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3 **Next-gen learning: Embracing immersive virtual**  
4 **learning approaches for food safety and sanitation**  
5 **education**

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12 **ABSTRACT**

13 Food safety and sanitation (FSS) training is essential, yet student engagement is declining. To address this  
14 concern, this study utilized a mixed-method approach to investigate the effectiveness of a Virtual 360°  
15 Simulation Environment (VSE) FSS learning platform on students' food safety attitudes, knowledge, food  
16 handling behaviors, and their VSE FSS perceptions and experience. Results showed significant behavioral  
17 improvements in personal hygiene and temperature monitoring. While the VSE FSS could enhance  
18 student engagement, there are some limitations. Nevertheless, the study offers valuable insights for  
19 educators seeking innovative approaches for teaching food safety.

20 **Keywords:** food safety and sanitation; immersive learning; virtual simulation; hospitality education

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INTRODUCTION

As an integral part of Americans' lives, restaurant dining generated \$1.1 trillion in revenues in 2024 (National Restaurant Association [NRA], 2024). However, dining out may pose inherent risks to the customers as data shows that foodborne diseases result in 128,000 hospitalizations and 3,000 deaths annually (Centers for Disease Control and Prevention [CDC], 2022). Additionally, there were more than 1,000 reports of foodborne outbreaks in the United States (U.S.) in 2021 with foods served by restaurants accounting for the majority (64%) of these cases (CDC, 2022). More recently, in 2024, the McDonald's Corporation was at the center of an *E. Coli* outbreak with over 100 cases that spanned 14 states in the U.S. and resulted in the hospitalization of 34 customers and one death (CDC, 2024). The growing statistics and incidences point to the importance of restaurant operators practicing rigorous food safety measures to protect public health.

Numerous factors could have contributed to foodborne outbreaks, including cross-contamination, improper cooling process, insufficient cooking temperature or time, poor personal hygiene, and food purchased from unsafe sources (Brown et al., 2018). While food safety training is known to improve food

handlers' knowledge, attitudes, and behaviors, which help reduce foodborne outbreaks (Al-Akash et al., 2022; Ercan Oruc et al., 2020), not all food safety training programs are effective in achieving their intended outcomes (Barjaktarovic-Labovic, 2018; Rajagopal & Strohbahn, 2013). Factors such as lack of engagement and motivation among learners, outdated instructional and delivery methods, lengthiness of the food safety training programs, and language barriers could reduce the success of the training program (Yu et al., 2018). Furthermore, the misalignment between the content of the training and work responsibilities, compounded by a lack of focus on the real-world scenarios also lead to the failures of such training programs (Intertek Alchemy, 2022).

Similar challenges have been observed in food safety and sanitation (FSS) certification programs, such as the ServSafe® Manager certification administered through the National Restaurant Association (Wen et al., 2023). Research conducted by Wen et al. (2023) showed that students demonstrated a low level of interest in taking food safety courses and were unwilling to sit for the food safety certification exam. The authors attributed this phenomenon to a lack of awareness regarding the severity and consequences of foodborne illnesses and indifferent attitudes among the student groups (as cited in Webster, 2017). Additionally, shortcomings in current teaching methods were also observed (Wen et al., 2023; Yu et al., 2018). For example, FSS materials were mostly taught in-person; classroom tests, exams, and quizzes were prevalent and only some educators used active learning approaches such as group discussions or labs to instill food safety knowledge and reinforce safe food handling practices among students. An earlier study by Feinstein et al. (2007) revealed that more than 80% of participants passed the ServSafe® exam when completing online training versus traditional (classroom/in-person) methods. These findings support the need for more innovative, technology-oriented food safety training program that engages and motivates students, one of which is the application of virtual simulations in teaching and learning.

A virtual simulation is described as “the recreation of reality depicted on a computer screen and involves real people operating simulated systems” (Padilha et al., 2019). This technology enables learners to gain practical experience, visualize abstract concepts, and interact meaningfully within simulated environments (Chen, 2009), making it a prime example of experiential learning. Virtual simulation environments (VSE) are particularly effective for fostering “authentic assessments,” allowing students to apply theoretical knowledge in practical contexts and reflect on their experiences (Nyanjom et al., 2020; Smith, 2022). For instance, Yu et al. (2018) found that food handlers’ motivation to learn food safety practices significantly improved after engaging with a tablet-based simulation game, suggesting that cognitive and affective engagement can optimize learning outcomes.

