CASE STUDY: Experiential learning exercises to enhance learning in a university nutrition course

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ABSTRACT

Two projects were conducted in a University of California–Davis undergraduate animal nutrition class as experiential learning experiences to reinforce concepts taught in the lectures. The objectives of the experiential learning exercises were to (1) reinforce the nutritional concepts that were presented in the lectures, (2) provide hands-on experiences with animals as well as analytical wet chemistry methods, (3) study fiber digestion and lipid metabolism as they relate to digestive systems, and (4) inspire students to learn more about nutrition. Students participated in project 1 to study the digestibility of NDF in sheep, horses, and rabbits and project 2 to study dietary lipid digestion and metabolism in mice. Both projects required participation outside of normal class time. Students were involved in collecting and analyzing samples, recording and analyzing data, and interpreting and reporting their findings. Project 1 concluded with graded written and oral reports, whereas project 2 concluded with summarization of findings. Students were asked at the end of the class to rate both projects on a scale from 1 to 5, with 5 being the best rating. Project 1 received an average of 4.4, and project 2 received an average of 3.7.

Key words: experiential learning, nutrition, teaching

INTRODUCTION

There are different ways to present biological concepts. Most experiential learning theorists suggest that the teaching condition should be determined by the subject matter being taught. The Cone of Experience constructed by Dale (1946) used a visual cone-shaped analogy to show how learning experiences progress from abstract to concrete. Listening is at the top of the cone because it is considered the most abstract learning experience, followed by reading. Progressing into what Dale called the pictorial experiences are viewing images, watching educational videos, attending exhibits, taking educational trips, watching demonstrations, and dramatized experiences. At the bottom of the cone are the most concrete learning experiences: contrived experiences such as simulations and models, and finally direct purposeful experiences where the student is able to “do the real thing” (Dale, 1946). Direct and contrived experiences are thought to allow students to have active participation in learning and building more concrete experiences (Dale, 1946). In our teaching of nutrition, a direct experience approach was employed to reinforce nutrition concepts presented in the lectures. Students participating in this approach learned from being “directly in touch with the realities being studied,” as stated by Keeton and Tate (1978). In our case, “realities” are the study of digestive systems and their effect on fiber digestion and lipid metabolism.

During the lectures, 4 main digestive systems were discussed: (1) simple stomach, nonruminant (e.g., pig, human); (2) avian (e.g., chicken, owl); (3) ruminant, 4-compartment stomach (e.g., sheep, giraffe); and (4) nonruminant, hindgut fermenter (e.g., horse, rabbit). Principles considered when comparing digestive systems included (1) anatomical differences, (2) type and location of agents of digestion, (3) chemical nature of the end products of digestion, (4) sites of end product absorption, and (5) waste elimination routes. To gain an understanding of the similarities and differences of digestive systems, students participated in laboratory exercises during class time as well as 2 projects that were conducted outside of class time. In project 1 the digestibility of NDF contained in alfalfa pellets was measured in sheep (ruminant), rabbits (cecal hindgut fermenter), and horses (colonic hindgut fermenter). In project 2 the effect of dietary lipid composition on milk and adipose composition of fatty acids was measured in a mouse (simple stomach, nonruminant).
nant). The objectives of experiential learning exercises were to (1) reinforce the nutritional concepts presented in the lectures, (2) provide hands-on experiences with animals and analytical wet chemistry methods, (3) study fiber digestion and lipid metabolism as they relate to digestive systems, and (4) inspire students to learn more about nutrition.

**MATERIALS AND METHODS**

In project 1 and project 2, information presented in lectures and laboratories was integrated to build a framework of knowledge about digestion across different animal digestive systems. In laboratory 1, students were exposed to feeds and diet preparation and to the feed library. Students were expected to be able to identify and learn the nutrients—protein, fiber, fat, and energy values—of the feeds in the feed library. In laboratories 2, 3, and 4, ration formulation principles were taught. Laboratory 5 covered comparative anatomy of digestion systems, and students dissected various animals to study the anatomical similarities and differences of the gastrointestinal systems. Animals dissected included chicken, duck, hamster, hawk, mouse, opossum, owl, pelican, pig, rabbit, raccoon, rat, sheep, and sturgeon.

