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Students' perceptions of Plickers and crossword puzzles in undergraduate studies

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Abstract

In higher education, there are calls to incorporate active learning experiences that place the student at the center of learning, rather than encouraging students to be passive listeners. For students to have a deeper and more meaningful learning experience, educators can use an active learning approach. This approach attempts to engage students at higher levels of thinking so that they are more interested in, better engaged with, and understand the course material better. The aim of this study was to investigate students' perceptions of Plickers and crossword puzzles as low-cost pedagogical tools to foster active learning in an undergraduate course in food science and technology. A mixed-method survey consisting of a 5-point Likert scale and open-ended qualitative questions was administered via Blackboard to elicit student responses. A total of 121 students were enrolled for the course and 70.2% ($n = 85$) completed the survey. Plickers were found to be easy to use (mean = 4.66), provided opportunities to answer to formative questions anonymously (mean = 4.60), and helped increase participation in class (mean 4.05). The majority of students felt that crossword puzzles required them to think critically (mean = 4.53) and provided them with the opportunity to assess how well they understood the course content (mean = 4.45). Moreover, a statistically positive relationship was found between student collaborative learning and crossword puzzle implementation scores ($r = .506$, $p < .01$). The findings demonstrated that when implemented effectively, Plickers and crossword puzzles contributed to greater enhanced student engagement. These pedagogical tools can be applied as formative assessment instruments and offer a low-cost alternative to the limitations encapsulated by didactic pedagogy.

KEYWORDS

active learning, constructivism, crossword puzzle, food science and technology, Plickers

1 | INTRODUCTION

Didactic lectures, where the lecturer occupies the central role (the sage on the stage) and students are passive listeners/receivers of knowledge, are common in higher education institutions. The drawbacks of didactic lectures in a conventional classroom are primarily a lack of attention, inadequate development of independent thinking, and limited opportunity for the student to self-assess (Datta, Datta, & Venkatesh, 2015; Marchalot et al., 2018). Food science and technology students need competencies in critical thinking, teamwork, problem solving, self-directed learning, and communication skills, all of which are seldom acquired through didactic lecturers.

Research has clearly demonstrated that the more students become involved with the "real life" situations, the more

they learn (Liverpool-Tasie, Adjognon, & McKim, 2019; Lo, Gdovin, Stankiewicz, Appezzato, & Garvey, 2006). Therefore, the current trends in teaching undergraduate students are to provide learning environments that are student centered, where the student can actively learn about the subject matter (Al-Samarraie & Saeed, 2018; Duffrin, 2006; Ma, Steger, Doolittle, & Stewart, 2018). Active learning is an approach to instruction that involves actively engaging students with the course material through discussions, problem-based learning, case studies, role plays, group projects, think-pair-share, peer learning, and other methods (Michael, 2004; Reitmeier, 2010). It gives students the chance to speak up, listen to others, and reflect on their own thoughts. To meet high expectations of teaching and learning, students must be clear about their learning goals and the importance of achieving objectives in the learning environment (Aricò & Lancaster, 2018).

Active learning approaches place a greater degree of responsibility on the student than passive approaches. However, the lecturer's guidance is still essential in the active learning classroom. Active learning falls within the ambit of constructivist learning theory in that it allows lecturers to engage students in the learning process and make their learning experience more effective, efficient, and meaningful (Crisp, Guàrdia, & Hillier, 2016; Saran & Kumar, 2015). A recent meta-study (225 studies) on active learning in science, engineering, and mathematics showed a 6% average increase in student assessment results and a significant reduction in the number of students failing. These findings affirm the benefits of active learning (Freeman et al., 2014). When students become active participants in the knowledge construction process, the focus of learning shifts from covering the curriculum to working with ideas.

In recent years, there has been a paradigm shift in the classroom from the traditional interaction focused on raising hands to a more technology-based audience response system (ARS), such as the use of Kahoot!, Socrative, Quizlet, Mastery Connect, Clickers, and Plickers (Blasco-Arcas, Buil, Hernández-Ortega, & Sese, 2013; Gauci, Dantas, Williams, & Kemm, 2009; Lantz, 2010). Empirical studies have found that the use of ARSs helps to increase students' attention and participation, improve their attendance, and enhance their learning performance (Aricò & Lancaster, 2018; Kay & LeSage, 2009; Ma, Steger, Doolittle, & Stewart, 2018).

Plickers is a relatively new ARS tool that is intended to provide immediate questions and feedback in a class by using "paper-clickers" (Chng & Gurvitch, 2018; McCargo, 2017). Plickers is simple to use, available free of charge (www.plickers.com), and allows the lecturer to collect real-time formative and summative assessment data without the need for any hardware devices on the side of the students (Chng & Gurvitch, 2018). Ruisoto and Juanes (2019) reported that Plickers promoted active engagement even with complex topics in neuroscience, whereas Elmahdi, Abdulghani, and Fawzi (2018) attributed the improvements in students learning experience on the implementation of Plickers in English language education. Moreover, the views of higher education lecturers about using Plickers in courses were positive and they were willing to use this tool for formative assessment (Wood, Brown, & Grayson, 2017). The implementation and effectiveness of using Plickers in food science and technology courses remain unexplored. A better understanding of students' perceptions on the use of Plickers would provide useful insight into the potential for application of such an educational tool to foster student engagement and participation in large classes and its use as a formative assessment tool.