Several educational theories, including experiential and constructivist learning, have informed the integration of virtual simulations into teaching practices. The experiential learning theory (ELT) proposed by Kolb (2014) posits that knowledge is constructed through active interaction and adaptation within an environment, rather than through passive, teacher-directed instruction. ELT bridges the gap between theoretical concepts and practical applications by immersing learners in problem-solving and hands-on activities (Gonczi, 2013; Kolb, 2014). In this model, learners demonstrate content mastery through active engagement rather than rote memorization. Similarly, constructivist learning principles emphasize the value of “learning-by-doing,” where knowledge is developed through active participation in real-world problem-solving tasks (Chen, 2009). Constructivism suggests that virtual simulations enhance learners’ motivation, self-efficacy, core competencies, and behavior change by providing interactive and immersive experiences.

Despite their advantages, virtual simulations should be thoughtfully designed to address cognitive load and to ensure an effective learning experience for learners. Cognitive load theory, as proposed by Sweller (1988), highlights the limitations of working memory and the potential for excessive information or overly complex tasks to hinder learning outcomes. If the cognitive demands of a simulation are too great,

learners may become overwhelmed, unable to process information effectively, and fail to meet the intended learning objectives. Therefore, the design of immersive FSS learning platform should account for cognitive load during its development to optimize usability and educational impact.

While the adoption of virtual simulations in education is rising, particularly in fields like nursing and computer sciences (Forondo et al., 2020), little is known if this innovative teaching strategy can be successfully applied in hospitality education. Therefore, this study sought to test the utilization of an immersive FSS learning platform in supporting FSS training and education. Specifically, the first objective of this study is to assess the effectiveness of a VSE FSS learning platform in enhancing hospitality education using a pretest-posttest research design (quantitative approach). The effectiveness of the FSS platform was measured based on: (1) knowledge acquisition (content mastery) through the ServSafe® Manager exam passing rate; (2) participants' attitudes toward food safety and sanitation; (3) participants' attitudes regarding perceived relevance, interest, and motivation associated with the new VSE FSS learning platform; and (4) self-reported behavioral change as a result of the training. The second objective of this project was to understand the participants' perceptions and experience using the VSE FSS learning platform through focus groups (qualitative approach). The combined outcome provided a thorough understanding of leveraging food safety simulations in higher education.

## **METHODS**

A mixed-method approach was implemented to evaluate the efficacy of a food safety learning platform and to collect participants' feedback on its perceived usefulness. The quantitative component of the research aimed to assess the platform's effectiveness by measuring participants' mastery of essential knowledge, as well as their attitudes and behaviors related to food safety. In contrast, the qualitative component sought to gather detailed feedback from participants to guide the platform's improvement.

The Institutional Review Board (IRB) of a university located in the southern region of the U.S. approved the study protocol (IRB #23-071 EX 2303). The targeted participants in this study were undergraduate students enrolled in food-related courses during Fall 2023, Spring 2024, and Fall 2024. These students were selected due to their active involvement in a campus-based teaching restaurant, where they engaged in practices involving food safety and handling. Additionally, as part of their curriculum, the students were required to study the ServSafe® program materials and complete the ServSafe® Manager certification exam. This preparation ensured that participants possessed foundational food safety knowledge and skills essential for the foodservice industry.

### **Development of FSS Learning Platform Prototype**

An FSS learning platform was developed, which includes several interactive components such as readings, audio recordings, interactive video-based scenarios, ten self-paced module assessments, and five 360° virtual simulation scenarios on the Canvas Learning Management System (LMS). These modules cover the ServSafe® Manager curriculum, including food safety practices, hygiene, food storage, preparation, service, cleanliness, and facilities. Each module features an introduction video, instructional content, formative assessments, and interactive scenarios based on a fictional restaurant, culminating in a multiple-choice quiz. The virtual simulation scenarios, created using 3D modeling software, immerse participants in realistic food service situations, while interactive video scenarios present dilemmas inspired by real-world foodborne outbreaks (See Traynor et al. [2024] for more details on the development of the FSS learning platform).

### **Quantitative Research**

A survey-based quantitative research study was designed to achieve the objective of assessing the platform's effectiveness. The survey instrument consisted of multiple sections. The first section assessed

the students' food safety knowledge through 50 true/false and multiple-choice questions adapted from ServSafe® Manager certification exam to test their knowledge levels. The second section comprised a series of attitudinal and behavioral questions. Specifically, the attitudes toward food safety were measured by eight (8) items related to food handlers' responsibilities and food safety training (Victoria et al., 2021). Attitudes toward the VSE FSS platform were measured by eight (8) items concerning relevance, interest, and motivation (Montesinos et al., 2022). Participants self-reported whether they practiced recommended food handling procedures with eleven (11) items based on a frequency rating (Byrd-Bredbenner et al., 2007). Attitudinal and behavioral questions were measured on a five-point Likert scale, ranging from "1" being strongly disagree to "5" being strongly agree. The third section collected participants' demographic information, such as their age, gender, work experience, and prior food safety training. Questions for both the pre-test and post-test were identical. Before administration, the questionnaire was reviewed by a panel of five (5) foodservice management educators for content validity, completeness, and clarity with revisions made based on their feedback.

