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Effects of a Game-Based e-Learning Module on Undergraduate Food Science Students' Planned Behaviors Concerning Good Manufacturing Practices

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Abstract: Understanding the role of food science education in developing undergraduate students' intentions to implement Good Manufacturing Practices (GMPs) may be a key strategy in developing the workforce's implementation of GMPs and other food safety programs. Previous research has demonstrated the effects of educational interventions on planned food safety behaviors in various settings; however, none have studied GMPs interventions and college students. This study applied the Theory of Planned Behavior (TPB) to evaluate the effects of a game-based e-learning module on undergraduate students' planned behaviors concerning GMPs. Forty-four participants were recruited from 42 food science clubs across the United States to complete a game-based e-learning module and pre- and posttest survey instruments. We compared changes in pre- and posttest scores using paired Wilcoxon signed rank tests and explored the role of GMP-related knowledge and TPB constructs (attitudes, subjective norms, and perceived behavioral controls) in predicting students' intentions to implement GMPs using multiple linear regression. We modeled pretest scores, posttest scores, and changes in scores while controlling for student demographic factors (for example, year in college, gender, and so on). Only participants' knowledge and perceived behavioral controls significantly increased ($P < 0.05$) after completing the game-based e-learning module. Posttest regression models explained twice as much variance than pretest models (up to 54% total). Changes in intentions to implement GMPs were predicted by changes in subjective norms, perceived behavioral controls, and knowledge, as well as previous enrollment in food safety courses and interest in working in the food industry. The only predictive variables for both pre- and posttest scores were subjective norms, previous enrollment in food safety courses and interest in working in the food industry ($P < 0.05$). A discussion of how these results provide insights for food safety educators to optimize their teaching impacts was presented.

Keywords: food safety education, good manufacturing practices, education, elearning, theory of planned behavior

Introduction

Equipping college students with competencies in food safety and quality assurance has become increasingly important in recent years. The Food Safety Modernization Act of 2011 created an urgent demand for a qualified workforce capable of implementing new food safety rules for much of the food industry in the United States (Stevenson, 2015). There were approximately 52230 food-safety managers and supervisors employed in the 2016 workforce (U.S. Bureau of Labor Statistics, 2017), and there is an expected increase in demand of approximately 10% for many food safety occupations between the years 2010 to 2020 (Stevenson, 2015).

There is a need to improve the workforce's implementation of Good Manufacturing Practices (GMPs), which are the regulatory requirements for manufacturing foods that are safe for human consumption enforced by the Food and Drug Administration (FDA). Good Manufacturing Practices are considered prerequisite programs for food safety management systems such as preventive controls and hazard analysis and critical control points (HACCP) (Baur, Getz, & Sowerwine, 2017). Inadequate implementation of GMPs are a cause of cross contamination in the food industry, which can lead to pathogen growth (Sousa, Tamagnini, Olmos, & Gonzalez, 2002) and therefore foodborne illness outbreaks (Soon, Manning, & Wallace, 2016). For example, an FDA investigation

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in response to a national ice cream *Listeria monocytogenes* outbreak in 2015 identified several GMP violations, such as condensation dripping from overhead pipes onto food contact surfaces, employees not wearing beard nets, and poor equipment maintenance (U.S. Food and Drug Administration, 2015).

Efforts to identify effective strategies for teaching college students GMPs are warranted. For example, GMPs encompass several IFT Education Standards (Institute of Food Technologists, 2016) and core competencies for undergraduate food safety curricula (Johnston et al., 2014). A survey of industrial advisory board members of a U.S. undergraduate food science program demonstrated that GMP-associated competencies were rated either important or very important (Morgan, Ismail, & Hayes, 2006). Despite the high need identified, "basic principles and practices of cleaning and sanitation in food processing operations" and "application of government regulations required for the manufacture and sale of food products" were among the lowest rated abilities of food science graduates from an undergraduate food science program as indicated in a survey of the graduates themselves and their employers (Bohlscheid & Clark, 2012). Effective strategies for teaching GMPs will equip students with marketable skills needed to more adequately apply government regulations.

