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A Pilot Study to Explore Innovative Technologies to Enhance Food Safety Training

ABSTRACT

Incorporating technology into food safety training creates opportunities to develop engaging and more effective learning programs. Using immersive and interactive technologies, we developed and evaluated online courses on water quality and soil amendments (available in English and Spanish) and 360-degree immersive tours of a small farm and a farmers' market. The training tools included knowledge checks, and voluntary post-training evaluation questionnaires to assess intention to change behaviors and satisfaction with the training. The online courses were accessible via the Food Safety Resource Clearinghouse and university websites. Participants experienced the immersive tours using a head-mounted display, incorporated into in-person university-sponsored trainings. To evaluate the training tools, we conducted a pilot study (n = 20 online course evaluations and 10 in-person training programs for the immersive tours). Participants reported enjoying the immersive and interactive aspects of the training and the novelty of the tours; however, some experienced technical difficulties and/or issues with using the headsets.

Intentions to change behavior was limited because many participants already followed the recommended practices. The pilot study findings suggest that these interactive and immersive approaches to education show promise in future food safety education efforts.

INTRODUCTION

Effective food safety training and technical assistance are key to ensuring food producers and processors have the information and support needed to produce safe food. Training and technical assistance are particularly relevant to small and mid-sized farms and businesses who may have different needs compared to larger operations. In a survey of small and mid-sized farms and processors, respondents requested both in-person and virtual farm tours and demonstrations that could provide a more “hands-on” approach to learning (9). A national survey also identified the need for novel hands-on methods to increase knowledge and self-efficacy among growers, which may lead to behavior change and faster implementation of food safety management practices (14).

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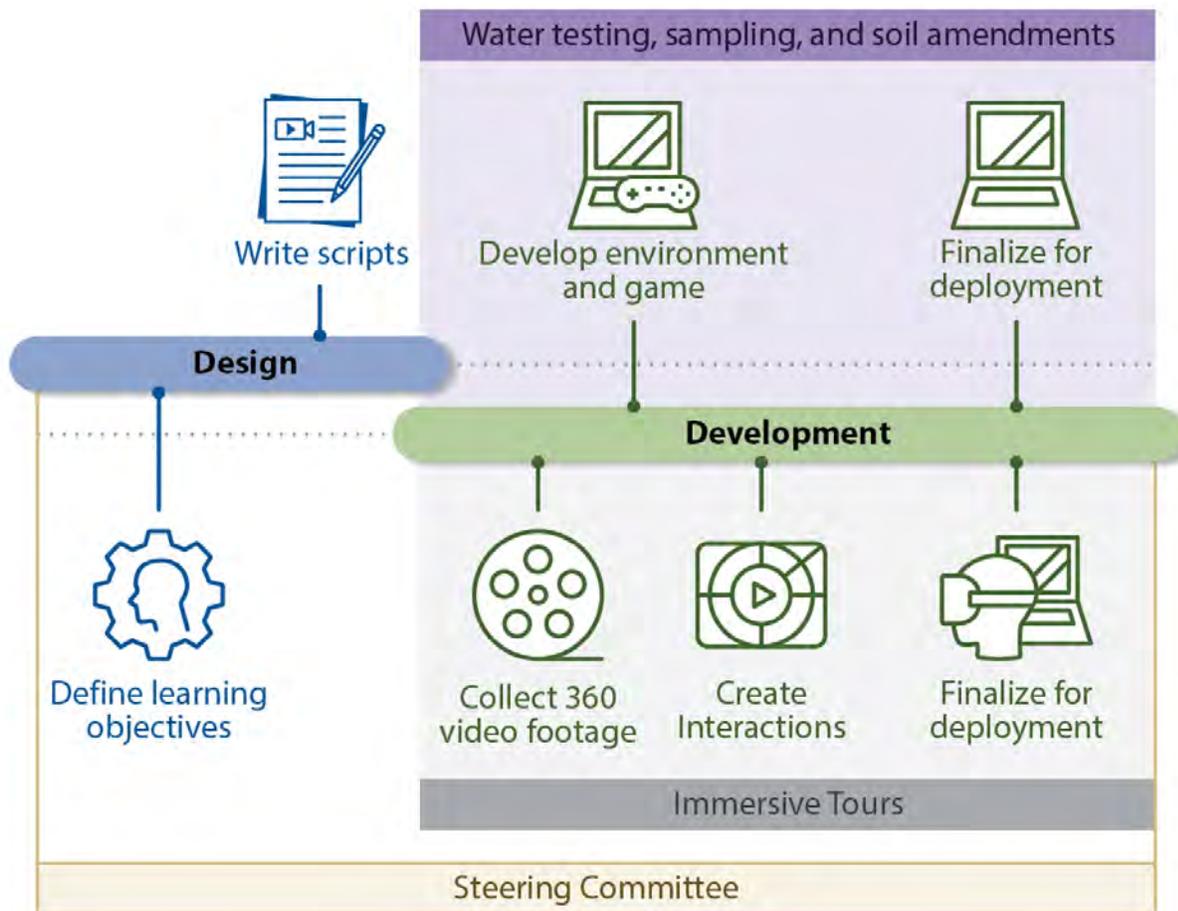


