スーパー・サイエンス・ハイスクールにおける英語による理科授業
―身近な混合物の分離と食品中のタンパク質の検出―

Science Classes in English at a Super Science High School: Separation of Daily Mixtures and Detection of Protein in Foods

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抄録：グローバル社会における理数科教育の充実・発展に寄与することを目指して，本研究では，グローバルな視野を持つ教員の養成に取り組む大学と，グローカル人材の育成や理数科教育に注力している高校が連携し，高校生が英語で諸外国の理科・数学を学ぶグローバルな理数教育を実践した。具体的には，徳島県内のスーパー・サイエンス・ハイスクール（SSH）において，身近な混合物の分離および食品に含まれるタンパク質の検出を学修課題とする２種類の化学の授業を実践した。本実践により，大学および高校がそれぞれ注力する教員養成および人材育成に寄与する教育効果が得られた。
キーワード：理科，英語，混合物，タンパク質，ビウレット反応

Abstract: For contributing to the enrichment and development of science and mathematics education in a global society, we implemented global science and mathematics education for high school students to experience foreign science and mathematics classes in English in collaboration with a teacher training college engaging in training teachers with a global perspective and a senior high school committed to fostering global and local human resources and science and mathematics education. Specifically, we conducted two types of chemistry classes about separation of daily mixtures and detection of proteins in foods at a Super Science High Schools (SSH) in Tokushima Prefecture. This practice was found to provide both the university and the high school with fruitful educational effects on global teacher training and human resource development, respectively.

Keywords: Science, English, Mixtures, Protein, Biuret test

I. Introduction

In science and mathematics education in a global society, it is important to develop universal learning activities which allow anyone to teach and learn anytime and anywhere, regardless of locations, languages, educational resources, environment, etc. Moreover, it is necessary to train teachers to implement these activities effectively, taking advantage of the universality of natural science. From above motivations, we have conducted science and mathematics classes taught in English at high school so far (Terahsima et al., 2018; Gulfan et al., 2019; Sanogo et al., 2020; Bonkoungou et al., 2021; Nderu et al., 2023). In this study, we performed foreign science classes in English for high school students in a collaborative project between a teacher training college engaging in training teachers with a global perspective and a senior high school committed to fostering global and local human resources and science and mathematics education. The outline of the lesson practice is as follows.

- **Date:** November 10th, 2023
- **Place:** Tokushima Prefectural Tomioka-nishi Senior High School (Super Science High School; SSH)
- **Instructors:** International students at the graduate school of Naruto University of Education (the authors' team)
- **Subject content area, lesson topic, and learners:**
  1. Chemistry, "Separation of daily mixtures" for 37 students of the 10th grade of science and mathematics course and 38 students of the 11th grade of general course
  2. Chemistry, "Detection of proteins in foods" for 25

students of the 11th grade of science and mathematics course and 35 students of the 11th grade of general course

In the following sections, we report on the actual results of the above two classes and discuss the outcomes and challenges of the classes based on the participants' performance and the results of the post-questionnaire surveys.

II. Separation of Daily Mixtures

1. Background and objectives

In the preceding lessons, these students had acquired foundational knowledge in the realms of chemistry, specifically focusing on the states of matter—solid, liquid, and gas—and the classification of matter into elements and compounds. The objective of the class was to advance their comprehension and practical skills in this subject. By the end of the lesson, the students were expected to master several key aspects. Firstly, the students were expected to be adept at discerning the most suitable technique for separating a given mixture, thereby enhancing their affective skills.

The lesson aimed to cultivate psychomotor skills as students engage in hands-on activities to separate mixtures composed of different substances. Furthermore, cognitive skills were sharpened through the classification of mixtures into homogenous, heterogenous, and mechanical categories. The overarching process skills involved included observation, description, identification, analysis, explanation, and communication in English. Finally, the integration of values emphasized, encouraged students to make informed decisions in the application of their newfound knowledge. This comprehensive approach ensured a well-rounded understanding of the subject matter and its practical implications.