There are certain challenges to teaching students GMPs in higher education settings that are common across institutions, several of which are associated with facilitating experiential learning opportunities. For example, not all campuses are in close spatial proximity to food/beverage processing facilities, which creates additional difficulty in terms of scheduling and providing transportation to observe and/or practice GMPs in real-world settings. Gaining access to nearby food/beverage processing facilities sometimes requires extreme time commitments and persuasion skills from instructors, as many managers in industrial settings are inundated with providing access to inspectors and auditors on a routine basis and are also concerned with the risk of cross contamination that visitors can present while touring their facilities. Therefore, there is potential for e-learning to overcome some of these challenges.

In addition to employing innovative learning strategies, effective GMP-related teaching will also target behavior change, as the goal of such teaching is successful implementation of GMPs in the workplace. Although observation of GMP implementation may be difficult, educators can assess behavioral intentions, which are predictive of actual behaviors. Theory of Planned Behavior (TPB) provides a framework to understand how to encourage behavioral intentions that may apply in a GMP context (Ajzen, 2012). The TPB outlines three constructs that predict intentions: attitudes (for example, thinking GMPs are important), subjective norm (for example, perceiving that others implement GMPs), and perceived behavioral control (for example, feeling one can effectively implement GMPs). Several studies have demonstrated that this framework is helpful in predicting various food safety behaviors (Hinsz & Nickell, 2015; Milton & Mullan, 2012; Mullan & Wong, 2009; Phillip & Anita, 2010; Shapiro, Porticella, Jiang, & Gravani, 2011). However, many of these studies are observational, and few have examined the role of education in changing intentions or any of its predictors within the TPB framework (Alberts & Stevenson, 2017). None to our knowledge have examined the role of undergraduate education in driving changes in behavioral intentions related to GMPs, nor have they examined the relative importance of changes in knowledge, attitudes, subjective norms, or behavioral control in predicting changes in intentions. Most food safety-related studies have not incorporated knowledge or other related factors that are relevant constructs in education and training programs into their surveys. However, several in education settings have incorporated knowledge as a copredictor or precursor to attitudes, social norms, and behavioral control (Kollmus & Agyeman, 2002).

The objectives of this study were to (1) create an instrument for assessing student's intentions to implement GMPs in their careers; (2) model how GMP-related knowledge, attitudes, subjective norms, perceived behavioral controls and other related factors predict such intentions; and (3) measure whether a game-based e-learning module would be associated in gains in knowledge, attitudes, subjective norms, or perceived behavioral control, and if so, the relative importance of these gains in predicting gains in behavioral intentions.

Methods

Game-based e-learning module development

A game-based e-learning module on GMPs was developed to address knowledge-based learning objectives as well as facilitate development of behavioral intentions through a TPB framework (Figure 1). The three learning objectives were to increase students' abilities to (1) recognize GMPs used in processing plants, (2) distinguish between GMP regulations and non-GMP regulations, and (3) identify GMP regulations that are specific to a particular location in a food processing plant. Through model design, we also sought to develop positive attitudes toward GMPs, develop social norms around GMPs, and increase the perceived behavioral control to implement GMPs. Key features of the module were a simulated plant tour, clear but conversational explanation by tour guides, and opportunity for practices in identifying GMPs. The simulated tour and emphasis by the guides around the importance of GMPs was meant to foster positive attitudes toward the importance of GMPs, the conversational tone by the guides was meant to foster a sense that this is the "way things are done" as a plant worker (that is, social norms), and the opportunity to practice was meant to build a sense of behavioral control.

The module (Stevenson, DeWitt, & Gordon, 2015) was created using Articulate Storyline® e-learning software (Articulate, 2015) and began with a 2-min instructional video of an instructor explaining the objective of the game and its features. Near the end of the introductory video, a button appeared for participants to click in order to transition to the next part of the exercise. This button transitioned into a full screen view of a graphic blueprint of the dairy processing plant located on campus at North Carolina State Univ., which manufactures milk, eggnog, and ice cream under the Howling Cow™ trademark. Twelve different hotspots appeared at different locations of the blueprint, each of which had a flat-design icon that represented the topic of the activity. Each hotspot opened a 1-to-3 min video of the plant manager and business manager of Howling Cow™ explaining food safety aspects of the particular location where the hotspot appeared (for example, a hotspot placed at a floor drain opened a video that discussed proper drainage and backflow prevention). A one-question multiple choice assessment activity that asked students to identify which GMP regulations were discussed in the video appeared after each video. Correct responses counted toward a total possible score of 37 points. A leaderboard was designed so students could see how they rank against other students after they submit their responses to each of the hotspot exercises using a button on the blueprint (also helping to facilitate development of social norms). JavaScript