Figure 1. Overview of the design and development stages for the online courses and immersive tours.

Novel, hands-on methods for training include interactive online courses and immersive technologies, such as 360-degree videos and virtual reality (VR refers to fully computer-generated [3D rendered] graphical content). Both have the potential to enhance and complement food safety training and outreach programs. Immersive environments increase users' sense of presence and situational awareness, and interactions can be added throughout the environment as pop-up boxes that provide information about a topic, prompt the user to identify high-risk areas, identify best practices being implemented, and quiz the user on a topic. Immersive technology allows real-world experiences to be replaced and amplified and provides a way to evaluate problem-solving and decision-making skills (12, 13). Studies have demonstrated that immersive tools result in high student engagement and motivation and potential for increased retention and transfer to real-world performance (7, 18, 19).

These tools have been rarely used for food safety training, education, and outreach efforts outside a classroom. To

explore the use of these technologies in food safety training, we developed, and pilot tested two immersive 360-degree tours of a small farm and a farmers' market and two online courses on pre- and post-harvest water testing and sampling and soil amendments.

MATERIAL AND METHODS

Figure 1 summarizes the design and development stages for the immersive tours and the online courses. In the design stage, we defined the learning objectives and wrote scripts for the immersive tours and the online courses. Those were then presented and discussed with the project's steering committee which was composed of eight individuals (3 individuals representing Cooperative Extension, 3 representing farm associations, 1 farmer, and 1 farmers' market director). We selected steering committee members based on their food safety expertise and/or experience working with small farms in the region (North Carolina and Virginia). We used feedback from the committee to revise the courses. We designed the immersive tours to be incorporated



Figure 2. Screenshots from the small farm immersive tour.

into in-person trainings, while the online courses were meant to be used independently on a computer or tablet.

The scripts identified the technical content for the training (e.g., best practices for sample preparation, risks associated with agricultural water), as well as quizzes, (i.e., “knowledge checks”), and pop-up interactions for the courses. For the immersive tours, a step-by-step plan for capturing the video in each of the sites (small farm and a farmers’ market) was included. The sites were selected based on how representative they were of similar operations in the region and the site’s willingness to participate. We specifically selected small farms that were growing produce and raising livestock in the same location. We developed the online courses to align with FSMA’s Produce Safety Rule (PSR) and Preventative Control Rule (PCR); however, that was not the primary goal since the target audience included small farmers who might be exempt from FSMA (10).

In the development stage for the immersive tours, the 360-video footage was collected and edited to be compatible for a Head Mounted Display (HMD) using a coded framework within a cross-platform game engine, Unity (San Francisco, CA). The tours included pop-up

boxes with information, quizzes, and navigation controls throughout so that participants could interact with the environment (Fig. 2a-d). Each tour included seven specific sections/environments (e.g., farmers’ market tour: preparing samples, and small farm: employee restroom - *Supplement Table 1* provides a detailed overview). The immersive tours were uploaded into 36 Oculus Quest headsets, so internet connectivity was not required (at the time of submitting this manuscript for publication, the cost for the most basic Quest was \$299.99 (15)). To pilot test the immersive tours, they were incorporated as part of 10 in-person trainings offered by Virginia Tech (VT) and North Carolina State University (NCSU) to extension personnel, small producers, and farmers’ market managers. The instructor helped participants set up the equipment and learn the basic controls and commands needed to navigate the tours. Using the instructor’s guide developed by our team, the instructor walked participants through the tours and led discussions related to each of the different “scenes” (e.g., what indicators of good practices did you see?). At the end of the training, instructors administered a retrospective paper-and-pencil questionnaire to measure participant’s self-reported change