Another interesting pedagogical tool that can be used to enhance active learning is crossword puzzles. Crossword puzzles encourage logical thinking, correct spelling, and can motivate students to know factual information (Abuelo, Castillo, & May, 2016; Bailey, Hsu, & DiCarlo, 2017; Raines, 2010). Crossword puzzles are commonly viewed as a way to use what is known to learn new words or facts. They have been shown to be effective teaching and learning techniques, which make the module fun and improve student learning outcomes in disciplines such as biochemistry (Saldana-Balmori & Delgadillo-Gutiérrez, 2010), medicine (Nazeer et al., 2018), pharmacology (Patrick et al., 2018), dentistry (Saran & Kumar, 2015), and nursing (Raines, 2010). Crossword puzzles can be solved individually or in groups as part of peer learning. When working through a crossword puzzle, students use critical thinking as they ponder the clues and systematically narrow the range of possible answers. As a pedagogical tool, crossword puzzles are helpful in identifying areas of understanding, as well as lack of comprehension and areas of weakness. When students identify answers correctly, they may have an increase in confidence (Crossman & Crossman, 1983). Vickrey, Rosploch, Rahmanian, Pilarz, and Stains (2015) reviewed research in several disciplines including physics, biology, chemistry, and computer science regarding the effectiveness of peer learning; they concluded that this pedagogy overwhelmingly improves students' ability to solve conceptual and quantitative problems. Peer learning has also been recognized as a useful educational strategy because students learn to explain their ideas to others and this can be described as moving beyond independent to interdependent learning (Aricò & Lancaster, 2018; Rodríguez, Díaz, Gonzalez, & González-Miquel, 2019). Peer learning is an effective, scalable active learning pedagogy ideally suited for a pragmatic transition from traditional lecturing toward an engaging constructive approach.

Despite evidence suggesting the potential benefits of active learning tools such as Plickers and crossword puzzles, no studies have been reported on the use of these pedagogical tools in undergraduate classes in food science and technology. Furthermore, little is known about the student's perceptions of Plickers and crossword puzzles in food science and

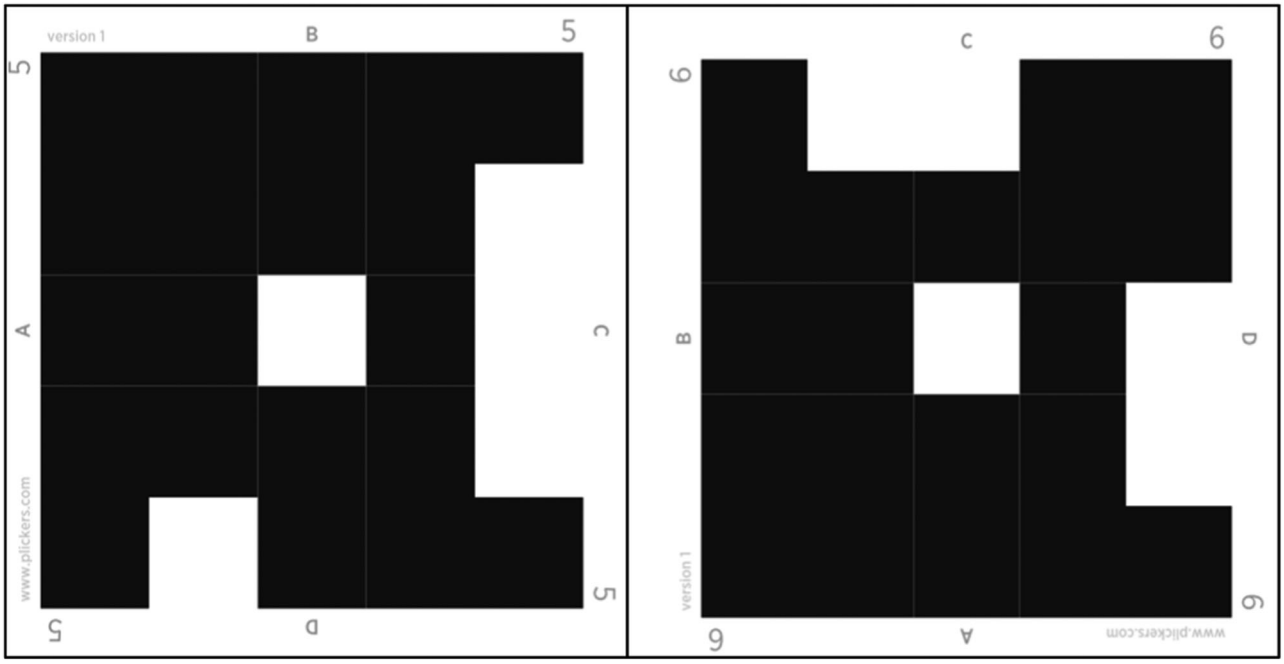

FIGURE 1 Example of paper-based response cards used by students (identified by the number) to respond to the multiple choice questions (alternative answers corresponded with the small a, b, c, and d letters) by holding upward the right alternative of answer

technology courses where students are required to grasp complex scientific concepts. With regard to creating the conditions for engagement and addressing the principles for effective undergraduate education, Plickers and crossword puzzles as pedagogical tools present an interesting potential that is yet to be explored. Moreover, it is critical to understand student opinions or perceptions of proposed teaching and learning activities or active learning strategies before they are implemented on a broad scale. The objective of this study was to evaluate the students' perceptions of Plickers and crossword puzzles as teaching tools in food science and technology course.

