

Enhancing Student Learning with Case-Based Teaching and Audience Response Systems in an Interdisciplinary Food Science Course

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Abstract: The purpose of this article is to discuss the implementation of case-based teaching and use of response technologies to graduate students in a food science course. The article focuses on teaching sensory science and sensometrics, presents several concrete examples used during the course, and discusses in each case some of the observed outcomes. Students' evaluations, peer feedback, and self-observations throughout the course collectively indicated that the particular initiatives were effective in engaging student participation and promoting a more active way of learning. Case-based teaching provided students with the opportunity to apply their knowledge and their analytical skills to complex, real-life scenarios relevant to the subject matter. The use of audience response systems further facilitated class discussion and was extremely well received by the students; this resulted in a more enjoyable classroom experience.

Keywords: case-based teaching, audience response systems, food science and technology

Introduction

Those who have been involved in education as teachers or students are probably familiar with a *teacher-centered* approach to lecturing in which a teacher is expected to create content and then deliver it to students in a traditional lecture format (Ahmed, 2013). Although increasingly challenged in recent years, evidence indicates that lecturing is still the dominant paradigm in higher education, owing to the fact that many current and prospective teachers may seldom have been exposed to significantly different ways of teaching (Davis & Arend, 2013). The popularity of lectures as a teaching method is also due to the fact that they are time and cost efficient and that they provide the teacher full control over the content (Bates & Galloway, 2012), resulting in a comfortable feeling that the important information has been covered (Schneider, 2007). Unfortunately, researchers have found that lecturing is actually not an effective way of promoting deep student learning (Bates & Galloway, 2012; Chew, 2014; Trigwell, Prosser, & Waterhouse, 1999).

Many researchers have shared classroom techniques, such as peer instruction, problem-based learning, role-playing, and collaborative exercises to engage students and achieve more effective teaching and better learning experiences (Bruff, 2009; Caldwell, 2007; Coorey & Firth, 2013; Greer & Heaney, 2004; Kay & LeSage, 2009). The purpose of this article is to share an example of how two of them—case-based teaching (CBT) and audience response systems

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(ARSS)—were implemented in an interdisciplinary Master of Science (MSc) course in food science and technology and to describe the outcomes.

Background and Literature Review

Case-Based Teaching

CBT is an active learning strategy in which students apply their knowledge and their analytical skills to complex, real-life scenarios relevant to the subject matter. CBT is considered a useful way to combine traditional lecture with problem-based learning, as it emphasizes social interactions between students and the development of learner autonomy and learning situations that resemble those relevant to the profession (Coorey & Firth, 2013; Van der Veken, Valcke, Muijtiens, De Maseneer, & Derese, 2008). Accordingly, the use of CBT has been found helpful for engaging and creating relevance for students and for helping the students to organize and identify gaps in their knowledge (Duffrin, 2003; Herreid & Schiller, 2013; Savery, 2015; Stern, 1996).

In CBT, students are introduced to complex situations requiring a decision. Such situations can be real (e.g., examples from past or current research), or just realistic, and can vary in degree of complexity (Biggs & Tang, 2011). The development of a case study starts with identifying a set of key concepts upon which the students should rely; careful consideration should be given to their potential to achieve learning outcomes (Duffrin, 2003; Savery, 2015). Students are often asked to work in groups and to evaluate each other's opinions before any plenum discussion takes place. Working in groups can help students develop interpersonal skills and the capacity to work in a team, and accordingly, CBT contributes to raising a student's ability to communicate about a topic (Coorey & Firth, 2013). After considering the case at hand, students (or groups) are asked to make a statement about their suggested solution to the case. The teacher in this case can facilitate a classroom discussion by asking questions to probe the reasoning behind the suggested solutions and ask other students to evaluate them. Assessment of case studies is usually offered at the end of the class discussion and, depending on the format, can be used both for formative and summative purposes either by the students or by the faculty about the students' suggestions (Biggs & Tang, 2011).

CBT is especially useful to assess the application of concepts to appropriate professional practices. By placing students in real situations and asking them to make decisions, case studies help students to connect their knowledge with their decision-making skills, as well as to distinguish high-priority from low-priority elements. Compared to lectures, cases are suggested as a better way for the teacher to see whether students are able to apply their knowledge of the subject matter and result in superior long-term retention of the subject matter and higher satisfaction among students (Strobel & Van Barneveld, 2009; Thistlethwaite et al., 2012).

A possible caveat to this is the argument that, in some instances, CBT may be less effective than lecturing because it relies on the assumption that the students are able to effectively integrate their previous knowledge to the new situation, which is not always the case (Kirschner, Sweller, & Clark, 2006). The implication is that CBT may work best in situations where students are not complete novices of the subject matter and possibly in combination with lecturing rather than as a standalone teaching approach.

Several examples of teachers employing CBT to improve students' understanding of the subject can be found in the literature. CBT is currently extensively applied in health professional

education, where the vast majority of studies report a favorable outcome of employing this pedagogical method (Thistlewhite et al., 2012). Application examples have been documented in other areas of science such as biology (e.g., Pai, 2009), chemistry (e.g., Yalçinkaya, Taştan-Kırık, Boz, & Yıldiran, 2012), engineering (e.g., Flynn, Squier, & Davidson, 2015), and math (e.g., Kogan & Laursen, 2014).