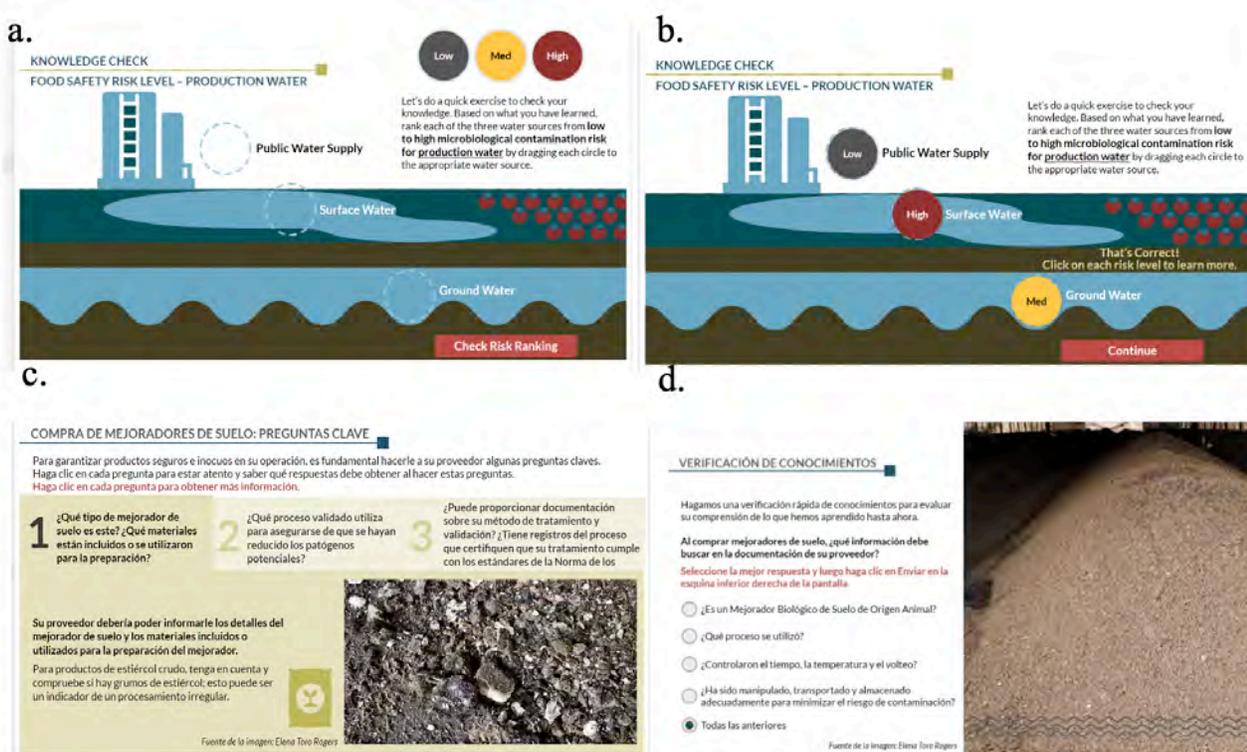


Figure 3. Examples of interactive activities used in the pre- and post-harvest water testing and sampling (English version) and soil amendments (Spanish version) online courses.

in knowledge, as well as overall satisfaction and feedback. For a subset, an independent third-party observer attended the trainings and used a standardized instrument to record participants' reaction to the training and assess the instructor's knowledge and comfort with the technology and their level of engagement when delivering the program.

