Abstract

Inspired by the inaccessibility of laboratory experiences during the COVID-19 pandemic, we designed an at-home experiment on diet and diabetes for a high school (9th grade) life science course. It promotes active learning through an affordable experiment, embedded hyperlinks, and video content to make virtual learning exciting and accessible.

Key Words: diabetes; virtual laboratory experiments; diet and nutrition; active learning; affordable experiments.

Introduction

The years 2019–21 presented many educational challenges for students of all ages, from kindergarten to the graduate level. The COVID-19 pandemic sent education into a tailspin as the virus spread worldwide, closing classrooms. Many classes were forced to rapidly transition to fully online meeting platforms and virtual team rooms. While online meeting tools allow teachers to connect with classes remotely, these platforms are often not adequate for courses with unique learning experience requirements. For example, in the United States, accredited undergraduate nutrition programs often require demonstrated mastery of specified learning outcomes (e.g., students achieve certification in safe food-handling techniques) and manual skills (e.g., physical assessment of nutrition status and indirect calori-metry). Although there are many publisher-produced online instructional tools for general content and introductory courses (e.g., introductory biology or introductory chemistry), there are few or, in many cases, no options for more specialized laboratory courses such as for food science, nutritional biochemistry, or nutrition therapy. Nor are there online labs constructed to examine fundamental science concepts through the lens of applied disciplines such as nutrition. This alternate viewpoint can be powerful for engaging students who might initially experience science as a set of abstract concepts somewhat removed from their day-to-day experience.

Special-topic classes such as lab-based science courses and the musical arts, where physical aspects of instruction are integrated into the curriculum, can be particularly hard to translate into online experiences. Baker & Dannatt (2020) reported on the difficult transition for two undergraduate chemistry labs. The traditional experiments included in the syllabi were designed to be performed in a lab, not a student’s living space (Baker & Dannatt, 2020). The lab instructors were uneasy giving their students at-home lab work due to the fast-paced transition to online learning and the safety concerns some experiments could present in a student’s home (Baker & Dannatt, 2020). This was a common theme for many science students, including those at Syracuse University. At Syracuse, students were often limited to working with prerecorded data sets rather than generating data through cognitively stimulating experiments. Given our experience with the rapid transition to online instruction, we asked, “If large institutions with the monetary means to create and implement education solutions struggle in these times, what do science students experience in revenue-limited lower-income high schools?”

The authors had a unique opportunity to observe firsthand the disruption of primary and secondary school science education due to COVID-19. The Nutrition Program at Syracuse University offers several education outreach programs through the university’s Mary Ann Shaw Center for Public and Community Engagement. One program, Food Busters, works with 9th-grade students enrolled in a pre–health professions course in the Syracuse City School District. These students interview at the end of 8th grade to be accepted into an advanced curriculum, hoping to eventually enter the allied health and medical professions. In a typical academic year, the students learn about health conditions and diseases through a case-study–based approach focused on a fictional woman named Anna Garcia. Food Busters provides eight supplemental, interactive nutritional biochemistry lab sessions during the year, covering topics such as diabetes, hyperlipidemia, and cardiovascular disease, with an overarching focus on contributing nutritional factors.

In the spring of 2020, the Food Busters sessions ceased as the pandemic brought in-person instruction to an abrupt stop. The Food Busters’ face-to-face lesson plans and experiments were inaccessible...
to the students, and there was no readily available platform to deliver the activities online. Food Busters remained on furlough for the entire 2020–21 school year. Inspired by this accessibility problem, we began designing a new virtual Food Busters model with an interactive website to deliver at-home lab experiments. The goal of the virtual model is to make Food Busters accessible to our specific class while distributing free online lab experiments to all students interested in the sciences.

Here, we present the first online lesson plan created for the Food Busters Program. It is a prototype for sixteen additional lab-based lessons and experiments. We are building a virtual program to be delivered outside of a classroom with the hope of broadly disseminating content to additional schools and more students. The lesson plan includes an overview of background material, activity objectives, required supplies, procedures, and a rubric for discussion. In addition, links to a website for the students to use before and during the lab procedure are included. The website hosts videos and diagrams for instruction; information students need to understand the lab concepts, and hyperlinks to encourage a more dynamic virtual learning experience.

