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(Citation)

紀要研究 : 神戸大学附属中等 論集, 10:1-6

(Issue Date)

2026-03-31

(Resource Type)

departmental bulletin paper

(Version)

Version of Record

(JaLCD0I)

<https://doi.org/10.24546/0100502602>

(URL)

<https://hdl.handle.net/20.500.14094/0100502602>



Essay

The “Nori” Irony: From Edible Seaweed as a PCR Template to Stationery Glue as a Negative Control

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Polymerase chain reaction (PCR) is a central technique in molecular biology with broad applications in contemporary society. In secondary education, however, its principles are often taught abstractly through lectures rather than hands-on experience. This study evaluated an educational practice designed to enhance students' familiarity with molecular biology and foster scientific inquiry skills by using nori (edible seaweed), a familiar food item, as a source for DNA extraction. A total of 210 students conducted DNA extraction from commercially available roasted nori, followed by PCR amplification of a target gene region and visualization by agarose gel electrophoresis. Pre- and post-activity questionnaires were administered to assess changes in students' perceptions. DNA amplification from processed seaweed was achieved with a high success rate, enabling students to recognize DNA in everyday food as a tangible biological entity. Notably, one group mistakenly brought stationery tape glue instead of nori. The absence of amplification from this sample unintentionally provided a powerful negative control, allowing students to directly observe the specificity of PCR reactions. This practice demonstrates that integrating familiar materials with advanced molecular techniques can effectively stimulate scientific interest and transform unexpected errors into opportunities for meaningful scientific discussion. Such approaches highlight the importance of contextualizing specialized scientific methods within everyday experiences to promote scientific literacy.

Keywords: PCR, Molecular Biology, Origin Identification, Marine Products

1. Introduction

In modern life sciences, the polymerase chain reaction (PCR) method has become an indispensable foundational technology across diverse fields such as genetic diagnosis, infectious disease testing, forensic science, and food inspection. Particularly following the recent SARS-CoV-2 pandemic, the term PCR has become widely recognized throughout society. However, the number of people who accurately understand its principles and scientific significance is not necessarily large, making the improvement of scientific literacy a societal challenge.

In Japanese secondary school biology education, molecular biology content has gained increasing emphasis year by year, with DNA structure, replication, and

gene expression mechanisms becoming core areas in the curriculum guidelines. However, molecular biology, which deals with microscopic phenomena within cells, is highly abstract and remains one of the most challenging fields for students to grasp. Traditional classroom-centered education often focused solely on acquiring textbook knowledge, limiting its ability to help students perceive DNA as a tangible substance and recognize it as a subject for scientific inquiry.

Introducing PCR methods into educational settings not only enables students to visually and tangibly grasp the principles of DNA replication but also provides a valuable opportunity to experience cutting-edge biotechnology firsthand. However, the current reality is that implementation remains postponed in many schools due

to challenges such as the lack of expensive experimental equipment (like thermal cyclers), the difficulty of conducting the experiments within limited class time, and the technical hurdles faced by teachers.

On the other hand, recent educational policies and advances in biotechnology are creating an environment capable of addressing the aforementioned challenges. Through the research and development outcomes of the Super Science High School (SSH) initiative promoted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), expertise in introducing and maintaining advanced experimental facilities has been accumulated. Consequently, an increasing number of schools, particularly hub institutions, are equipped with sophisticated analytical instruments. This trend is also spreading to surrounding schools through equipment lending and joint practical training programs, steadily strengthening the foundation for experimental research within high school settings.

Technologically, the significant trend is toward lower-cost, higher-performance equipment. Thermal cyclers, which cost over one million yen until around 2000, now have entry-level models priced below 500,000 yen by 2026, making their acquisition within limited budgets a realistic possibility. Furthermore, reagents with high stability at room temperature and high-performance, inexpensive products with dramatically improved reaction speeds have become widespread. Consequently, with the necessary knowledge and skills, even life science education in secondary schools can now introduce students to aspects of the technology used in actual life science research and development settings.

Furthermore, the expansion of custom DNA synthesis services has dramatically increased the freedom in designing educational materials. It is now possible to have primers (DNA oligonucleotides) synthesized for amplifying specific target genes at an extremely low cost of approximately ¥13 per base pair. A rapid supply system has been established, delivering the primers within days of ordering. The proliferation of such “low-cost,

high-speed, high-precision” tools has created an environment where educators can flexibly design unique inquiry projects, such as this practice’s “comparison of the origins of common foods,” without relying on existing kits. These shifts in social and technological context represent a crucial turning point, evolving PCR practice in high school biology education from a “specialized experience for a select few” into a “standard inquiry tool” that enables students to formulate their own questions and verify them.