### **Quantitative Data Collection**

The FSS learning platform prototype was integrated into an undergraduate-level food production and service course in a Bachelor of Science in Hospitality Management degree program. The VSE FSS platform prototype was administered through Canvas LMS, a web-based learning management system. The instructors of this course collected the pre-test data at the start of each semester before directing students to the platform. In the next 10 weeks, students completed each of the ten (10) modules at their own pace. Prior to the end of the semester, students completed their ServSafe exam and participated in the post-test surveys based on their willingness.

### **Quantitative Data Analysis**

One hundred and eighty-five students enrolled in the food production and service course during the data collection period (Fall 2023, Spring 2024, and Fall 2024 semesters). All students participated in the food safety knowledge test at the beginning of each semester to assess their baseline understanding. On average, students answered twenty-nine out of fifty questions correctly ( $M = 29$ ,  $SD = 7.92$ ), corresponding to an accuracy rate of approximately 58%, with individual scores ranging from 52% to 66% in the adapted ServSafe® exam. Given the fact that passing a ServSafe® Manager certification exam requires a minimum accuracy rate of 70%, it is evident that all students were not fully prepared with the necessary food safety knowledge at the beginning of each semester when data was collected, respectively. After implementing the VSE FSS platform throughout the respective semesters, the average passing rate for the ServSafe® exam was around 73% (135 out of 185) based on the official ServSafe® Manager certification exam results. This indicates that most students gradually mastered the necessary food safety knowledge as expected from the self-paced learning modules through the VSE FSS platform. These findings further suggest the significance of the VSE FSS platform as an effective learning tool for mastering essential food safety knowledge and helping students prepare for the ServSafe Manager certification exam.

As for the self-reported survey, 149 students participated in the pre-test survey, while that number reduced to 136 students during the post-test period with an average respondent rate of 77.03% (80.54 % for the pre-test group and 73.51% for the post-test group, respectively). A MANCOVA test was used to assess participants' perceptions of attitudes toward food safety and the VSE FSS platform as a learning tool, as well as to assess their self-reported behaviors. In the analysis, researchers controlled for the potential influence of prior experience in food handling and prior food safety training on these perceptions and behaviors during the pre-test and post-test periods.

## Qualitative Study

For the qualitative study, participants in the quantitative study were offered an additional opportunity to participate in follow-up focus group sessions to share their perspectives on the VSE FSS platform as a tool for food safety training and to understand the impact on their learning. Participants who expressed interest in joining the focus groups were then randomly assigned to one of five focus groups and were compensated with a \$30 gift card for their time. Each focus group consisted of five (5) to eight (8) students and lasted for 40-60 minutes (Fusch et al., 2022).

## Qualitative Data Collection

Before holding focus group sessions, the research team convened to agree on a standardized protocol and develop a comprehensive battery of questions. This ensured uniformity across all sessions, minimizing potential biases and variability while maintaining consistency in the data collection process. Furthermore, to enhance the engagement and quality of discussion during data collection, a structured approach suggested by Nyumba et al. (2018) was incorporated. Specifically, all focus group participants were briefed on the primary purpose of the study and the ground rules governing the discussion before the session began. This introductory process ensured that participants clearly understood the objectives and guidelines, fostering an open and respectful dialogue. Their feedback was recorded using the Zoom video conferencing platform that offers several features conducive to data collection in research including an AI-generated transcription that generated the text used for data analysis. Table 1 shows the questions that were utilized across the five focus groups.

**Table 1: Focus group questions**

No.	Focus Group Questions
1	Describe your preferred learning style. For example, are you a visual learner, hands-on, auditory, tech savvy learner, etc.
2	What are your thoughts about the importance of learning about food safety and sanitation?
3	Please share your feelings regarding the platform learning experience whether positive and/or negative. Considering the video-based scenarios, module page assessments, embedded videos and readings.
4	Specific to the virtual simulated scenarios, please share your feelings regarding these scenarios, whether positive and/or negative.