The focus of this article is on food science education. Food science is an interdisciplinary field in which the engineering, biological, and physical sciences are used to study the properties of foods, the principles underlying food processing, and the improvement of foods for the consuming public (Heldman, 2006). In this context, it is useful to note that previous research about CBT specific to food science education is very limited, in spite of the fact the applied and interdisciplinary nature of the field should be well suited for a problem-based approach (Duffrin, 2003; Coorey & Firth, 2013). To address this paucity of information, the present study addresses the effectiveness of CBT in the context of food science education.

Audience Response Systems

Another helpful strategy to improve student engagement is the use of ARSs that allow an entire classroom to respond to various questions projected on a screen using a remote control device with real-time visualization of results (Bruff, 2009; Caldwell, 2007; Greer & Heaney, 2004; Kay & LeSage, 2009). ARSs are usually associated with relatively large class sizes (e.g., Heaslip, Donovan, & Cullen, 2014) and with multiple-choice questions, though applications in smaller audiences and with different question formats are also found (Kay & LeSage, 2009). Student responses (anonymous or otherwise) can be stored and used for both summative and formative assessment by the teacher. With real-time feedback from the classroom, ARSs provide teachers the opportunity to facilitate a discussion about the concept being covered (Kay & LeSage, 2009). Some teachers have found it useful to combine ARSs with the peer instruction format, in which students answer the question, discuss their answers in pairs or small groups, and then answer the question again, as a way to engage the students even further through cooperative activities (Mazur, 1997; Smith et al., 2009). The use of ARSs in higher education was originally limited by technology but has become increasingly widespread due to the development of free web-based ARSs which allow students to easily answer questions with their own devices (laptops, tablets, smartphone, etc.; Kay & LeSage, 2009).

ARSs are associated with a number of benefits. Among other things, they have been found effective for improving student interaction, activation, and attention (Draper & Brown, 2004; Greer & Heaney, 2004; Hinde & Hunt, 2006); stimulating peer and class discussion (Kay & LeSage 2009; Pelton & Pelton, 2006); enabling formative assessment (Caldwell, 2007); improving student learning (El-Rady, 2006); and increasing classroom attendance (Bullock et al., 2002). Students and teachers who have used ARSs are generally positive or even enthusiastic about their effects on the classroom, and there is wide consensus that these technologies have great potential for improving student learning (Beatty et al., 2006; Blasco-Arcas, Buil, Hernandez-Ortega, & Sese, 2013; Caldwell, 2007).

As in the case of CBT, the degree to which the positive experience associated with the use of ARSs translates into actual learning has been a matter of debate, and it has been pointed out that much of the data on the effectiveness of ARSs is qualitative or even anecdotal in nature (Kay & LeSage, 2009; Blasco-Arcas et al., 2013). According to a recent meta-analysis of the relevant literature (Hunsu, Adesope, & Bayly, 2016), the use of ARSs is indeed associated with better learning outcomes, but the size of the effect is moderated by several variables such as

class size, the type of questions, and the level of feedback provided by the teacher. In particular, it is suggested that teachers in smaller classes and more applied knowledge domains may find the use of ARSs particularly beneficial, particularly when questions are designed to foster critical thinking rather than factual knowledge (Hunsu et al., 2016).

Aim of the Present Research

Situated within this context, the purpose of this article is to report on the implementation of the two classroom techniques discussed above—CBT and ARSs—in a graduate-level food science course to provide students with the opportunity to apply their knowledge and analytical skills to complex, real-life scenarios relevant to the subject matter. The context of the article is the MSc course Food Innovation and Health, and the focus is on teaching sensory science and sensometrics, the branch of statistics that involves the use of statistical methods in sensory and consumer science. The remainder of the article introduces the case study and the specific activities undertaken during the course, reports in each case some of the observed outcomes in terms of teaching effectiveness, and concludes with some considerations for the applicability of the proposed approach to other disciplines.

Method

Course Details and Intended Learning Outcomes

Food Innovation and Health is a thematic MSc-level course taught at the University of Copenhagen in Denmark. Typically, 15–20 students with a background in human nutrition, food science, or home economics enroll in this course. Most of them take the course as part of the eponymous MSc program, a highly interdisciplinary program focused on food product development and combining nutrition, food chemistry, culinary techniques, sensory science, consumer behavior, innovation, and entrepreneurship. This is their last course before their thesis work and is designed for the students to build on previous knowledge acquired in the first year of the program. The objective of the course is to give students knowledge of practical food production and innovation with a focus on palatability and health in food products as well as in meals.

The teaching begins with an intensive instructional period for the first 3 weeks, during which teaching takes place 4–5 days a week. For the rest of the block, students work in groups, and learning is self-directed. During this time, students develop, test, and pitch actual food products, based on challenges from food companies or other organizations. For example, at the time this research was conducted, students worked on a snack bar using brewers' spent grain, examined gastronomic strategies to masking boar taint in entirely male meat, and developed a nonalcoholic drink based on Nordic ingredients targeted at restaurant goers.