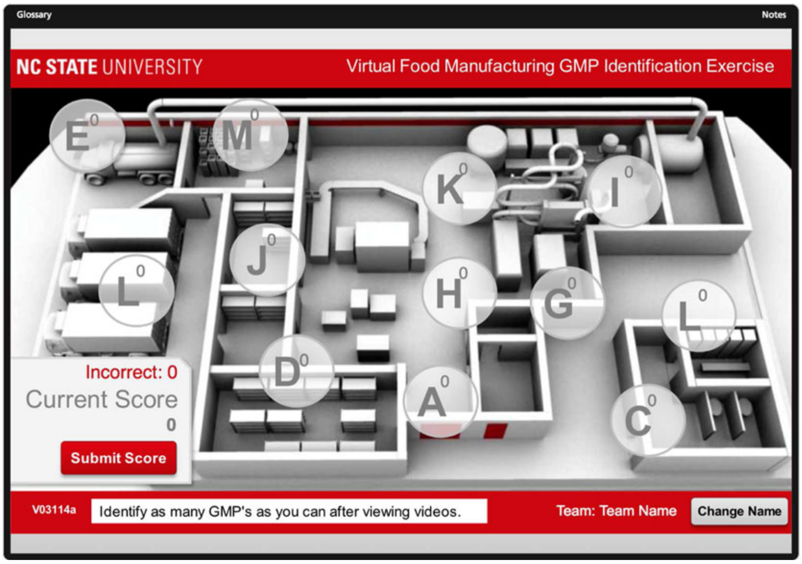

Figure 1–Plant Tour GMP e-Learning Game. The beginning consists of a video of an instructor explaining the objective of the game and its features. Then, each of the 12 buttons open a 1 to 2 min instructional video explaining GMPs concepts, followed by a one-question multiple choice assessment activity that asks students to identify which GMP regulations were discussed in the video.

code was developed to integrate the points and leaderboard system into Storyline and a secure website.

Instrument development

The TPB (Ajzen, 2012) was used to develop a model for predicting participants' plans to implement GMPs upon entering a career in the food industry. Because there were no published studies measuring these constructs in the context of GMPs, a draft instrument was developed using expert review. To measure GMP-related attitudes, a six-question scale was constructed using a 7-point Likert-type scale (for example, agree/disagree: All food facilities should implement GMPs, Table 1). Likert-type scales were used to rate the perceived behavioral control (Table 2), subjective norms (Table 3), and intentions (Table 4) using five, four, and one questions, respectively. Knowledge was assessed using eight multiple-choice questions related to participants' abilities to identify and differentiate between GMPs (Table 5).

Demographic questions were included at the end of the survey. Questions asked participants whether they were pursuing a degree in food science, have taken any food safety courses, were interested in working the food industry, and what university they attend. Additional questions collected the gender, ethnicity, and age of the participants.

Cognitive interviews (Willis, 2005) were conducted with 3 food science undergraduate students before collecting data for this study. This involved asking students to narrate their thought process while taking the survey and playing the game and noting items that needed revisions for clarity or face validity. All questions were revised to an 11th grade readability level using the Flesch Kincaid Reading Ease model and an online tool (Readability, 2017). The estimated time to finish the presurvey, game, and postsurvey was approximately 1 hr.

Sampling

Participants were recruited from all members of 42 food science clubs in United States universities. Food science club officers listed on the university food science club websites were emailed and asked to disseminate the survey to their membership and participate themselves. The email message provided an overview of the study, the purpose of the study, and compensation details for participating (a chance to win one of 15 $100 gift cards). This

Table 1–Attitudes score means, standard deviations (SD) and principle component analysis (PCA) factor loadings. Each question was paired with a 7-point scale ranging from strongly disagree (1) to strongly agree (7). Factor loadings and Cronbach's alpha were calculated from the pre-test data.

