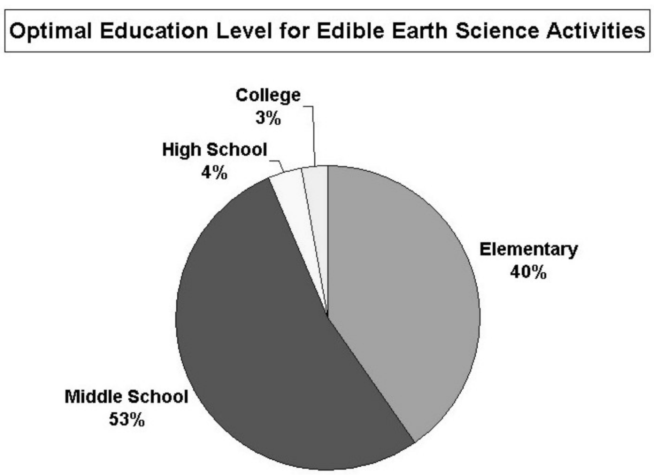

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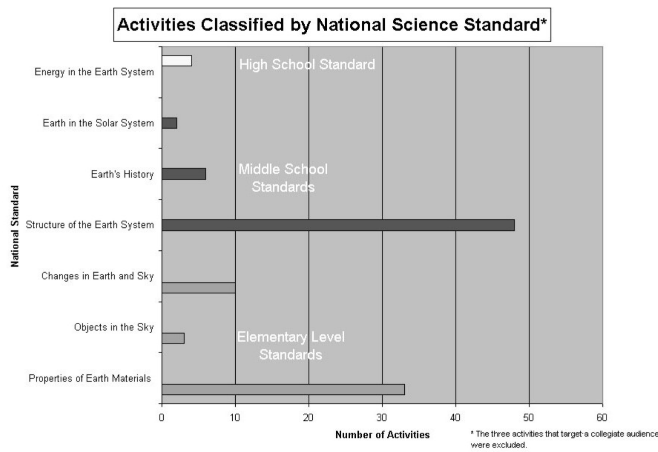

Figure 4.

disseminating education information through the World Wide Web. While the web gives instructors ease of access to materials, it should be noted that we observed some quality differences between print, which usually conformed to a systematic review process, and web resources, where the review process could be less apparent or non-existent. In general, a print edible activity has fewer grammatical errors, accompanying references, and useful illustrations.

In classifying earth science resources (Figure 1), over two thirds (68%) directly relate to geology, with 15% involving water science, 14% weather, and 3% relating to space science. Given the abundance and variety of activities relating to geology, we further divide the geology category to derive more workable subtopics (Figure 2). The geology category is thus subsumed to include 13 different content areas. Most activities relate to petrology (23%), historical geology (15%), tectonics (12%), and stratigraphy (12%). Other topics lending themselves to edible analogies include mineralogy (8%), volcanism (7%), weathering (7%) and mineralogy (7%).

Classification By Education Level and National Standards - Education Level - Our analysis categorized activities by "Elementary (K-5)," "Middle School (6-8)," "High School (9-12)," and "College" The great majority, over 90%, are designed for the K-8 audience. Only 3% of activities were specifically targeted for the college level (Figure 3).

While it is true that the majority of activities are tailored for a K-8 audience, most, like igneous fudge (Lind, 1991), edible conglomerates (McGee, 1991), and various weathering activities (AskERIC, 1996) could be adapted for introductory classes at the college level. After enjoying an edible activity, college level instructors could ask students to take a K-12 exercise and relate it to a systems approach, critique its shortcomings, or rewrite the exercise in light of some of the more advanced concepts covered at the college level.

National Standards - While most authors, web or print, indicate for what education level a specific activity is appropriate, few authors classify how their activity might meet National Science Standards. This is not surprising given that the K-12 National Science

Estimated Time Necessary to Prepare Activity	Total	Percent
Low: less than fifteen minutes	36	34%
Moderate: fifteen to thirty minutes	21	19%
High: more than thirty minutes	51	47%

Table 2. Earth Science activities categorized by estimated amount of preparation time.