The course has a broad range of learning outcomes covering the various disciplinary areas represented (see the Appendix for a full list). The most important intended learning outcomes (ILOs) in the context of this article relate to sensory evaluation of food and beverages. Essentially, students should learn how to measure and understand responses to food properties as perceived by the senses (sight, smell, taste, touch, and hearing; Martens, 1999). Sensory science has many applications in the food industry; it can be used to evaluate whether there exist perceptible differences between two stimuli (e.g., the same product stored at different temperature), to quantify specific properties in a food sample (e.g., its sweetness, color, or the hardness of its texture), or to evaluate the hedonic value of foods and beverages (e.g., quantify the degree of liking or whether a version is preferred over another). Given the breadth of

application, different sensory methods exist depending on the project purpose, the type of assessors available, the magnitude of differences between stimuli, and on other practical considerations. Furthermore, data sets resulting from sensory can be quite large and can have peculiar structures. A variety of methods of multivariate data analysis can be very useful in the exploration of the structure that is in such data (Dijksterhuis, 1995).

My contribution to this course can be expressed in terms of the following two ILOs:

ILO 1 (Sensory Methods): The students should identify existing sensory methods and their requirements to select the right method in relevant situations.

ILO 2 (Sensometrics): The students should be able to arrange and perform appropriate statistical analyses on data from different sensory methods.

Implemented Changes in Teaching Approach

Within this course, I am responsible for four lectures with a contact time of 8 hrs. The first lecture focuses on sensory methods (ILO 1), the second on practical planning of sensory tests (ILO 1), the third on data analysis or sensometrics (ILO 2), and the fourth is a tutorial on specific data analyses using sample datasets (ILO 2).

Previously, my teaching approach in this course had been exclusively teacher-oriented (2-hr lecture format). In line with increasing awareness of the benefits of a student-centred approach, I decided to implement a change in the lecture format, thinking that the applied nature of the course would lend itself very well to CBT. I thus devised a series of activities based on actual examples from ongoing research or from literature. The goal was challenging students with a scenario in which they needed to apply their knowledge of the subject matter, while providing them with immediate feedback on their learning (Mazur, 1997; Schneider, 2007).

The lectures consisted of short presentations (20 min) about a central point, followed by a case study related to the points being presented, which the students were invited to think about individually or in group. A variety of approaches to activate students was used, some of which were based on ARSs, and was presented using several different formats (group and pair discussions, multiple-choice questions, open-ended questions, etc.) as a way of providing a refreshing variation and of increasing students' attention (Schneider, 2007). Some of the activities were especially inspired by Mazur's (1997, 2009) concept of peer instruction. Peer instruction is built on the idea that better learning can be achieved if the students actively discuss the subject matter with their peers instead of just listening passively.

Regardless of the format, the common goals of these activities were that they should (a) engage students and make the lecture more student activating and (2) provide opportunity for formative assessment, either by making students discuss their understanding with their peers (peer instruction) or by allowing me to modify my explanations or ways of delivering the content according to the class discussion.

First example (ILO 1)

My first lecture concerned sensory methods and their applications. I introduced briefly the classification of sensory descriptive methods in verbal-based, comparison-based, and reference-based methods (Varela & Ares, 2012). Instead of me providing examples of applications, I thought

placing the students in the position of a sensory lab manager having to decide the best course of action would provide a more effective learning experience. Therefore, I developed a series of case studies in which the students were asked to determine the best sensory methods based on the three central aspects in any sensory study: the purpose of the project, the difficulty and number of samples, and the type of panel available for the job (Table 1). The students were given the case studies individually for 2 min. Then, I asked them to discuss with their neighbours and compare their respective answers for 5 min. Afterwards, to nudge the discussion toward some critical aspect, I also gave them an “extra hint” in the form of an additional element useful to understanding the case study (see Table 1) and provided a few more minutes to reconsider their assessment of the case. Finally, I reviewed the problem together with the students in a plenum discussion format. The latter was appropriate in view of the classroom size ($N = 15$), but also because all cases had more than just a singular acceptable solution. In doing this, I tried to facilitate further peer assessment (e.g. orchestrating a discussion between groups to argue against/defend their suggested solution) before offering my own assessment of the case.

Table 1. *Three Examples of Case Studies Discussed in Class*

	Case 1: “A new sea-buckthorn juice”	Case 2: “Common roasting defects”	Case 3: “The taste of water”
Purpose	Developing a new sea-buckthorn base beverage together with a local producer; the goal is to obtain a sensory description of the samples and identify preferred prototypes	A small coffee producer wants to investigate the effect of common roasting defects on the final sensory quality of their coffee	Assessing the sensory quality of Danish municipal water
Samples	8 prototypes developed by blending sea-buckthorn juice with either apple juice or orange juice	6 (1 reference + 5 common defects)	10 water samples collected at 10 different locations in Denmark
Trained panel available	No	No, but the company wants to train own employees (12 potential assessors) for that purpose	Yes (101–102 trained judges)
Extra hint	Both sensory and preference data are needed...	Coffee temperature rapidly decreases...	Previous studies suggest that the level of salinity (sodium concentration) and the total amount of dissolved solids are important parameters...