## Data Analysis

Feedback from the focus group discussions were transcribed verbatim to ensure accuracy and completeness. Following the guidelines outlined in Saldaña's (2021) coding manual for qualitative research, a two-step coding approach was conducted by first using theme-based topic modeling to identify major themes followed by discourse analysis to thoroughly examine the data. Theme-based topic modeling facilitated the identification of recurring themes related to students' learning experiences within the VSE FSS platform, while discourse analysis provided deeper insights into the language, communication patterns and underlying perspectives expressed by participants as the focused coding approach. This integrated approach allowed for a more comprehensive understanding of the participants' experiences and viewpoints.

## RESULTS AND DISCUSSION

### Pretest and Posttest Research Results

Of all the participants who completed the surveys, about 95% were Generation Z (born 1995-2012), 78% were female, and 88% were Caucasian. Additionally, 44.2 % were juniors, followed by sophomores (21.4 %), and seniors (26.3%). 86.7% of participants revealed prior experience with food handling across a variety of foodservice-related industry positions such as baker, server, and line cook, and had been previously trained on food safety practices on-premise (69.5%). Among the students who reported having prior work experience, the majority had worked for approximately 1 to 2 years.

The results indicate no significant difference in food safety attitudes between the pretest and posttest periods after students engaged with the VSE FSS platform at their own pace. This suggests that the intervention did not substantially alter participants' attitudes toward food safety. However, it is important to highlight that students demonstrated a profound understanding of the importance of food safety practices from the provider's perspective based on their agreement with those attitudinal items such as item 1, "Food handlers are responsible for preventing food poisoning", items 3 - 6, and item 8 that emphasize the significance of food safety handling. On the other hand, they were inclined to respond negatively to two deceptive statements, namely, item 2, "Consumers are responsible for preventing food poisoning" and item 7, "Food poisoning is not a serious threat to the restaurant industry" (See Table 2). This finding implies a tendency to attribute the responsibility for food safety to providers rather than to consumers.

**Table 2: Pretest-posttest results about food safety attitudes**

Food Safety Attitudes	Pretest vs. Posttest	M	SD	M Difference		p value
				( $M_{\text{Posttest}} - M_{\text{pretest}}$ )	SD	
1. Food handlers are responsible for preventing food poisoning.	Pre-test	4.42	0.07			
	Post-test	4.33	0.08	-0.14	0.12	.38
2. Consumers are responsible for preventing food poisoning.	Pre-test	2.43	0.09			
	Post-test	2.48	0.09	0.05	0.13	.65
3. Maintaining a clean cooking environment is a good way to control food safety.	Pre-test	4.77	0.06			
	Post-test	4.62	0.06	-0.15	0.09	.07
4. Self-checking food safety is important to restaurants and institutions.	Pre-test	4.58	0.07			
	Post-test	4.49	0.07	-0.09	0.10	.40
5. Food safety is more important than taste.	Pre-test	4.22	0.06			
	Post-test	4.36	0.07	-0.14	0.10	.26
6. Food safety knowledge is important to ensure food is prepared in a safe manner.	Pre-test	4.69	0.05			
	Post-test	4.62	0.06	-0.07	0.13	.28
7. Food poisoning is not a serious threat to the restaurant industry.	Pre-test	1.57	0.08			
	Post-test	1.67	0.09	-0.10	0.13	.46
8. Training on food safety is important to improve my knowledge and ability to process clean and safe food for my customers.	Pre-test	4.67	0.05			
	Post-test	4.69	0.05	0.02	0.07	.97

Note: \*\* denotes  $p < .01$ , \* denotes  $p < .05$

Analysis of the pre- and post-test results of students' attitudes towards using the VSE FSS platform reveals no significant differences (See Table 3). Despite this result, the overall attitudes toward the platform remained somewhat positive, with a mean score of 3.53 ( $SD = 1.10$ ) suggesting that, on average, students

held somewhat favorable views of the VSE FSS platform. This result also implies that, even though students are required to dedicate extra time and resources at their own pace, they do not exhibit substantial dissatisfaction, resistance, or other negative attitudes to engaging with the platform. The results also show moderate improvements on most items (1, 2, 3, 4, 6, and 7) measuring participants' attitudes towards the VSE FSS platform with item 8, "Simulation-based education did not require much of my effort" showing a decrease. This latter result indicates that participants realized in the post-test that the platform would require more effort than initially perceived. Previous studies performed by Akamu et al. (2024) showed that 66% of students in a microbiology lab enjoyed the use of virtual lab simulations but another 20% maintained a neutral attitude or were not favorable of this method. The students in this research demonstrated similar responses.