2 | MATERIALS AND METHODS

2.1 | Course description

The study was conducted at a larger public University of Technology (UoT) in Cape Town, South Africa. First-year students (n = 121) enrolled for the course Food Technology 1 (FOT150S) in 2019 were exposed to a blended learning approach. The 20 credit course consists of both theory and practical components. FOT150S is the foundation module in food science and technology curricula and it has no prerequisites. The course provides a very broad view of food raw materials, unit operations, and sensory evaluation of food products in an effort to provide a foundation for future courses. The majority of the students registering for the course are totally unfamiliar with the vocabulary of food processing. Pasteurization, centrifugation, fermentation technology, and organoleptic properties terminology have little or no meaning to these students. The face-to-face classes were facilitated using Microsoft PowerPoint slides with infusions of multimedia and online tools. The course website (MyClassroom, Blackboard Inc., Washington, DC, USA), an institutional learning management system, houses the course content and the student-centered learning practices implemented in FOT150S. Contact sessions of 3.75 hr were scheduled per week, where the students had the opportunity to meet each other and the lecturer. The sections below describe the implementation of Plickers and crossword puzzles in FOT150S and are followed by methods used for data collection and analysis.

2.2 | The implementation of Plickers

A real-time, formative assessment (Plickers) pedagogical tool was used to assess students understanding of the work covered during face-to-face classes. This was done consistently prior to the start of a new section, during, and at the end the classes. Plickers is an online software for the interaction between a mobile phone with camera and Plickers application installed for scanning a four sided QR code (Figure 1). There are 63 sheets of data and all of the answers will be processed and displayed on the lecturers' mobile phone and via the web browser (https://www.plickers.com) at the same time. Each lecture session incorporated many different Plickers activities, including multiple choice questions or survey-based activities. For example, the lecturer used Plickers at the beginning of the lecture to gauge an understanding of

FIGURE 2 Students responding to a question using Plickers

content and at the end of challenging sections in lectures to assess understanding and diagnose potential knowledge gaps. Specifically, after presenting a complex concept or process, the lecturer would present a slide with a question, to which students would respond on their own using their Plickers cards. After scanning the cards (Figure 2), there would be a peer discussion of the possible answers by the students and then the correct answer would later be revealed by the lecturer.

2.3 | The implementation of crossword puzzles

A total of three sets of crossword puzzles containing 20 questions each were constructed using the free online resource crossword labs website (https://crosswordlabs.com/) and were validated by two experts from the Department of Food Science and Technology (DFST) (supplementary material 1). These puzzles covered three different chapters completed in the module food technology 1 (FOT150S). The content validity of these crossword puzzles was ensured keeping in mind with the intended learning outcomes of the module. Printed copies of the crossword puzzle were provided to the students to solve during face-to-face classes and they were randomly placed in groups (six students per group). Group discussions were encouraged while solving the puzzle to promote collaborative and active learning. The time allocated for solving each crossword was 30 min. At the end of the allotted time, correct answers to the crossword puzzle were discussed by the whole class. The groups that obtained the highest scores were awarded prizes as an incentive.

2.4 | Data collection and analysis

The study was approved by the University Research Ethics Committee. A survey to elicit student responses on Plickers and crossword puzzles was administered via Blackboard. Survey participation was completely voluntary and anonymous. Students were informed that their grade for the course would not be impacted by their participation, or lack thereof, in the survey. The survey included two types of questions: (a) quantitative questions including Likert scale ratings (5-point, "*Strongly Agree*," "*Agree*," "*Neither Agree nor Disagree*," "*Disagree*," and "*Strongly Disagree*") and (b) students were also provided with an opportunity to respond to two open-ended questions about their study experiences using Plickers and crossword puzzles, respectively. The questions on crossword puzzles were later grouped in into three variables: (a) implementation, (b) student collaboration, and (c) impact on learning. A total of 121 students were enrolled for the course and 70.2% ($n = 85$) completed the survey. All quantitative data were analyzed using SPSS 25.0 (2005) (SPSS Inc., Chicago, IL). The quantitative data were analyzed using means (M) and standard deviation (SD). The open-ended question responses

were processed using Microsoft Excel® (2018) analysis by selecting the frequently appearing responses and/or keywords in the responses.

Research has shown that for sample sizes up to 100, Cronbach's alpha technique is a good measure of internal consistency for reliability (Kuriakose & Luwes, 2016). Because the sample size in this study was $n = 85$, Cronbach's alpha technique was administered on the specific set of the survey questions and produced $\alpha = .76$ and .78 for the Plickers and crossword puzzles, respectively. This value of alpha translates to a good internal consistency and therefore the study reported in this paper can be one that is reliable and valid for the purpose of gaining student perceptions to the use of Plickers and crossword puzzle as interactive pedagogical tools. Spearman correlation coefficients and analysis of variance were used to assess the association among crossword puzzle implementation, student collaboration, and impact on learning.