Table 1 Lesson plan of the class

Time/Activity	Student activity	Teacher activity	Remarks
Introduction (5 minutes)	Pay attention respond to teacher questions	Recap on the previous class. Explain concept map	Greeting
Engagement with the substances. (8 minutes)	Students will work in groups with substances	Introduce homogenous and heterogenous concepts. Supervise the students as they examine the labeled substances.	Hands-on activity.
Exploration of substance. (15 minutes)	Explore the difference between the substances and find appropriate separation technique.	Ask students to separate the mixtures.	Note taking on table and application of method.
Explanation of methods. (7 minutes)	Students will explain why they were able to/not able to separate some of the substances. Explain the methods that can be used to separate those substances.	Ask for students' ideas on ways the substances could be separated. Ask students to fill the table.	Presentation in groups.
Elaboration (10 minutes)	Elaborate on their findings using theoretical knowledge Categorize the substances according to mechanical, homogenous and heterogenous mixtures.	Teacher puts answers on board. Importance in real life	Presentation in groups.
Evaluation	1. Students understand why some substances can be easy to separate then others. 2. Students see the application of theoretical knowledge and get hand-on experience. 3. Students deepen their knowledge through discovery method.		

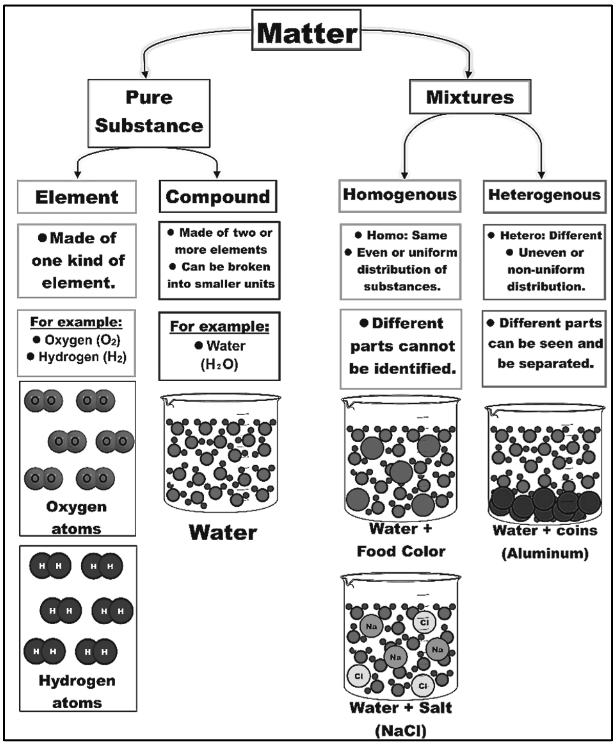

Figure 1 Concept map showing relationship between pure substances and mixtures

2. Lesson plan and materials

This lesson was performed based on the lesson plan as shown in Table 1. Students attentively participated and engaged well in a concept map explanation on the board as illustrated in Figure 1. The teacher initiated a recap of the preceding lesson about pure substances, setting the stage for the day's activities. Subsequently, students collaborated in groups, observing various substances on the table after the teacher introduced concepts of homogenous and heterogenous

Table 2 Part of the word list used in the lesson

English	日本語
1. Matter	物質
2. Compound	化合物
3. Element	元素，単体
4. Mixture	混合物
5. Pure substance	純物質
6. Homogenous	均質な
7. Heterogenous	不均質な
8. Even distribution	均一な分布
9. Non-uniform distribution	不均一な分布
10. Classification	分類
11. Separate	分離する
12. Atom	原子
13. Identification	識別
14. Coins	コイン