**Table 3: Pretest-posttest results about VSE FSS attitudes**

VSE Attitudes	Pretest vs. Posttest	M	SD	M Difference		p value
				(M <sub>Posttest</sub> - M <sub>pretest</sub> )	SD	
1. I would be interested in receiving simulation-based education.	Pre-test	3.52	0.92			
	Post-test	3.59	0.94	0.07	0.11	.48
2. It would be helpful to integrate simulation-based education methods to all applied courses.	Pre-test	3.51	0.92			
	Post-test	3.64	0.86	0.13	0.11	.21
3. Simulation-based education would increase my self-confidence in food safety practices.	Pre-test	3.61	0.83			
	Post-test	3.68	0.92	0.07	0.11	.54
4. Simulation-based education would be a good tool for learning about food safety.	Pre-test	3.85	0.76			
	Post-test	3.95	0.76	0.10	0.09	.31
5. Simulation-based education would increase my interest to learn about food safety.	Pre-test	3.53	0.89			
	Post-test	3.53	0.94	0.00	0.11	.97
6. Simulation-based education was fun for me.	Pre-test	3.18	0.97			
	Post-test	3.30	0.97	0.12	0.12	.31
7. Simulation-based education was worth my time.	Pre-test	3.13	1.02			
	Post-test	3.35	1.10	0.22	0.13	.08
8. Simulation-based education did not require much of my effort.	Pre-test	3.12	0.85			
	Post-test	3.00	0.95	-0.12	0.11	.25

Note: \*\* denotes  $p < .01$ , \* denotes  $p < .05$

Feedback regarding the food safety practices introduced through the VSE FSS platform revealed significant improvements in several key behaviors by the end of the semester based on the pretest-posttest comparison results. Specifically, there was a notable increase in the frequency of behaviors related to grooming hygiene, particularly in "How often participants kept their nails short and unpolished, and removed all adornments (such as earrings, rings, wedding bands, watches, and bracelets) before handling food". This behavior showed a statistically significant improvement, with a  $p$  value of  $< .05$ .

Additionally, food hygiene behavior related to handling certain illnesses during an employee's shift at the operation (i.e., "How frequently do you handle food when you have diarrhea or another illness or unprotected hands when you work in the foodservice industry?") significantly improved,  $p < .05$ . More importantly, a commonly-made mistake in handling food thawing handling practices (i.e., How frequently do you thaw foods outside of refrigerated areas (room temperature)?) was significantly different,  $p < .01$ , suggesting that students are less likely to thaw food outside the refrigerated area (room temperate) and may have a better understanding of how this action may cause cross-contamination.

Lastly, the findings also suggest that students demonstrate a heightened awareness of the importance of checking cooking temperature in the foodservice industry based on the pretest-posttest result of behavior item (i.e., "How frequently do you check the cooking temperature when you cook a food item when you work in the foodservice industry?") with  $p < .001$ . Apparently, the introduction of VSE FSS platform played a significant role in enhancing students' food safety knowledge, including correcting some practices that are challenging to address through a traditional training method. These findings were consistent with previous studies conducted by Akamu et al. (2024); the researchers incorporated virtual simulations in microbiology labs, allowing students to comprehend complex concepts and lab techniques without needing access to a physical lab. Table 4 shows all the pretest-posttest results about food safety behaviors.

### **Focus Group Results**

Focus groups participants expressed a range of preferred learning styles; for example, they described themselves as visual learners, hands-on learners, and auditory learners. Several participants described themselves as having mixed learning styles. For visual learners, the participants expressed the need to see diagrams, videos, or written content to fully understand the material. For instance, one participant said, "I'm a visual learner. So, I have to see it and write things down.... Sometimes I actually use different colors to help me remember things because I have more of a photographic memory". In addition, visual learners favored charts, graphs, and matching activities, as these helped them recall specific information, such as food safety temperatures.

Some participants preferred hands-on, interactive activities to engage with the materials. These participants found virtual simulations, which allowed them to mimic real-world tasks, such as checking temperatures or inspecting deliveries. One participant identified auditory learning as their primary style, expressed that listening to lectures or verbal instructions was more helpful than reading alone. They preferred video components that included spoken explanations alongside visual aids. "I have to hear stuff to actually understand it, because sometimes reading it won't help. So, I need to actually hear somebody talk about it, talk it through, but I could actually get it, figure it out."