○ The Activity

Materials

• Internet access and computer
• A clean workspace (countertop)
• Website access / downloaded lab worksheet / data sheet.
• Kitchen scale (or conversions—see procedure)
• Calculator
• Sugar cubes
• Pen and paper
• Five nutrition labels from foods commonly found in a kitchen

Time Required

The lab activity takes approximately two hours. Students should use the first half hour to explore the “Experiment #1: Carb Counting, Added Sugars, and Diabetes Content” tab on the interactive website. This page contains background information (summarized below) interspersed with video content and hyperlinks. Students learn about diabetes and how its development and management are linked to nutrition. They will also find descriptions of the skills required to complete the activity and information to help answer the discussion questions. The next hour should be spent on the lab procedure. The final half hour should be spent completing the postlab discussion questions and posting answers to the collaborative discussion board.

Objectives

This activity addresses three elements of Next Generation Science Standards (NGSS) K-LS1-1, “From Molecules to Organisms: Structures and Processes”: LS1.A, LS1.B, and LS1.C (see Table 1A and Table 1B). The main focus of the activity is the core idea of LS1.C: “Organization for matter and energy flow in organisms.” It requires analysis and interpretation of data and allows students to explore patterns in the human-designed world that can be observed and used as evidence (a crosscutting concept). Students who demonstrate understanding of this lab activity will be able to

• Use observations to describe patterns of foods (macromolecules) humans need to survive.
• Explain the connection between nutrition and diet and the pathophysiology of diabetes development.
• Quantify the sugar content of common household snacks.
• Read food labels to perform calculations to convert grams of carbohydrate, total sugars, and added sugars into calories.
• Explain carbohydrate counting and its importance in diabetes management.

Table 1A. Carb counting lab activities and learning outcomes mapped to NGSS core ideas and learning outcomes.

| Students Who Demonstrate Understanding Can . . . | Lab Activity—Evidence of Learning | NGSS Core Idea | NGSS Learning Outcome |
|-------------------------------------------------|-----------------------------------|----------------|----------------------|
| Use observations to describe patterns of foods (macromolecules) humans need to survive | • Prelab review  
• Prelab quiz  
• Discussion activity | K-LS1-1  
LS1.A  
LS1.B  
LS1.C | HS-LS1-1  
HS-LS1-2  
HS-LS1-4  
HS-LS1-6  
HS-LS1-7 |
| Explain the connection between nutrition and diet and the pathophysiology of diabetes development | • Prelab review  
• Prelab quiz | LS1.A | HS-LS1-2  
HS-LS1-6 |
| Quantify the sugar content of common household snacks | • Food label analysis activity  
• Carbohydrate to gram calculations  
• Carbohydrate to calorie conversion | LS1.C | HS-LS1-3 |
| Read food labels to perform calculations to convert grams of carbohydrate, total sugars, and added sugars into calories | • Food label analysis activity  
• Carbohydrate to gram calculations  
• Carbohydrate to calorie conversion | LS1.C | HS-LS1-3  
HS-LS1-6  
HS-LS1-7 |
| Explain carbohydrate counting and its importance in diabetes management | • Discussion activity | LS1.A | HS-LS1-6  
HS-LS1-7 |
Before the Activity

Instructors provide the virtual lab URL (mavoss.expressions.syr.edu) to students via email or online education platforms such as D2L or Blackboard. Students should review the online resources before beginning the procedure. The virtual lab webpage is interactive. Students can click on hyperlinks and watch videos to explain concepts. Although created for Food Busters based on a specific course syllabus, any student can complete the lab successfully with the information provided in the content tab. The prelab material links to concepts from an existing biology course syllabus while introducing new content for enrichment. This content includes overviews of diabetes, nutrition facts labels, carbohydrate counting, and nutrition conversions. After viewing the instructions and preliminary content, a prelab questionnaire lets students know when they are ready to begin the procedure.

Background Material

Type 2 Diabetes Overview

Students must be familiar with the pathophysiology of type 2 diabetes and how nutritional factors contribute to its development. Students do not necessarily need this information to perform the procedure correctly. However, they will need to relate data from this experiment to diabetes prevention and management in the postlab discussion.

