Interactive Taste Tests Enhance Student Learning

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If we could effectively engage students in general science curricula and lead them to recognize the everyday relevance of scientific concepts, we would significantly strengthen the understanding of science among our nation's future workforce. Here we show that increased levels of student cognition can be achieved through interactive taste tests; this universally applicable pedagogical resource can improve student learning and demonstrate the applicability of science to the real world. Demanding only modest resources, our interactive taste tests are easily translatable, scalable, and quick to implement, allowing for seamless integration into preexisting or evolving interdisciplinary science curricula across a broad spectrum of institutions. Our approach is equally effective for both science and nonscience majors and thus has strong potential to generate citizens with a stronger understanding of science. Our results provide a practical solution to implementing active learning strategies in science education and incite further studies of the unexplored realm of taste as a sensory cue in learning.

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Engaging undergraduate students in the process of discovery through active, inquiry-based approaches enhances knowledge retention and promotes higher levels of cognition (Freeman et al., 2014; Hake, 1998a, 1998b; Handelsman et al., 2004; Prince, 2004). Although there is much emphasis on active learning strategies in science courses, these can be challenging to implement in an undergraduate classroom. Here we show how simple classroom modules using food can improve student learning in an introductory, general education science course. Eating provides visual, auditory, and kinesthetic learning cues. Although eating has not been well characterized as a pedagogical tool, other multisensory approaches improve student learning in the classroom (Deslauriers, Schelew, & Wieman, 2011; Haak, HilleRisLambers, Pitre, & Freeman, 2011; Naiz, Aguilera, Maza, & Liendo, 2002; Ruiz-Primo, Briggs, Iverson, Talbot, & Shepard, 2011). Using methods that engage multiple learning styles is an effective strategy to improve student learning when teaching science in a diverse classroom setting (Keller, 1987; Lujan & DiCarlo, 2006; Slater, Lujan, & DiCarlo, 2007; Tanner & Allen, 2004). Moreover, when instructors incorporate varied pedagogical approaches, they are more likely to cater to a variety of learning preferences (Miller, 1998; Tanner & Allen, 2004). Eating has untapped potential as a unique teaching approach because it simultaneously engages multiple senses including taste, which is a distinct and unexplored sensory cue. Food also has the potential to help students connect formal scientific concepts to their everyday life experiences; this could provide opportunities for students to recognize the relevance of technical and potentially abstract course content to real-world issues.

Applying scientific concepts through eating

To explore the role of eating in learning science, we introduced a series of interactive taste tests into a general education science course ($n = 46$). The course is based on a course that we previously developed at Harvard University (Rowat et al., 2014), where one scientific concept is taught each week for the duration of the course. Our current curriculum teaches concepts in biophysics. Each week students attend 2 hours of lectures and one 2-hour lab section that all focus on the concept of the week. One additional hour of lecture each week is provided by a guest chef who highlights the application of the science concept to food and cooking. The class of 46 students was comprised primarily of female (53%), upperclass (84%), and nonscience (53%) students.

Our goal of this pilot study was to determine how interactive taste tests could impact student learning. We hypothesized that students who experienced taste tests representing the scientific concept being taught would achieve increased levels of cognition. Taste tests were conducted at the end of the week, after the students had already attended the lectures about the science concepts. We designed the taste test modules to be easily translatable, inexpensive, and implemented within 15 minutes. To determine how each module affected student learning outcomes, we developed a unique assessment framework centered on self-reflections written by students about their taste-test experiences. Independent external reviewers then coded these self-reflections on the basis of the hierarchy of cognitive dimensions commonly known as Bloom's taxonomy; these cognitive domains build progressively from remembering recurring patterns to understanding general concepts and applying, analyzing, evaluating, and finally creating new knowledge (Anderson et al., 2000; Bloom, 1956).