Several participants described a combination of learning styles. They appreciated having multiple ways to engage with the content (i.e., visual, hands-on, and auditory), depending on the complexity of the material, as indicated by one of the participants, "I can say that I am a mixture. I went through all the texts, and then the exercise which was which were using virtual reality. At the end of each chapter, I need to write down a summary of whatever I've learned". Another participant offered similar insights, stating "I'd say mine is visual and hands-on. Depending on what situation we are in. In lecture it's more visual, but in lab it's, I prefer hands-on lab stuff than lecture labs."

### **The Importance of Learning Food Safety and Sanitation**

The participants across the focus groups consistently emphasized the importance of learning food safety and sanitation for both professional and personal settings. Specifically, they noted that the food safety knowledge they gained was directly applicable to their jobs in the foodservice industry. One participant commented, "I mean it's super important as someone who's worked in the kitchen." Another participant added that the practicality of food safety and sanitation also extended to other sectors of the hospitality industry. "It is one of the most important parts of what our jobs are going to be in the future, no matter what track (culinary science, event management, hotel and restaurant management) we are on. It's really important. I actually start to apply whatever I learned from this when I am cooking at home."

The participants also acknowledged and recognized the critical role of food safety in protecting not only their own health but also the health of others. They emphasized the importance of avoiding foodborne illnesses and ensuring that their handling practices adhered to industry standards. One of them said, "I

think it's so important because even just a little mistake on the sanitation or whatever could lead to a huge issue in your entire business." Another participant added, "It's important for us going into the hospitality industry to know and understand it because we can teach people who don't know much about food safety and also it's legally regulated."

**Table 4 - Pretest-posttest results about food safety behaviors**

Food Safety Behaviors	Pretest vs. Posttest	M	SD	M Difference	SD	p value
				( $M_{\text{Posttest}} - M_{\text{pretest}}$ )		
1. How frequently do you clean your hands properly before handling food when you work in the foodservice industry?	Pre-test	4.67	0.55			
	Post-test	4.70	0.51	0.03	0.06	.57
2. How frequently do you keep your nails short and unpolished and remove all adornments (earrings, rings, wedding rings, watches, and bracelets) before handling food when you work in foodservice industry?	Pre-test	4.14	1.01			
	Post-test	4.42	0.84	0.28*	0.11	<.05
3. How frequently do you handle food when you have diarrhea or another illness or unprotected hands when you work in the foodservice industry?	Pre-test	1.52	0.90			
	Post-test	1.32	0.70	-0.20*	0.10	<.05
4. How frequently do you thaw foods outside of refrigerated areas (room temperature)?	Pre-test	2.58	1.14			
	Post-test	2.16	1.01	-0.42**	0.13	<.01
5. How frequently do you check the shelf life of the food at the time of receipt?	Pre-test	4.05	1.02			
	Post-test	3.96	0.99	-0.09	0.12	.47
6. How frequently do you use cleansing products when washing vegetables and fruits?	Pre-test	2.47	0.99			
	Post-test	2.64	1.39	0.07	0.16	.77
7. How frequently do you use foods with past the best-by dates when the food is unaltered in its smell and taste?	Pre-test	2.20	1.19			
	Post-test	1.99	1.09	-0.21	0.13	.13
8. How frequently do you use the same cutting board and knife to prepare raw foods and cooked foods when you work in the foodservice industry?	Pre-test	1.47	1.03			
	Post-test	1.36	0.84	-0.12	0.11	.29
9. How frequently do you check if the food is well-cooked before it is served when you work in the foodservice industry?	Pre-test	4.52	0.81			
	Post-test	4.39	0.78	-0.13	0.09	.14
10. When you store food in the refrigerator, how frequently do you put it in the refrigerator covered or in covered containers when you work in the foodservice industry?	Pre-test	4.39	0.92			
	Post-test	4.37	0.89	-0.02	0.11	.79
11. How frequently do you check the cooking temperature when you cook a food item when you work in the foodservice industry?	Pre-test	3.36	1.33			
	Post-test	4.25	0.89	0.89**	0.14	<.001

Note: \*\* denotes  $p < .01$ , \* denotes  $p < .05$

### ***Experience with Interactive Components of the Platform (Video-based scenarios, module page assessments, embedded videos, and readings)***

The most beneficial components of the platform that incorporated multiple elements were those that allowed students to engage with the material in different ways, catering to a range of learning preferences. Insights offered by the participants, such as "I like all the different options that you have of

*learning how you have the activities in the virtual simulator, or you can just read through, not necessarily slides, but the little information pieces that they have.” and “The material is comprehensive. It covers everything from reading and questions, and watching videos and involve yourself with, you know, stimulation and all that visual, the new technology”* pointed to these benefits.