	Pre-Test		Post-Test		Hypothesis Test	Factor Loadings	
Question	Mean	SD	Mean	SD	Significance	Component 1	Component 2
GMPs are important to controlling food safety in a facility	6.70	0.553	6.75	0.488	0.570		0.314
All food facilities should implement GMPs	6.57	1.021	6.80	0.462	0.133		0.915
Having GMPs in place result in a better quality product	6.41	1.085	6.50	0.902	0.456		0.959
GMPs are not important for controlling food safety in a facility	1.71	1.453	1.86	1.636	0.516	0.938	
GMPs are not necessary in a food facility	1.50	1.329	1.47	1.130	0.901	0.949	
GMPs have no relation to product quality	1.66	1.182	1.86	1.533	0.277	0.645	
Cronbach's alpha						0.730	0.869

Table 2–Perceived behavioral controls scale means, standard deviations (SD) and principle component analysis (PCA) factor loadings. Each question was paired with a 7-point scale ranging from strongly disagree (1) to strongly agree (7). Factor loadings and Cronbach's alpha were calculated from the pre-test data.

	Pre-Test		Post-Test		Hypothesis Test	Factor Loading
Question	Mean	SD	Mean	SD	Significance	Component 1
If and when I work in a food processing facility, I would be able to implement GMPs	6.25	0.811	6.50	0.665	0.020	0.781
If and when I work in a food processing facility, I can control whether someone contracts food poisoning by following GMP regulations	5.25	1.416	5.70	1.304	0.005	0.707
I can identify GMPs in processing plants	4.93	1.605	6.09	0.802	0.000	0.487
I will have control over the quality of a product by following GMP regulations	5.59	1.263	6.25	0.751	0.001	0.653
If and when I work in a food processing facility, I would be able to implement GMPs at every possible occasion	5.75	1.144	6.14	1.047	0.013	0.835
Cronbach's alpha						0.691

Table 3–Subjective norms scale means, standard deviations (SD) and principle component analysis (PCA) factor loadings. Each question asked whether each person was likely to implement GMPs and was paired with a 7-point scale ranging from very unlikely (1) to very likely (7). Factor loadings and Cronbach's alpha were calculated from the pre-test data.

	Pre-Test		Post-Test		Hypothesis Test	Factor Loading
Question	Mean	SD	Mean	SD	Significance	Component 1
My friends	5.68	1.029	5.75	0.991	0.627	0.805
My family	5.91	1.197	5.86	1.112	0.688	0.795
My teachers	6.18	1.167	6.30	1.112	0.229	0.723
My classmates	5.91	1.096	6.09	1.053	0.088	0.854
Cronbach's alpha						0.802

Table 4–Intentions scale means and standard deviations (SD).

	Pre-Test		Post-Test	
Question	Mean	SD	Mean	SD
How likely are you to implement GMPs?	6.61	0.655	6.73	0.585

study was approved by the NC State Univ. Institutional Review Board (protocol number 6056).

Data analysis

We began by recoding the negatively worded items on the attitudes scale (all other items were positively worded). Cronbach's alpha scores and principal component analyses (PCA) were calculated for each scale in the pre-test survey instrument to determine reliability and validity, respectively. To test for differences in pre- and post-test scores for each measure, we preformed Wilcoxon signed rank tests with 95% confidence intervals because each of the constructs were not normally distributed. Both *a priori* and experimental linear regression analyses were conducted to predict intentions with the various and the residuals represented normality. All statistical analyses were performed using IBM SPSS software (IBM Corp, 2016).

Results

Our sample size was 44 students from 8 different universities who were mostly female (70%) and Caucasian (41%), with fewer Asian (32%), African American (9%), multiracial (9%), and Hispanic (7%), students. Undergraduates represented 72% of the participants and seniors, juniors, sophomores and freshman comprised 3%, 10%, 32%, 55% of these undergraduates, respectively. The vast majority of students were interested in working in the food industry: 80%, 16%, and 4% of participants said "yes," "maybe," and "no," respectively. There was an 80/20 split between students who have previously taken food safety courses and who have not, respectively.

The reliability (Cronbach's alpha) of each scale of the survey was 0.691 or higher and the PCA factor loadings were 0.314 or higher (Table 2 to 6), which is within the range of acceptability (Hair, Black, Babin, & Anderson, 2010). Factor analyses revealed

Table 5–Multiple choice knowledge question scores before and after participant completed a game-based e-learning module on Good Manufacturing Practices. Proportion correct represents the proportion of respondents whose multiple choice answers were correct.