We administered three interactive taste tests each aligned with three key course concepts: diffusion, elasticity, and binding affinity (Figure 1A). For the diffusion taste test, we marinated tofu in soy sauce for different lengths of time to illustrate timescales of diffusion; for elasticity, we prepared Jell-O samples with different gelatin content to create a series of edible gels with different elastic moduli; and for binding affinity, we prepared aqueous solutions with and without salt and monosodium glutamate (MSG) to illustrate the interaction of molecules with taste receptors. We selected these three topics as they are each based on some aspect of the curriculum. For example, the concept of diffusion in marination was already covered in the course lecture; measuring the mechanical properties of gels is the basis of a lab exercise. These three concepts are also straightforward to demonstrate through a taste test. Moreover, the samples are simple to prepare and distribute to students in the classroom. The choice of these three topics also enabled the taste tests to be presented at similar intervals throughout the 10-week course, so they could be administered at regular intervals throughout the course.

In conducting these taste tests, we carefully chose a food-safe room. These activities should not under any circumstances be done in a science lab given the potential for cross-contamination of biological and chemical laboratory hazards (Roy, 2014). Alternative sites, such as a cafeteria, family and consumer science lab, or any other location that is designed for human food consumption, should be used. Prior to the taste tests, we alerted students that these taste tests were fully optional and warned them about potential hazards for allergic reactions. All food samples were prepared in accordance with food safety regulations. For example, teaching assistants wore hairnets and gloves while preparing samples.

We introduced the taste-test modules at the end of each week to ensure that all students had equivalent exposure to lectures and lab activities. Students were then randomly divided into three groups that received taste samples with varying levels of relevance to the scientific concept. The random assignment of student groups ensured the separation of students who may choose to sit together because of similar backgrounds and/or science aptitudes and also ensured that the three groups were different for each taste test. To confirm equivalency among the groups, we verified that there were insignificant differences among homework and/or quiz grades from that specific week in the course, average grades on final exam questions pertaining to the topics, and overall course grades (see supplemental Table S1, A–C, available at http://www.nsta.org/college/connections.aspx).

We then instructed students to eat their samples and prompted them to describe how their taste test related to the scientific concept (Figure 1B). Students were instructed to not speak with their classmates as they tasted their samples and to immediately complete their self-reflection. The entire taste test was performed within 10 minutes and self-reflections were collected from the students. We encouraged the students to share their experiences and reflections with their fellow group members. The activity concluded with a spokesperson from each group sharing their views with the rest of the class.