Some participants preferred traditional learning methods, like quizzes or matching exercises due to the ease of navigation. Quizzes, especially those with visual components like graphs and charts, were seen as highly effective for reinforcing food safety concepts. These activities allowed students to quickly assess their understanding and retain critical information. *“I think it’s made it easier than the information, especially because the professor lectures about the content and then we have the modules signed and so we can hear the lecture and go through the lecture and then have the information reinforced by the modules.”* Additionally, the flashcards and videos with embedded questions were well-received by the participants as they maintained students’ engagement.

While the students appreciated the variations of the elements and viewed that positively, they voiced concerns about the lengthiness of the entire training, which discouraged students from completing it. One student stated, *“I feel like some students may not be likely to finish it once it does that, because it takes a long time just to click on each button.”* Another agreed by saying *“The students may get bored because it was the repetition of the content of the modules.”*

Furthermore, there were issues with the contents, such as out-of-date information and trustworthiness of the information. *“It felt really outdated, like the video itself and so I wasn’t sure I could trust the information for that chapter. I did look in the textbook. There were better videos out there.”* A few students also commented on the set-up of the food safety training on Canvas LMS. *“It’s a little confusing the way that it’s laid out on Canvas. I wish that every topic, how module six, I wish that it was just all in one thing, versus being a bunch of different things you have to go through.”*

### ***Learning Experience Specific to VSE***

Regarding the benefits of VSE FSS platform for learning, several participants appreciated the realistic simulations, noting that they mirrored real-world tasks as one student noted, *“I guess it just puts you in those real-world situations and then helps you better apply it before you go to the lab because you’re seeing it before you’re in a situation that is actually real life”*. Participants who preferred hands-on learning found that engaging with scenarios such as inspecting deliveries or using thermometers made the concepts more relatable and memorable. For example, *“I like the 360 [360° virtual simulated environments], the go-around, and it actually gets me more involved in learning more about the temperatures.”*

Students appreciated how the simulator mimicked real-life kitchen settings, providing a safe space to practice without the consequences of making mistakes in a live environment. *“I apply my knowledge without being in a real kitchen setting, because I’m doing it at home, so I’m comfortable versus being nervous learning it in a real kitchen environment, where, if you mess up, someone’s right there.”* Another participant voiced a similar observation, *“It is definitely an effective learning tool. That’s how pilots learn to fly airplanes. Right? It is definitely a proven method for learning.”*

On the other hand, the shortcomings of VSE FSS platform were also discussed. Several participants noted that the simulations could be overly long, leading to disengagement. They suggested that shorter, more focused tasks would keep their attention and make the learning process smoother. For instance, one participant stated, *“You keep going around and around, and there’s more and more and more.”* Some students encountered technical difficulties while using the platform, such as frozen screens or unclear navigation paths. These issues made it harder to complete certain tasks and detracted from the overall learning experience. For instance, *“It almost needs to be a wider screen, because sometimes you can’t see where the next*

*button is pressed and you're like, Well, am I stuck here?" Another participant also felt that they should be able to bypass the explanations of the correct answers if they got the questions right, "My only issue with the virtual world simulations is that regardless of if you get the question right or wrong, it tells you the whole explanation on why it's correct, whether you get it right or wrong ...if you get it right it's kind of annoying."*

Overall, the findings from the focus groups indicated that the integration of the platform significantly enhanced students' food safety handling techniques or skills that are often difficult to teach effectively using traditional learning methods. The findings of this study also underscored the need of considering the diverse learning styles and preferences of the students to provide a better learning experience (Akamu et al., 2024). Students who are visual, kinesthetic, and/or auditory learners may benefit from the various interactive components integrated in the platform. Results from the focus groups further revealed the benefits of the VSE FSS, such as its mimicry of real-world scenarios and engaging nature. These findings supported previous literature that students, in general, enjoyed virtual simulations that were integrated in their course (Akamu et al., 2024). The learners found simulations used in the classroom were realistic; they also provided opportunity for the students to practice some difficult and abstract concepts (Chen, 2009; Spencer et al., 2019). The VSE also provides opportunities for students to learn and practice in a safe environment, without the fear of being penalized (Murray et al., 2002). On the other hand, the shortcomings of this platform were noted related to its lengthiness, navigation issues, and other technical challenges, the latter of which could be discouraging to learners (Akamu et al., 2024).

