ISSN 1447-0209

AJBE

Asian Journal of Biology Education

Vol.17, December 2025

Asian Association for Biology Education

The Asian Journal of Biology Education

Volume 17: December 2025

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_2

Practical Report

Diagnosing and remediating elementary students' misconceptions about the 'Growth of Plants' Unveiling misconceptions using drawing and crafting solutions for conceptual change

Rani Prasad[1)*], Narendra Deshmukh[2)], Rafikh Shaikh[3)]

[1)]*School of Education, Tata Institute of Social Sciences, Mumbai, India,*
[2)]*Homi Bhabha Centre for Science Education - TIFR, Mumbai, India*
[3)]*Centre of Excellence in Teacher Education, Tata Institute of Social Sciences, Mumbai, India*

(Received: 20 October 2024; Accepted for publication : 1 April 2025)

It is common for students to enter the class with various understandings of a biological concept. Any misconceptions, if left unaddressed, can persist and become more difficult to correct as students progress through their studies. Identifying and eliminating these misconceptions early is crucial. This study identified misconceptions held by elementary-grade students about the "Growth of Plants". It investigated the reasons behind the misconceptions in a government Hindi Medium School in the suburban area of Mumbai, Maharashtra, India. The study utilized a drawing method to identify the misconceptions. After diagnosing the misconceptions, a hands-on constructivist pedagogical approach was utilized to remediate the students' misconceptions. This approach consisted of three activities: student-led plant cultivation from seeds, experiments altering environmental conditions necessary for growth, and training using photographs depicting each stage of the plant life cycle. A thematic analysis for a holistic understanding of plant parts and plant growth was adopted for the study. This study revealed the effectiveness of drawing methods to diagnose misconceptions; some were similar to those in previous studies, such as the fact that seeds are not alive and attributing anthropomorphic explanations for the growth of plants. The hands-on constructivist pedagogical approach involving collaborative learning led to conceptual change, evidenced by the post-tests (drawings and interviews) conducted.
Key words: *conceptual change, constructivism, drawing, elementary students, growth of plants, misconceptions, remediation*
***Author for correspondence:** raniprasad010@gmail.com

INTRODUCTION

Children start to construct knowledge when they experience a phenomenon in real life. This informal construction of knowledge can happen while communicating and interacting with others; it is not always parallel and at times contradicts scientific claims. These are termed misconceptions, alternative conceptions, alternative frameworks, intuitive beliefs, preconceptions, spontaneous reasoning, children's science, and naïve beliefs (Karpudewan *et al*., 2017). The researcher has opted to employ the term "misconceptions" due to its widespread familiarity among teachers and students. For convenience, this term will be used throughout the study. However, we do not claim that these are purely misconceptions. Multiple research shows that students come to class with some prior knowledge (preconceptions/mis-conceptions) and construct their own knowledge on pre-existing knowledge. This fact could be a problem as the knowledge taught in schools may differ from everyday life understandings and this can impede comprehension. As a result, identification and reorganization of existing knowledge is necessary, and this process is usually referred to as conceptual change (Read, 2004).

Teachers should adopt appropriate and effective pedagogies to identify and remediate these misconceptions. The steps of conceptual change involve first the dissatisfaction with the current concepts and second, the new concepts must be intelligible, plausible, and fruitful, i.e. students must be able to recognize the concepts and use them to explain other new experiences (Duit and Treagust, 2003; Duit *et al*., 2013; Kural and Kocakulah, 2016; Posner *et al*., 1982). However, this process is often difficult and requires careful identification of the misconceptions, followed by appropriate pedagogical strategies to address those (Karpudewan *et al*., 2017).

A social constructivist approach involving activities and focus group discussions can effectively bridge the gap (Bruner, 1961; Dewey, 1933; Vygotsky, 1986) as it involves working together to solve problems or create products (Summers and Volet, 2010; Tolmie *et al*., 2010). While it requires training for effective implementation, it offers numerous benefits, including social skill development, positive interdependence, reduced anxiety, improved problem-solving, and enhanced academic performance (Clark and Baker, 2007; Tolmie *et al*., 2010). The objectives of the research encompass diagnosing misconceptions about plant growth through drawing, while also constructing a teaching strategy to improve conceptual understanding in this area.

The literature highlights the importance of identifying misconceptions early is essential to preventing the building of new concepts on flawed understandings. Addressing misconceptions before teaching and developing targeted pedagogical approaches promotes effective science learning. These misconceptions, if left unaddressed, can persist and become more challenging to correct as students' progress through their studies. Additionally, the instructions provided by the teachers may combine with the pre-existing mental models that the students hold, this can lead to formation of a hybrid/synthetic model (Goris, 2010; Fazio, *et al*., 2015). This model reflects a combination of the new concepts introduced by the teacher and the students' prior knowledge, beliefs, and understanding. These hybrid models have some explanatory power despite the fact that it is scientifically incorrect. Vosniadou and Skopeliti (2017) argue that misconceptions should be treated as hybrid conceptions as it represents attempts to bridge initial naive, and intuitive beliefs with scientific information. Identifying and eliminating these mis-conceptions or working on these hybrid models early on is crucial, but research on diagnosing and remediating them at the primary level is limited (Laeli *et al*., 2020; Verma and Choudhuri, 2022).

