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Articles

An Approach to Improving Science Knowledge About Energy Balance and Nutrition Among Elementary- and Middle-School Students

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Unhealthy diets, lack of fitness, and obesity are serious problems in the United States. The Centers for Disease Control, Surgeon General, and Department of Health and Human Services are calling for action to address these problems. Scientists and educators at Baylor College of Medicine and the National Space Biomedical Research Institute teamed to produce an instructional unit, "Food and Fitness," and evaluated it with students in grades 3–7 in Houston, Texas. A field-test group (447 students) completed all unit activities under the guidance of their teachers. This group and a comparison group (343 students) completed pre- and postassessments measuring knowledge of concepts covered in the unit. Outcomes indicate that the unit significantly increased students' knowledge and awareness of science concepts related to energy in living systems, metabolism, nutrients, and diet. Pre-assessment results suggest that most students understand concepts related to calories in food, exercise and energy use, and matching food intake to energy use. Students' prior knowledge was found to be much lower on topics related to healthy portion sizes, foods that supply the most energy, essential nutrients, what "diet" actually means, and the relationship between body size and basal metabolic rate.

Keywords: energy balance, nutrition, elementary-school students, middle-school students, obesity

INTRODUCTION

It is no secret many Americans, including children and adolescents, are overweight (U.S. Department of Health and Human Services, 2001). The National Health and Nutrition Examination Survey (NHANES) reports that in 1999–2000, about 15% of U.S. children and young adults aged 6–19 (about 9 million children) were overweight (Centers for Disease Control, 2002). This represents a 36% increase from the obesity figure (11% overweight) reported by NHANES for the same population group in 1988–1994. The long-term trend is even more alarming: between 1971–1974 and 1999–2000, overweight among 6- to 11- and 12- to 19-year-olds increased almost 400% (from 4 to 15%) and 250% (from 5 to 15%), respectively (Centers for Disease Control, 2002). This is not entirely surprising, since more than 60% of young people are reported to have too much fat in their diets, while less than 20% eat the recommended number of servings of fruits and vegetables each day (Centers for Disease Control, 2003). In addition, food portion sizes for salty snacks, desserts, fast foods, and soft drinks are increasing both inside and outside the home (Nielsen and Popkin, 2003).

Overweight and obesity are associated with a multitude of health risks, such as type 2 diabetes, heart disease, stroke, high cholesterol, asthma, and psychological difficulties. These conditions soon may be linked to as many preventable deaths as is cigarette smoking (U.S. Department of Health and Human Services, 2000; Office of the Surgeon General, 2001; Strauss and Pollack, 2001; Rodriguez *et al.*, 2002).

Clearly, childhood education on healthy eating and exercise is critical so that "individuals have the information and

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skills they need to protect and enhance their own health and the health of their families" (U.S. Department of Health and Human Services, 2000). It has been shown that nutritional and/or fitness deficits in school-age children and adolescents can be addressed, especially by promoting regular physical activity and dietary awareness (Dowda *et al*., 2001; Andersen *et al*., 2002; Centers for Disease Control, 2003). In addition, health education and school health promotion programs for the elementary- and middle-school grades have achieved statistically significant outcomes involving a number of variables, such as students' self-reported attitudes and behaviors (Hunter *et al*., 1996), reduction of coronary heart disease risk factors (Luepker *et al*., 1996; Bush *et al*., 1989), improvements in dietary intake and reduction of time watching television (Gortmaker *et al*., 1999a), and decreased obesity among girls in grades 6–8 (Gortmaker *et al*., 1999b).

However, despite the availability of successful education programs that address the link between food and health, overweight and obesity among young students continue to increase. Additional approaches are needed to supplement existing programs and provide mechanisms to reach students outside of traditional health education settings. One strategy is to teach more health-related topics as part of science classes. Even though nutrition is included within the National Science Education Standards (NSES) on Science in Personal and Social Perspectives (National Research Council, 1996), the topic most frequently is placed within the health curriculum in schools (National Center for Educational Statistics, 1996).

National agencies continue to appeal to educators to develop additional alternative approaches to providing students with the knowledge and critical thinking skills needed to adopt healthy eating and exercise habits, not only now, but as they grow into adults. Healthy People 2010 (U.S. Department of Health and Human Services, 2000), for example, states that "essential nutrition education topics [including the Food Pyramid, the benefits of healthy diet, how to choose and prepare healthy foods, using food labels, eating healthy foods, and balancing calorie intake with appropriate exercise/activity] should be integrated into science and other curricula to reinforce principles and messages learned in the health units."