In the class there were approximately 75 students divided into 5 individual laboratory sections of approximately 15 students. Many of the students are interested in the veterinary profession. A few desire to work in the livestock or dairy industry as nutrition professionals. Most students are majoring in animal science or animal science and management, but there are also students majoring in biological science who desire knowledge of nutrition and experience with animals. Most students have had few experiences with livestock. Students in this class are known as the NUT 115 Enthusiasts! Through a hands-on approach in combination with lectures and laboratory exercises, students are able to further their understanding of nutrition concepts and become familiar with handling animals.

**Project 1**

An objective was to measure the apparent digestibility of fiber (NDF) in a ruminant; a nonruminant, colon fermenter; and a nonruminant, cecal fermenter. In addition, each group of 3 students had a hypothetical herbivore to include in their project. The hypothetical animals used in class included the African and Asian elephants, Baird’s tapir, black and white rhinoceroses, camel, capybara, giraffe, hippopotamus, okapi, red-necked pademelon, and red tree kangaroos, saiga, wombat, and a variety of other herbivores. During laboratory 2 a member of each group tossed a dart at a board to determine what animal would be researched in their digestion study. The assumption was that the hypothetical animal (4 animals) would be included in project 1 along with the sheep, horses, and rabbits. Students discussed how they would design the feeding and collection of samples from their hypothetical animals. The students were encouraged to conduct a search of the published literature to find as much information as possible on their animal with respect to digestive anatomy and diet strategies in the wild to help them predict the digestibility of fiber if their animal were to consume the alfalfa pellets used in class. For example, the black rhinoceros is often classified as a browser, whereas the white rhinoceros is classified as a grazer based on their respective diets in the wild and their digestive anatomies. This could have implications with respect to fiber digestion by each animal. The oral and written reports were focused on a discussion of the apparent fiber digestibility in the sheep, horse, rabbit, and hypothetical animal.

The actual digestion study involved 4 wether sheep (castrated male), 4 mares (female horse), and 4 buck (male) or doe (female) rabbits. All animals were housed individually. Sheep were housed indoors in large metabolism pens. Rabbits were indoors in stainless-steel cages, and mares were in individual stalls with a dirt outdoor exercise area. The indoor stalls had rubber mats. No bedding was used for any of the animals so the animals would not eat bedding as feed and to enable collection of fecal matter. The digestion study was conducted at the Cole Facility for large animal research on campus. Alfalfa hay was ground and chromic oxide was added (0.2% DM basis) at the University of California Davis Feed Mill. Chromic oxide was used as the indigestible marker, although in class we discussed other markers (for example, lignin and acid-insoluble ash) as well as the advantages and disadvantages of the various indigestible markers. There is no perfect marker for digestion studies. The ground alfalfa hay and chromic oxide mix was pelleted at our university feed mill. All animals were fed only alfalfa pellets for the 14-d digestion trial project. The sheep were fed slightly over the maintenance energy requirement. This was done to ensure that all feed was consumed (i.e., avoid feed refusals) because the sheep were used for total collection estimates. In addition, the alfalfa was fed as a pellet so the particle size of the alfalfa was small; previous experience with feeding sheep alfalfa pellets at ad libitum intake resulted in off-feed situations. The assumption is that at high feed intakes, the rate of passage of fiber from feed is too fast to stimulate rumination and saliva production to prevent rumen upset. The rabbits were fed ad libitum because the rabbits wasted a considerable amount of feed, which would fall onto the fecal–urine trays below each cage. The horses were similar in body size and were fed at approximately their required energy intake. The horses were part of the herd and used for research, so it was important that the 2-wk study not compromise reproduction in the horses. The first 7 d of the digestion trial were used as an adaptation period to allow all the animals to adjust to the feed. The last 7 d were used for collection of feed and feces samples. The students signed up
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for time slots, either 7 to 8 a.m. or 4 to 5 p.m., to feed the animals, clean the pens and cages, and collect fecal and feed samples. During these times the teaching assistant or instructor was present and many times both were present to lead the discussion about the concepts involved in the digestion study. Feed for each animal was weighed, and the feed amounts were recorded. Water for the sheep and rabbits was changed at each feeding, whereas the horses had automatic waterers in each stall. Photos of the students participating are shown in Figure 1.