For the development of the online courses, we utilized Articulate Storyline 360 (New York, NY). The pre- and post-harvest water testing and sampling course and the soil amendments included eight and six sections, respectively covering key concepts such as the importance of testing agricultural water, steps involving in taking a sample, the risk associated with various types of soil amendments, and safe processes for using raw manure and compost (*Supplement Table 2* provides a detailed description). Each course integrated text, videos, and game-like activities to engage participants and were available in English and Spanish with an estimated completion time of 30 minutes. *Figures 3a-d* show two examples of interactive, game-like features used in these courses. In *Figure 3a*, the participant drags one of the three circles (low, medium, or high) to rank the relative microbiological risk for the three different water sources (public water supply, surface water, and ground water). The correct result is shown in *Figure 3b*. In *Figure 3c* the participant learns more about what to ask a supplier when buying soil amendments by clicking in each section

and answers a multiple-choice question to assess their knowledge (3d). At the end of the online courses, there was an optional post-course evaluation questionnaire to assess their willingness to implement the practices described in the training, whether the course was helpful, as well as satisfaction, and areas for improvements. The questionnaires were developed in RedCap (Research Electronic Data Capture, Ft. Lauderdale, FL) and were available in English and Spanish. To pilot test the courses they were posted on the NCSU Fresh Produce Safety webpage (17) and the Food Safety Resource Clearinghouse (1, 3, 4, 6) and the links were disseminated through emails to project stakeholders, through the International Association for IAFP Connect, and at scientific meetings by distributing printed cards with QR codes providing access to the courses. Demographic data were not collected in any of the evaluations.

RESULTS

Immersive Tours

The immersive tours were used in ten in-person programs for small producers and farmers' market managers (approximately 60 participants). The evaluation questionnaires were distributed in six of the programs but only 17 participants chose to complete them. Respondents felt more prepared to implement the food safety practices portrayed in the farmers market tour (e.g.: good handling practices and best practices

TABLE 1. Responses to evaluation questionnaire for immersive tours (N = 17)

Question	N	Mean
Overall, how satisfied were you with the information presented in this course? ^a	17	4.53
Overall, how satisfied were you with the immersive virtual tours in this course? ^a	16	3.94
The use of immersive virtual tours helped me understand the material presented in this course. ^b	16	3.94
Using the headsets kept me engaged with the information presented in the course. ^b	17	3.82

^aResponses were given as a Likert scale with 5 = Very Satisfied and 1 = Very Dissatisfied

^bResponses were given as a Likert scale with 5 = Strongly Agree and 1 = Strongly Disagree

when offering samples) compared to the small farm tour (e.g., separate livestock from produce/processing areas and identify high-risk areas and areas for improvement) after engaging with the immersive tours (data not shown). Before and after engaging with the immersive tours, respondents self-reported their knowledge for various food safety practices. After completing the small farm tour, respondents reported that their knowledge most improved in: i) knowing the importance of implementing separation of livestock and produce/processing; ii) strategies to separate livestock and produce/processing on farms, including water management, and iii) high-risk areas and areas for improvement. For the farmers market tour, knowing how to set up a three-compartment sink, and when that might be necessary were the topics that most improved. Respondents were satisfied with the information presented in the trainings and the use of the immersive tours helped them to understand the information presented and kept them engaged (*Table 1*).

To evaluate the implementation of the immersive tours, six of the ten in-person programs were also observed by a third party. For one program, two participants chose not to wear the headsets and two participants removed their headsets because of nausea or motion sickness, and in another program one participant removed the headset also because of nausea or motion sickness. The instructor wore a headset for most of the training to provide context for participants, helped trainees adjust the headsets, and ensured trainees had enough space to move around safely. Some participants initially needed assistance with headset setup and troubleshooting, but the majority were engaged, excited about the new technology, and asked relevant questions. The observer rated the instructors' knowledge about the immersive tours, their confidence with delivering the immersive tour training, their comfort with the headset technology, and their level of engagement during the training. The mean rating for each of these items was 4.7 to 5.0 indicating a high level of knowledge, confidence, and comfort

with the technology and high level of engagement. It took participants approximately 30 minutes to complete both tours. The tours were also made available via the Food Safety Resource Clearinghouse (2, 5).