In response to the identified need for supplementary approaches to teaching nutrition-related concepts, scientists and educators at Baylor College of Medicine (BCM) recently developed an interdisciplinary instructional unit aimed at increasing elementary and middle school students' science knowledge of energy, metabolism, and nutrition. Entitled "Food and Fitness" (Moreno *et al*., 2003), the unit is designed to complement health instruction in schools by providing activities that can be taught as part of upper elementary- and middle-school science classes. The activities in Food and Fitness address Science as Inquiry, Life Science, and Physical Science content standards outlined in the NSES (National Research Council, 1996). The unit also addresses benchmarks provided by the National Health Education Standards (Joint Committee on National Health Education Standards, 1995) and the standards for Science in the Personal and Social Perspective of the NSES.

Food and Fitness is the third unit in the instructional series, *From Outer Space to Inner Space*, developed by BCM in collaboration with the National Space Biomedical Research Institute (NSBRI). Created in 1997, NSBRI is a NASA-sponsored consortium of biomedical research institutions dedicated to the study of health risks associated with long-term space flight.

Units in the *From Outer Space to Inner Space* series pose challenges to students based on real biomedical concerns faced by astronauts in space and guide students toward discoveries about health issues facing people on Earth (for example, osteoporosis, jet lag, or specialized nutritional needs). Each unit consists of 6–10 activities designed to strengthen students' critical thinking skills; facilitate integration of physical, life and earth/space science topics; and introduce students to opportunities in science-based careers. Food and Fitness allows students to explore basic concepts, such as energy in living systems, metabolism, and nutrients, while building knowledge about diet, exercise, and health.

The field test version of the unit contained five guided inquiry activities in which students investigated questions posed to them and a final activity in which students applied their knowledge. The first activity provided a focus for the unit by guiding students through an exploration of what happens when a simple organism (yeast) is provided with a potential food source (sugar). Students made predictions and detailed observations of the appearance of yeast mixtures with and without added sugar. Using thermometers or electronic probes, students also observed that yeast mixtures with "food" became warmer. Next, students compared the amount of energy released as heat from two different food types. Students burned small equivalent pieces of a high-fat food (pecan) and a high-carbohydrate food (oat cereal) under containers filled with 50 ml of water and measured the resulting temperature changes in the water. Students used their data to calculate and compare the approximate number of calories given off by each of the foods. In the third activity, students estimated the amounts of calories needed by a typical U.S. 15-year-old boy and girl at rest (basal metabolic rate) using the Harris–Benedict (1919) equations and adjusted the figures to account for different levels of physical activity. Next, during the fourth activity, students investigated the number of calories found within a "typical" adolescent's diet or within their own. In the fifth activity, students compared the nutritional content of typical diets or their own diets with recommendations of the Food Pyramid and also learned to interpret the information reported on food labels. Finally, students learned about persons with special dietary needs and designed special, nutritionally appropriate menus for different cases. The examples considered by students were an astronaut in space, a person with type 2 diabetes, an athlete-in-training, a pregnant woman, a strict vegetarian, a person who is lactose intolerant, and a person with hypertension.

Even though the appropriateness of the Food Pyramid (U.S. Department of Agriculture, 1996) recently has come into question (Willett and Stampfer, 2003), the pyramid was included in the unit because it continues to appear on food packaging and in most health textbooks. At the same time, messages were woven throughout the unit about the importance of selecting whole grain carbohydrates, reducing intake of refined sugars and grains, choosing a variety of fruits and vegetables, and selecting healthy oils (instead of saturated and/or partially hydrogenated fats) (Lupton, 2003). All of the activities were designed to be conducted by groups of two to four students working collaboratively and to fit within 45-min blocks of time (although some activities required more than one class period).

As part of the curriculum development process, the draft version of Food and Fitness was field tested with students and teachers in Houston, Texas. The goals of the field test were to evaluate teachers' satisfaction with the unit and the effectiveness of each of the activities in promoting student understanding of science concepts, as well as to identify areas in which the unit and activities could be improved.