Second example (ILO 1)

A second example concerned the practical planning of sensory science experiments. This lecture is very fact based, and the background literature covers very straightforward principles of good practices required for this type of experiment (e.g. experimental design and treatment structures; sample preparation and serving procedures; International Organization for Standardization standards for sensory evaluation facilities, panel screening, selection, and training; and legal aspects/requirements for using humans as subjects of sensory tests; Lawless & Heymann, 2010). To increase students' activation, I decided to again use CBT, this time using the ARS called Socrative (MasteryConnect, 2014). The cases were meant to illustrate practical considerations during planning of sensory studies and varied in format (multiple choice, true/false, and open ended). A sample from the case studies is shown in Figure 1.

Identify whether the case described below has a sensory analytical or a hedonic character. Motivate your choice by suggesting which method to use. "A brewery wants to test if consumers can taste a difference between a freshly brewed beer and a beer that has been stored for some weeks. Both beers are pasteurised and have been stored in dark-brown bottles."

1.

(A) Discriminative

(B) Descriptive

(C) Affective (hedonic)

Identify whether the case described below has a sensory analytical or a hedonic character. Motivate your choice by suggesting which method to use. "A brewery wants to test if consumers can taste a difference between a freshly brewed beer and a beer that has been stored for some weeks. Both beers are pasteurised and have been stored in dark-brown bottles." They decided to go for a duo-trio test. Could they have chosen a paired comparison test instead?

2.

(A) Yes

(B) No

Identify whether the case described below has a sensory analytical or a hedonic character. Motivate your choice by suggesting which method to use. "A brewery wants to test if consumers can taste a difference between a freshly brewed beer and a beer that has been stored for some weeks. Both beers are pasteurised and have been stored in dark-brown bottles." They decided to go for a duo-trio test. How can the sensory manager at the brewery increase the reliability of the test?

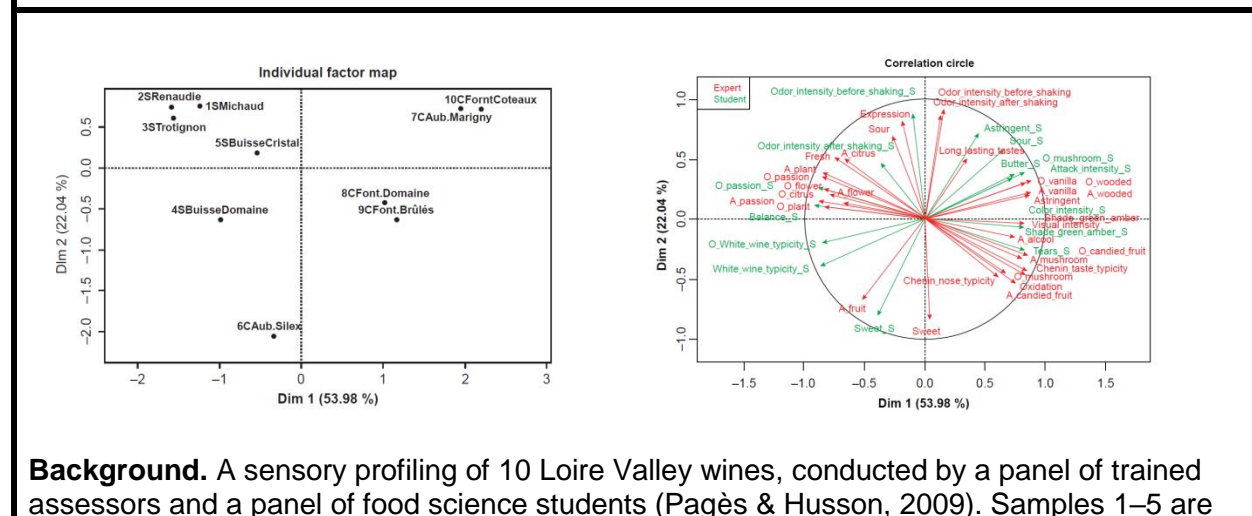
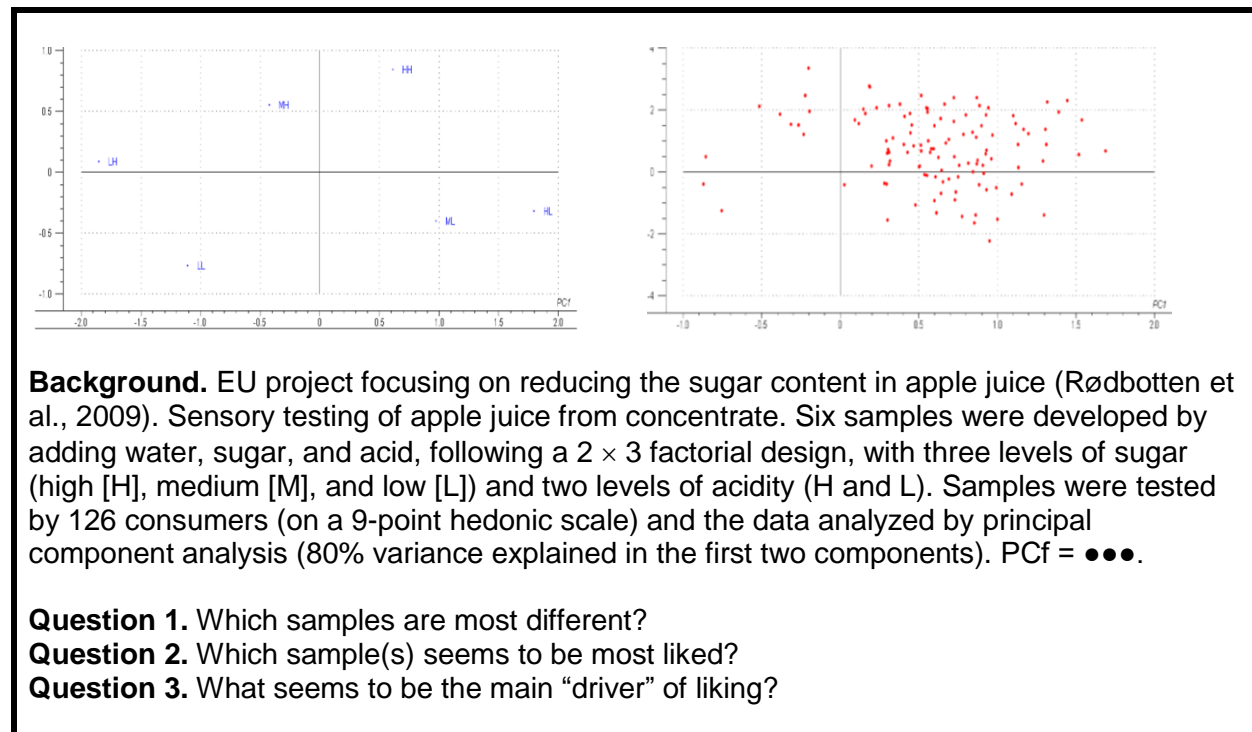
3.