During elementary grades, students have varied understandings of biological concepts through direct experiences with living things, their life cycles, and their habitats. These understandings of the physical and natural world do not align with the scientific community (Barman *et al*., 2006). According to Carey, S. (1987), young children's knowledge in domains such as biology develops by intuitive, experience-based ideas, which, while meaningful to them, are not initially consistent with scientific views. Over time, with exposure to formal education, these intuitive ideas gradually evolve and align more closely with accepted scientific concepts.

Building a conceptual understanding of plant life in the elementary grades is necessary to anchor a more complex understanding student's need in later grades to reason about the twenty-first century's global biological issues (Zangori and Forbes, 2015). Considering the concept of "Plants and Growth of Plants", various research has indicated that elementary students have reported various misconceptions. Some of it includes ascribing human characters to plants or anthropomorphic explanations for the growth of plants (Barman *et al*., 2006). Additionally, the widespread "plant blindness" and preference for studying animals over plants highlight the challenge of engaging students in plant-related concepts. Addressing misconceptions through hands-on, interactive methods is crucial to fostering appreciation and deeper understanding of plants' ecological and biological significance (Bawingan *et al*., 2024). Hence, it is crucial to diagnose and remediate the misconceptions around the topic "Growth of plants." Therefore, this study aims to address the following research questions:

Research Questions

1. What are the students' prior understanding of "growth of plants" concepts?
2. What is the effectiveness of the "Hands-on Constructivist Pedagogical Approach" model in remediating students' mis-conceptions about the "growth of plants"?

METHODOLOGY

Sample

The sample consists of 22 grade 3 and 28 grade 5 students (elementary students) from an urban school in the Suburban district. The methodology adopted is convenience sampling to get a school after permission from an accessible and physically proximity school, aligned with the researcher's language preference (Hindi).

The researchers were aiming to work with grade 3 students as the topic is a part of their curriculum, however, the school lacked teachers and the grade 3 class was merged with grade 5, creating a multi-grade class.

Site

The school, located in a suburban area of Mumbai, India, had separate sections for Marathi, Hindi, and Urdu mediums, each with its own principal. It operated in morning and afternoon shifts. Due to a teacher shortage, one teacher managed multiple grades and subjects simultaneously. The researcher visited during the afternoon session to collect data.

Method

A qualitative method design was used to diagnose misconceptions of elementary students in Environmental sciences, explicitly focusing on the "Growth of Plants", taught to Grade 3 students as a part of the Maharashtra State Board Environmental Sciences curriculum in the chapter "Growing Up and Growing Old" (For book link: https://books.ebalbharati.in/ebook.aspx). The chapter includes sections on "As we grow" and "Growth of plants" (p. 135-136). The chapter compares plant growth to human growth, which may lead to misconceptions, as children often ascribe human traits to plants (Barman *et al*., 2006). The germination process is explained in short, but a diagram could enhance understanding. The flowering stage is discussed without addressing variation in flowering times across plants, making it difficult for students to answer related questions. The growth process is not presented as a cycle, and abiotic factors like water, air, and sunlight are not included in diagrams. A well-labelled diagram would improve comprehension.

Tools for the study

Data was collected through pre-drawing tests that involved students being asked to draw how a seed becomes a plant (plant life cycle) and what plants need for their growth. It was followed by interviews with 20 students (5 boys and 5 girls from both grades 3 and 5). The students were selected for interviews based on their drawings, specifically focusing on those that displayed skipped stages or missing elements. The selection was intentional, as we aimed to understand the thought process behind their representations. The goal was to explore whether the omissions or inaccuracies in their drawings stemmed from a conceptual misunderstanding of the topic, or if they were due to factors such as limited drawing skills and/or lack of interest in the task. This approach allowed us to delve deeper into the students' reasoning and clarify the thinking behind their work. This approach aimed to uncover any gaps in their understanding of plant structure and function. It also consisted of multiple choice questions that aimed to assess students' understanding of plant biology, focusing on topics such as plant growth, functions of plant parts, and the development of plants. For example, students were asked what plants require for growth, with options including sunlight, water, air, and all of the above. Some true or false questions based on their textbooks also tested their comprehension of plant growth processes, including whether a sprout can grow without taking root in soil and whether seedlings absorb water and nutrients from the soil. Finally, students were asked about the origins of seeds and fruits, exploring whether they understood that these parts develop from flowers. Throughout the interviews, students were encouraged to explain their reasoning and were asked if they were confident in their answers, which provided additional insight into their thought processes and misconceptions.

