M^3 Challenge Fourth Place Team
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Columbus North - Team #3317, Columbus, Indiana
Coach: Michael Spock
Students: Tushar Chandra, Brian Pierson, Chris Von Hoene, Byron Zaharako

Problem: Lunch Crunch: Can Nutritious Be Affordable and Delicious?

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Team #3317

I. Executive Summary

Each day, 32 million students eat their lunch at their school [6]. Some students buy their lunches from the cafeteria; others participate in the Free or Reduced Lunch program to offset the cost of the meal. The students outside the 32 million may bring lunch from home or eat elsewhere. Regardless of how they eat lunch, its importance cannot be understated; nutrition and energy from meals are essential for proper functioning. There has been a recent policy initiative to encourage healthier eating and living in the United States, especially for students. School lunches are at the center of this push, as they must be affordable to schools but also nutritious and appealing to students.

The United States Department of Agriculture asked us to analyze the school lunch situation and create a number of models. Understanding that the United States is an incredibly large and diverse country, we first studied the effect of geographical variation on variables such as average age and hours of sleep. Using the statistical procedure two-sample *t*-test for the difference of means, we concluded that there is no significant geographical variation for such characteristics across the United States.

We were asked to develop a mathematical model that takes a student’s individual characteristics and gives as output the number of calories that student should eat at lunch. We incorporated a number of factors in this analysis, including age, gender, height, mass, physical activity, hours of sleep, frequency of breakfast consumption, and socioeconomic status to model caloric needs. We then performed a sensitivity analysis to find that the model is somewhat sensitive to changes in frequency of breakfast consumption, physical activity, and hours of sleep.

The USDA also asked us to determine distributions of US high school students based upon the characteristics accounted for in our model. We first determined that 825 calories is the the average intake required for high school students at lunch. We used randomly generated samples from the US Student Survey in order to calculate what proportion of students have their daily caloric needs met by an 825-calorie lunch, and found that just over 50% of students’ needs are met by such a lunch.

Last, we demonstrated that it is possible to for schools to serve meals that are healthy, affordable, and delicious. Given a budget of $6 per student per week, we created a simulation and developed a lunch plan that allowed students to eat one item from each of the five major food groups (grains, fruits, vegetables, dairy, and protein) in order to be nutritious, and an optional dessert in order to be appealing. Each meal plan included less than 850 calories, the maximum recommended by the USDA. We then analyzed the change in lunch plans if the budget were increased to $7 per student week. This change allows for greater variety and appeal of meals.

The conclusion from our analysis was clear: schools can serve healthy, affordable, and nutritious food. With this in mind, we can take steps to encourage better eating habits and create a healthier nation for years to come.

Table of Contents:

I. Summary 2

II. Introduction 4

1. Background 4
2. Restatement of the Problem 4
3. Notation 5
4. Global Assumptions 5

III. Analysis of the Problem and Our Models 5

1. Accounting for Geographic Variation 5
2. Modeling Students' Caloric Needs 7
3. The Distribution of Caloric Needs 12
4. Developing a Lunch Plan 15

IV. Conclusion and Recommendations 17

V. Bibliography 18

II. Introduction

1. Background

Each day, 32 million students across the United States eat lunch at school [6]. Some students bring their lunch, and others purchase lunch at school. Steps have been taken to ensure that every student has the opportunity to eat lunch [8]; programs such as Free and Reduced Lunch, administered by the USDA, allow many students to eat lunch at school even if they cannot afford to do so.

Since the election of Barack Obama, First Lady Michelle Obama has expressed concern over the poor quality of school lunches, rising obesity rates, and people (particularly young people) living increasingly unhealthy lifestyles. The Healthy, Hunger-Free Kids Act was passed to allow the USDA "to make real reforms to the school lunch and breakfast programs by improving the critical nutrition and hunger safety net for millions of children" [8]. Such changes included promoting whole grains, serving more fruits and vegetables, reducing the amount of sodium and fat, and providing healthier portion sizes [6].

However, there exist concerns even after these reforms. Policy implementation revealed problems with the school lunch system. Though the government is concerned with schools serving unhealthy food to students [6], some schools feel that they are unable to serve healthier alternatives because they are generally more expensive. Students, meanwhile, approve of reforms (one study found that 82% were supportive) but often do not eat the food served. Administrators have seen food thrown away simply because students do not like it [7].