## CONCLUSIONS AND APPLICATIONS

This study aimed to investigate a VSE FSS learning platform's effectiveness in hospitality education using a pretest-posttest design. Effectiveness was measured by knowledge acquisition, attitudes toward food safety, perceptions of the platform, and self-reported behavioral changes. Additionally, focus groups explored participants' experiences and perceptions with the platform. The findings from both the quantitative and qualitative research highlighted the effectiveness of the virtual environmental platform focused on food safety and its potential for use among various types of learners. Although the simulation-based platform required a considerable investment of time and effort for learners (Román-Calderón et al., 2021) to become accustomed to the format, the overall outcomes from this study, based on the quantitative data were positive. Students displayed favorable attitudes toward the platform, even after the actual use. In essence, students were willing to dedicate additional time and energy as long as the learning tool proved beneficial in terms of relevance, motivation, and interest. Despite the benefits of the VSE FSS platform, some challenges were also noted for its integration in the classroom.

The practical implications of immersive FSS learning platforms extend beyond academia, reaching various sectors and industries where food safety and sanitation practices are paramount. Immersive FSS learning platforms can equip hospitality sector professionals with practical skills and knowledge crucial for ensuring food safety standards. By using these platforms, foodservice businesses can train their staff more effectively, reducing the risk of foodborne illnesses and enhancing customer satisfaction. This ensures compliance with regulations, reduces the likelihood of foodborne outbreaks and protects the reputation of the establishment. Similarly, immersive FSS learning platforms can benefit food manufacturers and suppliers by providing training on safe food handling practices throughout the supply chain. This helps prevent contamination during production, processing, and distribution, reducing the risk of foodborne illnesses and product recalls.

In addition, health departments and other public health agencies can leverage immersive FSS learning platforms to conduct training programs for food inspectors and other personnel involved in food safety regulation and enforcement. Enhanced training can lead to more thorough inspections and better enforcement of food safety regulations, ultimately safeguarding public health. Lastly, immersive FSS

learning platforms can also be used to educate consumers about safe food handling practices at home. By increasing consumer awareness and knowledge, these platforms empower individuals to take proactive measures to prevent foodborne illnesses and maintain food safety in their households.

This study has several limitations. First, the findings of this study are not generalizable to all education and professional settings. The sample consisted of students enrolled in a food service and production class in a Bachelor of Science in Hospitality Management degree program at one institute over three semesters. This limits the extent to which the findings can be applied to a broader population, particularly students in other fields of study that require food safety and sanitation training, such as nutritional science majors. These students may have a greater scientific understanding of food safety and sanitation due to the food science material in their curriculum.

Moreover, the effectiveness of the VSE FSS program observed in this study may not translate directly to the training and development of professionals working in real-world hospitality settings. The student's specific characteristics and experiences, such as their academic background, learning environment, and familiarity with educational technology, differ significantly from those of industry professionals who may have varying levels of practical experience, job responsibilities, and training needs.

While the study aimed to evaluate the effectiveness of the VSE FSS program, it is challenging to determine the true effectiveness of the virtual simulation environment. Factors such as participants' prior knowledge, motivation, and external influences (e.g., course instructors) could have impacted the results, making it difficult to isolate the effect of the VSE FSS program alone (Vaz-Fernandez & Caeiro, 2019). Because the food handling behaviors in the surveys were self-reported, there were no direct observations of the students' practices and behaviors during pre- and post-assessments in a real-life setting. Future research may include an observational study to examine these behaviors at two of these time points.

Lastly, the virtual simulation environment itself had certain limitations that may have influenced the study's outcomes. These include the lengthiness of the program, navigation issues, and the time and effort required for learners to become accustomed to the format. These factors could have affected participants' engagement and overall experience with the platform. Future studies should consider employing an experimental design to evaluate the effectiveness of the VSE FSS program more rigorously. This could involve randomly assigning participants to either an intervention group using the VSE FSS platform or a control group using traditional learning methods. Such a design would help isolate the impact of the VSE FSS program and provide evidence of its effectiveness.

Additionally, future research should include students from other institutes and disciplines to enhance the generalizability of the findings. By involving a more diverse group of participants, researchers can better understand how different types of learners respond to the VSE FSS platform and identify any variations in its effectiveness across different educational contexts. Evaluating the effectiveness of the VSE FSS program with industry professionals could determine how well the platform translates to real-world settings and its impact on practical food safety skills and behaviors. This would provide valuable insights into the applicability and benefits of the VSE FSS program beyond academic environments. Finally, exploring the use of Virtual Reality (VR) as a fully immersive experience could further enhance the learning outcomes. VR technology has the potential to provide an even more engaging and realistic simulation of food safety scenarios, which could lead to greater improvements in students' food handling practices and behaviors. Future studies should investigate the feasibility and impact of integrating VR into the FSS learning platform.

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