3 | RESULTS AND DISCUSSION

3.1 | Demographics and student performance

In order to establish a context for the study findings, the online survey elicited student's responses on two demographic questions. Survey results from 85 students ($n = 85$) who voluntarily responded to the survey revealed that the gender distribution of the students was 72.73% female and 27.27% male. The respondents can be placed in two major categories, 19 years and younger (44%) and 20 to 24 (43%) years old. All students participated in active learning using Plickers and crossword puzzles and as a result, all of the respondents had the required experience to complete the questionnaire.

3.2 | Students perceptions of Plickers

This study evaluated the student's perception of a Plickers implemented in FOT150S lectures undertaken by undergraduate food science and technology students with the anticipation that this would promote student-centered active learning and student engagement and may have a positive impact on student learning outcomes.

The mean (M) scores of each question are depicted in Table 1. The respondents liked the instant feedback from the Plickers ($M = 4.33 \pm 0.84$) and as such the pedagogical tool motivated them to prepare for classes ($M = 4.27 \pm 0.76$). The ability of the Plickers to provide students with an opportunity to reflect upon their own learning early in the module, through prompt formative feedback, is highly beneficial—both to the student and also to the lecturers.

Plickers provides instant feedback and affords the students an opportunity to increase interaction with the lecturer and thus enhance engagement and active learning.

TABLE 1 Survey of student perceptions of Plickers usage in FOT150S

Statements/questions	Mean ± *SD*
Like the way Plickers give instant feedback.	4.33 ± 0.84
Plickers usage helped motivate me to be more prepared for class.	4.27 ± 0.76
Plickers usage helped me to gauge my understanding of class content.	4.58 ± 0.56
Discussion of the Plickers answers helps me to clarify my knowledge about FOT150S.	4.52 ± 0.58
Being able to answer anonymously is important to me.	4.60 ± 0.49
Plickers usage helped me stay interested during class.	4.28 ± 0.88
Plickers are easy to use.	4.66 ± 0.48
Overall, I have enjoyed using Plickers.	3.83 ± 0.75
Plickers usage helped me participate in the class.	4.05 ± 0.90

Note. A 5-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree* was used for each quantitative question.

Student responses indicated that Plickers helped them gauge their understanding of class content ($M = 4.58 \pm 0.56$), clarified and focused knowledge ($M = 4.52 \pm 0.58$), maintained interest during class ($M = 4.28 \pm 0.88$), assisted them to participate ($M = 4.05 \pm 0.90$), and helped make learning more enjoyable in food science and technology ($M = 3.83 \pm 0.75$). In addition, students liked the anonymity ($M = 4.60 \pm 0.49$) and ease of use and overall enjoyed using Plickers (4.66 ± 0.48). Large lectures may be intimidating for first-year students who are not accustomed to the number of students at higher institutions of learning, and thus students who do not understand something may be reluctant to ask questions. Plickers afford students the opportunity to voice their misunderstandings anonymously and as a result, the lecturer can respond to those students without pointing them out when incorrect responses are seen on the screen. These findings align with previous research studies in that students in higher education are supportive of using ARSs, such as Plickers, because they may improve their ability to learn new concepts, attend class more regularly, and prepare for required course assignments (Chan, Wan, & Ko, 2019; Kay & LeSage, 2009; Ma et al., 2018; Shieh, 2012).

Moreover, these findings demonstrate the applicability of Plickers as a low-cost ARS that can be used as a formative assessment tool especially when dealing with complex food science and technology concepts such as thermal processing of foods, food safety, and sensory evaluation of foods. The results from this study extend the literature in that it offers insight into what type of pedagogical tool is preferred by the millennial generation, particularly in food science and

TABLE 2 Themes that emerged from the open-ended question on Plickers

Feedback theme	Illustrative quote
Anonymity	*"I like Plickers because you are not pressured into choosing something because nobody really sees the answer that you picked."*
Engagement and fun	*"Plickers is a good way to obtain instant feedback on what you understand or not in a topic. I like the fact that it was fun answering the questions and I was able to be active in class."*
Reinforce important concepts	*"FOT150S is a challenging module and to be successful you need to be constantly studying. Plickers helped me to remember important concepts and in class because we were learning in a fun way which is better than the normal exam."*
Motivation for learning	*"I think that the Plickers were beneficial because it encouraged me to study on a regular basis."*
Fun	*"Plickers makes everyone in the class to participate in class and makes the learning fun as it is like a game."*

technology. The use of paper response cards provides an opportunity for breaking the monotony of traditional face-to-face classes, even in classrooms with a large number of students. In addition, it increases interactivity without relying on expensive clicker devices, minimizing the costs and addressing some of the major drawbacks of previous response systems, economic costs, and complexity.

3.3 | Student response to open-ended questions regarding Plickers

In addition to responding to Likert-scale questions, students also wrote comments in response to the open-ended questions: "What did you like about the use of Plickers in FOT150S?" A representative selection of responses showing different students' perspectives is included Table 2. The main themes were anonymity, engagement, and fun, reinforcing important concepts and motivation for learning and fun. Aside from engagement and anonymity, the use of Plickers encourages students to commit to an answer, hence actively engaging in the classroom discussion that follows. By displaying the outcome of question polling, this tool also provides immediate feedback to students, developing their ability to appraise their skills and eliciting self-regulatory behaviors. These findings align with previous research studies in that students in higher education are supportive of using ARSs, such as Plickers, because they may improve their ability to learn new concepts, attend class more regularly, and prepare for required course assignments (Aricò & Lancaster, 2018; Bakon, Craft, Christensen, & Wirihana, 2016; Chan et al., 2019). Students most liked Plickers that gave them an opportunity to interact and learn from other students. Educators need to consider this aspect in designing their active learning activities. Student interactivity has been reported to be an important aspect of active learning pedagogy (Everly, 2013). Making use of learning technologies such as Plickers also has the advantage of generating large basis of data, which can be analyzed to uncover learning patterns and help students who are experiencing specific difficulties.