During the last 7 d of the study, feed and fecal samples were collected from each animal twice daily. Each wether sheep was fitted with a fecal collection harness for total collection of feces (Figure 1). Feces were collected from each wether twice daily, and the feces were weighed and data recorded. For the horses and rabbits, grab samples of feces were collected twice daily that were representative of the fecal output of the animal. Fecal grab samples were collected from the stall floor or exercise area of each horse (Figure 1) and from the fecal–urine tray of each rabbit. For the rabbits, the fecal pellets were contaminated with urine because each rabbit defecated and urinated in one corner its cage. These issues were discussed with the students as well as ways to improve the collection method. Likewise, during the lectures we discussed the difference between apparent and true digestibility of nitrogen. Again, the focus of the project was apparent fiber digestion and not apparent nitrogen digestibility. Each animal had a large composite fecal sample bag where the a.m. and p.m. samples were placed. These composite bags were stored in a refrigerator to minimize mold growth.

At the conclusion of the study, the graduate teaching assistants mixed each animal’s composite fecal sample. A subsample was taken, and the feces were dried at 100°C to determine the moisture content. Another subsample was spread on large trays and dried at 55°C for approximately 2 d; then the dried feces were ground through a 1-mm screen using a Wiley mill. The sample of alfalfa pellets was processed in a similar fashion. These ground samples of the feed and feces were used during laboratories 6 and 7, in which students, with the help of teaching assistants, determined the NDF, crude fat, N (CP = % N × 6.25), and total ash of the fecal samples and alfalfa pellets. The chromium concentrations of the alfalfa pellets and feces were determined for the students.

The data collected from each of the 5 laboratory sections were summarized and distributed to the entire class. With these data students determined the fiber digestion (apparent digestibility of NDF) in the sheep using a total collection method and in the horse and rabbit using an external indicator method. Both of these methods of calculating digestion are used in research.

Project 1 concluded with written and oral reports. Each student prepared and submitted for grading a project paper written in a scientific format that would be acceptable for a research journal. Each group of 3 students provided a 20-min oral presentation on their findings to their laboratory members during the last laboratory session. The oral presentation compared apparent NDF digestibility in the sheep, horse, rabbit, and hypothetical animal. Justification and explanations for estimated fiber digestibility by the hypothetical animal were important criteria for grading. The teaching assistant and instructor graded the oral presentations according to presentation style; interpretation of results; knowledge of the hypothetical animal; and ability to answer questions from classmates, the teaching assistant, and the instructor.

Project 2

An objective was to determine the effect of the fatty acid composition of the diet fed to a nonruminant (mouse) on the sex ratio of offspring and the fatty acid composition of milk and adipose lipids. To achieve this goal, 2 dietary treatments were created using a commercial, pelleted mouse diet (Formulab Diet 5008, Purina, PMI, Brentwood, MO). Diet 5008 was ground and either corn oil (Mazola Corn Oil, ACH Companies Inc., Memphis, TN) or Energy Booster 100 (Milk Specialties Company, Boscobel, WI) was added to the ground Formulab Diet 5008 to provide a total dietary lipid content of 13%...
(as-fed basis). The corn oil created the unsaturated lipid diet (UNSAT), and the Energy Booster 100 created the saturated lipid diet (SAT). The UNSAT diet contained fatty acid in the triacylglycerol form, whereas the SAT diet contained free fatty acids. The UNSAT diet contained 5.11% stearic acid (C18:0) and 41.05% linoleic acid (C18:2), and the SAT diet contained 28.43% C18:0 and 14.81% C18:2 (Figure 2).

Twelve female CD-1 mice and 6 male CD-1 mice were assigned to each dietary treatment and fed their respective diets during an approximately 14-d breeding period. The females were fed their assigned diet through gestation and lactation. Fresh feed was offered once daily ad libitum, and fresh water was provided via water bottles. Feed containers were cleaned daily. It was essential to begin feeding the diets to female and male mice before the class actually began so that timing of parturition could occur by wk 6 and 7 of the quarter. This also allowed students the opportunity to help feed and weigh mice, clean cages, and observe parturition.