Thus, a triangle of competing interests has been created. Students care primarily about taste of the food; school systems care about how much foods cost; the government cares about promoting a healthy lifestyle. We have been asked to provide insight into the problem of competing interest through mathematical modeling. We assess in this analysis the impact of geographical variability in caloric needs and how much individual attributes matter in a student's individual caloric needs. We also model the distribution of United States high school students based on those attributes. Last, we developed potential school lunch plans within a constrained food budget of $6 per student per week.

2. Restatement of the Problem

In this paper, we were asked by the United States Department of Agriculture to develop mathematical insights into the problem of competing interests. We were asked to model the caloric needs of a student based upon various individual factors, such as whether they eat breakfast and their daily activity level. We were then asked to model the distribution of high school students among the categories used in the first model. Last, the USDA requested we create sample lunch plans staying within budgets of $6 and $7 per student per week while still being healthy and appealing.

3. Notation

For simplicity, we use the term “calorie” to refer to dietary calories, also known as Calories or kilocalories. The scientific definition of calorie (heat required to raise 1g of water by 1 degree Celsius) will not be used in this paper.

4. Global Assumptions

1. The proportion of vegetarians, vegans, and those with other dietary restrictions is too insignificant to merit a significant change in models.

III. Analysis of the Problem and Our Models

1. Accounting for Geographic Variation

Approach:

When the federal government considers implementing anything on a national scale, it is necessary to analyze the feasibility of a policy in various diverse communities. Each of the 50 states, let alone cities and school systems, is unique in the characteristics of the students there. Therefore, we first analyze differences between the student populations of various states.

Using data from Census at School, we first randomly sampled 500 students in the United States and examined characteristics including age, gender, hours of sleep per school night, and outdoor activity per week [2]. We then took samples of size 100 from seven randomly generated states: Utah, New Jersey, Nebraska, Connecticut, Texas, West Virginia, and California. With each of these samples, we calculate the mean and standard deviation for age as well as the mean and standard deviation for hours of sleep per school night.

The mean age of students sampled in the United States is 15.48 years, with a standard deviation of 3.71 years. (The population sampled consisted primarily of middle school and high school students.) We perform a two-sample *t*-test for the difference of means. The conditions required for inference [3] are the following:

1. *Randomness*: The eight samples taken are all random samples.
2. *Independence*: Because the samples are random and the data for one student

does not depend on that of another, the data points are independent.
3. *Independent Groups*: Each sample is independent of the rest.
4. *Nearly Normal*: All eight samples are nearly normally distributed. This is due primarily to the large sampling size, for at sample sizes of *n* = 40 or more, the central limit theorem states that sample distributions will be nearly normally distributed regardless of the distribution of the population.

Because the conditions for inference are satisfied, we can proceed with the *t*-tests. We first test the average age of students in each state. Our null hypothesis is

$$H_0: age_{US} - age_{state} = 0;$$

that is, there is no difference between the average age of students in the United States and in a particular state. We calculate the test statistic,

$$t = \frac{age_{US} - age_{state}}{SE(age_{US} - age_{state})} \text{ where } SE = \left(\frac{s_{US}^2}{n_{US}} + \frac{s_{state}^2}{n_{state}}\right)^{1/2},$$

and perform the *t*-test.[1] Using an alpha level of $\alpha = .05$, we get *p*-values $p > \alpha$ in every case. Because $p > \alpha$, we do not reject H_0. We are able to conclude, then, that there is no significant difference between the average age of students in the United States and students in each of these seven states. Assuming that our sample of seven is representative of the United States as a whole,[2] we conclude that there is not a significant difference between the average age of students in each state across the United States.

Repeat the procedure, testing this time for average hours of sleep on school nights. (Later models will incorporate this value, so it is helpful if there is no significant difference in this statistic across the United States.) The null hypothesis is

$$H_0: sleep_{US} - sleep_{state} = 0,$$

meaning that there is no difference between the average number of hours of sleep on school nights for students in the United States as a whole and in a particular state. The test statistic is calculated in the same fashion, and once again using an alpha level $\alpha =$ .05, we have *p*-values $p > \alpha$. Since we used the same seven states, the sample of

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[1] Note that *s* represents the standard deviation of the sample, and *n* represents the sample size.