	Pre-Test		Post-Test		Hypothesis Test
Question	Mean	SD	Mean	SD	Significance
Which of the following is not included in GMP regulations?	0.61	0.493	0.91	0.291	0.002
Which of the following is not included in GMP regulations?	0.66	0.479	0.95	0.211	0.000
Which of the following is not included in GMP regulations?	0.30	0.462	0.77	0.424	0.000
Which of the following is not included in GMP regulations?	0.59	0.497	0.77	0.424	0.058
Which of the following is not a GMP requirement for a walk in cooler?	0.75	0.438	0.82	0.390	0.473
Which of the following is not a GMP requirement for the Clean out of Place (COP) procedure?	0.39	0.493	0.73	0.451	0.000
Which of the following is not a GMP requirement for warehousing?	0.20	0.408	0.43	0.501	0.024
Which of the following is not a GMP requirement for the loading dock?	0.36	0.487	0.55	0.504	0.031

Table 6–Regression models of participants' pre-test and post-test intentions to implement GMPs as predicted by the Theory of Planned Behavior constructs (subjective norm, perceived behavioral control, and attitude), knowledge, and demographic factors (year in college, interested in working in the food industry, and having taken food safety courses before).

	Pre-Test Intention		Post-Test Intention	
	Standardized Beta Coefficient	*p*	Standardized Beta Coefficient	*p*
(Constant)	*N/A*	0.001	*N/A*	0.003
Knowledge			0.389	0.001
Subjective Norm	0.372	0.002	0.351	0.007
Perceived Behavioral Control			0.366	0.004
Attitude	0.231	0.126		
Year in College	0.388	0.033	0.320	0.010
Interest in working in the food industry (yes/maybe/no)	−0.265	0.145	−0.204	0.078
Taken food safety courses before (yes/no)	0.254	0.150		
Adjusted R^2	0.246		0.540	

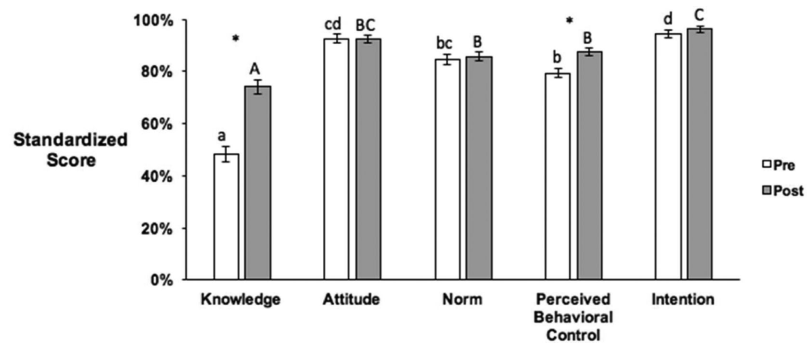

Figure 2–Participants' knowledge, attitudes and subjective norms, and perceived behavioral controls concerning Good Manufacturing Practices before and after completing a game-based e-learning module. Each score represents the average percentage of the total possible score. Error bars represent standard errors. Attitude, subjective norm, perceived behavioral control, and intention scores represent the aggregate scores ranging from 1 (negative responses such as strongly disagree) to 7 (positive responses such as strongly agree). Lowercase and uppercase letters represent significant differences (alpha = 0.05) within pre-test and post-test constructs, respectively. Asterisks represent significant differences ($p < 0.05$) between pre-test and post-test treatments.

one factor for each of the scales (Table 1 to 3) except for attitudes, in which case two factors corresponded with positive and negative attitude questions (Table 1). Whereas each of the constructs was measured with four survey questions, the intentions construct only contained one question. Therefore, future iterations of this evaluation instrument should consider adding questions to the intentions construct to establish more reliable and valid results.

Participants' intentions to implement GMPs were the highest of all constructs at both the pre- and posttest treatment times (Figure 2), whereas their knowledge about GMPs was the lowest scoring construct. Participants' attitudes toward GMPs were significantly higher ($P < 0.05$) than their perceived behavioral controls at the time of the pretest. At the time of the posttest, however, there were no significant differences between attitudes, subjective norms and perceived behavioral controls ($P > 0.05$).

Participants significantly increased perceived behavioral control scores, both in the aggregate (standardized pretest mean = 0.793, SD = 0.122; posttest mean = 0.876, SD = 0.101; t-ratio = 5.72 $P < 0.001$; Figure 2) and on each individual perceived behavioral control question (Table 2). There were also significant increases in participants' knowledge scores both in aggregate (pretest mean = 47.5%, SD = 23.56%; post-test mean = 74.1%, SD = 15.64%; t-ratio = 6.92; $P < 0.001$; Figure 2) and on each individual knowledge question ($P < 0.05$) except for questions related to determining what is included in GMP regulations (question 4, Table 5) and the GMP regulations for walk-in cooler (question 5, Table 5).