Standards were not published until 1995 and that their dissemination and adaptation is still an ongoing process. Many states also have their own set of benchmarks and standards based on the National Standards that their school systems follow. Because of this, state standards are often mentioned in the activities instead of the National Standards. We found that the National Standards could be easily applied to most edible earth science activities. Some activities, like forming an ice core (Kopaska-Merkel, 1995) and ice cream glaciers (Bloomfield, 1993) are not explicitly related to major National Standards benchmarks but did meet local state standards where glaciation is regularly studied as part of the curriculum.

In terms of frequency, most activities (48) match the middle school "Structure of the Earth" National Standard, which includes layering of the earth, the rock cycle, and plate tectonics (Figure 4). Second is "Properties of Earth Materials," an Elementary level standard with 33 activities. This objective includes rock and mineral properties. "Changes in the Earth and Sky," a primary school standard, includes activities relating to weathering, volcanoes, and weather, and is next with 10 activities.

Other content standards that could apply are the "Science as Inquiry" standards, which call for students to identify a problem, carry out a design for solving the problem, and then communicate the solution. The other common non-subject standard is "Science and Technology," which emphasizes students' ability to use technological designs in exploring science. These standards are represented in a number of edible activities, like the use of spreadsheets in expressing water's physical properties in "Water, A Sticky Subject" (McCarty, 2000) or investigating dehydration and mass changes in "Corn Dehydration (Holden, 1998). An interesting extension for edible activities might be to have upper level students read over several articles that use edible science and then design experiments with food that meet these two standards.

One of the big advantages of edible science is the opportunity for integrated interdisciplinary curriculum incorporating standards across a number of different disciplines. Using bread as an analogy to observe rock texture, as in "Turning Bread Into Rocks: A Multisensory Unit Opener" (Smith, 2000) can also be used as an opportunity to learn about different global bread making customs from around the world. Another example of where interdisciplinary linkage is possible comes with popcorn to demonstrate the Gas Law and then use mathematics for understanding basics of sampling and how to represent percent, volume, mean, and median (Graber, 1999). Linkages with technology use can be achieved by having students collect, organize, and analyze data with spreadsheets. There is also the potential to enhance language arts skills (Dahl, 1998) through the use of science journals (Yamamoto and Silva, 1999).

Cost	Total	Precent
Low < $10	48	44%
Moderate $10-$20	37	34%
Expensive >$20	24	22%

Table 3. Earth Science activities categorized by estimated cost

Group Earth Science	Total	Precent
Class Demonstration	43	32%
Pairs/Group	43	39%
Individual	23	21%

Table 4. Optimal group size for Earth science activities.

Classification by Amount of Preparation Time - Most activities (53%) take less than thirty minutes to prepare allowing for fairly easy incorporation into daily lessons (Table 2). Almost half (47%), however, of all edible activities were estimated to take more than thirty minutes of preparation. This remains a drawback although having students assist with setup and cleanup could shorten preparation time.

The "Cookie Mining" activitiy (American Geological Institute, 2003) which involves the use of chocolate chip cookies, toothpicks, graph paper, and play money, or "Our Earth's Living Skin" (Earth Net, 1999) that uses the peeling of an orange to represent the amount of usable soil on the earth, are simple and quick to prepare. Other activities involve considerably more preparation time because of the need to gather more materials and follow more intricate setup procedures. For example, "Layer Cake Geology"(Wagner, 1987) is an activity that demonstrates the stratigraphy of the earth by using a layer cake. The preparation for this activity can be time consuming because it involves the baking of seven different colored cake layers. In some cases preparation time is high, not because of setup of laboratory materials, but because coordination is required between several instructors like, "Popcorn: An Explosive Mixture of General Mathematics" (Westerberg and Whiting, 1992). This activity involves the interdisciplinary integration of back-to-back math and science classes where students can use popcorn to better understand sampling distributions and the role of temperature and pressure in regard to Gas Law.