METHODS

Participants

During 2001–2002, BCM developed the draft version of Food and Fitness. Initial contributors and reviewers included scientists and educators in BCM's Center for Educational Outreach, members of the NSBRI research team focused on astronaut nutrition and a member of the USDA Children's Nutrition Research Center, Houston, Texas. The unit was field tested in 17 Houston, Texas–area schools, among a cohort of 24 teachers representing 447 students in grades 3–7 ("field-test group"). Seventy percent of these teachers identified their school settings as "urban;" 30% as "suburban." They identified more than 69% of their students as Hispanic or African-American. A "comparison group" of 18 teachers (representing the same 17 schools and an additional 343 students in grades 3–7) did not receive Food and Fitness materials or professional development. Students in these classes completed the same content pre- and postassessment as students in the field-test group. All teachers in both groups participated voluntarily.

Field-test teachers had participated in previous BCM programs or were recommended by their lead teacher colleagues. BCM sought teachers who had demonstrated effective, responsible teaching practice, who were innovative, and who would be thorough in teaching and thoughtful in reviewing the Food and Fitness unit.

Because BCM selected individual teachers (and not particular schools) to conduct the field-testing, the classrooms and students impacted were entirely dependent on the teachers who agreed to participate. Once field-test teachers were selected, project leaders worked with these teachers and their school administrators to identify partner comparison teachers at field-test teachers' respective schools. The authors are aware that this nonrandomized selection process held potential for introducing bias into the field test. However, the aim of the field test was not only to estimate student learning as a result of using the draft unit, but also to obtain teacher feedback and input for improving the unit. It should be noted that most comparison group teachers taught the same grades as their field-test teacher partners, and their students' performance histories were similar to those of field-test students. As can be seen in the results of the independent sample *t*-test reported below, there were no statistical differences among the preassessment performances of the field-test and comparison groups of students.

Food and Fitness field tests were conducted in the spring of 2002. Comparison-group teachers taught their schools' traditional curricula, which did not necessarily include nutrition concepts, during the field-test period. Field-test teachers required more or less time to complete the unit, based on their teaching styles, their students, and the frequency with which they conducted Food and Fitness hands-on activities with their students. In every case, it took at least 1 month to complete all of the unit's activities. Teachers administered the prestudent content preassessment before introducing any concepts or activities related to the unit.

To determine the compatibility between the field-test group and the comparison group, an independent-sample *t*-test was conducted on the prestudent assessments of nutritional knowledge. Results from this assessment showed no statistical mean differences between field-test and comparison groups ($t = 1.405$, $df = 789$, $p = .160$). This signifies that postassessment results may be used to support the hypothesis regarding effectiveness of the field-test materials and the assertion that changes in student content knowledge may be attributable to the field test.

Instruments

Two instruments were used to gather data about field-test participants and estimate the effectiveness of the Food and Fitness materials. The first instrument was a 24-item field-test Teacher's Evaluation form, developed at BCM. (Comparison teachers were not asked to complete the form, as they would have had no responses for most of the items.) This was the fifth administration of the Teacher Evaluation instrument, which has been used during the field-testing of other similar educational units. The consistency of scores across all administrations, and subsequent appraisals of resulting content have led the authors to believe that the instrument shows strong content validity (Popham, 2000).

Instrument items 1–4 request information about teachers' schools, students, and curricula. The remaining 20 items ask teachers to rate the Food and Fitness unit overall and to indicate their level of agreement with a series of statements related to the unit's impact on their students. The scale on the first of these 20 items is 1 (didn't like it) to 5 (loved it). On the final 19 items, the scale is 1 (strongly disagree) to 5 (strongly agree). In addition, teachers were asked to provide open-ended responses regarding the quality of the unit and to document modifications that they made to any of the procedures or student handouts.

Field-test teachers filled out and returned this form immediately after completing field-testing, which was conducted between mid-March and the end of May 2002. All completed teacher evaluation forms were received by the first week of June.

The second instrument was a 15-item multiple-choice Student Content Assessment designed to measure students' content knowledge of topics (e.g., energy in food, energy expended during different physical activities, healthy food choices, special diet needs) covered by Food and Fitness instruction and activities. The Food and Fitness Student Content Knowledge Assessment (Figure 1) shows correct answers in boldface.