TABLE 3 Mean scores for quantitative questions regarding students perceptions crossword puzzles in FOT150S on effect on learning ($n = 85$)

Statements/questions	Mean ± *SD*
The puzzles provided me with an opportunity to assess how well I understand FOT150S.	4.45 ± 0.72
Helped me to remember important terms from the topics we have studied.	4.45 ± 0.75
Solving crossword puzzles made me think critically.	4.53 ± 0.57
The puzzles reinforce basic concepts discussed in during the lectures.	4.38 ± 0.60
Challenging and problem solving.	4.35 ± 0.68
Using crossword puzzles improved my learning experience.	4.27 ± 0.75

Note. A 5-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree* was used for each quantitative question.

3.4 | Students perceptions on crossword puzzles

Strong positive ratings were reported in all six questions measuring student's perceptions of crossword puzzles (Table 3). The respondents strongly agreed that crossword puzzles offered them an opportunity to assess how well they understood the content ($M = 4.45 \pm 0.72$) in FOT150S and helped them remember vital terms or concerts in food science and technology ($M = 4.45 \pm 0.75$). Food science and technology students need to become familiar with a complex and multifaceted vocabulary. This is an ongoing endeavor as the range of terms and concept grows with each year of progress. The results obtained in this study through the use of crossword puzzles suggest that there was success in solidifying concepts presented in the course through the use of crossword puzzles. Statements that the student agreed with included solving crossword puzzles made me think critically ($M = 4.53 \pm 0.57$) and improved my learning experience ($M = 4.27 \pm 0.75$). As far as student's perceptions toward the crossword puzzles are concerned, the findings of this study are consistent with previous studies (Bailey et al., 2017; da Silva & Toledo, 2018; Nazeer et al., 2018; Patrick et al., 2018; Saran &

TABLE 4 Themes that emerged from the open-ended questions on crossword puzzles

Feedback theme	Illustrative quote
Peer learning	*"The FOT150S crossword puzzles allowed for me to interact with my classmates. I have not met many of them so this crossword activity was a chance for me to meet new people as well as learn more about my Food technology work."* *"What I liked most was that it made me realize how important group study is, because there might be a concept I do not understand but another student does and we can thus share information and thoughts and it helps everyone to do well and succeed."*
Engagement	*"I became more involved with my classmates. When trying to figure out the crossword puzzles my group and I truly engaged and tried to really apply the work we have learned."*
Fun and formative feedback	*"I found the crossword puzzles to be fun and a good way to learn and grasp new information. It was a great way to exercise our brains and work together."*
Fun	*"I also enjoyed the learning experience and realizing how the information we are given can be interpreted and asked."*
Feedback	*"It is a good way of getting feedback on your strengths and weaknesses and understanding on what you need to look at."*

TABLE 5 Mean scores for quantitative questions regarding students perceptions on group collaboration in solving crossword puzzles in FOT150S ($n = 85$)

Statements/questions	Mean ± SD
My group and I collaborated well in solving the crossword puzzles.	4.36 ± 0.92
Group discussion in the classroom, such as crossword puzzles, is helpful for me to understand information.	4.25 ± 0.77
Opportunities to discuss information among classmates work well for me.	4.15 ± 0.76

Note. A 5-point Likert scale ranging from 1 = *strongly disagree* to 5 = *strongly agree* was used for each quantitative question.

Kumar, 2015). Moreover, in this study students agreed that the crossword puzzles were helpful in the enhancement of cognitive/mental skills as well as their attitude toward learning. This is an indication that students strongly supported the use of crossword puzzles and highlight the potential behind the use of peer learning to enhance learning experiences in the classroom teaching. This study also builds upon the scarcity of literature focusing on the use of crossword puzzles with food science and technology students, thereby serving to contribute to the understanding of student's perceptions in the field.

3.5 | Student response to open-ended questions regarding crossword puzzles

In addition to responding to Likert-scale questions, students also wrote comments in response to the open-ended questions: "What did you like BEST about FOT150S crossword puzzles?" A representative selection of comprehensive responses showing different students' perspectives is depicted in Table 4. Peer learning, engagement, fun, and formative feedback were the most predominant themes cited by the students. The use of crossword puzzles not only acted to engage the students in food science and technology teaching thus promoting understanding and enthusiasm but also acted to develop student confidence in their own capability and ability, thus acting as an empowering exercise. These results concur with the findings of Swanson, Frankel, and Sagan (2005) who describe the ability of crossword puzzles to compel or empower reluctant learners to engage in classrooms and Nazeer et al. (2018) who describe the development of active learning in a group of medical students.