Classification By Cost - A nice feature of these activities is that over three quarters cost less than twenty dollars to prepare (44% < $10 and 34% = $10-$20) for a class of twenty-five students (Table 3). If the same activity is used repeatedly, as in back-to-back classes, then the use of leftovers can help lower costs even more. Generally, activities that cost the least are also activities that took the least amount of time to prepare like "Edible Solar System" (The NASA/Ames Research Center, 2001) where the students use candies to construct a model of the solar system and the "Whipped Topping Ozone Demo" (Benson, 2001) in which students use whipped cream and small paper plates or Cool Whip© container lids to demonstrate how stratospheric ozone is depleting.

On the other hand, those activities, like "Making Ice Cream with Liquid Nitrogen" (Fairmont Center, 2003) which uses liquid nitrogen to represent changes in state in making homemade ice cream, and "Rock Classification," (Rector, 2001) that involves the making of three different recipes of edible "rocks," have extensive preparation time, have more materials involved, and are more costly. There are also activities that cost little but require fairly substantial amounts of preparation time. In "Making an Ice Core" (Kopaska-Merkel, 1995), for instance, free (water) and inexpensive (food coloring) materials are used but several preparatory sessions are needed to create successive ice layers with food coloring.

Classification By Optimal Size for Activities - Table 4 suggests that the majority of activities are designed as class demonstrations (43%) or for pairs/ groups of three to five students (43%). Common reasons for designating an activity as a "Demonstration" are cost, preparation, or safety concerns. In the "Mount Rainier Birthday Cake" (Earth Science World, 2000), for instance, the teacher prepares a cake in a way so that it looks like a volcano, making it impractical for everyone to cook. Another activity that is best done as a class demonstration is "Rock Candy Crystals" (Church, 1995), because it involves cooking sugar water at very high temperatures.

Twenty three percent of all activities emphasize individual participation. In these cases, like in "Gourmet Geography" in which students observe and eat a layered fruit cake to relate to rock and mineral properties (Bloomfield, 1993), the main objective of the lesson can best be realized if students are individually observing and handling the fruit cake as the cake's "minerals" could be too small to observe in a group setting.

Some group activities, for example, "The Building Blocks of Geology," (Gibson, 2001) which uses cereals and blocks as analogies to understand rock and mineral formation, are specifically designated to be carried out with two to five students so as to bolster cooperative learning skills, such as communication, which is a goal of the National Science Standard: "Science as Inquiry." Other examples of cooperative group activities are "Edible Curriculum: Modeling Lava Viscosity Using Pudding" (Gitlin, et al.1997), "Rock Deformation Inexpensively Demonstrated" (Heideman, 1974), and "The Building Blocks of Geology" (Gibson, 2001). Instructors can assign tasks to groups based on the strengths of individual team members. Examples of roles within a group could be materials manager, recorder, encourager, sanitation engineer, artist, mathematician, leader, graphic designer, recorder, or chief builder.

Regardless of designation, many of these activities are adaptable for individuals, pairs, cooperative groups, or for a class demonstration. It seems that the ideal number of individuals to participate in these activities is more a function of instructor creativity and resources available.

Disadvantages of Using Food as an Instructional Tool - Safety Issues - Some of the food used in these student activities, like chocolate, peanut butter, or milk, can promote allergic reactions, some of which might be severe. Therefore, it is important that instructors ask students and parents ahead of time if an edible activity can promote health problems. Allergic students can still participate in activities through observation as long as the allergy is not elicited by touch or smell.

Instructors also need to take precautions for those activities that involve the use of hot pots or Bunsen burners. Students need to remember to keep long sleeves and hair away from heat sources and to regulate heat on viscous mixtures of chocolate or pudding, like in the "Igneous Fudge" (Lind, 1991) and "Edible Curriculum: Modeling Lava Viscosity Using Pudding" (Gitlin, et al.1997). If uncomfortable with a class' maturity level or the availability of safety equipment, opt for a class demonstration rather than direct student participation.

One of the appealing aspects of the edible curriculum is that students can consume the product of their experiment, but even here caution needs to be exercised. Placing food items on dirty laboratory benches, possibly contaminated with chemicals from previous experiments, is a potential hazard. In addition, colds can be spread between students when all students handle the same food item before consuming it. Washing hands, using plastic gloves, using paper plates or towels to protect food from potential contamination sources, and asking sick students not to handle food will help minimize these problems. Instructors should also consider using non-food objects like clay, paper, or other physical models that can give students "hands on" experience but avoid some of the safety issues discussed above.