Questions on this assessment were tied directly to the unit's content, and they covered a range of concepts considered most important by Food and Fitness authors. Students in field-test classes completed the assessment immediately before (pre) and after (post) field-testing. Comparison teachers assessed their students at the same times as their partner field-test teachers assessed their own classes. The Student Content Knowledge Assessments were administered as part of regular classroom activities.

As noted earlier, all field-test teachers required at least 1 month to complete the unit, so there would have been at least that much time between administration of the pre and that of the post Student Knowledge Content Assessments for all students. Item numbers were changed from pre to postassessments, but the items themselves were not altered. Although the instrument yielded only moderately high scores for reliability ($\alpha = .7236$ [Crocker and Algina, 1986]), α was disattenuated by the fact that on both the pre and the postassessments, students tended to score homogeneously within their respective groups (field-test and comparison). For the purposes of this study, the instrument showed high criterion-related validity by having a point biserial correlation of 0.500 ($p < .001$) between students' outcome scores and their respective groups (field-test and comparison) (point biserial correlation is a special case of the Pearson correlation, where one variable is dichotomous and the other is continuous [McNemar, 1969]).

RESULTS

Teacher Evaluation

Overall, field-test teachers rated the Food and Fitness unit highly. The mean rating of the unit was 4.4 of a possible 5.0, indicating a strong positive response. None of the teachers gave the unit a rating of 1 (didn't like it) or 2; 4.5% of the teachers gave the unit a rating of 3 (neutral), 54.5% rated it as 4, and the remaining 40.9% of teachers rated the Food and Fitness unit as 5 (loved it).

Food and Fitness Field Test:

Student Content Knowledge Assessment

Circle one answer for each of the following questions.

1. Energy in food is measured in
   a. total fat units
   b. calories
   c. kilowatts
   d. grams
2. Which activity uses more energy
   a. playing tennis
   b. sleeping
   c. reading a difficult book
   d. playing video games
3. Essential nutrients are
   a. minerals and vitamins
   b. proteins
   c. carbohydrates and fats
   d. all of the above
4. If you are lactose intolerant, which food should you avoid?
   a. beans
   b. cottage cheese
   c. spinach
   d. chicken
5. A portion representing one recommended serving size of meat should be about the size of
   a. your hand
   b. a large hamburger patty
   c. a plastic CD case
   d. a deck of cards
6. What does yeast give off when it uses sugar as food?
   a. carbon dioxide gas and heat
   b. water vapor and heat
   c. oxygen and carbon dioxide gas
   d. heat and oxygen gas
7. Which provides the most energy? (assume equal portions of each item)
   a. bread
   b. nuts
   c. rice
   d. tofu
8. A person's basal metabolic rate is figured based on
   a. physical activity
   b. amount of daily rest
   c. foods eaten
   d. height and weight
9. The amount of food a person eats should match
   a. the amount of energy he or she uses
   b. his or her age
   c. stored fat
   d. each food label
10. Which of the following is a nutritious breakfast for a vegetarian who eats dairy products?
    a. yogurt, sliced apple, whole wheat toast
    b. scrambled eggs, orange juice, whole wheat bagel
    c. waffles, reduced fat bacon, half grapefruit
    d. sausage biscuit, orange juice
11. According to the food pyramid, most of a person's food should come from
    a. meats and other proteins
    b. fats and oils
    c. milk products
    d. breads and cereals
12. Someone with Type 2 diabetes should
    a. eat fewer sweet or greasy foods
    b. get insulin shots
    c. eat more protein
    d. avoid exercise
13. Astronauts need a different diet in space because
    a. it is hard to work
    b. there is almost no gravity
    c. they have to wear a space suit
    d. they have trouble sleeping
14. A person's diet is
    a. a way to lose weight
    b. the same as the food pyramid
    c. shown on food labels
    d. everything someone eats
15. Which of the following does not carry out photosynthesis?
    a. yeast
    b. green plants
    c. seaweed
    d. ferns

Figure 1. Student Content Knowledge Assessment test.

Teachers also indicated their levels of agreement with the items in Table 1, using the 5-point scale described under Instruments, above (1 = strongly disagree; 5 = strongly agree). Mean scores and accompanying standard deviations for each item are shown in parentheses.