3.6 | Students performance in crossword puzzles

The results of the student's group performance in the three respective puzzles are depicted in Figure 3. As it can be seen, the mean scores were 66%, 59%, and 53% in puzzle 2, 1, and 3, respectively. The mean score is indicated by the black dot and the lowest score was 25% in puzzle 3 and the highest was 85% in both puzzle 1 and 2. Interestingly, the answers to the puzzles were not discussed in class until all three sets were completed. Therefore, these results suggest that the students were capable of solving and completing the crossword puzzles. A feature unique to this study is that the crossword puzzles were constructed from three topics (introduction to food science and technology, composition and nutritional value of foods, and fundamentals of sensory evaluation). This is in line to inculcating a culture of complex practice that allows students to apply critical thinking skills. These findings generally agree with prior research that crossword puzzles can promote students' academic performance by increased student engagement and more interaction between the lecturer and the students (Abuelo et al., 2016; Saldana-Balmori & Delgadillo-Gutiérrez, 2010). Because the crossword puzzles were part of a group activity, this study also explored the student's perception of peer learning in solving crossword. In this study, most respondents felt that they collaborated well ($M = 4.36 \pm 0.92$) with peers in solving crossword puzzles (Table 5). Further, the students indicated that this type of pedagogy works well for them ($4.15 \pm .0.76$). The peer-to-peer discussions during solving crossword puzzles are critical in getting the students

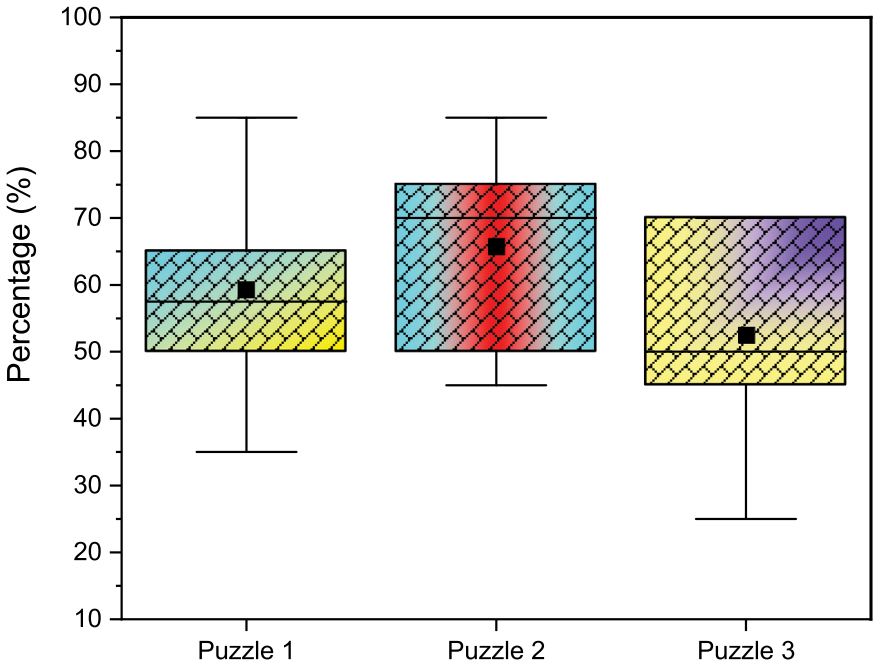

FIGURE 3 Box plots showing puzzle scores

Note. The boxes provide the median score as denoted by the black horizontal lines, the mean score is indicated with the black dot, and the lower and upper hinges represent the 25th and 75th percentiles, respectively. The whiskers represent plus and minus 1.5 times the interquartile range.

TABLE 6 Correlations relating to crossword puzzle implementation, student collaboration, and effect on learning in FOT150S

Variables	Collaboration	Implementation	Impact on learning
Student collaboration	1		
Implementation	.506**	1	
Impact on learning	.354**	.569**	1

**Correlation is significant at the .01 level (two-tailed).

to think (activating their cognitive resources), thus enabling them to see the problems in a new light.

3.7 | Relationships between measured variables

In order to study the potential relationship between implementation of crossword puzzles, student collaboration, and impact of crossword puzzles on learning, the Spearman's correlation coefficients between these variables were calculated and the results of which are shown in Table 6. The effect sizes are judged in terms of Cohen's (1992) criteria in which 0.1 is a small correlation, 0.3 is medium, and 0.5 is large. First, a statistically positive relationship was found between student collaborative learning and crossword puzzle implementation scores ($r = .506, p < .01$), indicating that students who reported high levels of collaborative learning tended to be highly satisfied with the implementation of crossword puzzles in FOT150S. Second, the relationship between student collaborative learning and impact of crossword puzzles on learning was statistically significant ($r = .354, p < .01$) indicating that if students perceived their learning to be enhanced by the crossword puzzles, then they also reported being more satisfied with collaborating with their classmates. Taken collectively, the results presented in this paper indicate the appropriateness of crossword puzzles in the context of food science education and support a greater reliance on this pedagogical tool to engage students and improve their learning experiences.

3.8 | Limitations of the study

FOT150S was the first course in the Department of Food Science and Technology at University of Technology to incorporate the use of Plickers and Crossword puzzles in lectures, thus the students were likely new to using these pedagogical tools. In the future, it would be appropriate to examine the use of Plickers and crossword puzzles across a variety of content areas within food science and technology, as well as across various pedagogical approaches. These results are instrumental in the pursuit of interactive teaching and learning tools, particularly in food science and technology in a much more dynamic and progressive manner. In addition, research evaluating the effect of Plickers and crossword puzzles as teaching tools on examination grades and overall course grades is recommended.