Significant differences for the other TPB-related factors (attitudes, subjective norms, and intentions) were not observed. Attitude scores increased in magnitude, however this difference was not significant ($P > 0.05$) between pre- and posttest aggregate scores (Figure 2) or the individual questions (Table 1). There was not a significant difference between the pre- and posttest aggregate subjective norms ($P > 0.05$; Figure 2), nor were there any significant differences in each individual category (Table 3).

Experimental investigation determined that the model that explained the most variance for the pretest intentions (adjusted $R^2 = 24.6\%$) included the following constructs in descending order of effect size: year in college, subjective norm, interest in working in the food industry, enrollment in previous food safety courses, and attitude (Table 6). The experimental model for posttest intentions explained 54.0% of the variance and significant effects were observed for knowledge, subjective norm, perceived behavioral control, year in college and interest in working in the food industry, in descending order of effect size (Table 6). Finally, the experimental model for changes in intentions from pre- to posttest explained 51.5% of the variation and significant effects of knowledge, change in subjective norms, change in perceived behavioral controls, previous enrollment in food safety courses, interest in working in the food industry, and pre-intentions (adjusted $R^2 = 51.5\%$) (Table 7). Gender was not a significant predictor in any of these regression models.

Regression revealed that the TPB-related factors alone only explained 13.3% of the variance when applied at the pretest, as

Table 7–Regression models of participants' change in intentions to implement GMPs from pre- to post-test as predicted by the Theory of Planned Behavior constructs (subjective norm, perceived behavioral control, and attitude), knowledge, and demographic factors (interested in working in the food industry, and having taken food safety courses before).

	Standardized Beta Coefficient	*p*
(Constant)	*N/A*	0.000
Change in Knowledge	0.312	0.010
Change in Subjective Norm	0.199	0.093
Change in Perceived Behavioral Control	0.266	0.053
Taken food safety courses before (yes/no)	−0.401	0.003
Interested in working in the food industry (yes/maybe/no)	−0.263	0.037
Pre-test intentions	−0.536	0.000
Adjusted R^2	0.515	

compared to 28.8% of the variance during the post-test (data not shown). Only subjective norms predicted pretest food safety intentions of the participants, whereas at the time of the posttest, perceived behavioral controls predicted their intentions (data not shown). The change in participants' intentions was not predicted by changes in any of the constructs.

Discussion

This experimental application of the TPB toward an educational intervention provided insights into how food science college students' intentions to implement GMP's as they enter the workforce are influenced by their learning experiences. Whereas previous studies commonly reported TPB-related factors (attitudes, subjective norms, and perceived behavioral controls) as explaining approximately 40% of the variance in behavioral intentions (Armitage & Conner, 2001; Godin & Kok, 1996), these factors only explained 13.3% and 28.8% of the variance before and after the educational instrument, respectively, in the present study. However, year in college, interest in working in the food industry, and previous enrollment in food safety courses increased the R^2 values to 24.6% and 54.0% in the pre- and posttest, respectively, and 51.5% in the model of changes in intentions. Although there was not a significant increase in participants' intentions after the educational intervention, the amount of variation explained by the experimental regression model increased by 29.4% after participants completed the game-based e-learning module. Therefore, the TPB was a useful framework for generating ideas on how to influence college students' intentions to implement GMPs as they enter the workforce. Future research should continue to design interventions specifically to impact TPB constructs and consider experimental testing with control groups receiving non-e-learning modules.