[2] The sample of seven states included Utah, New Jersey, Nebraska, Connecticut, Texas, West Virginia, and California. Note that this sample was randomly selected, and it also includes a great variety of states: high income and low income; east coast, west coast, and central; high and low populations; and other similar characteristics. We can safely say that this sample is representative of the United States as a whole.

states is representative of the United States. We conclude there is not a significant difference between the average hours of sleep of students in each state across the United States.

Conclusion:

We have shown that there is not sufficient evidence to conclude that a difference exists between these two characteristics (age and hours of sleep) across the United States. Because of this, we can conclude that geographical variation does not underlie factors like age and hours of sleep, and we can safely leave it out of our model for an individual's caloric needs except as an influencing agent for other variables.

2. Modeling Students' Caloric Needs

Assumptions:

1. Being below the poverty line and eating breakfast are independent of each other. Students often do not eat breakfast in large part due to lack of time or other causes independent of poverty. This assumption is also made for the sake of simplicity.

2. The average American student eats a total of 580 calories in snacks per day [9]. We left this figure at a flat number of calories rather than a percentage of total caloric intake, because a typical snack is a single prepackaged item (a muffin, a brownie, a bag of chips, etc.) that is not eaten in portions.

3. All high school students follow or at least attempt (see Assumption 4) to follow a standard three-meal plan and consume breakfast, lunch, and dinner (or just lunch and dinner, if breakfast is skipped) at ordinary times. We make this assumption on the basis of its universality in the United States.

4. Although students may skip breakfast, they will always receive dinner. We make this assumption on the basis that (a) time constraints are far less of an issue with dinner than with breakfast and (b) dinner is generally perceived as more important than breakfast.

5. Caloric intake is spread evenly among meals. Although any one person may usually consume more calories at one meal than the other two, specific proportions are difficult to calculate without detailed knowledge of the person in question. Additionally, when many people's eating habits are averaged together, we find that consumption trends toward being uniform.

Approach:

One of the tasks assigned to us by the USDA was to develop a mathematical model that takes an individual student's characteristics as input, and gives as output the number of calories the student should eat at lunch. We define the following variables:

$a = age\ (years)$,
b= *proportion of weekdays on which breakfast is eaten (%),*
$h = height\ (meters)$,
$l = calories\ added\ due\ to\ poverty\ (cal/d)$.
$m = body\ mass\ (kilograms)$,
$P = physical\ activity\ coefficient$,
S=*caloric value of snacks consumed in a day (cal/d),*
$t = time\ slept\ the\ night\ before\ school\ (hours)$,

We believe that these statistics should be sufficiently easy to gather for a particular student. They are straightforward physical or societal figures that are likely already tracked and stored; if not, they are easily obtainable. By ensuring that all of the values are easily obtainable, we can minimize error due to the unlikelihood of any given figure being a incorrect representation of its student.

When we begin to construct our model, we maintained the same attitude that we did when choosing variables: by keeping terms simple and readable, we can also reduce confusion and error in the final production. As such, we decided to break our model into smaller and more definable potions. These portions are

$$C(a,P,m,h) = \ normal\ caloric\ intake \quad (1),$$
$$F(t) = \ the\ effects\ of\ sleep\ deprivation\ on\ caloric\ intake \quad (2),$$
$$M(b) = \ the\ portion\ of\ total\ caloric\ intake\ relegated\ to\ lunch \quad (3).$$

Again, we believe these portions to be comprehensible and meaningful to anyone who would choose to use our model. We also believe that these formulas fit together in easily understandable manner. By adding the normal caloric intake $C(a,P,m,h)$ with the extra caloric intake from sleep deprivation $F(t)$, and then subtracting the calories consumed outside of regular meal time (S), we find the quantity of calories that need to be consumed in meals. We then divide by 3 to find the number of calories assigned to lunch when three meals are consumed. Once we have this value, we multiply by the breakfast coefficient $M(b)$, which gives us the average number of calories required to be consumed at lunch to compensate for a loss of breakfast. Finally, we add l if the student in question falls below the poverty line, which will be explained later. Our final model is

$$Lunch\ Caloric\ Intake\ = \frac{C(a,P,m,h) + F(t) - S}{3} \times M(b) + \ l \quad (4).$$

We next look at the mathematics behind each of these portions.

