https://doi.org/10.1038/s41570-023-00473-2

The Science of the Modern Kitchen

Stephanie Sebastiampillai, Wayne Wing Him Law, Yong Jia Bu, Andrew P. Dicks & Deborah B. Zamble

The kitchen offers chemists an opportunity to cook up chemistry using everyday ingredients. This is the inspiration behind 'The Science of the Modern Kitchen', a chemistry course offered to non-science undergraduates.

From sautéed onions to Grandma's decades-old sourdough starter, the everyday chemistry of our kitchens is the inspiration behind CHM209H: The Science of the Modern Kitchen, a popular second-year undergraduate course at the University of Toronto. The course explores the physical and chemical basis behind the transformations that occur when manipulating food[1]. It is offered to students enrolled in non-science programmes who are looking to fulfil their 'physical and mathematical universes' breadth requirement for graduation with a bachelor's degree. Enrolment has grown from 23 students since the course's inception in 2018 to 87 students completing the course in the Winter 2022 semester, and with 106 students enrolled for the Winter 2023 semester. The course outline is available through the link near the end of the article and on the departmental website of undergraduate courses offered in chemistry at the University of Toronto.

The teaching philosophy

As a course targeted towards students who are not formally trained in the natural sciences, our goal is to deepen their ability to think critically, to identify reputable sources of information and to ask important scientific questions. Translating these skills into a broader context is critical as society continues to face pressing issues, such as the COVID-19 pandemic and the global climate crisis, in which awareness and acceptance of scientific methods in decision-making are required. Given that food and cooking are an integral part of everyday life, they represent a natural starting point for connecting the familiar actions we perform in the kitchen to the fundamental principles governing our physical world. The course aims to demystify the subject of chemistry by conveying key concepts through the medium of food. We believe that if chemistry concepts, which can often be perceived as overly complex and abstract, can be made accessible, inviting, and tangible to our students, they will feel empowered and more confident when making judgements or forming opinions about the societal impacts of science.

Chemistry happens in the kitchen

The modern kitchen course offers plenty of opportunities to explore fundamental chemical concepts within both in-person and online course delivery modes[2,3]. The course is loosely divided into two main sections: first, the introduction (or re-introduction) of concepts such as atoms, ions, molecules, states of matter, stereochemistry, polarity, acids and bases, and electronic transitions; and second, application of the aforementioned concepts to food macromolecules (such as carbohydrates, proteins, and fats and oils) and their reactivity. In the first section, the material covered is cumulative and student understanding is crucial for comprehension of the subsequent classes. The second section of the course delves into more complex chemical concepts. Each weekly 2-hour class is subdivided into a 90-minute interactive content discussion and a 30-minute food-based demonstration. The demonstrations are the 'bread and butter' of the course and are meant to be fun and engaging, while offering the students a tasty treat. They are incorporated to allow the students to appreciate the scientific method with familiar foods or techniques that they would use in their own kitchens. Many of the demonstrations were created by graduate students in the Department of Chemistry in collaboration with the Chemistry Teaching Fellowship Program (CTFP)[4]. For instance, Fig. 1 shows the product of a 'mango egg' demonstration that is performed during a discussion of carbohydrates. In this class, the topics of polymers, intermolecular versus intramolecular bonds, and diffusion are initially discussed. Thereafter, the scientific principles are conveyed to the students through the preparation of the agar 'whites' of the egg and the mango 'yolk' of the egg using reverse spherification with sodium alginate and calcium lactate[5]. In addition, and as part of the 2020 CTFP in response to the online delivery of the course during the

Fig. 1 | Examples of demonstrations performed in CHM209. Amongst several other demonstrations, the students investigate the pH sensitivity of butterfly pea-infused marshmallows, egg protein denaturation in lemon curd, fermentation in sourdough starter, differences in the taste and smell of pure versus artificial vanilla, and a mayonnaise emulsion battle with various potential emulsifying agents.

COVID-19 lockdowns in Ontario, numerous demonstration videos were created in place of the in-class demonstrations. Many of these demonstrations were adapted so that students could continue to attend the course at home without requiring specialized equipment and ingredients (such as the sous vide method, use of liquid nitrogen and others)[2].

Fostering critical thinking and independent learning

Since its inception, the course has seen student enrolment from diverse academic backgrounds ranging from engineering to the humanities to performance arts. It is no easy feat to design a course where students with disparate academic perspectives can all enjoy the content and its pace of delivery. In group projects comprising about one third of their overall course grade, students are given the opportunity to investigate a specific food and cooking-related topic of interest to them. This assignment culminates in either a video collaboration where students prepare their own demonstrations, or an informational poster presentation allowing the students to peruse and compare scientific literature to more general news articles. Throughout this process, many students develop the ability to solidify and apply concepts presented to them during the classes, which further piques their interest in chemistry. The group project assignment is also broken down into several parts for a more guided approach: at each checkpoint, groups are given constructive feedback on their understanding of scientific principles, their choice of references, and their ideas. The feedback prompts students to actively incorporate the scientific method when dissecting their chosen topics. Some examples of questions students have explored in their assignments include: Why do onions make you cry? How to make glow-in-the-dark candy? Can you preserve vegetables against decay? What is the chemistry behind wok seasoning?

Course reception and its future

The Science of the Modern Kitchen is popular among non-science major undergraduates at the University of Toronto. Not only does the course offer new and interesting perspectives through food chemistry, but it also invites students who may have preconceived notions that chemistry is difficult and unapproachable to re-evaluate their mindset by entering a low-risk and engaging learning environment. The Science of the Modern Kitchen has become an integral chemistry course at the University of Toronto and benefits graduate students interested in teaching, as it presents an opportunity to learn how to teach material to a general audience. Our overarching goal with a course of such breadth is to ensure that students can take the perspectives of thinking and learning introduced in this course out of the classroom setting and into their daily lives.

Stephanie Sebastiampillai ✉, **Wayne Wing Him Law**, **Yong Jia Bu**, **Andrew P. Dicks** & **Deborah B. Zamble**
Department of Chemistry, University of Toronto, Toronto, Ontario, Canada.
✉e-mail: stephanie.sebastiampillai@mail.utoronto.ca

Published online: 16 February 2023

References

1. Vega, C., Ubbink, J. & van der Linden, E. (eds) *The Kitchen as Laboratory: Reflections on the Science of Food and Cooking* (Colombia University Press, 2012).
2. Nguyen, J. G. & Keuseman, K. J. Chemistry in the kitchen laboratories at home. *J. Chem. Educ.* **97**, 3042–3047 (2020).
3. Radzikowski, J. L., Delmas, L. C., Spivey, A. C., Youssef, J. & Kneebone, R. The chemical kitchen: toward remote delivery of an interdisciplinary practical course. *J. Chem. Educ.* **98**, 710–713 (2021).
4. Kim, K. S., Rackus, D. G., Mabury, S. A., Morra, B. & Dicks, A. P. The chemistry teaching fellowship program: developing curricula and graduate student professionalism. *J. Chem. Educ.* **94**, 439–444 (2017).
5. Provost, J. J., Colabroy, K. L., Kelly, B. S. & Wallert, M. A. *The Science of Cooking: Understanding the Biology and Chemistry Behind Food and Cooking* 247–250 (John Wiley & Sons, 2016).

Acknowledgements

M. J. Laccase is acknowledged for his contributions to the development of the course demonstrations in 2018, during CHM209H's inception.

Competing interests

The authors declare no competing interests.

Related links

CHM209H course details: https://www.chemistry.utoronto.ca/undergraduate/current-students/undergraduate-courses#chm209h1-accordion-1