Table 3 Worksheet for group activity

MATERIAL	SEPARATE YES	SEPARATE NO	Technique used	Explain method used/to be used.	Substance Classification
Example, MIXED NUTS	○		Pipette	-Mechanical mixture.	Homogenous
			○ Hand/Manually	-Solid substances of	
			Filter paper	**same size.**	○ Heterogenous
			Magnet	-Possible to separate	
			Sieve	by **hands.**	
1. SAND + WATER			Pipette		Homogenous
			Filter paper		
			Magnet		
			Hand/Manually		Heterogenous
			Sieve		
2. SALT + WATER			Pipette		Homogenous
			Hand/Manually		
			Filter paper		Heterogenous
			Magnet		
			Sieve		
3. OIL + WATER			Pipette		
			Hand/Manually		Homogenous
			Filter paper		Heterogenous
			Magnet		
			Sieve		
4. FLOUR + RICE			Pipette		Homogenous
			Hand/Manually		
			Filter paper		Heterogenous
			Magnet		
			Sieve		
5. COFFEE + WATER			Pipette		
			Hand/Manually		Homogenous
			Filter paper		Heterogenous
			Magnet		
			Sieve		
6. IRON POWDER + SAND			Pipette		Homogenous
			Hand/Manually		
			Filter paper		Heterogenous
			Magnet		
			Sieve		

mixtures. Prior to the lesson practice, we prepared a word list used in this lesson as exemplified in Table 2 and distributed it to students for preparation.

3. Lesson practice

1) Engagement

The students worked through hands-on activities involving the examination of labeled mixtures; Mixed nuts, sand and water, salt and water, oil and water, flour and rice, coffee and water, iron powder and sand. To separate these mixtures the students were given a sieve, a filter paper and a funnel, a pipette and a magnet.

2) Exploration

In the exploration phase, students noted the differences among substances and identified suitable separation techniques, documenting their observations and application methods.

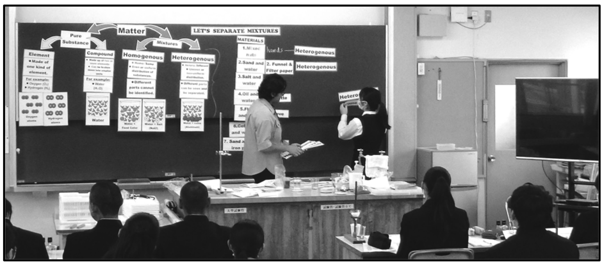

Figure 2 A student answering question on the board

3) Explanation

Students explained their success or challenges in separating substances and expounded on applicable separation methods using the group worksheet as shown in Table 3. The teacher facilitated this process by eliciting students' ideas and encouraging them to complete the worksheet collaboratively.

4) Elaboration

In the elaboration phase, students applied theoretical knowledge to categorize substances into homogenous, and heterogenous mixtures, while the teacher put answers on the board. The teacher highlighted the real-life significance of the experiments, students presented their findings in the worksheet and on the board as shown in Figure 2.

5) Evaluation

The evaluation phase gauged students' understanding of substance separation, the practical application of theoretical knowledge, and the deepening of their understanding through a discovery-based approach. An online questionnaire was distributed to assess individual students' understanding.

4. Challenges and limitations

The completion of four separation experiments, involving the isolation of sand from water, iron fillings from sand, rice from flour, and oil from water, proved to be more time-consuming than anticipated. The constrained space of the narrow lab bench exacerbated the challenges encountered during the procedures, hindering effective communication among students. It is evident that a wider lab bench would have been more conducive to the intricate nature of the separation processes. In the specific case of separating sand from water as shown in Figure 3, the designated method employing filter paper and a funnel deviated from the more appropriate technique of decantation, especially considering the volume of water present in the samples. The use of filter paper and funnel led to complications, as the sand stuck to

Figure 3 Students separating sand from water using the filter paper and funnel

the base of the cup, hindering the separation process.

5. Results and discussion

1) Student questionnaire

The questionnaire was distributed to a total of 75 students. The data collection period spanned one week. A total of 59 respondents completed the questionnaire, leading to the response rate of 79%. The questions and the results are shown in Figure 4.

The purpose of the questionnaire was to analyze and present the feedback received from students regarding the lesson. The experiment aimed to enhance students' understanding of the differences between heterogeneous and homogeneous mixtures. While overall satisfaction and comprehension were positive, there were notable areas of concern raised by some students.

2) Summary of positive feedback

All students, without exception, expressed enjoyment of the class. They appreciated the content of the lesson and demonstrated a clear understanding of the distinctions between heterogeneous and homogeneous mixtures. This positive response suggests that the fundamental goals of the experiment were achieved in terms of engaging students and imparting key concepts.