In this study, I selected “nori” (dried seaweed or roasted seaweed), an ingredient extremely familiar on Japanese dining tables, as the material for extracting DNA to serve as a template for PCR. Nori is one of the important marine products, and its quality labeling is appropriately managed based on laws and regulations. Sawada et al. (2014) of the Food and Agricultural Materials Inspection Center (FAMIC), an independent administrative agency under Japan’s Ministry of Agriculture, Forestry and Fisheries, investigated a method for identifying the origin of nori using DNA analysis with one primer set and two restriction enzymes. Experiencing this technique could provide students with a practical molecular biology laboratory exercise. Generally, molecular biology labs often use *E. coli* or specialized reagents, which tend to appear as “unknown substances” far removed from students’ daily lives, contributing to the abstraction of learning content.

In contrast, nori is a biologically derived material sourced from red algae (such as *Susabi-nori*), yet it circulates as a processed product, making it an extremely familiar presence for students. The process of extracting invisible DNA from this familiar food ingredient and amplifying/visualizing specific gene regions via PCR is highly effective for making students realize how science and technology are closely linked to daily life and food safety (such as preventing food fraud and identifying varieties). Furthermore, demonstrating that genetic information can be analyzed even from processed foods helps students understand the usefulness and robustness of bi-

otechnology. This is expected to serve as a powerful motivator, sparking students' curiosity and desire for inquiry.

This study conducted practical sessions on PCR-based gene amplification and electrophoresis for high school students at Kobe University Secondary School (KUSS). This paper presents strategies for effectively conducting experiments within limited educational resources. Based on pre- and post-surveys and descriptive analysis of worksheets, it reports on changes in students' interest in molecular biology and the educational effects on enhancing scientific inquiry skills.

2. Methods

2.1. Implementation Targets and Educational Context

This study prepared two methods—Basic and Advanced—tailored to students' learning levels and class hours. The Basic method set the goal of confirming band appearance via agarose gel electrophoresis of PCR-amplified products. While this experiment cannot identify the seaweed's origin, it allows students to experience the molecular biology workflow: amplifying DNA extracted from a sample and verifying its presence. The Basic Course was implemented in February 2025 with 117 fourth-year (10th grade) students and 59 fifth-year (11th grade) students who had selected specific subjects at Kobe University Secondary School. Using “nori” (seaweed), a familiar food for students, as the subject, the aim was to deepen their understanding of molecular biological techniques by examining genetic differences based on origin. The lesson was conducted over three 50-minute periods. The first session served as preparatory learning. Using Sawada et al. (2014) as background, the research design was shared with students. Each student was given one 1.5mL microtube and instructed to collect their own nori sample. The second session covered DNA extraction and PCR reaction mixture preparation. The third session involved confirming results via electrophoresis and conducting analysis, totaling three hours.

The advanced section adds to the basic content by

digesting PCR products with one of two restriction enzymes, MspI (1150A, Takara) or XspI (1095A, Takara), and performing electrophoresis with the undigested products. These steps enable the detection of nucleotide sequence differences originating from single-base substitutions in ancestral populations through electrophoresis patterns. For example, using nori seaweed—often sold as furikake seasoning without specific origin labeling—as a sample provides a more practical experience. This activity was conducted as part of the Future Innovator Training (FIT) program at Kobe University Secondary School (KUSS), involving 14 students from grades 1 to 6 at the school, along with 20 high school students and 6 accompanying teachers in Hyogo Prefecture. These training sessions were conducted in accordance with the school's safety guidelines.

2.2. Selection of Experimental Materials and Sample Preparation

Students used nori (edible seaweed) samples they brought individually. Additionally in one case, a student incorporated “tape glue” from stationery brought by students due to a misinterpretation of instructions into the experimental system as a comparison control lacking biologically derived DNA. Each sample was cut into approximately 3 mm squares, suspended in 75 μ L of lysis solution (25 mM NaOH, 0.2 mM EDTA), heated at 95°C for 10 minutes, and then neutralized with neutralization solution (40 mM Tris-HCl, pH5.0) followed by inversion mixing (Truett et al., 2000). The supernatant was then spun down and used as template DNA solution for subsequent PCR reactions.