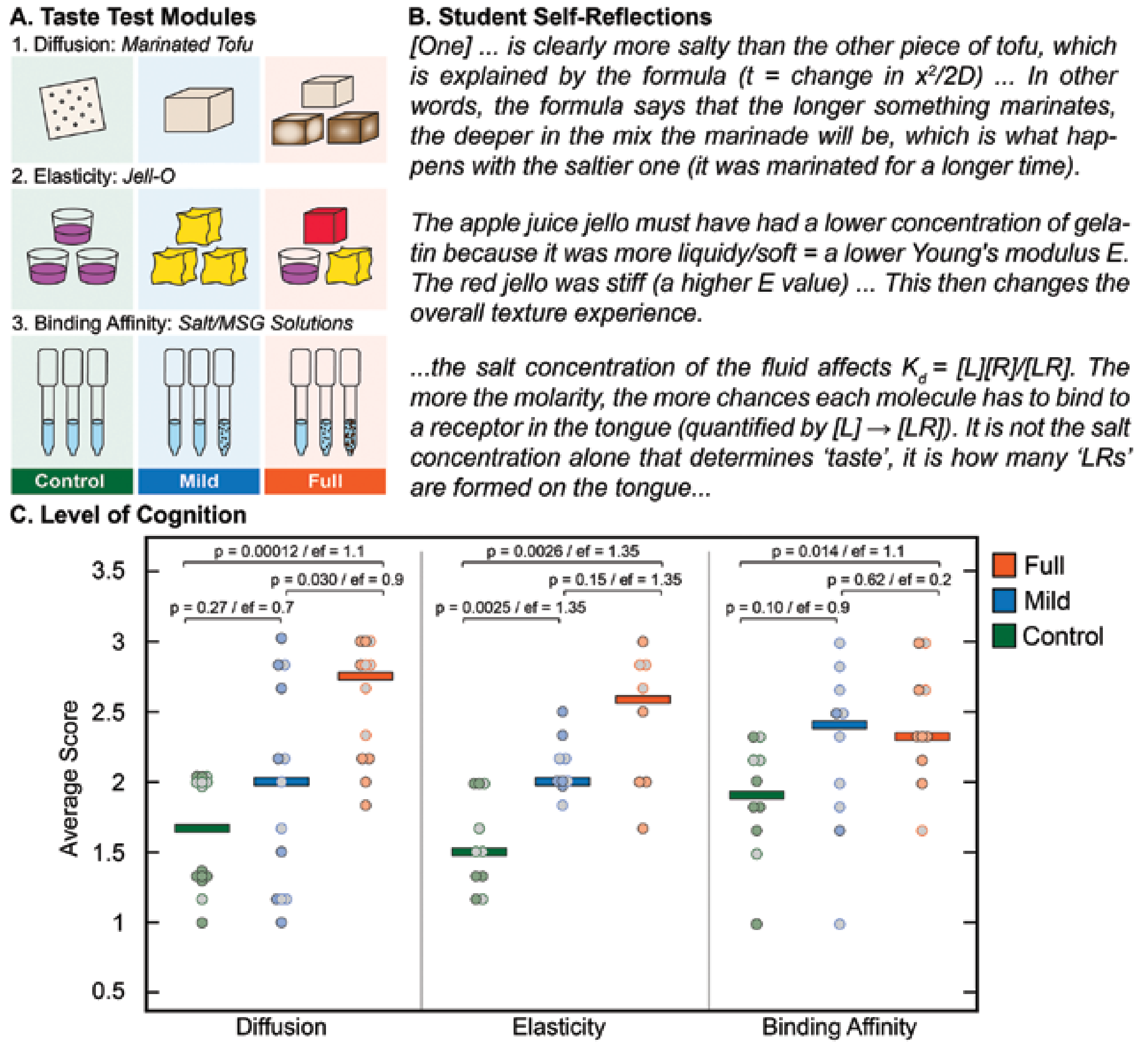
Student responses were coded by independent, external reviewers based on three cognitive skills in Bloom's taxonomy: remembering, understanding, and applying. We focused on these three skills because they are relevant to recognizing science concepts in everyday life. Reviewers assigned three points for applying, two points for understanding, and one point for remembering (Table S1). Our analysis of the self-reflection data revealed that the median assessment scores increased from the control to full-intervention groups, revealing that students are demonstrating higher levels of cognitive skills as they experience taste samples that exemplify a scientific concept. Across three independent taste tests, the median scores were significantly higher for the full versus control groups. In all three tests, we also observed a noticeable increase from control to mild groups, suggesting that achievement of higher Bloom's taxonomy levels may result from a mild yet crucial intervention. For example, the mild group from the binding affinity module received a salty solution that was as effective as the full taste test, which included an additional umami solution.

Our results are further corroborated by the responses to pre- and postsurveys that were administered to the entire class. Surveys assessed student engagement during the course as well as satisfaction with various components of the curriculum through a series of 20

FIGURE 1

Eating improves student learning outcomes.

(A) Students were divided into three groups: (i) a full intervention group that received a sample that exemplified the scientific concept; (ii) a mild intervention group that received a sample that was moderately associated with the scientific concept; and (iii) a control group that received a sample that was unrelated to the scientific concept. For example, students in the elasticity full intervention group received Jell-O samples of varying stiffness, whereas students in the control group received liquid juice. (B) Representative examples of the self-reflection data from the full intervention groups. Examples from the mild and control groups are provided in Supplemental Tables S2 and S3 (available at http://www.nsta.org/college/connections.aspx). (C) Student responses were coded based on three cognitive skills in Bloom's taxonomy: remembering (1 point), understanding (2 points), and applying (3 points). Each dot represents an average score for one student response as determined by three independent reviewers (Table S1). Colored circles represent nonscience majors; grey circles represent science majors. Horizontal lines represent median values for the control, mild, and full intervention groups where *N* (diffusion) = 14, 13, 12; *N* (elasticity) = 10, 9, 8; *N* (binding affinity) = 10, 10, 10. The following *P*-values were determined by the Kruskal-Wallis test: *p* (diffusion) = .0012, *p* (elasticity) = .0014, *p* (binding affinity) = .0524. Pairwise Mann Whitney U-tests were then conducted for the diffusion and elasticity groups as reported in (C). We interpret our pairwise results accounting for the Bonferroni correction, $p < .017$. Effect sizes (ef) were determined using a modified Cohen's *d* (Hollander & Wolfe, 1973) and only reported for significant differences.