Preparation and Cleanup - The use of an edible curriculum requires thoughtful and sometimes time-consuming preparation. Even activities that require relatively little time to prepare can be difficult to implement with back-to-back classes. Indeed, there are situations in which the use of different colored modeling clay for demonstrating stratigraphic columns is easier to prepare and cleanup than making a layer cake.

In some cases due to lengthy set up time, like in "Taffy Pulls-It Matters" which investigates states of matter (Nagle, 1996), or the creation of an ice cream glacier in "Gourmet Geography" (Bloomfield, 1993), it is prudent to use these activities as demonstrations rather than individual student activities. The disadvantage of relying too much on demonstrations is that it defeats the constructive "hands on" nature for which these activities are designed.

A final issue that needs to be considered is the nature and amount of equipment that is needed in support of an edible curriculum. Useful materials could include rock and mineral hand specimens (Byerly, 2001), maps (Hannibal, 1999), hand lenses, balances (Graber, 1999), and exemplary images. Such resources are not a necessity but certainly will help students better recognize the analogy between food and the actual earth science concept being discussed.

"Is this Really Science?" - A final argument against edible science is that some of these activities are juvenile and inane, especially for high school and college students. After all, only three percent of all activities are designed for a college audience. Can a primary school activity like "Can I Make Raisins?" (Reach Out, 2001) which focuses on evaporation by turning grapes into raisins, have any merit for an advanced class in geophysics? Not usually, but most activities can be adapted to the college level and there are a few examples of food-related activities that specifically earmark a college audience, like "Sequential fragmentation: the origin of quasihexagonal patterns," an article in the American Physical Society's Journal Physical Review E, (Jogla and Rojo, 2002) which shows how to use a simple cornstarch experiment to mimic the formation of columnar basalts. Another article which targets a college audience is Mansfield's (1978) "Benioff, Bowen, and Popcorn."

It is true that many of the food analogies are not perfect. Most edible activities, for example, depict natural processes through unnaturally fast timelines or catastrophically violate principles of uniformitarianism but this should be viewed as an opportunity rather than a problem. Students can be asked to critically reflect on the shortcoming and strengths of a particular activity. What, for example, is obviously not true about an activity? What could be changed in the experimental design to better reflect reality? In the "Favorite Demonstration—Differential Weathering" exercise, which simulates chemical and physical weathering, not all "minerals" in the candy (caramel and peanuts) are equally exposed to the mouth's saliva "weathering" because the encasing chocolate layer initially protects the caramel and peanuts from breakdown (Francek, 2002).

CONCLUSION

The edible earth science activities reviewed here can promote active learning, appeal to visual, hands on learners, be used for cooperative learning, and cultivate interdisciplinary links. Though the materials and procedures used to illustrate edible earth science are often simple, the potential outcomes are not given that students can test hypotheses, experiment, and communicate results. Current resources, both print and web-based, primarily target a primary and middle school audience. With a little imagination on the part of college instructors, however, edible lessons have the potential to make a contribution at the introductory collegiate classroom. Still, there are concerns with this approach, like having suitable preparation time to implement exercises, safety issues, and the validity of particular food analogies.

A limitation of this study is that many of the cost and preparation time estimates made here are just that—estimates. To make our classification system even more objective and useful, we plan to seek external funding and have K-12 instructors evaluate the suitability of our classification system, and more significantly, rate the usability of these activities. In the future, we also hope to see more activities in the area of space science. As pointed out, there is an abundance of earth science activities relating to geology, with adequate numbers of activities dealing with topics in water science and weather.

In the meantime, we are compiling edible resources for biology, physics, chemistry, mathematics, and environmental science, summarizing and evaluating activities using the same procedure set out in this study. Eventually we hope to create a new web site called "Edible Science" which can serve as a clearinghouse for information for those interested in using food to demonstrate science concepts. This new site will be referenced prominently on the "Resources for Earth Science and Geography Instruction" web page (http://personal.cmich.edu/~franc1m/homepage.htm).

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