Field-test teachers also provided valuable qualitative feedback on the Teachers Evaluation form that reflects some of the most critical issues related to nutrition and fitness for young people. For example, one fifth-grade teacher noted, "It's tough to get the kids to continue a healthy lifestyle without parental willingness to change." A sixth-grade teacher wrote, "Students do not consider exercise important." Other comments included, "They [the students] were shocked to see what a 'serving' of food consisted of" and "My students were surprised at the differences between their diets and healthier ones."

Student Content Assessment

Field-Test Students. The mean prescore on the Student Knowledge Content Assessment for field-test students was 6.6 (SD = 2.7). Field-test group scores increased on all 15 items, from pre- to postassessment. Because multiple *t*-tests were performed, a Dunn–Sidak correction was applied to the criterion α level of .05, lowering it to .003. The Dunn–Sidak correction controls for experimentwise (or familywise) error that otherwise would occur when making *post hoc* comparisons, such as the comparisons made here between pre and post means on individual questions (Lomax, 2001). The only questions that did not show statistically significant improvement after applying the Dunn–Sidak correction were Nos. 2 and 10. The mean total score for field-test students showed a statistically significant postassessment increase, to 8.7 (SD = 3.9, $p < .001$). Field-test students showed the *greatest* prior knowledge on the following five items of the pre Student Knowledge Content Assessment.

1. Energy in food is measured in . . . *calories*. [68.3% of students provided correct answers on the preassessment]
2. Which activity uses more energy? *Playing tennis* [82.4%]
4. If you are lactose intolerant, which food should you avoid? *Cottage cheese* [60.7%]

Table 1. Teacher perceptions of unit effectiveness and impact

	Mean	SD
I think this unit on Food and Fitness will . . .		
help children learn about the relationship between food and good health.	4.5	0.72
motivate children to practice better eating habits.	4.2	0.82
help teachers feel more comfortable with nutrition content.	4.6	0.49
help teachers feel more comfortable with science activities.	4.0	1.10
encourage students to consider careers in health or science.	3.8	0.98
After using this unit, my students demonstrated increased abilities to . . .		
understand that food is the body's energy source.	4.5	0.51
recognize the importance of exercise in maintaining a healthy body weight.	4.0	0.69
match a person's daily calorie needs and calorie expenditures.	4.3	0.67
identify healthy foods.	4.4	0.78
After using this unit, my students demonstrated increased knowledge about . . .		
how energy is produced during the breakdown of food.	4.1	0.79
what calories measure.	4.3	0.62
the different amounts of energy provided by certain foods.	4.1	0.92
the amounts of energy their own bodies need in a day.	4.3	0.62
the importance of balancing daily caloric intake with caloric expenditure.	4.1	0.72
the nutrients their bodies need and the foods that provide them.	3.8	1.10
making healthy food choices.	4.2	1.10
the effect of exercise on the body.	4.2	0.49
Appropriate serving sizes for a health diet.	3.4	1.30
how nutritional requirements vary with individuals and their activity levels.	4.3	0.70

Teachers responded to each item using a scale of 1 to 5, in which 1 = strongly disagree and 5 = strongly agree.

10. Which of the following is a nutritious breakfast for a vegetarian who eats dairy products? *Yogurt, sliced apple, whole wheat toast* [66.8%]
13. Astronauts need a different diet in space because . . . *there is almost no gravity*. [63.0%]

All of these items also were among the top six scores on the post Student Knowledge Content Assessment, although increases on items 2 and 10 were not statistically significant. Post Student Knowledge Content Assessment scores on these items were 1 (86.2%), 2 (86.2%), 4 (79.1%), 10 (69.8%), and 13 (78.4%). Field-test students also scored particularly well on the following items of the postassessment.

9. The amount of food a person eats should match . . . *the amount of energy he or she uses*. [75.9% of students provided correct answers on the postassessment]
11. According to the food pyramid, most of a person's food should come from . . . *breads and cereals*. [66.8%]
12. Someone with Type 2 diabetes should . . . *eat fewer sweet or greasy foods*. [70.5%]

Field-test students showed the *least* prior knowledge on the following items of the pre Student Knowledge Content Assessment.

