In an age-appropriate remote learning activity developed by a researcher-teacher team, junior high school students learned about the link between human health and food safety. The students were introduced to basic concepts about the innate immune system and food safety through a learning activity that focused on peanut allergens in food products. The students (a) learned how to distinguish between the concepts of immunity and allergy; (b) learned about cross-contamination and the link between allergies and food safety; (c) learned what antibodies are and how they can be used for science; (d) applied basic knowledge about the immune system and food safety to screen for peanut residues in suspect non-peanut food products using a commercial test kit; and (e) applied basic knowledge about the immune system and food safety to create individual poster presentations on other types of allergies, such as soy or dairy allergies.

**Key Words:** immunity; allergy; peanut allergy; remote learning; food safety.

**Introduction**

Food allergies refer to allergies developed against certain foods. The incidence of food allergies is high: eight percent of children and five percent of adults are affected by some type of food allergy (Sicherer & Sampson, 2014). Peanut allergy is one of the most common food allergies and has the distinction of often persisting into adulthood (Iweala et al., 2018). Avoiding the consumption of allergenic foods is often the only practical solution for preventing allergic reactions. However, industrial food products not containing peanuts can often be cross-contaminated with peanut allergens when manufactured in the same facilities as products containing peanuts (Gowland & Walker, 2015). For example, in one European study, peanuts were detected in 43% of chocolate products and 25% of cookie products that had been labeled with the warning “may contain peanuts.” In addition, peanut residues can often be detected in products NOT labeled with any warnings at all (Gowland & Walker, 2015).

The goal of this learning activity is to introduce students to the link between human health and food safety. The primary objectives of this activity are to 1) teach about food safety issues by raising awareness of the problem of peanut allergen cross-contamination and 2) employ the issue of food allergens to instruct students about basic elements of the innate immune system.

While there are resources available online to teach about peanut and other food allergies (Dine, 2016), to date we are unaware of a junior high school activity where students actually tested for a food allergen using the type of antibody-based tools routinely used by the food industry (Croote & Quake, 2016). Using food industry tools to test industrial food products increases the realism of these activities.

Likewise, while there are many activities that teach about antibodies and the innate immune system, there are none that we could find for junior high students that teach how antibodies can be used as a detection tool or, for that matter, how these antibody-based tools can be used to prevent food contamination. Likewise, we are unaware of any activity that establishes the link between food safety and the innate immune system.

In addition, because of limitations in current schooling methods due to COVID-19, hands-on laboratory activities that can be easily carried out in both the classroom and remotely are required. These are currently scarce, as instructors have shifted from true hands-on experiences to demonstrations of experiments and/or techniques. This outcome is unsurprising given social distancing requirements and the widespread use of remote learning strategies during the COVID-19 pandemic.
In an age-appropriate remote learning activity developed by a researcher-teacher team, junior high students (a) learned some of the differences between immunity and allergy; (b) learned how cross-contamination occurs and how allergens are a food safety issue; (c) learned what antibodies are and how they can be used for science; (d) applied that basic knowledge by screening for peanut residues in suspect non-peanut food products using a commercially available test kit; and (e) applied that basic knowledge to create individual presentations on other types of food allergies. The goal of this activity was to link human health, scientific tools, and food safety issues. We describe here the basic, easily incorporable activity for students to learn about food allergies.

○ Health and Safety

Due to COVID-19 restrictions, the junior high students had already been divided up into learning pods of 9–11 students. Each pod physically had access to only one homeroom instructor. All other instructors could only reach the students remotely, including the guest instructor who helped design the activity and guided the students during its implementation. Students who participated in the classroom wore masks at all times, followed social distancing restrictions, and wore gloves and eye protection throughout the lesson. Under no circumstances should any peanuts or peanut-based foods be brought into the classroom. The students should bring only items labeled as “may contain nuts” or “made in a factory that uses nut ingredients.” This is to minimize the possibility of provoking a reaction in students who may be allergic to peanuts. Students who suffer from peanut allergies should be encouraged to bring a food item that they already consume regularly. Affected students who suffer from peanut allergies should be encouraged to bring a snack foods. Interestingly, all the tested food products gave a negative result with the notable exception of two sunflower seed-based snack foods. Interestingly, all the tested food products gave a negative result with the notable exception of two sunflower seed-based snack foods. The students were informed that in the following session they would be testing food items for traces of peanuts. The students were assigned the task of bringing a snack or other packaged food item to school. The packaging of these items should preferably contain the warning “may contain peanuts” or the warning “made in a factory that uses nut ingredients.”

Part II: Lab Activity (One Hour in Class or ~30 Minutes with Remote Students + 20 Minutes for Assessment/ Q&A)

Each student brought a non-peanut food product from home and was instructed remotely on how to use a commercial antibody-based test kit (Morinaga, catalog #M2265, cost $150/ten assays). For an explanatory student handout and a YouTube playlist of instructional videos (Videos 1–3), see the Supplemental Material available with the online version of this article.

Peanut Test Process Steps (see Supplemental Material)

1) Food items were ground to a powder with a blender or mortar and pestle.
2) One gram of the powder was weighed out and placed in the 50 mL tube provided in the kit (Video 1).
3) One pouch of extraction solution was added to the food sample powder and agitated by hand or by vortexer for one minute (Figure 2A, Video 1).
4) 100 uL of the food sample extraction mixture was added to the microcentrifuge tube included in the kit (Figure 2B, Video 2).
5) 900 uL of dilution solution was added to the extraction mixture (Video 2).
6) 200 uL of the diluted mixture was added to the antibody application (Video 3).
7) The class waited 15 minutes for the application to develop (see Figure 1C).