Eleven water course users (10 in English, 1 in Spanish) and nine soil amendments course users (9 in English) completed the optional post-course evaluation questionnaire (*Table 2*). Respondents found the interactive features, quizzes, and exercises helpful and engaging. Over 75% of respondents would recommend the course to others; even though they reported average knowledge gain from both courses. Regarding plans to implement the recommended food safety practices presented in the courses, most respondents for the water course planned to adopt some of the practices within the next 12 months (73%). Intentions to adopt the food safety practices for the soil amendments course was lower (33%), likely because 56% of the respondents reported already using the practices.

DISCUSSION

We developed, deployed, and conducted a pilot study to evaluate two immersive tours and two interactive online courses. Although this was a pilot study with a limited number of participants and users, it offers useful information for the development and application of future immersive and interactive trainings in food safety.

Overall participants' comments were positive and related to the high level of engagement that the immersive tours provided. This finding is consistent with other educational efforts using more engaging technologies that found high levels of participant enjoyment and a real sense of realism and presence (11, 16, 19). When shooting live videos to develop the immersive tours, it is not possible to control all variables which is possible in a computer simulated environment. Nonetheless, this provides an opportunity for training, since they mimic real-life situations that food safety educators and growers are likely to encounter. For instance, in the farm tour

TABLE 2. Responses to evaluation questionnaire for the pre- and post-harvest water sampling and testing and soil amendments online courses

	Pre- and post-harvest water sampling and testing (N = 11)		Soil amendments (N = 9)	
	N	%	N	%
Plans to Implement Information Presented in the Courses				
I already use the information covered in the course on my farm.	2	18%	5	56%
I will use it in the next 6 months.	6	55%	3	33%
I will use it in the next 7 to 12 months.	2	18%	0	0%
I will consider using it in the future.	1	9%	1	11%
I do not plan to use it.	0	0%	0	0%
Likelihood of Recommending Online Courses to Others	N	%	N	%
Very likely	5	45%	2	22%
Somewhat likely	5	45%	5	56%
Neither likely nor unlikely	1	9%	0	0%
Somewhat unlikely	0	0%	2	22%
Very unlikely	0	0%	0	0%
Opinions about the Online Courses^a	N	Mean	N	Mean
There were enough interactive features (i.e., questions and exercises) in the course to keep me engaged.	6	4.17	9	4
The questions asked throughout the course helped me learn the information covered in the course.	6	4.17	9	4.56
The exercises will help me apply the information covered in the course.	7	4.29	9	4.22
I obtained useful knowledge and skill(s) from this course.	8	3.75	8	3.88
The information I learned from this course will help me improve the food safety practices on my farm.	10	3.60	9	4

^aResponses were given as a Likert scale with 5 = Strongly Agree and 1 = Strongly Disagree

the video captured a cat walking through the farm; there was also produce stored on the floor of the walk-in cooler. These riskier practices provided points for discussion during the training and stimulated critical thinking by encouraging participants to actively look for positive and negative examples of food safety practices using a real-life situation. Those are also opportunities for making the training more collaborative, which is an important feature when using virtual or augmented reality in trainings (12). Videos also make the cost of producing these immersive tours more affordable than a 3D rendered environment.

As observed by other researchers (11, 19), a few participants experienced nausea due to motion sickness and

something akin to vertigo due to how their height compared to the height of the camera. Discomfort with the technology or strain on their head/neck were a few other issues reported. This participant hesitancy, with some researchers going as far as to describe potential participants as “anti-technology,” has also been described in other research (16). In the pilot training programs, there was only one instructor present for about 10 participants, so troubleshooting technological issues was challenging. In future trainings it would be helpful to consider having multiple instructors present to ease participation and help troubleshoot technological issues. To accommodate participants that do not want to use a headset, it may be useful to connect the instructor’s headset to a screen and project

the immersive tour and/or have slides with pictures of the tour so those without headsets can also partake. Projecting the 360 videos from one headset can also be an option when not enough headsets are available since the cost of the equipment can be a limitation for using it more widely and inclusively.