5. A portion representing one recommended serving size of meat should be about the size of . . . *a deck of cards*. [11.7% of students provided correct answers on the pre-assessment]
6. What does yeast give off when it uses sugar as food? *Carbon dioxide gas and heat* [25.1%]
7. Which provides the most energy? *Nuts* [16.9%]
8. A person's basal metabolic rate is figured based on . . . *height and weight*. [22.6%]
14. A person's diet is . . . *everything someone eats*. [17.2%]

Despite showing statistically significant increases (items 5, 7, and 14 showed the greatest improvement on the post-assessment), all of these items still were among the lowest six scores on the postassessment: 5 (46.7%), 6 (51.1%), 7 (54.1%), 8 (38.6%), and 14 (48.6%). Item 3 ("Essential nutrients are . . . *all of the above*") was the only other question for which less than 50% of field-test students provided correct responses on the postassessment (43.5%). Table 2 provides itemized pre and postassessment results for field-test and comparison students.

Like their teachers, field-test students provided comments regarding their experiences with the Food and Fitness unit. One third-grader noted that "Michael Jordan would use more energy than a school librarian," while another wrote, "If a person ate too many calories and didn't use them, he would become overweight." Finally, a fifth-grade student reported, "I stopped eating chips because they are full of empty calories."

Comparison Students. The mean pre-Student Knowledge Content Assessment score for comparison students was 6.0 (SD = 2.8). Data from the comparison group also were analyzed using the Dunn–Sidak correction, with the criterion α set at .003 in order for scores to be considered statistically significant. The comparison group's postassessment mean score dropped on 7 of the 15 items, and the group's mean total score dropped to 5.8 (s = 3.0), from pre- to postassessment. The postassessment mean scores of the comparison group and the field-test groups were found to be statistically significantly different ($t = 27.17$, $p < 0.001$, df = 788). Comparison-group students showed a statistically significant decrease on item 1 of the postassessment. There were no statistically significant increases or decreases on any of the other items, from pre- to postassessment.

Table 2. Pre- and post-Student Content Knowledge Assessment results

Item No.	Pretest	Posttest	p	Cohen's d
		Field-test group		
1	68.3%	86.2%	<.001	
2	82.4%	86.2%	.063	
3	35.3%	43.5%	.022	
4	60.7%	79.1%	<.001	
5	11.7%	46.7%	<.001	
6	25.1%	51.1%	<.001	
7	16.9%	54.1%	<.001	
8	22.6%	38.6%	<.001	
9	56.2%	75.9%	<.001	
10	66.8%	69.8%	.484	
11	47.4%	66.8%	<.001	
12	55.5%	70.5%	<.001	
13	63.0%	78.4%	<.001	
14	17.2%	48.6%	<.001	
15	50.8%	61.9%	.002	
Total	6.6 (44.0%)	8.7 (58.0%)	<.001	1.007
		Comparison group		
1	64.8%	52.9%	.002	
2	76.7%	76.3%	.580	
3	36.1%	29.2%	.021	
4	61.8%	65.4%	.318	
5	12.2%	10.6%	.457	
6	25.1%	30.6%	.308	
7	18.2%	22.4%	.102	
8	23.0%	21.2%	.726	
9	50.7%	46.8%	.117	
10	60.9%	59.3%	.698	
11	37.6%	40.7%	.400	
12	45.7%	50.6%	.318	
13	54.3%	57.4%	.352	
14	20.3%	20.8%	.769	
15	46.6%	47.8%	.748	
Total	6.0 (40.0%)	5.8 (38.7%)	.587	− .052

Cohen's d was computed for the paired-sample t-test, where $d = d_4/\sqrt{1-r}$ (Cohen, 1988, p. 49).

Comparison-group students showed greatest prior knowledge on the same five items of the pre-assessment that the field-test students did: 1 (64.8% providing correct answers on the pre-assessment), 2 (76.7%), 4 (61.8%) 10 (60.9%), and 13 (54.3%). These same five items received the highest percentage of correct scores on the comparison students' postassessment, although scores for three of them actually dropped: 1 (52.9%), 2 (76.3%), 4 (65.4%), 10 (59.3%), and 13 (57.4%). The only other item on which more than 50% of comparison students provided the correct answer on the postassessment was question 12 (50.6%).