The internal transcribed spacer 1 (ITS-1) region, located between the 18S ribosomal RNA gene region and the 5.8S ribosomal RNA gene region, has been found to be useful as an analytical target. This region is widely used for sequence comparisons within and between species (Niwa et al., 2006; Touhara et al., 2013). Following Sawada et al. (2014), the primer set used regardless of origin is as follows: Forward Primer: 5'-CCG TAG

GTG AAC CTG CGG AAG GAT CAT-3', Reverse Primer: 5'-CAA GAT ATC CAC CGC TAA GAG TTG TAT-3'. This primer pair is designed to amplify a 432 bp DNA fragment from the target region (Sawada et al., 2014).

2.3. PCR Reaction and Thermal Cycling Conditions

The PCR reaction mixture was prepared using TaKaRa Ex Premier™ DNA Polymerase (RR371A, Takara) in a total volume of 10 µL. Amplification was performed using a thermal cycler (GE-96G, GeneExplorer, Bioer Technology) with the following thermal cycle: The cycle consisting of denaturation (98°C for 10 seconds), annealing (55°C for 15 seconds), and extension (68°C for 20 seconds) was repeated 35 times to complete the reaction. After the reaction, the reaction mixture was stored at 16°C until product extraction to protect the thermal cycler. The second class period ended after the students loaded the samples into the thermal cycler.

2.4. Visualization and analysis by electrophoresis

Confirmation of PCR amplification products was performed using electrophoresis on a 1.5% agarose gel (Midori-Green Xtra, NE-AG13, NIPPON Genetics). The gel was run at a constant voltage of 100 V for 15 minutes. Amplified fragment sizes were estimated using a DNA size marker (GeneRuler Ready-to-Use DNA Ladders, SM0333, Thermo Fisher Scientific) as a reference. Since the Midori-Green contained in the agarose gel binds to the DNA after electrophoresis, the presence and intensity of bands were observed under a transilluminator equipped with a blue LED. Comparing electrophoresis patterns confirmed commonalities and differences between origins, while the presence or absence of amplification in the adhesive paste served as an indicator of reaction specificity.

2.5. Evaluation of Educational Effectiveness

To measure the educational impact of this practice, a questionnaire survey was conducted before and after

the practical training. The questions covered descriptions and evaluations of the experimental results, analysis of the underlying causes, the extent to which the lab notebook was utilized, interest in molecular biology, understanding of the societal implementation of PCR technology, and changes in awareness regarding “the relationship between everyday objects and science.” Qualitative analysis of the written responses was conducted, with particular evaluation of how insights gained from the unusual sample of “tape adhesive” influenced students’ scientific thinking (understanding of control experiments).

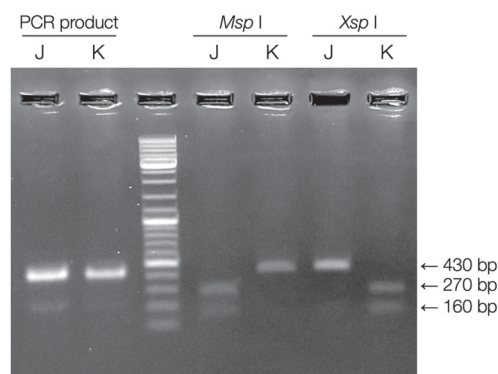


Figure 1 | Agarose gel electrophoresis patterns of PCR products, MspI digestion products, and XspI digestion products when using Japanese seaweed (J) and Korean seaweed (K) as samples. Products derived from Japanese seaweed undergo MspI digestion, while those derived from Korean seaweed undergo XspI digestion.

3. Results

3.1. ITS-1 region amplification and electrophoresis

PCR and electrophoresis performed using samples prepared by each group revealed a distinct band around 430 bp, corresponding to the targeted ITS-1 region, in most samples of nori from Japan, Korea, and those without labeling indicating origin. Furthermore, in the advanced practical session, samples digested with restriction enzymes clearly distinguished between Japanese and Korean origin based on their band patterns (Fig. 1). The bands from both types of samples matched in migration distance, indicating no significant size difference between origins at least within the target region of

the primers used in this experiment. However, some Korean seaweed samples showed a band around 350 bp, consistent with the report by Sawada et al. (2014). In contrast, no amplification bands were detected at all in samples using stationery “tape glue.” This visually confirmed the absence of contamination in the reagents and equipment used in this experimental system.