Figure 1. Examples of case studies used in relation to Intended Learning Outcome 1. Correct answers: (1) A; (2) No, because paired comparisons assume prior knowledge of the nature of the difference; (3) Several possible answers (e.g., improve statistical power, increase number of tests/subjects, select more sensitive subjects, provide training, etc.).

Third example (ILO 2)

A third example concerned the data analysis methods (ILO 2). Teaching data analysis to students without a firm grasp on statistics (often the case in a particular course) is always a

challenge. The risk that the students will adopt surface learning strategies is much higher than for other parts of the curriculum. I wanted to use apply CBT learning in statistics, as students are more motivated and better understand concepts when real data sets are used. I also wanted to structure my student activation activity around visual results interpretation, both because this is the key skill students will need when communicating the results from sensory tests to other professionals and because visual explanations have been mentioned to be very effective in food science education (Schmidt, 2009). In order to do that, I developed a series of concept tests based on different plots from multivariate data analyses of sensory and consumer science data. They were designed so that the students would learn how to interpret and draw conclusions from multivariate plots. The students discussed the cases with their neighbours, and then a plenum discussion followed.



Sauvignon and Samples 6–10 are Chenin (Samples 7 and 10 are aged-casked [woody taste] and Sample 6 has high residual sugars [10 g/l]). A = ●●●; O = ●●●; S = ●●●.

Question 1. What seem to be the main sensory differences between the samples?

Question 2. Are the two panels describing the wines similarly?

Figure 2. Two examples of case studies discussed in class.

Fourth example (ILO 2)

An additional example involving both CBT and ARS was devised in order for the students to think about different data structures resulting from sensory experiments. For each of them, they would indicate the most appropriate data analysis method among the four covered in the course, using a multiple response question format in Socrative. The key elements the student would have to think about in this task were essentially (a) the number of data matrices (one, two, or more than two) and (b) the type of data (quantitative or categorical) obtained in the study. The idea with this exercise was for the students to work out the essential elements during the task. Ideally, there is a simplified decision tree one can use (Figure 3), which I in fact used to summarize the discussion after the task.

Q1. Researchers at UCPH ran a study to investigate the effect of cooking time and temperature on the sensory properties of beef cooked sous-vide. Three different cooking temperature (56, 58, and 60 degrees C) and four cooking times (3, 6, 9, and 12 hours) were considered producing 12 samples in total. The data consists of a sensory evaluation by a trained panel, averaged over assessors and replicates. Now you want to use a MV to visualize the main differences in sensory properties between your samples and assess the effect of time and temperature. Think about how the data would look like, then indicate what MV method seems most appropriate. NB: more than one answer may be correct..

1.