During the breeding period female mice were checked for plug formation. The female mice with plugs were placed in individual shoebox cages and remained on their assigned diets during the remainder of gestation and the subsequent lactation period. Cages were bedded with 50% CareFRESH (Absorption Corp., Ferndale, WA) and 50% Soft Paperchip (Shepherd Specialty Papers, Watertown, TN). During the entire study mice were fed ad libitum, and the amount offered once daily was adjusted based on the previous day’s consumption, which allowed for changes in intake in response to the nutrient and energy needs of gestation and lactation. It was not possible to measure the feed intake of the female mice because they spilled feed from the feed cups and eventually the pups were also consuming dry feed. Following parturition, the students counted the number of pups born, weighed the pups as a litter, and determined the sex of each pup based on anogenital distance. Data were recorded weekly during each of 5 laboratory sections in a common logbook.

Between d 7 to 10 of lactation, the students gave each female (dam) a 0.1-cc i.p. injection of oxytocin (Bimeda-MTC Animal Health Inc., Cambridge, Canada) to induce milk letdown. Using a milking system with constant vacuum described previously (DePeters and Hovey, 2009), students milked each dam (Figure 3), and milk samples were stored frozen for subsequent fatty acid analysis. At the conclusion of the study, all mice were euthanized using carbon dioxide according to the animal care protocol, and adipose tissue from the abdomen and kidney was collected. Both milk and adipose were analyzed for fatty acid composition by gas chromatography (DePeters et al., 2001). Photos of the students participating are shown in Figure 3.

**RESULTS AND DISCUSSION**

**Project 1**

Students worked in groups of 2 during laboratories 6 and 7, where they learned the methods used for chemical analysis of feed and feces. Each laboratory section worked with approximately 6 to 8 samples so that each individual sample was analyzed during 2 different laboratory sections. This allowed a way to check the laboratory results for accuracy. The students learned the following laboratory methods: moisture by drying sample at 105°C to a constant weight, ash by combustion at 500°C, total lipid by ether extraction, NDF by a fiber method, and total nitrogen (to calculate CP) by thermal combustion. Chromium was determined by atomic absorption, and the results of the analyses were distributed to the students because of the time required to do the analyses.

Digestibility data are presented in Table 1. The chemical compositions of the feed and feces are the averages of student analyses from all 5 laboratory sections. There were data for only 2 rabbits during this year because 2 were dropped from the study because of low feed intake. The alfalfa hay was made into a 1.91-cm (3/4 inch) pellet. The pellet is easily consumed by the sheep and horses, but it is too large for the rabbits. Students reduced the pellet size fed to the rabbits by breaking up the pellets; however, the feed then contains fines and becomes

**Figure 2.** Fatty acid (FA) composition of the diets. UNSAT diet = unsaturated lipid diet; SAT diet = saturated lipid diet.
dusty, which reduces feed intake by some rabbits. In addition, the rabbits were colony raised and were accustomed to eating a small pellet as well as seeing few individuals. Some rabbits did not adjust to the large number of students, the feed offered, and the cage setting outside of the colony situation.

Students should work in their groups of 3 to do the digestibility calculations for each animal in preparation for the oral reports. For the sheep, the students must use the total collection method. The following digestibility calculation (for Gustavy, a wether) shows how to calculate the DM and NDF digestibility values for the total collection method.

- 7-d feed intake (as-fed basis) = 7,000 g of alfalfa pellets
- Alfalfa pellets (DM) = 87.94%
- DM intake = 6,155.8 g
- NDF content (DM) of alfalfa pellets = 42.83%
- NDF intake = 2,636.6 g = \( (6,156 \times 0.4283) \)
- Fecal output for 7 d (as-is basis) = 6,311.4 g
- DM of feces = 41.27%
- Fecal DM output = 2,604.7 g = \( (6,156 \times 0.4283) \)
- NDF content (DM basis) of feces = 56.86%
- Fecal NDF output = 1,481.0 g = \( (2,605 \times 0.5686) \)
- Apparent DM digestibility = \( \frac{(6,156 \times 2,605)/6,156}{100} = 57.7\% \)
- Apparent NDF digestibility = \( \frac{(2,636.6 \times 1,481.0)/2,636.6}{100} = 43.8\% \)

For the horses and rabbits, the indicator method (using chromic oxide) must be used. In the case of the sheep, the Cr indicator method can also be used because Cr is in the alfalfa pellets. In the following, digestibility calculations for the indicator method are shown for one sheep, Gustavy.