B. Student Self-Reflections

[One] ... is clearly more salty than the other piece of tofu, which is explained by the formula (t = change in $x^2/2D$) ... In other words, the formula says that the longer something marinates, the deeper in the mix the marinade will be, which is what happens with the saltier one (it was marinated for a longer time).

The apple juice jello must have had a lower concentration of gelatin because it was more liquidy/soft = a lower Young's modulus E. The red jello was stiff (a higher E value) ... This then changes the overall texture experience.

...the salt concentration of the fluid affects $K_d = [L][R]/[LR]$. The more the molarity, the more chances each molecule has to bind to a receptor in the tongue (quantified by $[L] \rightarrow [LR]$). It is not the salt concentration alone that determines 'taste', it is how many 'LRs' are formed on the tongue...

questions that required ranking using a 4-point Likert scale of agreement in addition to open-ended responses. Two Likert-scaled questions on the survey were relevant to the broader goal of the taste tests; paired sample *t*-test analyses were conducted on the mean results of these two questions from the pre- and postsurveys. First, after taking the course, students felt there was a stronger emphasis on applying concepts from their science coursework to practical problems (pre = 2.65; post = 3.25, $N = 23$; $p = .01$, paired sample *t*-test analysis); these results emphasize the notion that food can be a translatable access point for teaching science. Additionally, students perceived a stronger real-life relevance of what they learned in science courses (pre = 2.78; post = 3.42, $N = 23$; $p = .004$), emphasizing the notion that food can be a translatable access point for teaching science.

Multisensory strategies for undergraduate science education

Our findings from this pilot study suggest that eating food can positively impact the way students learn science. We envision that similar taste-test modules could be adapted and implemented more broadly in any science classroom. For example, marinating meat with fresh pineapples could showcase enzyme catalysis in a biochemistry course, or salting mushrooms could demonstrate diffusion in a physics course. Because food and eating are familiar and universal entry points for students irrespective of academic background or precollege preparatory experiences, the curriculum presented through these modules may be more accessible to students who struggle to recognize the relevance of science concepts in an introductory-level and/or general science course (American Association for the Advancement of Science, 2009). Because these taste test modules are scalable and universally applicable, they can be adapted in any undergraduate classroom. These hands-on modules are also affordable and require little equipment, making them ideal for distance learning as they can be implemented at home.

Further studies should build on these findings and investigate how these interactive taste tests can play a role in longer term retention of scientific knowledge. Although these findings indicate that students are achieving higher levels of cognition at the time of the taste tests, we did not observe a corresponding increase in exam or homework grades. More research is needed to investigate how other curricular, pedagogical, or environmental factors impact student performance in the entire course. Future studies should also explore the mechanism through which eating can enhance learning. The process of eating can trigger multiple senses, ranging from touch and sight to taste and smell. By exploiting these sensory triggers, instructors could cater to multiple learning styles and thereby enhance student learning (Keller, 1987; Tanner & Allen, 2004). Translating these taste-test modules into a larger science course should thus be an effective way for science educators to create a more inclusive classroom and engage a more diverse student population; this is a major priority across the country, as highlighted in recent national reports (National Academy of Engineering, 2005; National Academy of Sciences, 2007; National Science Board, 2004). In addition, students can easily relate food to their own personal experiences. Cultural backgrounds or childhood memories may play a role in how students respond to a particular taste test; presenting a particular food in the context of multiple cultures may further broaden student participation. With evidence-based teaching methods becoming increasingly recognized as a successful strategy for students learning science (Allen & Tanner, 2005; Dirks, 2011; National Research Council, 2003, 2012; President's Council of Advisors on Science and Technology, 2012), our findings support the positive impact of active, multisensory pedagogical strategies in undergraduate science education. ■

Note: The University of California, Los Angeles Institutional Review Board approved this research study (IRB# 13-000346).