4 | CONCLUSION

This study has shown that incorporating interactive teaching strategies in food science and technology through the use of low-cost tools such as Plickers and crossword puzzles provided students with an opportunity to think critically,

collaborate, discuss salient concepts, and actively engage in class. The use of Plickers and crossword puzzles can relieve the tedium of lecture and traditional teaching methods, thereby providing a more relaxed and friendly classroom atmosphere. The student perceptions of Plickers and crossword puzzles were largely positive. A statistically positive relationship was found between student collaborative learning and crossword puzzle implementation. To be sustainable, educational interventions must be effective, accepted by students, and practical to implement. Crossword puzzles and Plickers tick all the boxes. These findings hold significant implication for the implementation of interactive teaching pedagogies in higher education institutions. Based on these findings, the author recommends the adoption of Plickers and crossword puzzles in undergraduate food science and technology courses to make the lecture room more interesting and engaging.

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AUTHOR CONTRIBUTIONS

The author conducted the study and wrote the manuscript.

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REFERENCES

Abuelo, A., Castillo, C., & May, S. A. (2016). Usefulness of crossword puzzles in helping first-year BVSc students learn veterinary terminology. *Journal of Veterinary Medical Education*, *43*(3), 255–262. https://doi.org/10.3138/jvme.0915-149r

Al-Samarraie, H., & Saeed, N. (2018). A systematic review of cloud computing tools for collaborative learning: Opportunities and challenges to the blended-learning environment. *Computers & Education*, *124*(March), 77–91. https://doi.org/10.1016/j.compedu.2018.05.016

Aricò, F. R., & Lancaster, S. J. (2018). Facilitating active learning and enhancing student self-assessment skills. *International Review of Economics Education*, *29*(June), 6–13. https://doi.org/10.1016/j.iree.2018.06.002

Bailey, C. M., Hsu, C. T., & DiCarlo, S. E. (2017). Educational puzzles for understanding gastrointestinal physiology. *Advances in Physiology Education*, *276*(6), 1–18. https://doi.org/10.1152/advances.1999.276.6.s1

Bakon, S., Craft, J., Christensen, M., & Wirihana, L. (2016). Can active learning principles be applied to the bioscience assessments of nursing students? A review of the literature. *Nurse Education Today*, *37*, 123–127. https://doi.org/10.1016/j.nedt.2015.11.030

Blasco-Arcas, L., Buil, I., Hernández-Ortega, B., & Sese, F. J. (2013). Using clickers in class. the role of interactivity, active collaborative learning and engagement in learning performance. *Computers & Education*, *62*, 102–110. https://doi.org/10.1016/j.compedu.2012.10.019

Chan, S. C. H., Wan, J. C. L., & Ko, S. (2019). Interactivity, active collaborative learning, and learning performance: The moderating role of perceived fun by using personal response systems. *International Journal of Management Education*, *17*(1), 94–102. https://doi.org/10.1016/j.ijme.2018.12.004

Chng, L., & Gurvitch, R. (2018). Using Plickers as an assessment tool in health and physical education settings. *Journal of Physical Education, Recreation & Dance*, *89*(2), 19–25. https://doi.org/10.1080/07303084.2017.1404510

Cohen, J. W. (1992). A power primer. *Psychological Bulletin*, *12*, 155–159.

Crisp, G., Guàrdia, L., & Hillier, M. (2016). Using e-Assessment to enhance student learning and evidence learning outcomes. *International Journal of Educational Technology in Higher Education*, *13*(1), 16–18. https://doi.org/10.1186/s41239-016-0020-3

Crossman, E. K., & Crossman, S. M. (1983). The crossword puzzle as a teaching tool. *Teaching of Psychology*, *10*(2), 1–10.

da Silva, E., & Toledo, M. (2018). Diabetes crossword puzzle game. *Journal of Diabetes Research*, *4*(1). https://doi.org/10.16966/2380-5544.134

Datta, R., Datta, K., & Venkatesh, M. D. (2015). Evaluation of interactive teaching for undergraduate medical students using a classroom interactive response system in India. *Medical Journal Armed Forces India*, *71*(3), 239–245. https://doi.org/10.1016/j.mjafi.2015.04.007

Duffrin, M. W. W. (2006). Integrating problem-based learning in an introductory college food science course. *Journal of Food Science Education*, *2*(1), 2–6. https://doi.org/10.1111/j.1541-4329.2003.tb00017.x

Elmahdi, I., Abdulghani, A.-H., & Fawzi, H. (2018). Using technology for formative assessment to improve students' learning. *TOJET Turkish Online Journal of Educational Technology*, *17*(2), 182–188.