3) Areas of concern

Difficulty in following the lesson: One student strongly disagreed that the lesson was easy to follow, and three students expressed a similar sentiment and disagreed. This raises a concern about the clarity and accessibility of the instructional materials or teaching methods used during the experiment.

Relevance of content to daily life: Eight students disagreed that the content was relevant to daily life. This indicates a potential gap in demonstrating the real-world applications of the concepts covered in the experiment. Addressing this concern could enhance the perceived utility of the material.

Lack of stimulated interest: The experiment failed to stimulate the interest of three students. Further investigation is required to identify the specific aspects of the experiment that failed to capture their attention and engagement.

Time constraints: Ten students reported a lack of sufficient time to complete the experiment. This issue may be attributed to the complexity or length of the experiment, indicating a need for adjustments in future implementations to ensure that each student can comfortably complete the tasks within the allotted time.

Dislike of studying chemistry in English: A significant number of students (12) disagreed with the statement that they like studying chemistry in English. This raises questions about language preferences and potential challenges faced by students in comprehending the material presented in English.

6. Brief summary

The class successfully aimed to enhance students' comprehension and practical skills in the separation of mixtures, fostering psychomotor and cognitive skills. Despite positive feedback on overall satisfaction and understanding, several challenges and areas of concern

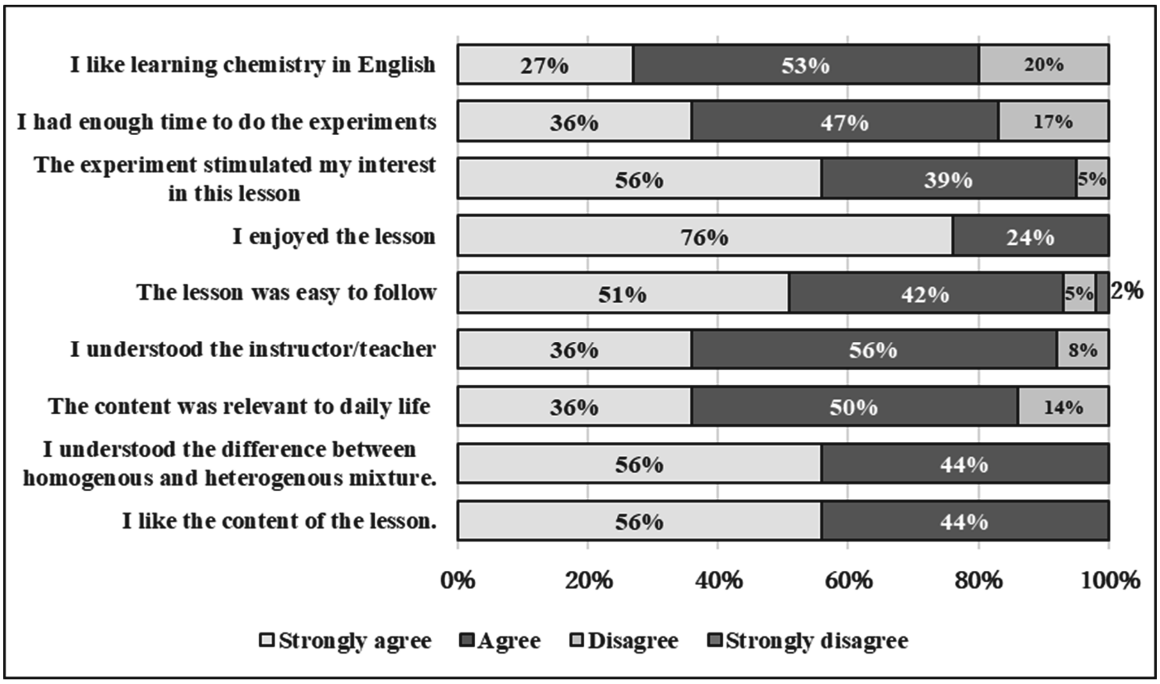

Figure 4 Results of questionnaire conducted for the 10th and 11th grade students (n = 59)

emerged. Time constraints and spatial limitations impacted the efficiency of separation experiments, suggesting the need for better-equipped facilities. Addressing students' difficulty in following the lesson and enhancing the relevance of content to daily life are crucial for improving instructional methods. Additionally, investigating the lack of stimulated interest and addressing language preferences, especially the dislike of studying chemistry in English, can contribute to a more engaging learning experience. This comprehensive feedback informs future adjustments to optimize the effectiveness of similar lessons and ensure a better understanding of the subject matter.

