



Inquiry-Based Science Learning through Culinary Science: A Practical Collaboration between University and Junior High Schools

Mika Tsuyukubo¹, Yorikazu Nouchi², Kenichi Goto³

¹Toyo University, Japan

²Nihon University, Japan

³Toyo University, Japan

Abstract

To promote interest and deepen understanding of science among junior high school students, universities and educational institutions are developing inquiry-based programs in collaboration with experts. This report describes a project between a university and multiple junior high schools designed to highlight the appeal of science beyond regular classroom learning.

Twenty students participated in a course held in a university cooking laboratory. The course applied concepts from culinary science, examining physicochemical changes during cooking through instrumental measurement and sensory evaluation. In the first half, students conducted introductory experiments, learning theoretical principles and measurement techniques. In the second half, they designed their own experimental plans and hypotheses based on these foundations and verified their ideas through experimentation. Finally, each group presented findings in a poster session and engaged in discussion.

The experiments focused on leavening in cooking. The first examined cupcakes, clarifying how varying amounts of sugar affect the final baked product. The second investigated steamed buns, comparing the effects of baking soda and baking powder. Before beginning, students individually predicted outcomes to foster scientific observation and inquiry. Objective comparisons were then conducted using microscopic observation of air bubbles in batter, hardness measurements of finished products, and colorimetric evaluations. These analytical instruments were not available in junior high school settings, demonstrating how collaboration with a university enabled otherwise inaccessible measurements.

After the experiments, instructors explained mechanisms related to sugar's influence on leavening properties, including egg protein denaturation, thermal expansion of air bubbles, and the Maillard reaction. Students responded positively, noting that culinary science was a new field to them and that cooking offered meaningful scientific connections. Others emphasized that independently identifying research topics and conducting experiments enhanced their learning. These comments indicate a high level of engagement and suggest that such collaborative programs provide an effective system for promoting scientific inquiry that transcends subject boundaries.

Keywords: *Culinary Science, Inquiry-Based Science Education, University–School Collaboration, Hands-on Experimentation*

1. Introduction

In recent years, STEM education has increasingly emphasized the importance of enabling learners not only to acquire scientific knowledge as abstract concepts but also to understand science in relation to real-world problems and familiar phenomena. In particular, experiencing scientific practices—such as formulating hypotheses, controlling variables, conducting measurements, interpreting results, and communicating findings—has been shown to contribute to both conceptual understanding and increased motivation toward science learning [1].

However, at the secondary education level, scientific concepts are often presented in abstract and theoretical forms, making it difficult for learners to perceive meaningful connections between school science and their everyday lives. As a result, many students come to view science as difficult or irrelevant to themselves, which may lead to declining interest and motivation in science learning [2].



To address these challenges, educational approaches that integrate science learning with daily-life activities have attracted increasing attention. Cooking is an activity that inherently involves a wide range of physical and chemical phenomena, including heating, phase changes, chemical reactions, and changes in material properties. Moreover, cooking is highly familiar to learners and allows for easy manipulation of conditions and variables, making it a suitable context for scientific inquiry activities.

Despite this potential, opportunities to treat cooking systematically as scientific inquiry in school education remain limited. Cooking has traditionally been positioned within the context of home economics or life skills education, and the concept of “culinary science” itself is not widely recognized among students. Consequently, the scientific principles underlying cooking processes are rarely addressed explicitly [3].

In recent years, research and educational practices related to molecular gastronomy and culinary science have demonstrated that cooking activities can support scientific understanding and inquiry-based learning [4]. However, most of these initiatives have targeted higher education or professional audiences, and there remains a lack of systematic educational practices and empirical studies focusing on junior high school students.

From a STEM education perspective, the authenticity of learning experiences has also been emphasized. Authentic learning environments involve the use of real tools and materials, engagement with problems that do not have predetermined outcomes, and opportunities to communicate results to others, all of which contribute to the development of learners’ scientific identities[5]. Cooking activities are well suited to creating such authentic learning environments.