<u>*C(a,P,m,h)*: Daily Caloric Intake:</u>

We first look at the formula for the daily caloric requirement of the student. This is already a heavily documented subject, and as such we found it unnecessary to create our own model from the ground up. We decided to use the latest Estimated Energy Requirement (EER) equations [4] published by the Institute of Medicine, which form the basis for the government's 2005 Dietary Guidelines for Americans as well as the new food pyramid, MyPyramid. Since we are primarily interested in high school students, we use the equations for the age range 9 to 18 years old. We also use two different equations for male and females, to observe the biological differences associated with calorie requirements. The equation for males is

$$EER\left(\frac{cal}{d}\right) = 88.5 - 61.9a + P(26.7m + 903h) + 25 \quad (5),$$

and the equation for females is

$$EER\ (cal/d) = 135.3 - 30.8a + P(10.0m + 934h) + 25 \quad (6).$$

This gives us functions that output caloric requirements based on body type and physical activities. The *P* coefficient is found by calculating the Physical Activity Level (PAL), which we did using time-based criteria [4]. The PAL value found can then be converted to the *P* coefficient with the following table:

PAL to *P* coefficient conversion chart	Boys (3–18 years old)	Girls (3–18 years old)
Sedentary 1.0 ≤ PAL <1.4	1	1
Low Active 1.4 ≤ PAL <1.6	1.13	1.16
Active 1.6 ≤ PAL <1.9	1.24	1.31
Very Active 1.9 ≤ PAL <2.5	1.42	1.56

source: http://www.globalrph.com/metabolic_equivalents.htm

Using the newly found *P* coefficient, we can now calculate normal caloric intake. The simplified equation, as well as the notation, that we will be using when referencing these equations is

$$C_m(a, P, m, h) = -61.9a + P(26.7m + 903h) + 113.5 \quad (7)$$

for the equation for males and

$$C_f(a, P, m, h) = -30.8a + P(10.0m + 934h) + 160.3 \quad (8)$$

for the equation for females.

<u>*F(t):* Sleep:</u>

The second factor in total caloric intake is based on sleep, or the lack thereof. Sleep deprivation is a fairly common issue among high school students [16], and recent studies [17] show it has a major effect on caloric intake. When a person sleeps for two thirds of the recommended amount of time, caloric intake increases by 559 cal/d. When coupled with the recommended amount of time spent asleep, 9 hours a night [18], some basic algebra brings us to the value of 186.33 cal/d/hour of sleep deprivation. We format this in equation as

$$F(s) = 186.33 \times (9 - s) \quad (9).$$

We use $9 - s$ to represent sleep lost because hours spent asleep is a more easily recordable value than hours of sleep lost.

<u>$M(b)$: The Breakfast Multiplier:</u>

A large number of teenagers skip breakfast. To compensate for this loss, we need to add to the number of calories consumed during lunch. Multiplying the total amount of calories required per meal by the function

$$M(b) = 1 + .5 \times (1 - b) \quad (10)$$

results in the new total number of calories required from a lunchtime meal in order for caloric intake to average to the mean number required in the long run. The variable b represents the proportion of weekday breakfasts the student in question consumes. For example, a student missing one breakfast per week will have a b-value of 0.8. The multiplier of .5 results from the assumption that calories missed due to skipping breakfast will be halfway split between breakfast and dinner.

<u>S and l:</u>

S is a constant used to compensate for snack intake per day. The average American consumes an average of 580 calories in snacks per day [9], and we assume teenage students to be sufficiently representative of the population in this respect. Because of this, we subtract 580 calories from the total number of calories required per day.

l is a heuristic we created in order to account for the fact that people in poverty eat a poorer quality diet [19] and would therefore benefit from having a greater portion of their caloric intake per day come from a balanced source of nutrition. We chose 200 calories as the amount to add for students living in poverty as a number sufficiently small to reduce potentially destabilizing effects into our equations but large enough to significantly improve the quality of a meal.

Final Model:

Combining all of the previous equations yields the final formula for our recommended Lunch Caloric Intake (LCI) for males and females:

$$LCI_m(a, P, m, h, t, b, l) = \frac{-61.9a + \mathrm{P}(26.7m + 903h) + 186.33(9 - t) - 466.5}{3} \times \left(1 + .5(1 - b)\right) + l \quad (11),$$

$$LCI_f(a, P, m, h, t, b, l) = \frac{-30.8a + P(10.0m + 934h) + 186.33(9 - t) - 419.7}{3} \times \left(1 + .5(1 - b)\right) + l \quad (12).$$

Sensitivity Analysis:

Factors such as age, mass, height, and being impoverished are generally out of an individual's control. However, there are three factors that can be controlled: hours of sleep, breakfast consumption, and the physical activity coefficient. Consider the function LCI_m, particularly with respect to the three aforementioned variables.