Type 2 diabetes is a chronic disease that affects blood glucose levels. In a nondiabetic person, the beta cells of the pancreas release the hormone insulin into the bloodstream when blood glucose increases after a meal (Centers for Disease Control and Prevention [CDC], 2020). Insulin travels through the blood and attaches to receptors on the muscle and fat cells of the body. This action
“unlocks” the door for glucose to enter cells, clearing glucose from the bloodstream for use in cellular metabolism. In contrast, the cells of a person with type 2 diabetes become resistant to insulin, and glucose remains in the bloodstream. Thus, the cells have less glucose to fuel metabolism. Over time, because of this insulin resistance, the beta cells of the pancreas secrete larger and larger amounts of insulin to maintain blood glucose within a normal range. Eventually, overworked beta cells can no longer maintain high levels of insulin secretion, and glucose accumulates in the bloodstream.

Insulin resistance, and the resulting type 2 diabetes, can originate in several ways (Figure 1). Chronic inflammation may trigger the biochemical pathway leading to insulin resistance, resulting in excess weight gain (Bruening & Burrell, 2021). Alternatively, excess weight gain from an energy imbalance may occur when a person consumes more food energy than they expend. When chronic, this positive energy imbalance can also trigger insulin resistance (Bruening & Burrell, 2021). Therefore, inflammation is both triggered by excess body fat and triggers insulin resistance, which leads to greater weight gain. Typically, a diet high in refined foods, saturated fats, and added sugars combined with an inactive lifestyle is linked to positive energy imbalance and chronic inflammation (Figure 1). This dietary pattern usually increases the accumulation of fat in the midsection of the body, called central adiposity. Central adiposity is dangerous because this fat secretes pro-inflammatory adipokines, chemical messengers that signal inflammation in the body (Bruening & Burrell, 2021). Figure 1 shows a basic overview of two alternate pathways leading to inflammation and type 2 diabetes and illustrates why nutrition may play a significant role in its prevention.

Food Label Overview
To complete the lab, students must be familiar with the nutrition facts label and understand how to interpret it. The U.S. Food and Drug Administration (2020) regulates food labels, ensuring people can make informed decisions regarding the food they eat. The nutrition facts label contains food serving sizes, calories per serving, and nutrient information such as added sugar and fat content. Students will focus on the grams of carbohydrate and total / added sugar information on the nutrition label in this activity. These can be found in the nutrients section alongside total fat, cholesterol, sodium, and protein.

Carbohydrate Counting Overview
Students will also learn about the carbohydrate counting system for diabetics, a topic they have not likely encountered before. Carbohydrate counting allows patients with diabetes to track the amount of carbohydrates consumed daily and at each meal, to maintain normoglycemia, or a regular amount of glucose in the blood (CDC, 2021). Ideally, individuals with diabetes will participate in Medical Nutrition Therapy provided by a registered dietitian nutritionist (RDN). In that case, the RDN creates a meal plan with a set amount of carbohydrate in grams and teaches the patient how to accurately count their daily intake (CDC, 2021). Unfortunately, many people with diabetes will not have access to or take advantage of the opportunity to work with a dietitian (Early & Stanley, 2018). Thus, many individuals with diabetes must learn to track carbohydrate intake on their own.

To count carbohydrates, one must first identify carbohydrate-rich foods (American Diabetes Association [ADA], 2014). Examples include starches, fruits and fruit juices, milk and yogurt, nonstarchy vegetables, and sweets/desserts (ADA, 2014). A person with diabetes must also understand how to measure carbohydrate servings (ADA, 2014). Carbohydrate content is reported in grams on a nutrition facts label. One carbohydrate serving is equal to 15 grams of carbohydrate (ADA, 2014). For example, a basic guideline for someone with diabetes might be to consume three carbohydrate servings per meal, equal to 45 grams of carbohydrate total. RDNs and certified diabetes educators work with diabetic patients to create eating plans specific to their individual needs (ADA, 2014).

Nutrition Conversions Overview
Each macronutrient (carbohydrates, fat, protein) has a different conversion factor that dietitians use to convert from grams of nutrients to calories of food. Students will only focus on converting grams of total sugar to calories and grams of added sugar to calories for this lab. The conversion factor is 1 gram of carbohydrate “sugar” = 4 calories.

Procedure
1. This activity is to be completed in your home kitchen. Begin by visiting the Nutritional Biochemistry webpage at mavoss.expressions.syr.edu. Locate the menu with drop-down options at the top of the webpage and click on the tab labeled “Everything but the Kitchen Sink: Experiments to do at Home.” The drop-down menu shows the list of experiments. The first tab is labeled “Lab Experiment 1: Carb Counting, Added Sugars, and Diabetes Introduction.” Read through the prelab overview, lesson objectives, and timeline.