The students tested food items that they chose themselves. They did not know in advance if the item they had chosen actually contained peanut residues. Since the outcome of the peanut allergy tests was unknown in advance, this activity followed the predict-observe-explain (POE) structure of hands-on learning experiences (White & Gunstone, 1992). Students collectively examined several different food products such as sunflower seeds, cereals, and snack foods. Interestingly, all the tested food products gave a negative result with the notable exception of two sunflower seed-based snack products, both of which were labeled “made in a factory that uses nut ingredients.”
Figure 1. Figure showing how antibody-based assays function. (A) A classic example of an antibody-based assay is the pregnancy test, which detects the HCG hormone. Two lines on the indicator are consistent with pregnancy. Meanwhile, a single line indicates both a negative result and that the test itself worked. (B) An antibody-based assay, such as a pregnancy test, contains an absorbent material upon which a test liquid is placed. Capillary action causes the liquid to flow to the other end of the material. The liquid flows past a bed of antibodies specific to HCG. These antibodies, now bound to HCG, are carried by the flow to a line of anti-HCG antibodies that are fixed to the surface of the material, creating the first line on the test. The second line is created by a set of antibodies specific to the anti-HCG antibodies, which ensures that anti-HCG is indeed present and has traveled the length of the material. This serves as a control that the test is working. (C) Anti-peanut antibody-based assays function similarly: here, a dilution of peanut butter has been applied to the device. A similar flow to the right is observed. The vertical line is an indication of a positive result. Meanwhile, the pink-colored circle indicates that the test worked. Parts A and B of the figure have been adapted under a Creative Commons license (Hristov et al., 2019).

Figure 2. (A) The homeroom instructor with student as student adds the kit extraction solution (step 3) to a food sample. (B) Homeroom instructor and students watch an instructional video being presented by the guest instructor on the classroom screen while carrying out step 4 of the activity. (C) Student listens to the homeroom instructor connected via a classroom screen while carrying out step 3 of the activity. (D) Students finish step 3 of the activity. (E) Example of a student poster about allergens.
Part III: Poster-Making Activity (Homework Assignment)

To reinforce the learning from the other parts of the activity, students researched and created a poster on a common food allergy, such as soy, peanut, dairy, etc. (see Figure 2E). For instructions and an assessment form, see the Supplemental Material.

Remote Learning

Students interacted with the remote guest instructor using Google Meet (meet.google.com; Figure 2: B, C, D). Three sets of students participated: two nine-student pods in the classroom with their homeroom teacher present and remote learners who participated from home. The guest instructor, who connected remotely, gave the lecture and explained the steps of the hands-on activity. The in-class students could see and hear the guest instructor and see his presentation slides and videos via a dedicated screen in each classroom (see Figure 2: B, C, D). The homeroom teachers arranged the materials and equipment (blender, vortexers, mortars, and pestles) and gave instructional handouts to the students.

Prior to the activity, the parents of the remote learners picked up pre-assembled kits that included all materials and handouts necessary to complete the activity. Remote learners were expected to have a blender or a mortar and pestle at home.

Assessment

In order to gain some insight into some of the limitations of remotely guided hands-on activities, it is important to compare the outcomes of in-class students guided remotely and purely remote students studying from home. Knowing some of these limitations may help inform the future design of remotely guided activities and help instructors adapt these activities to their particular circumstances.

Interestingly, communication by chat or voice was easier between the guest instructor and remote students. These students also completed their activity about 20 minutes sooner than the classroom pod students. A quicker completion was presumably due, in part, to not having to share equipment and space with other students. A purely remote learning regime (i.e., from home) for this hands-on activity may be preferable to the in-class student pod scenario in case ease of communication or time constraints are issues of concern.

Students were not only excited to see their own results (particularly if they appeared positive) but also the results of their peers. This reaction was most pronounced among the in-class students who could directly visualize their peers’ results. Interestingly, less enthusiasm was observed among the remote learning students. We have only anecdotal evidence for this observation since the sample sizes are extremely small. However, we believe that engagement was generally higher among students in the in-class group pod than among students working in isolation.

These differences in engagement were also observed during the lecture period. Answers to the instructors’ queries came more often from in-class students. Likewise, in-class students were more likely to ask questions.

The students’ allergy posters were assessed for quality and depth (see Supplemental Material). The results indicated that the students had gained some conceptual understanding about the problem of food allergies and health. In addition, learning outcomes were evaluated using a set of three open-ended questions as homework assigned by the homeroom teacher (see Supplemental Material). The results from the homework assignments indicated that students gained some understanding of concepts about the immune system, the similarities and differences between immunity and allergy, and the link between food allergens, food safety, and health.

Conclusion

All students successfully completed the activity, and allergens were detected in only two sunflower seed-based products. Importantly, in the interest of time, not all of the steps in the commercial test kit were followed: the heating and cooling steps were removed. This meant that the tests were not as sensitive as they could have been. The heating and cooling steps should ideally be included in future iterations to increase the realism of the activity and adhere more closely to the test manufacturer’s instructions. The junior high students found the pipettes included in the kit hard to use. Therefore, syringes are recommended in future iterations of this activity. Ideally, a dedicated moderator should be included to facilitate communication between different sets of students (in-class vs. remote learners). Based on the learning outcomes and informal assessments, this was ultimately a successful activity that can serve as a model for other institutions seeking to carry out hands-on activities for mixed groups of in-class and remote learners. Importantly, utilizing real food samples and authentic testing kits appeared to encourage student engagement and helped drive home the connection between human health and food safety.

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Supplemental Material

Appendix S1. Instructional student handout
Appendix S2. Poster activity instructions
Appendix S3. Homework questions
Appendix S4. Background information

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