When we hold constant *a = 18* years, *w = 62* kg, *h = 1.68* m, and *l = 200* calories, we obtain the function

$$LCI_m(P, t, b) = \frac{-61.9(18) + P\left(26.7(62) + 903(1.68)\right) + 186.33(9 - t) - 466.5}{3} \times (1 + .5(1 - b)) + 200 \quad (13),$$

which, after algebra that will not be shown for brevity, reduces to

$$LCI_m(P, t, b) = 248.12 + 1586.22P - 93.165t - 16.046b - 528.74Pb + 31.055tb,$$
$$P \geq 1;\ 4 \leq t \leq 12; 0 \leq b \leq 1 \quad (14).$$

To perform our sensitivity analysis, we take partial derivatives:

$$\frac{\partial \mathrm{L}}{\partial \mathrm{P}} = 1586.22 - 529.74b \quad (15),$$
$$\frac{\partial \mathrm{L}}{\partial \mathrm{t}} = -93.165 + 31.055b \quad (16),$$
$$\frac{\partial \mathrm{L}}{\partial \mathrm{b}} = -16.046 - 528.74P + 31.055t \quad (17).$$

We can approximate change in the function from (P,t,b) = (1.1,9,1)[3] by using the linear approximation

$$\begin{aligned} LCI_m(P,t,b) &\approx 1057.5P - 62.1t - 318.2b + 550.2 \\ &= 105.75(10P) - 62.1t - 31.8(10b) + 550.2 \quad (18). \end{aligned}$$

As a reference value, $LCI_m(1.1,9,1) = 836$. From this, we see that for every increase $\Delta P = .1$ (an increase in physical activity), calorie requirements for lunch increase by about 106 calories (13%). For every increase $\Delta t = 1$, getting 1 more hour of sleep a night, calorie requirements for lunch decrease by about 62 calories (7%). Last, for every increase $\Delta b = .1$, an increase of 10% in the frequency of breakfast consumption, calorie requirements for lunch decrease by about 32 calories (4%).

Note that for this sensitivity analysis, we use the model LCI_m, which is the model for lunch caloric intake for males. While there is a separate equation for females, the parameters are the same; the models differ only in the coefficients and constants in the equations. The same process would have worked for a sensitivity analysis for the female caloric intake model, and it is reasonable to conclude that the results would have been largely the same.

Our model is therefore slightly sensitive to changes in the variables of physical activity, hours of sleep, and breakfast consumption frequency. Even if there is moderate error in our models, the conclusion does not change; calories required at lunch increase as one is more physically active and decrease as one sleeps more at night and eats breakfast more frequently.

Conclusion:

The caloric intake for an individual can be accurately modeled by a function incorporating a sufficient number of factors, including age, weight, and physical activity. The model we have created is slightly sensitive to changes in the input variables but not so much that our results rely too much on the assumptions we have made.

3. The Distribution of Caloric Needs

Assumptions:

1. An average school lunch will provide 825 calories, just below the maximum recommended amount by the US Department of Agriculture as of 2010 [11]. After the implementation of the Healthy, Hunger-Free Kids Act of 2010, many schools had to work to cut the calories in their lunch offerings to below the maximum of

[3] We choose this point as a reasonable set of parameters for low calorie requirements. P = 1.1 represents little to moderate physical activity, which is common among Americans; $t = 9$ represents the recommended 9 hours of sleep each night; and b = 1 represents eating breakfast every day.

850 calories [14].

2. All factors to be analyzed except income are independent of geographical region. We make this assumption based on the results from part 1, in which we analyzed the geographic variation in various statistics.

3. Variation in randomly generated factors is insignificant due to our large total sample size (*n* = 2434).

Approach:

To determine the number of students whose caloric needs will be met, we ran random samples of 250 high school students generated from data collected from the Census at School organization through a computer program that utilized Equations 11 and 12 to determine average caloric needs per student. The average effect of poverty level by region and the average number of breakfasts skipped was incorporated by a weighted random number generator using data from the US Census Bureau and healthychildren.org, respectively.