The comparison group had the least prior knowledge on the same five pre Student Knowlegde Content Assessment items as the field-test students did: 5 (12.2% of students gave correct answers on the pre assessment), 6 (25.1%), 7 (18.2%), 8 (23.0%), and 14 (20.3%). All of these items also were among the lowest six scores for comparison-group students on the post assessment: 5 (10.6%), 6 (30.6%), 7 (22.4%), 8 (21.2%), and 14 (20.8%). Item 3 was the only other question for which less than 30% of comparison students provided correct responses on the post assessment (29.2%).

DISCUSSION

Through field-testing of Food and Fitness, BCM gained desired information about the unit's strengths and weaknesses. As measured in the student assessments and reported in qualitative teacher and student feedback, the unit appeared to increase student knowledge about the science and health concepts targeted. At the same time, outcomes of the field test were used to inform modifications to the final version of the unit. For example, based on feedback from teachers, the procedure for the first activity was simplified to facilitate student observations of carbon dioxide production by yeast. A new activity on estimating portion sizes and comparing student estimates to sizes recommended by the Food Pyramid was developed for the unit. In addition, procedures, instructions, and student reproducible pages were rewritten and redesigned based on teacher feedback. The final version of Food and Fitness has been published and is available at the NSBRI Website (http://www.nsbri.org/Education/Mid_Act.html).

Beyond providing an indicator of the unit's overall effectiveness, the Food and Fitness field-test results offer a glimpse into elementary- and middle-school students' knowledge and beliefs regarding a specific set of concepts related to energy, living systems, and diet. The National Research Council (2000) notes, "Students build new knowledge and understanding based on what they already know and believe . . . by modifying and refining their current concepts and by adding new concepts to what they already know." Thus, understanding students' existing knowledge is essential for the development of instructional programs that help students learn new concepts (National Research Council, 2001).

Because the present study was conducted entirely within Houston, Texas, the authors cannot assert that the findings represent student populations in other locations. However, it is important to note that both student groups participating in the field test had similar prior knowledge on all items on the pre-Student Knowledge Content Assessment. Each item and the students' total scores were compared in multiple independent-sample t-tests to ensure that the two groups were compatible in terms of previous knowledge. After adjusting the p calculated to account for the multiple t-tests using the Dunn–Sidak correction (Lomax, 2001), no statistically significant differences were noted in the mean scores of any item or in the total test scores for the preknowledge content assessments. This analysis provides strong justification for considering the two groups together in terms of their initial knowledge set about the topics covered.

Preassessment results for both groups indicate that almost all students (>75%) can identify "tennis" as an activity that uses more energy than sleeping, reading a difficult book, or playing video games. More than half of the students in both groups also were able to identify "calories" as the units of measure of energy in food, select cottage cheese as a food that might be avoided by someone who is lactose intolerant, report that a person's energy intake should match his or her energy use, identify a nutritious breakfast for a vegetarian who eats dairy products, and report that astronauts have different dietary needs because of the microgravity environment in which they work. However, far fewer students were able to identify healthy portion sizes, foods that supply the most energy, essential nutrients, what "diet" actually means, and the relationship between body size and the amounts of

Table 3. (a) One-way ANOVA of student grade level on pre-Student Content Knowledge Assessment test scores and (b) Tukey HSD *post hoc* test for homogeneous subsets

a

Source	SS	df	MS	F	Sig.	η^2
Between	326.518	4	81.630	12.454	<.001	.104
Within	2811.961	429	6.555			
Total	3138.479	433				

b

		Subset for $\alpha = .05$	
Grade	N	1	2
Third	32	4.09	
Fourth	165		6.94
Fifth	48		6.25
Sixth	37		7.34
Seventh	152		7.30
Significance		1.000	.174

calories burned at rest (basal metabolic rate). All of these concepts (and misconceptions) are linked to overweight, obesity, and other health problems among children and adolescents.

On the pre-Student Knowledge Content Assessment, fewer than 50% of the members of both groups correctly answered the item related to dietary needs of people with type 2 diabetes, even though this is a growing problem among children and adolescents in the United States, especially among Hispanics, African-Americans, and Native Americans (Fagot-Campagna, 2000; Nesmith, 2001; Rotler, 2001; Matthews and Wallace, 2002).