We did not track participants' movements, actions, body position, and head direction; however, those are additional functions that could be incorporated to generate information about where participants are focusing their attention, what they observe from their own specific vantage points, and their reactions to the environment (8). This feature could be used to determine what the participant is viewing, if the participant is prompted to identify potentially high-risk areas, good agricultural practices being implemented, or areas for improvement. We also did not collect any demographic data from participants, it would have been helpful to see how participants from different ages interacted with the tours and their level of comfort.

Despite the efforts to promote the online courses via professional networks and extension specialists, the uptake was low based on the small number of completed evaluation questionnaires. Originally, we were tracking users' answers to each knowledge check and interactive activities using Veracity Learning, a learning management software that records and reports learning performance (Pensacola, FL). However, this system only captured data for one year and assigned a new ID every time a user accessed the online courses making it difficult to accurately determine the number of users and quantify correct answers. Low uptake may be due to the voluntary nature of the training. Additionally, small farmers face competing priorities and may have limited time for training. Even though our water course was not specific to PSR FSMA requirements, the fact that the requirements were still evolving when we developed the online course in 2021/2022, could have caused many users to forgo this training and wait until more definition and agreement around water quality requirements was solidified. Users reported enjoying the interactive features, which has also been shown to increase student's interest in other online interactive courses (20). Given the limited response to the post-course evaluation questionnaire and the fact that many respondents indicated they had already adopted or planned to adopt the recommendations provided, these and other online short courses could be better framed as refreshers to

build upon a more robust training. As regulations continue to evolve, future course designers will need to contextualize the course information, so potential users know whether it is relevant to them and provides the most up-to-date information. Having audio available with the courses would also be beneficial.

CONCLUSIONS

Incorporating technology into food safety training creates opportunities to develop engaging and more effective learning programs. While incorporating headsets into future training programs holds promise, the technology can be costly and may not be suitable for all, therefore adjustments might need to be made so it can be used in an inclusive manner. The use of immersive tours may be more effective among those who have experience using headsets or have a greater degree of technological curiosity. Exploring opportunity for using this tool outside the classroom should also be explored.

ACKNOWLEDGMENTS

The research team would like to acknowledge the work done by the RTI Team (Ethan Burch, Erin Love, Kellie Jones, Dilsey Davis, William Ferris, Rebecca Hipp, Nicole Breuninger, John Jones, Ari Kirschenbaum, Nunzio Landi, Michael Reedy, Shana Sund, Julie Shogren, and Cheryl Velez) in the development of the online courses and immersive tours. We thank Dr. Katheryn Parraga-Estrada for translating the online courses to Spanish.

Special thanks to the members of our steering committee (Kim Hutchinson from the Virginia Farmers Market Association, Matt Mulder from Arcadia Farms, Elena Rogers from NCSU extension, Debbie Hamrick from the North Carolina Farm Bureau, Billy Mitchell from the National Farmer's Union [currently with the Organic Partnership Program], Sarah Sharpe from Virginia Cooperative Extension, Dr. Armitra Jackson-Davis from Alabama A&M University, and Lisa Dearden from Manakan farmer's market) for donating their time and expertise to this project.

This work was conducted under a grant (2020-70020-32278) from the National Institute for Food and Agriculture at the United States Department of Agriculture (NIFA/USDA), Food Safety and Outreach Program (FSOP).

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SUPPLEMENT MATERIALS

Supplement Table 1. Overview of immersive tours of a farmers' market and a small farm