2. After reviewing the activity, navigate to the “Lab Experiment 1: Carb Counting, Added Sugars, and Diabetes Introduction” link. (Note: the resource page is designed to engage students through a variety of learning modalities, including written information, embedded images, videos, and hyperlinks to enhance understanding.)

3. At the end of the page, the pre-experiment questionnaire will let you know if you are ready to begin the lab procedure. A link to the “Experiment #1 Lab Worksheet” is also found on this page. You may download the lab worksheet/datasheet to organize your lab data or write answers on paper if a printer is unavailable. Data collected from the experiment will be used to post to the discussion board after the activity is complete.
4. Next, click the “Lab Experiment 1: Procedure & Materials” link. Before beginning the activity, be sure you have all required lab materials assembled. Any five food or snack items can be used for this activity, as long as complete nutrition labels are present. Look for labels that include both total sugar and added sugar information.

5. Select a food item and record it in your datasheet under “Food #1 Name.” Next, focusing on carbohydrates and total/added sugars, record the total carbohydrate content, the total sugar content, and the added sugar content in grams.

6. Now use the information from the prelab to determine how many carbohydrate servings this food represents using the total carbohydrate content (in grams) of your selected food. (Note, the goal here is for numbers to take on “real-world” meaning through measurements and conversions.)

7. A gram may be an unfamiliar unit that you have not had to use before. However, you are probably familiar with units of calories. In this step, you will convert the grams of total sugars and added sugars you recorded into calories using the conversion factor supplied in the prelab resource material. The lab worksheet will guide you in these calculations.

8. The last step is to visualize the volume of sugar found in the foods you eat. Starting with “total sugar,” stack sugar cubes onto a scale until you have reached the grams of total sugar you recorded for one serving of your food. Alternatively, if you do not have access to a scale, use the conversion of one sugar cube = 4 grams of sugar to estimate how many sugar cubes your food snack contains. (Note, using sugar cubes to visualize the volume of sugar hidden in everyday foods is a tangible and powerful illustration of carbohydrate content).

9. Take a picture of your sugar cube stack to be posted and properly labeled to the online discussion thread when you have completed this activity.

10. Next, remove the sugar cubes from the scale and set them aside while you repeat the process for the added sugar content of your food. Now you have measured out two piles of sugar, one of total sugar in grams and one of added sugars in grams. Record your thoughts about how much sugar is really in the food you eat.

11. Repeat procedure steps 6–10 for the next four nutrition labels, using the lab worksheet as a guide.

12. After completing all measurements, respond to the online postlab discussion to link the data you have collected to the concepts presented in the prelab.

**Assessment Strategy**

Data from the lab activity can be used for an online discussion to connect methodology and observations with conclusions. Teachers can create class-specific discussion boards within their learning management system or use the discussion board provided on the virtual lab website. Students should create posts based on the following prompts:

1. Pick the snack that most surprised you in terms of its sugar content. Answer the following questions about this snack:

   - How many calories came from total sugar?
   - How many calories came from added sugar?
   - How many sugar cubes did you measure out for total sugar?
   - How many sugar cubes did you measure out for added sugar?
   - Did you expect this snack to have more or less than this amount of sugar in it? Explain your original expectations and what you think about your results. Will this observation change how you think about your snack selections in the future?

2. Why do you think it is important for people with diabetes to pay attention to the servings of carbohydrate they eat? Which one of your snacks had the most servings of carbohydrate?

3. Explain in your own words how the food people eat can help lead to the development of type 2 diabetes?

   Students should be given guidance on how the quality and level of their participation will be assessed. We provide a suggested rubric (Table 2) that can be mapped to letter grades (Table 3). General guidance for online discussions should include reminding students that posts and responses should be thorough and thoughtful; simply posting “I agree” is inadequate. Where appropriate, encourage students to support statements with examples, experiences, or references. Individual posts do not need to be long. Each post or response should be only one or two short paragraphs, usually 50–150 words. All posts and responses should address the question, problem, or situation as presented for discussion. Every post should build on and respond to posts of others. Students should be encouraged to compare and contrast their findings, as they may differ markedly between food items selected for analysis. In particular, students should explore differences in the analysis of food items at first may seem very similar. For example, different brands of granola bars may vary greatly in added sugar content. Discussion about what these observed differences might mean for health outcomes and future food choices should be encouraged. A particularly interesting topic of discussion might be the analysis of added sugar for snacks labeled or marketed as healthy. Does the food label analysis support the marketing claims or student perceptions? Where relevant to the discussion at hand, students should be encouraged to extend the conversation to include prior knowledge, references, websites, resources, etc. (citing as appropriate). And finally, students should be reminded that all posts and responses must be in complete sentences and free of grammatical or structural errors.