Acknowledgments

Funding was provided by a National Science Foundation CAREER Award to ACR (DBI-125418), the UCLA Office of Instructional Development, and the UCLA Department of Integrative Biology and Physiology. We thank Utpal Banerjee, Jeffrey Gornbein, Mark Morris, Deborah Pires, and Erin Sanders for critical comments, feedback, and discussion.

References

Allen, D., & Tanner, K. (2005). Infusing active learning into the large enrollment biology class: Seven strategies, from the simple to complex. *Cell Biology Education, 4,* 262–268.

American Association for the Advancement of Science. (2009). *Vision and change in undergraduate biology education: A view for the 21st century*. Washington, DC: Author.

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., . . . Wittrock, M. C. (2000). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. New York, NY: Pearson, Allyn & Bacon.

Bloom, B. (1956). *Taxonomy of educational objectives. Handbook I:*

Cognitive domain. New York, NY: David McKay.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science, 332,* 862–864.

Dirks, C. (2011, October). *The current status and future direction of biology education research*. Paper presented at the Second Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research, Washington, DC. Retrieved from http://sites.nationalacademies.org/DBASSE/BOSE/DBASSE_071087

Freeman, S., Eddya, S. L., McDonough, M., Smith, M. K., Okokorofor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, USA, 111,* 8410–8415.

Haak, D., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased structure and active learning reduce the achievement gap in introductory biology. *Science, 332,* 1213–1216.

Hake, R. (1998a). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics, 66*, 64–74.

Hake, R. (1998b). *Interactive engagement methods in introductory physics mechanics courses.* Unpublished manuscript.

Handelsman, J., Ebert-May, D., Beichner, R., Bruns, P., Chang, A., DeHaan, R., . . . Wood, W. B. (2004). Scientific teaching. *Science, 304,* 521–522.

Hollander, M., & Wolfe, D. A. (1973). *Nonparametric statistical methods*. New York, NY: Wiley.

Keller, J. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development, 10*(3), 2–10.

Lujan, H. L., & DiCarlo, S. E. (2006). First-year medical students prefer multiple learning styles. *Advances in Physiology Education, 30,* 13–16.

Miller, J. A. (1998). Enhancement of achievement and attitudes through individualized learning-style presentations of two allied health courses. *Journal of Allied Health, 27,* 150–156.

Naiz, M., Aguilera, D., Maza, A., & Liendo, G. (2002). Arguments, contradictions, resistances, and conceptual change in students' understanding of atomic structure. *Science Education, 86,* 505–525.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century.* Washington, DC: National Academies Press.

National Academy of Sciences. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future.* Washington, DC: National Academies Press.

National Research Council. (2003). *Improving undergraduate instruction in science, technology, engineering, and mathematics: Report of a workshop*. Washington, DC: National Academies Press.

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. Washington, DC: National Academies Press.

National Science Board. (2004). *An emerging and critical problem of the science and engineering labor force: A companion to science and engineering indicators*. Arlington, VA: National Science Foundation.

President's Council of Advisors on Science and Technology. (2012, February). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93,* 223–231.

Rowat, A. C., Sinha N., Soerensen, P., Campas, O., Castells, P., Rosenberg, D., . . . Weitz, D. A. (2014). The kitchen as a physics classroom. *Physics Education, 49,* 512–522.

Roy, K. (2014). Eating in the lab: A recipe for disaster. *Science Scope, 37*(5), 82–84.

Ruiz-Primo, M., Briggs, D., Iverson, H., Talbot, R., & Shepard, L. (2011). Impact of undergraduate science course innovations on learning. *Science, 331,* 1269–1270.

Slater, J. A., Lujan, H. L., & DiCarlo, S. E. (2007). Does gender influence learning style preferences of first-year medical students? *Advances in Physiology Education, 31,* 336–342.

Tanner, K., & Allen, D. (2004). Approaches to biology teaching and learning: Learning styles and the problem of instructional selection—engaging all students in science courses. *Cell Biology Education, 3,* 197–201.

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