Section Name	Objective(s)
Farmers' market tour	
Farmers' market entrance	Orient the user with the immersive environment
Handwashing station	Demonstrate set up for a portable handwashing station
Three compartment sink	Demonstrate set up and use of a 3-compartment sink Describe steps to properly clean and sanitize equipment
Baked goods handling	Describe importance of temperature control for certain food products
Using coolers	Explain best practices when using coolers (e.g., using a thermometer to check temperatures and using potable water to make ice) Summarize risker practices when using coolers (e.g., not having enough ice and keeping non-food and personal items co-mingled with food for sale at the market)
Transporting food best practices	Describe the importance of hygiene and temperature control when transporting produce Identify the importance of not reusing grocery bags to pack or hold products
Preparing samples	Describe best practices when preparing samples (e.g., proper cleaning and sanitizing, temperature control, and engaging with customers to keep them from possibly contaminating other samples)
Making sanitizers	Demonstrate steps to prepare a bleach sanitizing solution Describe importance of following manufacturer's instructions when preparing and using sanitizing solutions
Small farm tour	
Farm parking lot	Orient the user with the immersive environment Identify the risks associated with free roaming animals on the farm environment
Produce handling	Review proper safe storage temperature for time-and-temperature control for safety produce Describe detectable <i>E. coli</i> limits for post-harvest water and importance of changing and testing water frequently Identify importance of frequently cleaning and sanitizing food contact surfaces and equipment Describe the importance of storing and handling produce separately from animals and in a way to prevent animal intrusion and not using equipment for livestock
Cleaning and sanitation	Explain importance of frequent cleaning and sanitizing of food contact surfaces Describe the differences between cleaning and sanitizing Explain the importance of proper, frequent handwashing
Open field	Discuss the role flooding can play in contaminating crops downstream Describe best practices when watering plants to avoid contamination Discuss how to apply knowledge of flood risk when planting crops

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Supplement Table 1. Overview of immersive tours of a farmers' market and a small farm (cont.)

Section Name	Objective(s)
Compost	Recognizing the importance of compost pile location to avoid contamination of crops Describe ways to mitigate runoff from a compost pile
Animal enclosure	Recognize risk of animal feces and byproducts to contaminate fresh produce Describe methods of keeping animals and their waste contained to reduce risk of contamination
Employee restroom	Demonstrate how to set-up restroom facility for farm employees Describe how to mitigate risks associated with reusable towels in employee restroom

Supplement Table S2. Overview of online course sections (same for English and Spanish versions)

Pre- and post-harvest water testing and sampling course

Section Name	Objective(s)
Introduction	Welcome user, inform about the optional survey at the end Why water testing is important Provide the training overview
Section 1: Production and post-harvest water definitions	Describe the different water types: agricultural, production, and post-harvest
Section 2: Water sources and their risks	Describe the different agricultural water sources: surface, ground, and public water and the risk associated with each of them
Section 3: Suggested food safety standards for production and post-harvest water	Discuss suggested standards for production and post-harvest water
Section 4: Suggested water testing frequency	Discuss the testing frequency according to the source of agricultural water used
Section 5: Microbiological water test options for production and post-harvest water	Describes the potential microbiological tests producers can order and if they are applicable for testing production and post-harvest water
Section 6: Preparing for sample collection	Walks user through detailed steps needed to prepare for sample collection of agricultural water, that include selecting an appropriate location for the sampling
Section 7: Collecting, and shipping the sample	Details the steps needed to collect and ship the water sample for both surface and ground water. It includes a video
Section 8: Analyzing water test result	Two examples of a water test result are provided for the participant to evaluate and familiarize themselves with how it is reported

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Supplement Table S2. Overview of online course sections (same for English and Spanish versions) (cont.)

Section Name	Objective(s)
Soil Amendments course	
Introduction	Welcome user, inform about the optional survey at the end Importance of soil amendments for fresh produce Provide the training overview
Section 1: Categories of soil amendments	Describes the different types of soil amendments: biological soil amendments, and biological soil amendments of animal origin (BSAAO), as well as treated and untreated soil amendments
Section 2: Examples of soil amendments	Discusses the different soil amendments: raw manure, non-fecal animal byproducts, agriculture tea, synthetic fertilizers, cull pile and compost
Section 3: Evaluating the risks associated with soil amendments	Describes how the user can assess the risk of the soil amendments related to the type of amendment, type of crops, time of application, how it is applied and quantify and frequency of application. Includes a link to a decision tree to help estimating the risks
Section 4: Detailed processes: raw manure and compost	Details the processed for both types of soil amendments, including time and temperature, storage, turning frequency, methods location of the pile Discuss what materials to avoid when composting
Section 5: Working with suppliers	For those buying soil amendments, it describes important question to ask suppliers to ensure the soil amendments was handled appropriacy to reduce food safety risks
Section 6: Recordkeeping	Provides important information that should be described and recorded. Provides a template example