Everly, M. C. (2013). Are students' impressions of improved learning through active learning methods reflected by improved test scores? *Nurse Education Today*, *33*(2), 148–151. https://doi.org/10.1016/j.nedt.2011.10.023

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS*, *111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Gauci, S. A., Dantas, A. M., Williams, D. A., & Kemm, R. E. (2009). Promoting student-centered active learning in lectures with a personal response system. *Advances in Physiology Education*, *33*(1), 60–71. https://doi.org/10.1152/advan.00109.2007

Kay, R. H., & LeSage, A. (2009). Examining the benefits and challenges of using audience response systems: A review of the literature. *Computers & Education*, *53*(3), 819–827. https://doi.org/10.1016/j.compedu.2009.05.001

Kuriakose, R. B., & Luwes, N. (2016). Student perceptions to the use of paperless technology in assessments—A case study using clickers. *Procedia—Social and Behavioral Sciences*, *228*(June), 78–85. https://doi.org/10.1016/j.sbspro.2016.07.012

Lantz, M. E. (2010). The use of "Clickers" in the classroom: Teaching innovation or merely an amusing novelty? *Computers in Human Behavior*, *26*(4), 556–561. https://doi.org/10.1016/j.chb.2010.02.014

Liverpool-Tasie, L. S. O., Adjognon, G. S., & McKim, A. J. (2019). Collaborative learning in economics: Do group characteristics

matter? *International Review of Economics Education*, *31*(February), 100159. https://doi.org/10.1016/j.iree.2019.100159

Lo, Y. M., Gdovin, S. L., Stankiewicz, J. B., Appezzato, L., & Garvey, E. M. (2006). A dynamic food science internship program: Integration of problem-based learning and student-centered mentoring. *Journal of Food Science Education*, *1*(3), 45–51. https://doi.org/10.1111/j.1541-4329.2002.tb00013.x

Ma, S., Steger, D. G., Doolittle, P. E., & Stewart, A. C. (2018). Improved academic performance and student perceptions of learning through use of a cell phone-based personal response system. *Journal of Food Science Education*, *17*(1), 27–32. https://doi.org/10.1111/1541-4329.12131

Marchalot, A., Dureuil, B., Veber, B., Fellahi, J. L., Hanouz, J. L., Dupont, H., … Compère, V. (2018). Effectiveness of a blended learning course and flipped classroom in first year anaesthesia training. *Anaesthesia Critical Care & Pain Medicine*, *37*(5), 411–415. https://doi.org/10.1016/j.accpm.2017.10.008

McCargo, M. G. (2017). *The effects of Plickers as response cards on academic engagement behavior in high school students* (Master's theses). The University of Southern Mississippi, Hattiesburg, MS. Retrieved from http://aquila.usm.edu/masters_theses%0Ahttp://aquila.usm.edu/masters_theses/300

Michael, P. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(July), 223–231. https://doi.org/10.1038/nature02568

Nazeer, M., Sultana, R., Ahmed, M. M., Asad, M. R., Sami, W., Hattiwale, H. R., & Sreekanth, T. (2018). Crossword puzzles as an active learning mode for student directed learning in anatomy teaching: Medical undergraduate perceptions. *International Journal of Medical Research and Health Sciences*, *7*(10), 12–19.

Patrick, S., Vishwakarma, K., Giri, V. P., Datta, D., Kumawat, P., Singh, P., & Matreja, P. S. (2018). The usefulness of crossword puzzle as a self-learning tool in pharmacology. *Journal of Advances in Medical Education & Professionalism*, *6*(4), 181–186.

Raines, D. A. (2010). An innovation to facilitate student engagement and learning: Crossword puzzles in the classroom. *Teaching and Learning in Nursing*, *5*(2), 85–90. https://doi.org/10.1016/j.teln.2008.08.003

Reitmeier, C. A. (2010). Active learning in the experimental study of food. *Journal of Food Science Education*, *1*(3), 41–44. https://doi.org/10.1111/j.1541-4329.2002.tb00012.x

Rodríguez, M., Díaz, I., Gonzalez, E. J., & González-Miquel, M. (2019). Reprint of: Motivational active learning: An integrated approach to teaching and learning process control. *Education for Chemical Engineers*, *26*, 8–13. https://doi.org/10.1016/j.ece.2019.01.002

Ruisoto, P., & Juanes, J. A. (2019). Fostering student's engagement and active learning in neuroscience education. *Journal of Medical Systems*, *43*(3), 66. https://doi.org/10.1007/s10916-019-1192-x

Saldana-Balmori, Y., & Delgadillo-Gutiérrez, H. (2010). *Crossword puzzles as alternative didactics in biochemistry*. Proceedings of EDULEARN10 Conference, July, 3971–3978.

Saran, R., & Kumar, S. (2015). Use of crossword puzzle as a teaching aid to facilitate active learning in dental materials. *Indian Journal Applied Research*, *5*(4), 456–457.

Shieh, R. S. (2012). The impact of technology-enabled active learning (TEAL) implementation on student learning and teachers' teaching in a high school context. *Computer Education*, *59*(2), 206–214. https://doi.org/10.1016/j.compedu.2012.01.016

Swanson, S., Frankel, R., & Sagan, M. (2005). Classroom encounters: Exploring the impact of cultural differences. *Culture*, *39*, 213–222.

Vickrey, T., Rosploch, K., Rahmanian, R., Pilarz, M., & Stains, M. (2015). Research-based implementation of peer instruction: A literature review. *CBE Life Science Education*, *14*(1), 1–11. https://doi.org/10.1187/cbe.14-11-0198

Wood, T. A., Brown, K., & Grayson, J. M. (2017). *Faculty and student perceptions of Plickers. American Society for Engineering Education Zone II Conference, 1–7*. Retrieved from http://zone2.asee.org/sessions/program/3/84.pdf

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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