Weight was generated randomly based on information from the CDC published in 2000 [12]. Due to time constraints, we were unable to correlate weight with height (which, conversely, was available in our survey data).

The proportion of high schoolers regularly skipping breakfast is 20% [13]. “Skipping breakfast” is taken to mean that they miss all or nearly all (60% to 100%) of breakfast meals on school days. To account for this, our program generated a proportion of missed breakfasts between 0.6 and 1.0 for 20% of the students. We assumed that missing breakfast was independent of all other factors for simplicity.

A 95% confidence interval will be created for each of the proportions of students with caloric needs met. The conditions for such an interval are as follows:

1. *Randomness*: The sixteen samples taken are all random samples.

2. *Independence*: Because the samples are random and the data for one student does not depend on that of another, the data points are independent.

3. *Independent Groups*: Each sample is independent of the rest.

4. *Nearly Normal*: All sixteen samples have nearly normally distributed caloric needs. This is due primarily to the large sampling size, for at sample sizes of *n = 40* or more, the central limit theorem states that sample distributions will be nearly normally distributed regardless of the distribution of the population.

The four regions analyzed were the northeast, the midwest, the south, and the west, as well as the United States as a whole. The sixteen random samples we generated were taken from 2010 to 2013 and contained a total of 2434 students with complete and viable information (obviously false or incomplete claims disqualified the data of the student in question). Based on Equations 11 and 12, the percentage of students in each region whose caloric intakes would be satisfied by an 825-calorie school lunch is as follows:

Region	Northeast	Midwest	South	West	National
Average Calories Required at Lunch	830	837	842	837	837
Proportion of Satisfied Students	52.8%	52.7%	51.3%	52.8%	51.8%
95% Conf. Interval	41.5-64.2%	42.3-63.1%	42.5-60.2%	45.1-60.5%	42.3-61.4%

For the purposes of accuracy, we also decide to incorporate proportions based on changing our variable l (the extra calories required for a student whose family's income is below the poverty level) to 100 and to 0. The table for the proportion of satisfied students by region for $l = 100$ for impoverished students is as follows:

Region	Northeast	Midwest	South	West	National
Average Calories Required at Lunch	819	816	822	818	820
Proportion of Satisfied Students	54.3%	54.9%	54.2%	54.6%	54.8%
95% Conf. Interval	44.9-63.8%	44.9-65.9%	42.4-66.0%	50.0-64.3%	44.2-65.2%

Setting l equal to zero for impoverished students nullifies differences between region, leaving us with the following national figures:

Region	National
Average Calories Required at Lunch	807
Proportion of Satisfied Students	55.3%

95% Conf. Interval	41.7-69.0%

The 95% confidence interval in each of the three tables is based on the standard error between sample means. The source code for the code used in generating these figures can be found at https://github.com/vonHub/M3-Part-2 in the form of a NetBeans Java project.

Conclusion:
Our program indicates that slightly over half of students across the United States will be satisfied by a lunch providing 825 calories. Income causes moderate variation but can be readily accounted for and does not cause catastrophic error when generalized to the entire United States.

4. Developing a Lunch Plan

Assumptions:

1. Students will eat the entire meal that is provided to them. While it is almost certain that some students will not enjoy the food served, some will be unable to eat it (due to vegetarianism, allergies, intolerances, etc.), and some will simply not eat all of it, it is nearly impossible to account for this random variation. Moreover, this is a factor out of the control of the school district, the cafeteria staff, and the federal government.

2. Having a food from each food group ensures that the lunch is sufficiently nutritionally balanced.

Restatement:
Our goal in this portion is to create a sample lunch plan that “stays within the budget, meets the nutritional standards, and appeals to students.” We interpret this as:

1. The cost per student per week is less than or equal to $6.00.

2. The meals provide enough energy to students. From the code utilized in part 3, we know that the average student requires roughly 825 calories in their lunch.

3. The meals provide adequate nutrition, meaning that it includes foods from all five food groups (grains, fruits, vegetables, dairy, and proteins).

4. There are a variety of potential meals, and they include an optional dessert in order to appeal to students.

Approach:
In our simulation “School Lunch Simulator 2014,” we allow simulated students to pick one of five choices from each food group with the option of one dessert. Simulated students choose their foods in order to fit the daily caloric intake to within 50 calories.

The program uses food price data from Costco Wholesale, and caloric data is provided by the United States Department of Agriculture.