A Principal Component Analysis (PCA)

B Correspondence Analysis (CA)

C Partial Least Squares Regression (PLSR)

D Multiple Factor Analysis (MFA)

Q2. You are the panel leader of a sensory lab running a project about chicken meat fed with 4 different feeding strategies. You run a sensory profiling with 10 sensory panelists in triplicates. Now you need to explore the data and to find out whether the feeding strategies affect the sensory quality of chicken meat. At the same, you want to evaluate whether your panelists are generally agreeing with each other, and whether the different replicates produce the same results. Think about how the data would look like, then indicate what MV method seems most appropriate. NB: more than one answer may be correct..

2.

A PCA

B CA

C PLSR

D MFA

Q3. Together with a small local producer, you are working on a project developing new fruit juices based on nordic ingredients. You are asked to provide recommendations based on sensory insights. You set up a large consumer test (N=200) where consumers report their liking for the juices and also describe their sensory properties by a CATA questionnaire. You want to visualize the sensory properties of the juices and relate this information with the preference data. Think about how the data would look like, then indicate what MV method seems most appropriate. NB: more than one answer may be correct..

3.

A PCA

B CA

C PLSR

D MFA

Q4. You are running a study investigating chemical and sensory properties of apples with different storage time (10 days and 20 days at -0.5 °C) and regimes (air vs controlled atmosphere). The data consists of some physico-chemical data (volatiles analysis, firmness, % solubles solids, etc) and of sensory assessment by a trained panel. You need to analyze the data in order to determine the relationship between sensory and instrumental parameters and the influence of storage period and storage atmosphere on the chemical and sensory composition of the apples. Think about how the data would look like, then indicate what MV method seems most appropriate. NB: more than one answer may be correct..

4.

A PCA

B CA

C PLSR

D MFA

Figure 3. Example of case studies used in connection to Intended Learning Outcome 2. Correct answers: (1) A; (2) D; (3) B, C, D; (4) C, D. UCPH = ●●●; NB = nota bene; MV = ●●●; CATA = ●●●.

Assessment of Teaching Effectiveness

In order to assess the effectiveness of the implemented changes in the course, a number of formal and informal approaches were considered. The former included quantitative course evaluations provided by the students on the following six statements using 5-point Likert scales (ranging from 1= *totally disagree* to 5= *totally agree*): (a) “I have acquired the competences described in the learning outcomes for this course,” (b) “There was a good consistency between the different course components,” (c) “The teaching material was relevant in relation to the course,” (d) “I received relevant and professional feedback on my oral and written work in the course,” (e) “I had access to relevant information regarding the course,” and (f) “Overall, participating in the course was a rewarding experience.”

Additionally, students’ impressions of the course were assessed qualitatively by conducting a focus group with a subset of students ($n = 7$) shortly after the end of the course. The format of the focus group was a group discussion with a moderator who would introduce a broad question and steer the conversation until everybody felt that no more input on that topic was needed. In order to reduce a possible confirmation bias, the task was led by another colleague with several years of experience of moderating focus groups, whereas I acted as an observer and only intervened sporadically (e.g., to ask clarification or further elaboration on specific points). The main topics of inquiry covered in the focus groups included satisfaction with the course (including the teaching format), self-evaluation of learning, best and worst aspects of the course, relationships with other courses and their previous knowledge, among others. The focus group lasted 45 min. The students volunteered and were not compensated for their time.

Finally, assessment of teaching effectiveness was also informed by critical feedback provided by two senior colleagues who sat through some of the lectures, as well as by self-reflections and observations gathered during the course.

Results

Student evaluations for the course are shown in Figure 4. The mean ratings for all Likert items were in the positive range of the scale. In particular, all students ($N = 15$) who completed the online evaluation fully agreed with the statement that participation in the course was a “rewarding” experience, and most of them agreed with the statement that they have acquired the competences described in the learning outcomes for the course (mean rating 4.3 on a 5-point scale).