Experimental regression models that included non TPB-related factors provided insights that may inform the goals of GMPs-related curricula. Our finding in the pretest that the subjective norm was the strongest predictor of behavioral intentions was consistent with a previous study of food handlers in hospitality settings (Phillip & Anita, 2010) and workers in a poultry processing plant (Hinsz & Nickell, 2015). Attitude was not a strong predictor of intentions in the pre- or posttest, which was consistent with a previous study of first-year psychology students (Mullan & Wong, 2009). This is perhaps due to social desirability bias (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003) because attitude scores were the highest of all TPB constructs and there was over 90% agreement that GMPs are important to controlling food safety in our study. The pretest result that subjective norm was a significant predictor of intentions and attitude was not a significant predictor in both our study and that of Mullan and Wong (2009) supports their conjecture that "young adults are more concerned about social normative influences than their own attitudes towards food handling." This is a reasonable assumption since students' GMP behaviors in the future once they become professionals may have a direct effect on their friends, family and superiors who consume the food they produce. Therefore, instructors of GMPs courses should consider redesigning their courses to address student-peer or student-instructor norms more so than students' attitudes toward GMPs. Perceived behavioral control and changes in perceived behavioral control were the most powerful predictors of posttest intentions and changed in intentions, respectively. Therefore it seems reasonable to design lesson plans that specifically promote students' self-efficacies and personal agencies. Together, these results seem to suggest a course that teaches GMPs should consider adopting constructivist learning theories such as case-based learning, problem-based learning, and social development (Crawford, 1996; Srinivasan, Wilkes, Stevenson, Nguyen, & Slavin, 2007).

Participants who were more interested in working in the food industry and who were farther along in their college careers indicated slightly higher intentions to implement GMPs, as evidenced by pre- and posttest experimental regression models. Perhaps students who fit into these categories have spent more time considering what they will do in the workforce and therefore have realized that implementation of GMPs is a job task for many careers in food science. Thus, it was unclear whether a course on GMPs should be placed toward the beginning or end of a typical 4-year degree program.

Given the numerous constraints associated with teaching students GMPs in face-to-face settings (for example, spatial proximity of a college campus to food/beverage processing facilities, limited space for large class sizes, scheduling, transportation, and the added risk of cross contamination from bringing visitors into a processing facility), the result in our study that implementation of a game-based e-learning module significantly increased college students' knowledge and perceived behavioral controls about GMPs was promising for college instructors who intend to integrate e-learning into their teaching practices. The increase in knowledge is consistent with many knowledge-based educational interventions, and the practice identifying GMPs likely facilitated greater confidence (that is, behavioral control). The insignificant increase in subjective norms in our study may be explained by the fact that the participants in this study did not personally know the characters in the educational intervention or engage with their peers, instructors or supervisors as they played it. For example, the responses may have increased if the participants completed the game as part of a class they were taking and their instructor emphasized the importance of the subject matter. The educational intervention did not affect participants' attitudes and behavioral intentions, which may be attributed the participants' high scores for these constructs before they experienced the educational intervention. Nor was the change in behavioral intentions as a result of the educational intervention predicted by changes in any of the TPB-related factors or knowledge change, which may be explained by the insignificant change in behavioral interventions. Nonetheless, the educational intervention had an overall positive effect on all measures, as it resulted in significant increases in the 2 lowest scoring factors observed in the pretest (knowledge and perceived behavioral controls) and did not result in a decrease in the highest scoring factors (attitudes, subjective norms and intentions).

A limitation of this study was the sample size of 44 participants was relatively small compared to the population of approximately 4,000 undergraduates enrolled in food science and technology (Stevenson, 2016), and therefore, the interpretation of these findings should be treated as a pilot study. However, our sample represented students from eight different universities and was diverse in terms of gender and race.

Future iterations of this pilot study should also consider including more questions to measure the behavioral intentions construct since our study only included one to ensure the scale for measuring this construct is as valid and reliable as the other constructs assessed in this study, which were within the range of acceptability.

Conclusions

This experimental application of the TPB to assess the effects of an educational intervention on undergraduate food science students' intentions to implement GMPs provided insights for instructors to optimize the teaching impacts in GMPs courses. E-learning has potential to build knowledge and behavioral control concerning GMPs. Subjective norm was a significant predictor ($P < 0.05$) of behavioral intentions before and after participants completed the educational intervention, whereas afterward, perceived behavioral control and knowledge became significant predictors ($P < 0.05$). Experimental addition of other factors to the model revealed other significant predictors, including year in college ($P < 0.05$ before and after the intervention), interest in working in the food industry ($P < 0.1$ before and after the intervention), and knowledge ($P < 0.01$ after the intervention). Significant increases of participants' knowledge and perceived behavioral controls about GMPs were observed ($P < 0.05$), but not for their attitudes or subjective norms.

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Author Contributions

Clint Stevenson led the survey design, development of the Plant Tour GMP Game, data analysis and drafting this manuscript.

Kinsey Porter assisted with survey design, participant recruitment, preliminary data analyses, and drafting this manuscript.

Kathryn Stevenson assisted with data analysis, evaluation of the survey research instrument, and drafting this manuscript.

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