Based on this background, the present study implemented an experiential learning program titled “The World of Culinary Science” for junior high school students, positioning cooking activities as scientific inquiry. The purposes of this study were twofold: first, to quantitatively examine changes in students’ awareness of and interest in culinary science before and after the program; and second, to qualitatively explore changes in students’ conceptual understanding, scientific thinking, and perceptions of science as a familiar and meaningful activity through analyses of free responses and inquiry activities.

2. Overview of the Program and Methods

2.1 Positioning of the Program

The program “The World of Culinary Science” was conducted as a university-led experiential outreach program for junior high school students. It is part of an annual, ongoing initiative designed to provide opportunities for scientific inquiry at the secondary education level by utilizing university educational and research resources.

A key feature of this program was the explicit positioning of cooking activities as scientific inquiry rather than as mere skill acquisition or experiential learning. The program focused on physical and chemical phenomena inherent in cooking processes and emphasized a sequence of practices in which students formulated questions, manipulated conditions, observed and compared results, and communicated their findings to others.

2.2 Participants

Participants were 20 junior high school students: eight seventh graders, eleven eighth graders, and one ninth grader. Most participants had limited prior experience with culinary science or specialized scientific experiments. The program was implemented in a mixed-grade learning environment.

This heterogeneous grouping was considered educationally meaningful, as it allowed students with differing levels of knowledge and experience to learn collaboratively through inquiry activities, which is an important feature of outreach education.

2.3 Program Structure and Experimental Activities

The program consisted of two main phases: foundational experiments in the first half and student-led inquiry activities in the second half.

2.3.1 Foundational Experiments



In the first phase, two experiments were conducted to visualize and quantify representative changes occurring during cooking.

Experiment 1: Leavening and Physical Properties of Steamed Bread

Steamed bread was used to examine the effects of different leavening agents on product characteristics. Flour, sugar, and water were kept constant, while baking powder (Condition A) and sodium bicarbonate (Condition B) were used as leavening agents. After preparation, the dough was steamed for a fixed duration.

The hardness of the cooked samples was measured using a creep meter, and color was quantified using a colorimeter based on the L*a*b* color system (Fig.1). In addition, students conducted sensory observations of appearance, aroma, taste, and texture. Through this experiment, students learned the principles of chemical leavening and the value of objective measurement in comparing cooking outcomes.

Experiment 2: Batter Composition and Bubble Structure in Cupcakes

In the second experiment, cupcakes were used to examine how differences in sugar content affect batter structure and final product characteristics. Eggs, flour, and milk were kept constant, while sugar content was set at 20 g (Condition A) and 65 g (Condition B).

After whipping the eggs and mixing the ingredients, the batter was baked under fixed conditions. Remaining batter was observed under a microscope to examine bubble structures. After baking, hardness and height were measured using a creep meter, color was measured with a colorimeter, and sensory observations were conducted. This experiment enabled students to understand how compositional differences influence structure and physical properties at both microscopic and macroscopic levels.

Across both experiments, cooking was treated not as a subjective sensory outcome but as a scientific object that can be controlled, measured, and compared.



Fig. 1. Experimental procedures: left, color measurement; right, physical property measurement.

2.3.2 Student-Led Inquiry Activities

In the second phase, students conducted inquiry activities based on the knowledge and measurement experiences gained in the foundational experiments. Working in groups, students formulated research questions and designed experiments with attention to independent and dependent variables.

Inquiry topics included questions such as: Does kneading time affect the softness of steamed bread?; How can we make cupcakes fluffier?; Can baking powder be reproduced using sodium bicarbonate?; and What are the differences between rice flour and wheat flour?

Each group organized their results, conducted analyses based on measurements and observations, and presented their findings in poster format. Through this process, students experienced a full cycle of scientific practices, including hypothesis generation, variable control, measurement, interpretation, and communication.