The possible food choices, with price per serving and calories per serving, are shown in this table:

Grains	Fruits	Vegetables	Dairy	Protein
Bread ($.04, 185 cal)	Grapes ($.12, 98 cal)	Carrots ($.16, 35 cal)	Skim Milk ($.17, 90 cal)	Hamburger ($.33, 204 cal)
Bagel ($.10, 245 cal)	Apple ($.05, 95 cal)	Broccoli ($.13, 50 cal)	Chocolate Milk ($.20, 209 cal)	Egg ($.14, 78 cal)
Ramen ($.06, 190 cal)	Banana ($.06, 105 cal)	Asparagus ($.07, 3 cal)	Strawberry Milk ($.73, 230 cal)	Chicken ($.31, 250 cal)
Oatmeal ($.14, 158 cal)	Pear ($.09, 102 cal)	Corn ($.12, 77 cal)	Yogurt ($.29, 100 cal)	Ham ($.21, 145 cal)
Rice ($.11, 111 cal)	Kiwi ($.08, 42 cal)	Celery ($.09, 6 cal)	Cheese ($.11, 104 cal)	Catfish ($.37, 199 cal)

The optional dessert offerings were a Reese's Cup ($.29, 105 cal), a cake slice ($.12, 205 cal), a chocolate chip cookie ($.24, 105 cal), and a snickerdoodle ($.18, 95 cal).

The following table gives the results two different samples, of a school of size 1000 students and a school of size 2000 students:

	1000 students	2000 students
Total cost per day	$1154	$2283
Average cost per student per day	$1.15	$1.14
Average cost per student per week	$5.75	$5.70

Source code: https://github.com/thatapplefreak/SchoolLunchSimulator

This simulation results in a number of potential meals that satisfy all of our criteria stated above, four of which are shown below.

1. Oatmeal, banana, celery, chocolate milk, chicken, and a snickerdoodle ($.98, 823 cal)

2. Ramen, kiwi, broccoli, yogurt, ham, catfish ($1.14, 726 cal)
3. Bread, rice, grapes, 2 carrots, skim milk, hamburger, cake slice ($1.07, 758 cal)
4. Bagel, banana, corn, strawberry milk, 2 boiled eggs ($.79, 813 cal)

Budget Increase:

A potential option is to increase the weekly food budget by $1 to $7.00 per student. The simulation process does not change, and our results are largely predictable. When we increase the amount of food students can take, students become able to select multiple items from one food group while still including an item from all five groups. They select more food and often take healthier options than before due to this.

Another factor that can change with an increased budget is the food options themselves. Schools become able to purchase a greater variety of foods for the students because the budget is no longer so prohibitive. Moreover, they can purchase higher quality foods, as a common complaint of students is that cafeteria food is of low quality [7]. Increasing the budget clearly demonstrates positive side effects.

Conclusion:

It is possible for schools to serve nutritious and appealing meals that provide enough calories and stay within a budget. Even with the seemingly prohibitive budget of $6.00 per student per week, there are a plethora of potential lunch plans. When the budget increases to $7.00 per student per week, the options expand even more. While it was once thought that lunch plans could not appeal to students, provide nutritious value, and stay within a budget, we have shown that this is possible. Nutritious can indeed be affordable and delicious.

IV. Conclusion and Recommendations

Geography in and of itself accounts for no significant variation in caloric intake, nor does it significantly impact factors other than economic status. As such, we conclude that it is more important for states or regions looking to alter their lunch meal plan would be best advised by taking their economic status into account.

We can accurately model the caloric intake a particular student requires for a lunch meal by considering a variety of factors such as height, weight, age, and the number of hours of sleep they get. The equation we have generated accurately predicts the number of calories required for a satisfying lunch and is reasonably stable with regard to its inputs.

The majority of American high school students will have their caloric needs met by an 825-calorie school lunch. Between 50% and 55% of students at a national level have attributes that suggest that 825 calories provides adequate sustenance. Due to the approximately normal distribution of calories required for lunch, a small increase in the number of calories provided for a lunch meal would yield a relatively large increase in the number of students whose caloric needs were met.

A lunch budget of $6 per week is capable of producing a variety of balanced meals appealing to students, with a budget of $7 increasing both the possible quality and the variety of the meals offered. Our overarching conclusion is that it is indeed possible to be nutritious, affordable, and delicious.

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