An even more disconcerting outcome, included here only as a *post hoc* finding, is the lack of difference among scores on the pre-assessment across all grade levels. For pre-assessment scores, we conducted a one-way ANOVA (Table 3) with five levels to investigate whether or not students in different grades were performing at different levels. There were statistical differences in student scores by grade, but in the *post hoc* analysis, the only group that had significantly statistical different mean scores from the others was the third grade; all other grades were indistinguishable statistically. This means that the fourth-, fifth-, sixth-, and seventh-grade students were performing at equivalent levels (statistically) in terms of their knowledge of nutrition on the administered pre-assessment. Put another way, this finding suggests that in terms of nutrition and energy knowledge (as tested), students in the seventh grade knew *nothing more* than their fourth-grade counterparts. This is particularly disturbing, given that the Texas Education Agency, under the Texas Essential Knowledge and Skills, explicitly includes concepts related to diet and nutrition as part of required health education for all grade levels covered in this study (Texas Education Agency, 2002).

By identifying concepts about which students have more or less understanding, the pre-assessment findings suggest starting points for educators seeking to improve their students' awareness and habits related to energy, nutrition, diet, and exercise. The findings also indicate that Food and Fitness and similar science-based models can be effective with middle-school students.

Since comparison students did not use Food and Fitness materials, their pre-Student Knowledge Content Assessment scores are not discussed here. However, because field-test and comparison students achieved such similar results on the pre-assessment, observed changes in field-test students' postassessment scores can reasonably be attributed largely to the introduction of Food and Fitness materials.

In fact, the field-test student group, which initially demonstrated very limited knowledge of many concepts on the pre-assessment, performed dramatically better (at least 26% more students answered correctly on the postassessment than on the pre-assessment) on items 5, 6, 7, and 14, related to portion size, products of respiration, energy in foods, and the meaning of "diet."

The field-test group also showed statistically significantly increased understanding of the concepts related to calories as a measure of energy in food, essential nutrients, special dietary needs (e.g., lactose intolerance, type 2 diabetes, and needs of astronauts), basal metabolic rate, recommendations of the Food Pyramid, and the relationship of food consumption to energy exertion (items 1, 3, 4, 8, 9, 11, 12, 13, and 15).

The only improvements that were not statistically significant occurred on items 2 and 10. Students' scores on item 2 (energy requirements of different activities, such as tennis) already were high on the pre-assessment and did not change significantly after students took part in the field test. Item 10 dealt with vegetarian diets, which were addressed only in the final activity in the unit. In response to the low rate of improvement on this question by students, additional information about vegetarian diets and nutrient contents of foods was added to the final version of Food and Fitness.

The instructional approach of Food and Fitness, in which students investigate questions posed to them, appears to have been effective in improving student knowledge in all of the areas in which existing knowledge was weak. However, the most dramatic gains were seen on items 5, 6, 7, and 14. As noted earlier, these items also presented extremely low pre-assessment scores, so offered the greatest room for improvement. However, the items also reflect concepts that were taught explicitly by activities in the unit: one portion size of meat is about the size of a deck of cards, carbon dioxide and heat are given off during respiration by yeast, nuts yield more energy (calories) than do carbohydrates or tofu, and a person's diet consists of everything he or she eats. It is noteworthy that the most dramatic hands-on activity in the unit, in which students compare the calories released when pieces of oat cereal and pecan are burned, also led to the greatest pre/post gains in student knowledge (item 7).

At the same time, it is important to acknowledge that while the Food and Fitness teaching materials clearly had a strong positive impact, the field-test results also demonstrate that students still require more information and additional classroom experiences related to energy, nutrition, and related ideas. Even after completing the unit, the mean score of the student field-test group was only 8.7 of a possible 15 (58% correct).

CONCLUSION

While outcomes of the field test of the Food and Fitness instructional unit are not suitable for generalization to other populations, the data collected do suggest that the unit had a positive impact on elementary- and middle-school students' knowledge of selected health and science concepts. Furthermore, the field test provides evidence that guided inquiry investigations, such as those in Food and Fitness, can increase students' abilities to answer questions correctly about key science, health, or nutrition issues. At the same time, the information collected during the field test suggests that energy and nutrition concepts need to be taught in greater depth at all grade levels if students are to achieve levels of mastery that fulfill benchmarks set forth by the National Science Education Standards.

ACCESSING MATERIALS

The curriculum unit, Food and Fitness, can be downloaded at http://www.nsbri.org/Education/Mid_Act.html.

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