- DM digestibility = 100 − \( [100 \times (% \text{ Cr feed}/% \text{ Cr feces})] \)
- DM digestibility = 100 − \( [100 \times (0.284/0.653)] = 56.5\% \)
- NDF digestibility = 100 − \( [100 \times (% \text{ Cr feed}/% \text{ Cr feces}) \times (% \text{ NDF feces}/% \text{ NDF feed})] \)
- NDF digestibility = 100 − \( [100 \times (0.284/0.653) \times (56.86/42.83)] = 42.3\% \)

The students often compared the 2 methods, total collection versus indicator, using the sheep data. Both methods give similar results. However, the indicator method for the sheep is not exactly comparable to the method used for the horses and rabbits. We discussed throughout the study the advantages and disadvantages of the methods used. For the sheep, the fecal sample used for analysis was from the total fecal output for the 7-d period, whereas only grab samples of feces over the 7-d period were taken for the horses and the rabbits.

The students summarized their digestibility data for their written and oral reports, as shown in Table 2. The data showed that apparent digestibility of fiber (NDF) was highest in the sheep (total collection) and lowest in the rabbit. These data were discussed by the students in their oral and written reports with respect to differences in the digestive anatomy and feeding strategy of the animals. Feeding strategy could involve the effect of particle size of alfalfa on fiber digestion (rate of passage and rate of digestion) in the sheep, horse, and rabbit or the effect of feeding the sheep at slightly above maintenance compared with feeding the horses and rabbits at a higher level needed for growth and reproduction.

Apparent fiber (NDF) digestibility was highest in the sheep and lowest in the rabbit (Table 2). This agrees with what was discussed in the lectures. The sheep is a bulk grazer with a digestive anatomy and strategy that evolved to digest fiber. Fiber (cellulose and hemicellulose) is slowly digested by microbes compared with starch and sugar. Retention of fiber in the rumen of sheep allows the microbial population to digest fiber. In contrast, the horse, which in class was classified as a nonruminant hindgut, colon fermenter, has a rapid passage rate of fiber through the digestive tract, so less time is spent by the microbial population in the hindgut on fiber fermentation. This difference in passage rate of fiber is demonstrated to students through observation of the difference in fecal particle
The particle size in the feces of the horse is larger than that in the feces of the sheep. For the sheep there is a particle size restriction for passage out of the rumen through the reticulo-omasal orifice, whereas for the horse there is essentially no particle size restriction. The rabbit digestive anatomy (nonruminant, cecal fermenter) evolved with a strategy to spend less time fermenting fiber compared with other nutrients. The fiber is passed in a fecal pellet. The rabbit practices coprophagy—eating feces. The rabbit consumes its soft fecal pellet, which is from cecal fermentation of pectin and protein. This soft pellet provides the rabbit with microbial protein and some vitamins (B and K). We discussed the potential problem of coprophagy with respect to our marker, chromic oxide. These differences in digestive anatomy and diet strategy were presented in the lectures.

Examples of what students predicted for fiber digestion in some selected hypothetical animals are presented in Table 2 for the African elephant and the red kangaroo. The data for the hypothetical animals are directly from student reports. Grades for the oral presentations and written reports ranged from 85 to 100%. The oral and written reports demonstrated that students were integrating concepts and thinking about nutrition from a comparative approach.

**Project 2**

At approximately d 7 of age, the sex of each mouse pup was determined by students based on anogenital distance. There was no effect of diet on sex of offspring born, as shown in Figure 4. Students were presented with data from the previous year, which also showed no difference in sex in response to UNSAT or SAT.

Diet did affect the fatty acid composition of milk lipids (Figure 5). Milk lipids of mice fed SAT were higher in saturated fatty acids (C14:0, myristic acid; C16:0, palmitic acid; C18:0, stearic acid) and lower in linoleic acid (C18:2), an unsaturated fatty acid. Diet altered the fatty acid composition of adipose lipids, as shown in Figure 6. Adipose lipids of mice fed SAT were higher in saturated fatty acids (C14:0, myristic acid; C16:0, palmitic acid; C18:0, stearic acid).