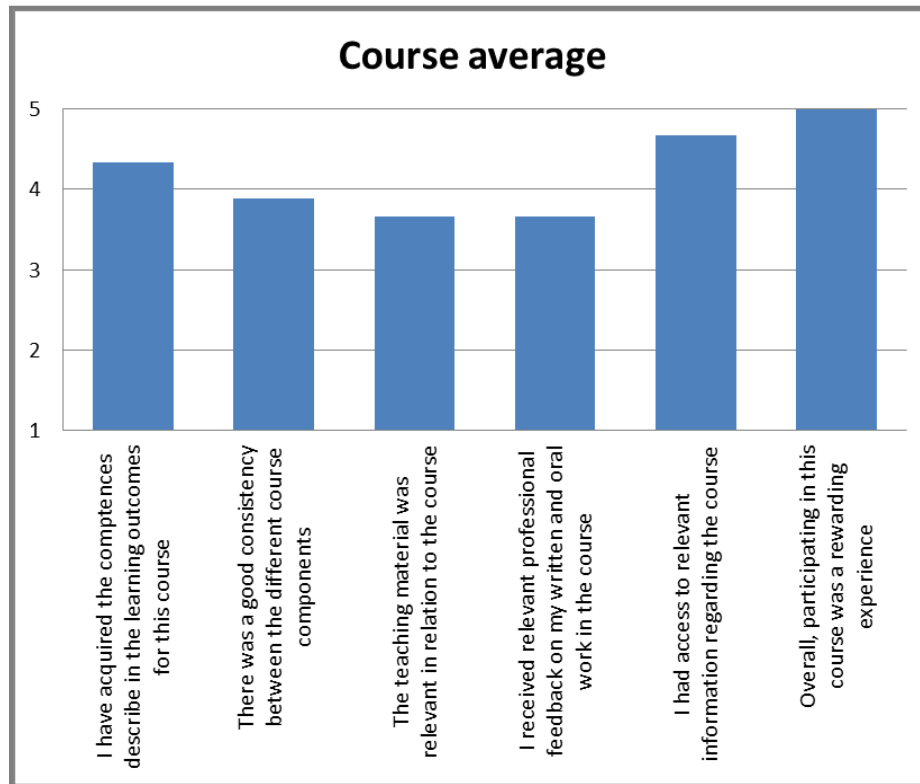


Figure 4. Average student evaluations of the course (on a Likert scale from 1 = *totally disagree* to 5 = *totally agree*).

The ratings were supplemented by anonymous comments provided by the students during the open-ended section of the same online evaluation. The comments (C) important to the present discussion (i.e., those addressing the general set-up of the course and the case studies) were the following¹:

- C1. “Really applied course with interesting projects”
- C2. “So much fun! Both with the kitchen exercises and the project work. It is nice to be able to use the knowledge from my previous courses in [Food Innovation and Health]—everything comes together in this course”
- C3. “It gave us the opportunity to work on a real case scenarios”
- C4. “The course rounds off perfectly what we have learned during the MSc programme. Very exciting and relevant”

Students did not comment explicitly on the use of ARSs during the online course evaluation, but my own observations as well as those from two independent observers during the course strongly indicated that the students liked it and found it very entertaining. Students confirmed that this was case during the qualitative focus group interview, as some of the quotes (Q) collected suggested that the teaching format was effective in reaching the learning outcomes:

- Q1. “Socratic was nice and useful also to make it [i.e., the course] more entertaining”

¹ Students’ comments pertaining to other aspects (e.g., administrative support, the schedule of the courses, syllabus, etc.) are not reported here.

- Q2. "Very nice with Socratic!"
- Q3. "Case studies very useful"
- Q4. "Some overlap with sensory science teaching in previous courses, but good to get the basics"
- Q5. "Clear approach to choosing methods, good decision path, was easy to match methods with goals b/c of the teaching"
- Q6. "Statistics is a difficult topic, but cases helped making it understandable"
- Q7. "Long lecturing streaks sometimes. We could get faster to the parts where we do something!"

Discussion

Student evaluations of the course were very positive, with both quantitative and qualitative feedbacks indicating that the course was well received. As anticipated, the course was an optimal venue for implementing CBT. The applied aspect of the course and the real-world relevance appeared in both the comments and the focus group quotes as the most significant positive aspect of the course, as well as the fact that the course provided an opportunity for the students to apply the knowledge and concepts acquired during their previous courses in the programme to real case scenarios. Two of the quotes from the focus group (Q5 and Q6) are particularly relevant, as they directly address the effectiveness of the teaching in relation to the two ILOs; they were raised by two different students, but all present indicated that they agreed with the statements when prompted by the focus group moderator.

An additional element that may have contributed to the appropriateness of CBT was the fact that this was an advanced course and that, therefore, the students were not complete novices with respect to the basic concepts pertaining to the two ILOs. This was indicated by the students (e.g., C4 and Q4), and seem to corroborate earlier claims that the effectiveness of CBT is positively related to student expertise (Kirschner et al., 2006).

The activities that had a peer instruction component were particularly successful in engaging the students and the discussions between neighbours were relevant and animated as confirmed by the senior colleagues who sat through the lectures. As a teacher, I tried to facilitate the plenum discussion and to fully discuss each point of view before moving on to the next exercise, as this aspect has been emphasized as key in enhancing the effectiveness of both CBT and ARSs (Kirschner et al., 2006; Hunsu et al., 2016). A key observation regarding this step is that it is important to allow enough time to exhaust all arguments put forward from the students. From a teacher perspective, it may be challenging to resist the temptation to end the ambiguity and move on to providing your own assessment of the case. My experience in this study was that as soon as you do that, all potential for further discussion is quickly lost because of the institutional aspect involving in the teacher speaking. It is well known that less experienced teachers may have need some time adjusting to students feedbacks (Kay & LeSage, 2009), so more experience with this teaching style should enable a better pacing of the discussions. Moreover, the inclusion of a peer instruction component in addition to the plenum discussion could also be useful in making sure that students achieve the right level of activation (Smith et al., 2009).

Regarding the use of ARSs, quotes Q1 and Q2 from the focus group discussion and observations during the course strongly indicated that the students liked it a lot and found it very entertaining. This finding is well in line with other studies (e.g., Kay & LeSage, 2009; Miller, Ashar, & Getz, 2003) and confirms that ARSs provide easy-to-use tools to enhance attention and enthusiasm among the students.