3.2 Qualitative Analysis of Learners' Attitude Change

The results of questionnaires administered before and after the practicum showed an increase in students' interest in molecular biology and biotechnology. For example, one student stated: “I think I gained a much better understanding of the PCR test, which I had only known about through words, by actually performing the experiment. Using everyday materials like processed foods in experiments suggested that abstract genetic concepts became linked to tangible understanding, reinforcing the importance of thoroughly verifying theories and deepening comprehension precisely because the topics were closely related to daily life.”

3.3 Educational Impact of the “Tape Glue” Incident

The most noteworthy outcome of this experiment was how the mistakenly brought “tape glue” inadvertently served as a negative control, deepening students' logical thinking. When electrophoresis results showed a distinct band for nori seaweed, yet no DNA amplification was observed in the reaction solution containing tape adhesive, the classroom erupted in surprise and spontaneous discussion about why the results diverged. Analysis of worksheet entries revealed descriptions pointing to the logical significance of control experiments, such as: “The fact that only the tape nori reacted confirmed that no foreign substances were mixed into the chemicals used in the experiment.”

3.4 Stimulating Scientific Inquiry Through Regional Comparison

The comparative study of Japanese and Korean seaweed provided students with a perspective on “scientific

analysis.” Regarding the lack of visible differences between the two samples, students expressed opinions such as, “It's surprising that the basic genetic sequences of the cells are the same, even though they look and taste different,” and “Would more detailed examination reveal differences?” These comments reflected a desire for further inquiry. This outcome demonstrates that compared to experiments examining a single sample, a design involving the comparison of multiple origins effectively deepens students' insights into the commonality and diversity of living organisms.

4. Discussion

4.1 The Effectiveness of Nori as Educational Material and the Tangible Understanding of DNA

In this practice, the stable amplification of the ITS-1 region from commercially available “roasted nori” suggests the importance of material selection in molecular biology education. While DNA is typically considered prone to fragmentation by heat and processing, DNA was demonstrated to be sufficiently detectable even from foods subjected to harsh processing steps. By analyzing “table nori,” a familiar food item for students, DNA—previously a mere symbol in textbooks—was redefined as a tangible substance common to all living organisms. This “connection between everyday life and science” is considered the primary factor supporting the high level of interest and improved understanding observed in the post-experiment survey.

4.2 Deepening Scientific Literacy Through the “Tape Adhesive” Case Study

The incidental occurrence of bringing “tape adhesive” during this practice provided an excellent opportunity to reconsider the significance of control experiments in scientific research. While “failure” in experiments is often dismissed as procedural error, in this case it was elevated into powerful evidence proving the specificity of the reaction: “DNA is not detected from non-biological samples.” The moment when the student spontaneously realized that “the absence of bands on the

tape adhesive confirms the validity of the nori results” transcended mere knowledge acquisition. It was a moment where logical thinking based on scientific evidence—scientific literacy—was cultivated. The decision to utilize the misunderstanding arising from ambiguous instructions as an educational “control” rather than eliminating it demonstrates the importance of flexible teacher intervention in inquiry-based learning.

4.3 Considerations on Commonality and Diversity through Regional Comparison

The matching ITS-1 region bands observed in Japanese and Korean nori visually demonstrated the fundamental biological principle of “commonality of life.” The ITS-1 region exists between the regions encoding ribosomal RNA factors, making it present in many species. However, sequence differences between groups are significant, making it suitable for identifying lineages. While students anticipated differences based on origin, obtaining identical results provided an experience touching on a fundamental biological truth: “Even when appearance and taste (phenotype) differ, the basic blueprint for sustaining life (genes) is shared.” Conversely, this outcome suggested that more detailed origin identification requires advanced techniques, such as analyzing base sequences via Sanger sequencing to construct phylogenetic trees, thereby sparking students’ further curiosity for inquiry.

4.4. Future Challenges and Recommendations for Educational Practice

This study confirmed the feasibility and high educational effectiveness of PCR experiments in high school settings. However, challenges remain, including the cost of introducing equipment and managing time to complete the process from extraction to electrophoresis within class hours. While thermal extraction was used this time to reduce time, further exploration of cheaper and faster methods is needed. Furthermore, the next focus for practice will likely be how to incorporate “learning born from misunderstanding,” as seen here, into a

reproducible curriculum, or how to set tasks connected to more societal contexts, such as actual food fraud issues or environmental DNA surveys.

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Acknowledgements

This work was supported by the Discretionary Funds of the Director of Attached Schools’ Department allocated to the author by Kobe University Secondary School (KUSS), and incorporates findings obtained with support from JSPS KAKENHI Grant Number JP23K14220.

Competing interests

The author declares no competing interests.

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