![Figure 4. Sex ratio of offspring. UNSAT diet = unsaturated lipid diet; SAT diet = saturated lipid diet.](image-url)
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and lower in unsaturated fatty acids (C18:2, linoleic acid; C20:4, arachidonic acid). The increase in oleic acid (C18:1) with SAT was not anticipated by students, and later during the lecture the importance of the stearoyl CoA desaturase enzyme (delta-9-desaturase) was discussed. The delta-9-desaturase enzyme converts C18:0 to C18:1 by inserting a double bond at position 9 from the carboxyl end. Basically the SAT diet supplied more C18:0, and thus there was more substrate to be converted to C18:1.

The fatty acid composition of the diet did not influence the sex of the pups born. We have no data to support an expected change in offspring sex, but the hypothesis was proposed and the students collected the data to prove or disprove the hypothesis. The fatty acid composition of the diet (SAT vs. UNSAT) did affect the fatty acid composition of milk and adipose lipids as expected. The diet higher in unsaturated fatty acids (UNSAT) increased linoleic acid (C18:2) in milk and adipose lipids compared with the diet low in unsaturated fatty acids (SAT). The mouse has a nonruminant digestive system, with no foregut fermentation and little hindgut fermentation. The changes in milk and adipose lipids reinforce information taught in the lecture regarding how nonruminants (without foregut fermentation) are what they eat with respect to fatty acid composition of lipids. The definition of a nonruminant, simple-stomach animal is an animal with no fermentation in the foregut and little fermentation in the hindgut, which would include the human, pig, dog, and mouse. In the lectures we discussed that for lipids, ruminants are not what they eat because of rumen biodesaturation of unsaturated fatty acids. Basically the fermentation process in the rumen converts unsaturated fatty acids to saturated fatty acids, and therefore ruminant lipids are more saturated in fatty acid composition. In the mouse, there is no foregut fermentation to hydrogenate fatty acids before their absorption from the small intestine.

In projects 1 and 2, by actively participating in the experimental and data sequestering process, students had the opportunity to observe firsthand the effect of differing digestion systems. It is theorized that these exercises allow students to increase their understanding of lecture material. In a study conducted at the University of Georgia, students enrolled in a companion animal class were taught using 4 methods of teaching: 1) general lectures by guest instructor; 2) special topics presented by guest professors; 3) videos shown in class; and 4) out-of-class experiential learning projects” (Murry and Downs, 1998). These students were asked to evaluate each teaching method on a scale of 1 to 5, with 5 being very good. Method 4, the experiential teaching method, had the highest rating at 4.6 ± 0.62 for usefulness in learning the course material (Murry and Downs, 1998).

Students in the nutrition class also got the opportunity to rate projects 1 and 2 and comment on their experience with project 2. Project 1 received an average score of 4.4. Project 2 received an average score of 3.7.

When asked anonymously whether they thought project 2 should be continued during next year’s class, students gave many positive responses:

- “Research studies prepare us for doing actual research beyond undergraduate school.”
- “1. I got to see firsthand a chemical injected into the mouse, oxytocin, to increase milk production. 2. Hands-on experience measuring the weight of mouse and pups for weight differences. 3. Handling and injecting oxytocin to the mouse.”
- “Project let students get some hands-on experience with lab animals.”

However, we also received some differing opinions for project 2:

- “Maybe, if we did something with the results like calculations or a project.”
- “Though milking and weighing the mice were fun, I need more background and actual interaction with the data and results analysis to learn anything from it.”

These comments lead us to believe that project 1 was rated higher than project 2 because of the amount of experience analyzing and discussing the data to complete the paper and project. Project 1 accounted for 15% of their course grade, whereas project 2 did not contribute to the course grade. These results support the idea that experiential learning contributes
to the educational process and has the ability to increase a student’s understanding of lecture material. In the case of project 2, the student responses of constructive criticism highlighted the need for a well-designed experiential learning project, and in the future project 2 could be redesigned to include a paper or an oral report to attain the goal of increasing retention of the material.

**IMPLICATIONS**

By employing a direct experience method through experiential learning, there is the opportunity for students to increase their concrete experiences as described by the Cone of Experience. Previously reported studies showed evidence that a hands-on approach may increase understanding of material taught in a lecture format while stimulating a student’s interest in the subject matter. Integrating concepts with an experiential learning experience helps students retain information, hopefully inspires students to think about how nutrition plays a role in their lives, and makes the educational experience more enjoyable.

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**LITERATURE CITED**