2.4 Evaluation Methods

To examine the educational effects of the program, both quantitative and qualitative data were collected. Quantitative data were obtained through pre- and post-program questionnaires assessing students' awareness of and interest in culinary science using a seven-point Likert scale.

Qualitative data included free-response questionnaire items, students' inquiry plans, and poster presentations. These materials were analyzed with attention to language use and conceptual content to identify characteristics of students' understanding and scientific thinking.



2.5 Analytical Framework

For quantitative data, mean scores before and after the program were calculated and compared. Qualitative data were categorized to examine changes in conceptual representations. Inquiry activities were analyzed from the perspectives of scientific practices, including hypothesis setting, variable manipulation, observation and measurement, interpretation, and presentation.

3. Results

3.1 Changes in Awareness and Interest in Culinary Science

Results of the pre- and post-questionnaire are shown in Table 1. Both awareness of and interest in culinary science increased markedly after the program.

Mean awareness scores increased from 2.5 to 5.5, and mean interest scores increased from 2.8 to 5.8, with mean differences of +3.0 for both items. These results indicate substantial changes over a relatively short experiential program.

Such changes suggest that explicitly positioning cooking activities as scientific inquiry strongly influenced students' cognitive and affective engagement. Experiential learning has been shown to enhance understanding and interest more effectively than abstract explanations alone [1], and the present findings are consistent with this literature.

3.2 Conceptual Changes Evident in Free Responses

Analysis of free responses revealed qualitative shifts in students' conceptual understanding. Before the program, responses frequently referred to everyday notions such as "cooking," "making meals," or "fun activities," and some students indicated unfamiliarity with the term "culinary science."

After the program, responses increasingly included scientific terms such as "chemical reactions," "heating," "physical changes," "measurement," and "changing conditions," as well as inquiry-related concepts such as "experiments," "comparison," and "hypotheses." These findings suggest that students began to reconstruct cooking as an object of scientific inquiry rather than as a purely practical activity. This transformation aligns with previous findings that attitudes toward science are more likely to change when learning is grounded in personal experience [2].

3.3 Characteristics of Scientific Practices in Inquiry Activities

During the inquiry phase, students demonstrated engagement in a sequence of scientific practices, including question formulation, manipulation of conditions, observation and measurement, organization of results, and poster presentation. Notably, students attempted to quantify outcomes using measurement tools and to interpret results through comparison across conditions.

The poster presentations further provided opportunities for students to articulate their reasoning and explain findings based on evidence, supporting the development of scientific communication skills emphasized in STEM education [5].

4. Discussion

The results of this study indicate that cooking-based inquiry activities can effectively enhance junior high school students' awareness of and interest in science while supporting conceptual understanding and scientific thinking.

Cooking, as a familiar and meaningful context, appears to promote affective engagement, consistent with models of interest development emphasizing the importance of personally relevant learning experiences [6]. Furthermore, the observed conceptual shifts suggest that cooking activities can function as a bridge between everyday experience and scientific abstraction.

The inquiry activities provided authentic learning experiences in which outcomes were not predetermined and students were required to interpret unexpected results. Such environments align with contemporary views of inquiry-based STEM education that emphasize modeling, reasoning, and explanation rather than procedural adherence alone [7].



Importantly, this program required no highly specialized laboratory equipment, suggesting high feasibility for implementation in school and outreach contexts. The mixed-grade setting further demonstrated the adaptability of inquiry-based learning to diverse learner backgrounds.

5. Conclusion

This study examined the educational effects of an experiential culinary science program for junior high school students. Both quantitative and qualitative analyses revealed improvements in students' awareness, interest, conceptual understanding, and engagement in scientific practices.

These findings suggest that cooking-based inquiry offers a promising and accessible approach to science and STEM education. By integrating everyday activities with scientific inquiry, such programs can provide meaningful learning experiences that foster both cognitive and affective engagement with science. Future studies should examine long-term learning outcomes and expand participant populations to further validate the educational value of culinary science in secondary education.

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