There has been some questioning in the literature as to whether or not this positive attitude toward ARSs, which is often encountered, is associated with actual learning (Kay & LeSage, 2009; Kennedy, Cutts, & Draper, 2006). In the more quantitative question formats, students' responses were extremely good, so that suggests that there was success in solidifying concepts presented in the lecture. Although ARSs are most often associated with teaching larger audiences, this case study shows that they might be welcome in smaller classrooms as well, because students liked them and they have the additional benefit of providing summative assessments. In fact, recent research actually suggests that the performance of ARSs in terms of learning outcome is higher in classroom sizes up to 25 students (Hunsu et al., 2016), arguably because with smaller classroom sizes, it will be easier to adequately address any misconceptions in the discussions that follow ARS questions. The feedback provided by the students and the observations gathered throughout the course of this study support the findings of Hunsu et al. (2016).

Taken collectively, the results presented in this article indicate the appropriateness of CBT and ARSs in the context of food science education and support a greater reliance on these methods to engage students and improve their learning experiences. The most interesting suggestions for improvement during the focus group were to avoid what were perceived to be "long lecturing streaks" and to more quickly get to the part where they "do something" (Q7), confirming indirectly that the change of format in the direction of active learning was well received by the students.

Two main limitations should be emphasized to qualify these findings. The first one is that teaching effectiveness was assessed either on the basis of student self-report or qualitatively (e.g., teacher's observations). In future studies, it would be advised to enforce more robust criteria to assess the effect of such a teaching approach on actual academic achievement. This could be ascertained by conducting a follow-up test sometime after the course to quantify how much of the course curriculum was retained or, alternatively, by comparing the final grades with a previous version of the course with a more teacher-centered approach.

The second limitation pertains to the fact that this article is based on a particular case study and a small student population, which may limit somewhat the generalizability of the findings. Although the effectiveness of CBT and ARSs has already been reported for other disciplinary areas, it would be relevant to investigate whether the same results would be obtained when changing some key aspects such as the classroom size, the nature of the subject matter, the prior level of experience of the students, and the type of feedback provided.

Conclusions

This article focused the use of CBT and ARSs for teaching sensory science and sensometrics into a food science graduate course. Based on qualitative and quantitative students' feedback, as well as peer evaluation, it was observed that the CBT was effective in engaging student participation and promoting a more active way of learning. ARSs further facilitated class discussion, in addition to providing a real-time assessment of the teaching effectiveness. The use of both CBT and ARSs was well received by the students and was facilitated by the applied profile of the course, which required integration of several disciplinary areas to solving "real-world" problems in the context of food product development. Most importantly, the results suggest that the implemented teaching approach was effective in promoting the ILOs and therefore call for a greater reliance on these tools to support student learning in this area. The actual effect of CBT and ARSs on academic achievement and the effectiveness of methods with different student

profiles and subject matters are identified as key questions that should be addressed for future studies in the area of food science education.

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Appendix

Overall Course Intended Learning Outcomes (ILOs)

The ILOs most related to the activities described in the present article appear italicized.

ILOs for an MSc in Food Innovation and Health

Knowledge

1. Experience with ideation and business model generation for developed food products
2. General knowledge of basic operations and tools for gastronomic food production
3. Innovation, intra-, and entrepreneurship in relation to foods
4. Describe carbohydrates, lipids, and proteins basic function and characteristics in food and point out the effects of culinary processes on physical, chemical, and sensory conditions of food components
5. Adapt methods of preparation for different raw materials based on a rational gastronomic foundation
6. Reflect on the nutritional aspects of raw materials and their changes in culinary processes
7. Pointing out the essential microbiological risks connected with especially low temperature preparation methods and the necessary precautions for handling raw material
8. Describe the effect of physical processes such as pressure treatment and freeze-drying on the structure of food and how physical treatment can be used for developing gastronomic dishes
9. Give an overview over aesthetics in relation to food, meals, and eating

Skills

10. Use techniques to foster innovation and creativity related to development of new foods
11. Production of prototypes of complex foods, production in pilot scale of complex foods, including demonstration of practical abilities with culinary techniques
12. *Consumer tests of complex foods*

13. Reflection upon own development, and ability to see opportunities and the potential for students' professional competences in intra- and entrepreneurship and innovation
14. Work in a gastronomic laboratory with chosen experimental techniques and culinary methods
15. Communicate in writing the topics in the gastronomic area with regard to innovation in foods
16. Integrate aesthetics in relation to food, meals and eating
17. Communicate gastronomic concepts to professionals and relevant employers/purchasers

Competences

18. A scientific approach to food innovation and small scale food production
19. *New Product Development of healthy and palatable foods*
20. Integrate academic disciplines (food chemistry, sensory science, and nutrition) to innovation and business development in the food sector
21. *Use and adapt techniques for characterization of sensory properties and consumer experiences*
22. *Interdisciplinary cooperation with other students on planning, carrying out and evaluating experiments in relation to new product development of healthy and palatable foods*
23. Work independently and efficiently together in a group on joint projects

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