III. Detection of Protein in Foods

1. Background

Chemistry is a branch of natural science that deals principally with the properties of substances, the changes they undergo, and the natural laws that describe these changes. Chemistry is also related to other scientific areas, such as math, physics, biology, geography. Chemistry seeks to combine theory and practice to explain various everyday phenomena. It is in this context that the theme of the lesson "Identifying the existence of proteins in food using the biuret test" links aspects of chemistry and biology. The biuret test

Table 5 Experimental setting for Biuret test

Materials and reagents
5 test tubes, 5 backer cups,2 pipettes, 2 pair gloves, soy protein powder, 2 eggs, milk, distillated water, rice, agar powder, gelatin powder, cooper sulphate ($CuSO_4$) aqueous solution, and Sodium hydroxide (NaOH) aqueous solution
Procedure
1-Prepare five solutions of soy protein, eggs, milk, distillated water and rice in each backer cup. 2-Put each solution of 5 mL into each test tube. 3-Put five drops of NaOH solution into the five test tubes respectively, and shake them. 4-Put five drops of $CuSO_4$ solution into the five test tubes respectively and shake them very well. 5-Observe what happens in each solution and take the note.
Expected results and conclusion
- The colors of the solutions of soy protein, egg, and milk turns to violet/purple. - For the solution containing egg, the violet color is intensive than those for others solutions. - The colors of the solution of rice and distillated water remains unchanged. - From the results of Biuret test, soy protein, egg and milk include protein, especially egg has much protein, while rice water and distilled water include little or no protein.

Table 4 Lesson plan for the chemistry class about detection of protein in foods

Duration/ Part of the lesson	Teacher's activity	Students' activity	Teaching strategy
Pre-requisites 5 min	- Ask the students to give four examples of foods. -What are the types of foods that you know?	- Give examples about foods. - Answer the question.	- Questions and answers
Development 15 min	- After the responses and clarification, ask the name of the main nutrients included in foods. -Instruct and demonstrate the practical activity to the students by comparing the results for soy protein and distilled water.	- Answer to the questions. - Observe and listen attentively.	- Questions and answers - Observation
Activity 20 min	- Give orientation for the group work. - Ask what did you identify in the observation.	- The students perform experiments and fill in the results in the worksheet. - Two groups make the presentation.	- Group work - Presentation
Conclusion 5 min	- Demonstrate the additional experiment using agar and gelatin powders. - Orient the students to make a summary about the lesson and give conclusion	- The students state what they learned during the lesson.	- Group work

Table 6 A part of worksheet for students' activities

1- Fill in the table below regarding the results you obtained in each solution.

Solutions	Color	
	Before	After
Egg		
Milk		
Rice		

2- Observing the experiment which solution do you think has more protein than others?

is commonly used in chemistry labs as a quick way to detect the existence of protein in food samples.

2. Lesson topic and objectives

The theme of the lesson is "Nutrients (Proteins)". The key question for this topic is "What foods contain protein?". To answer this question, it is necessary to carry out a test known as "Biuret test". Biuret test can detect protein in solutions by changing solution's colors into violet or purple. This experiment is simple to practice and requires only simple materials and reagents. The lesson was prepared and performed to facilitate the students' understanding of the materials used, and to improve their experimental skills in learning chemistry in English.

3. Teaching plan, materials, and experimental procedure

This lesson was performed based on the teaching plan as shown in Table 4 with the experimental setting as listed in Table 5. We also prepared a simple worksheet with a word list for students' recording and learning aids, and distributed it to each student. A

Figure 5 Examples of actual scenes of the class

part of the worksheet is shown in Table 6.