**How Do We Meet the Needs of Students through This Lesson Plan?**

The “Food Busters” program was designed to enrich basic biology instruction by linking chronic diseases to nutrition and demonstrating how nutrition and diet impact disease progression. High school students often do not learn much about nutrition and its essential connection to health; this activity provides this connection through hands-on experiments and discussion.

Active learning brings classroom material to life. Unfortunately, our students often lacked this during the 2020–21 academic year as lab classes could not function normally. Therefore, this lesson
plan was designed to replicate a hands-on lab experience in a home kitchen.

Students will continue to either need or want online learning opportunities postpandemic. A recent poll suggests that in the 2021–22 academic year, approximately one-quarter of students preferred to remain online due to continued health concerns (Leonhardt, 2021). Furthermore, a survey of 1,413 students registered at U.S. higher education institutions for the 2020–21 academic year showed that 73% would like to continue to take some classes fully online (McKenzie, 2021). The content provided by our online lab platform provides students with the interaction needed to get back to experiential science education.

Finally, students everywhere need greater access to accessible and affordable science education. Virtual lab websites, as highlighted

| Required Elements | Scoring Criteria | Score |
|-------------------|------------------|-------|
| **Level of Participation** | | |
| Excellent (8) | | |
| Good (6–7) | | |
| Fair (4–6) | | |
| Poor (0–3) | | |
| • Student responds to peer comments or posts questions 6–7 times. | • Student responds to peer comments or posts questions 4–5 times. | • Student responds to peer comments or posts questions 2–3 times. | • Student responds to peer comments or posts questions only once or not at all. |
| **Relevance of Post** | | |
| Excellent (5) | | |
| Good (4) | | |
| Fair (3) | | |
| Poor (0–2) | | |
| • Answers are substantive and address prompts. | • Answers are substantive and address prompts. | • Answers do not address the prompts. | No or minimal answer(s) posted. |
| • Answers show ability to integrate content into lifestyle or apply new skills. | • Answers address most prompts. | • Remarks are brief and/or irrelevant. | |
| • Posts reference assigned content but may not exhibit an ability to apply the concepts. | | | |
| **Quality of Answers** | | |
| Excellent (4) | | |
| Good (2–3) | | |
| Fair (1) | | |
| Poor (0) | | |
| • Appropriate comments that are thoughtful, reflective, and respectful. | • Comments are appropriate. | • Responds, but with minimum effort. | No posts. |
| • Builds on the posts of others. | • Responses are respectful. | • No references used to support alternative viewpoint when applicable. | |
| • More than one reference used to support alternative viewpoints. | • A single reference or source is used to support alternative viewpoint when applicable. | | |
| **Posts help others understand the material** | | |
| Excellent (4) | | |
| Good (2–3) | | |
| Fair (1) | | |
| Poor (0) | | |
| • Posts are unique and meaningful, with creative application of the concepts. | • Posts attempt to share relevant answers, but the application may not be correct. Posts demonstrate a willingness to interact. | • Minimum effort is made to participate in the discussion. | Unwilling to interact with others or comment on other posts. |
| • Writing is free of spelling, grammatical, or punctuation errors. | • Writing includes 1–2 spelling, grammatical, or punctuation errors. | • Writing includes 3–4 spelling, grammatical, or punctuation errors. | • Writing contains >4 spelling, grammatical, or punctuation errors. |

Table 2. Suggested rubric for grading online discussion.
here, allow broad dissemination of enrichment programs to more schools, supporting classes that prepare students for future health professions or students interested in any aspect of science.

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Table 3. Grading rubric mapped to letter grades.

| Grade Assigned | Points Earned |
|----------------|---------------|
| A              | 27–30         |
| B              | 24–26         |
| C              | 21–23         |
| D              | 18–20         |
| F              | 0–17          |