4. Results and discussion

The lessons were successful in both classes as the students understood the purpose and procedure of the experiment and carried it out without any difficulties. Figure 5 shows a few scenes of the class. Through the group activities, the students were able to find egg and milk contains protein as well as soy protein based on their experimental results.

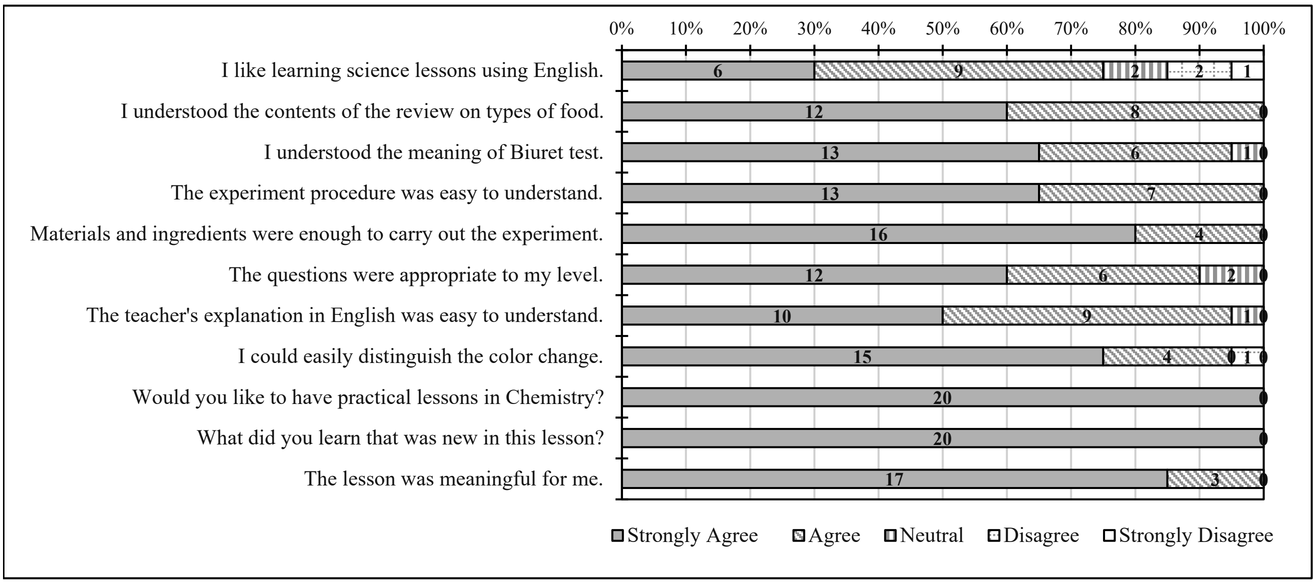

Figure 6 Results of the post-questionnaire survey on the chemistry class (n = 20)

After the lessons, we conducted a questionnaire survey for the students via online response form to collect their feedback, and 20 students responded. The questions and the results are shown in Figure 6. We found that most of the students responded to all questions positively. The survey revealed that this chemistry lesson taught in English was suitable for students' scientific interest and skills and the experiment was easy and clear to perform and understand correctly. Based on the results mentioned above, the students were found to achieve the lesson's objectives and understood that not all foods contain protein successfully.

IV. Conclusions

We conducted aforementioned chemistry classes about separation of daily mixtures and detection of protein in foods in English for high school students. Based on the students' performance in the classes and their feedback obtained from the post-questionnaire surveys, the objectives of the classes were evaluated to be achieved successfully. This achievement could result from not only the teachers' careful preparations but also helpful supports from assistants and school teachers. Moreover, the school laboratory had sufficient conditions with enough materials to carry out the experiment as group activities.

The partnership between the Naruto University of Education and Tomioka-nishi Senior High School can play an important role in helping Japanese students improve their ability to understand aspects of the natural sciences in English. The students' passive responses during the lesson cannot be due to the lack of understanding in the contents of the lesson but difficulties in expressing themselves in English. Such activities should be continued in order to increase Japanese students' ability to express themselves in English and to interpret various everyday phenomena and then to enable them to interact with the world.

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