Activities: The researcher facilitated three hands-on constructivist activities to address misconceptions. Based on the misconceptions and their reasoning identified, the researcher designed four sessions for 1.5 hours each over the span of 12 days and performed activities. The activities that were performed by the students consisted of the following:

Activity 1:

This activity involves plant growth from seeds like moong/green gram (*Vigna radiata*), methi/ fenugreek (*Trigonella foenum-graecum*), and/or coriander (*Coriandrum sativum*). It will help the students observe the different stages of plant growth and its requirements during the process (air, water, and sunlight) (Ramadas, 1998).

Activity 2:

This included making different set-ups to check the importance of sunlight, air, and water for growth. The students were expected to make the following set-ups:

1. Covering a plant with a black box with holes - sunlight,
2. Covering a plant with a plastic bag - air.
3. Not watering the plant - water.

A control plant was used to compare and understand the differences.

Activity 3: The life cycle of Mango (conducted during Session 3)

The students had to arrange the pictures of the life cycle of the mango.

1. They were given 2-3 pictures per group.

2. They had to label all the parts they saw in the pictures.
3. One student was called to the board with a chart paper and asked to stick to the picture orderly, from preparing seeds for growth to getting flowers, fruits (seeds in fruits), and tree/plant death.
4. The end result was the life cycle of the mango tree on the board.

The researchers focused on light, air, and water as key growth conditions for plants, as it is particularly relevant for grade 3 and 5 students. At these educational stages, students are typically introduced to fundamental concepts of plant biology, such as the basic needs of plants and their growth conditions. While nutrients and temperature are also crucial for plant growth, they tend to be more complex topics, often requiring deeper understanding and are typically introduced in later grades. Focusing on light, air, and water allows the research to provide a manageable and age-appropriate introduction to plant biology, which is in line with the developmental stage of students in grades 3 and 5.

Post-session, a drawing test and interviews (with the same 20 students selected for the pre-test interviews) were conducted to assess conceptual change.

Data Analysis

The data was analyzed using qualitative coding to analyze students' drawings and interviews, identifying themes that uncover underlying misconceptions.

RESULTS AND DISCUSSION

The lack of hands-on learning and prior exposure to plant growth concepts, which led to persistent misconceptions among students. They highlight the need for interactive, exploratory teaching methods to address misunderstandings and deepen students' conceptual understanding by interacting with the plants.

A. Problems encountered

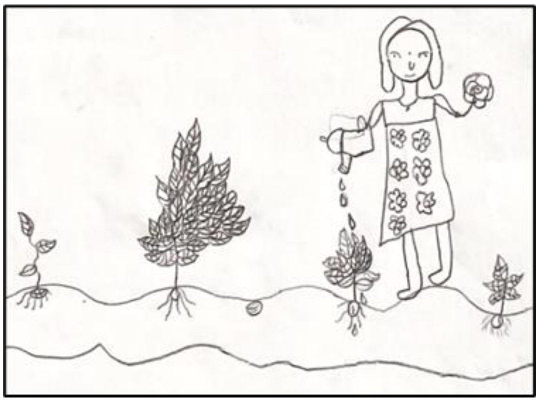
Initial student teacher interactions

During previous interactions with the teacher and students helped us understand that the Grade 5 students had been introduced to this topic, but only through a brief lecture method without in-depth exploration. Even the activity mentioned in the textbook as a part of the exercise to grow a plant in a pot and observe its growth by taking pictures of each stage were not carried out in class.

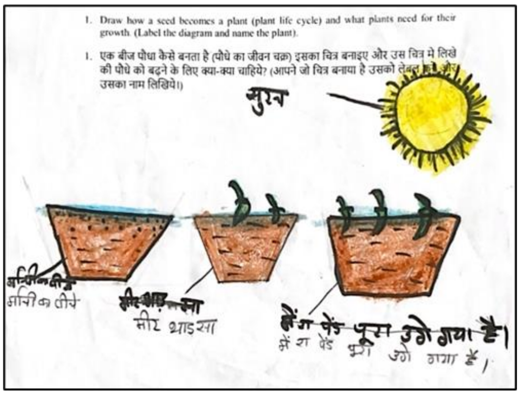
Pre-tests

The students were asked to draw how a seed becomes a plant (plant life cycle) and what plants need for their growth. The drawing tests showed the students of grade 3 drew plants growing from seeds with some showing sun and water as important for plant growth. The majority of students drew flowers in the plants as the end stage, skipping the germination stage. Many students who drew fruits skipped the flowering stage and jumped directly to fruits (like apples). Other students first showed small mango fruits that slowly grew big, skipping the flowering stage. A student made a drawing showing that seeds are present throughout the plant's life cycle, and roots grow around them in the soil (Drawing 1).

The grade 5 students showed a similar pattern to Grade 3 students. A few students drew plants whose roots are not necessarily attached to the plants. A student made a drawing showing that chillies (fruits) grow directly from the seeds (Drawing 2). One student drew the process where small fruits (mangoes) slowly grow big, which is correct in the case of mangoes, but there exists a flowering stage followed by fruiting.



Drawing 1: Drawing by a Grade 3 student showing seeds present throughout the plant's life, with roots growing around them



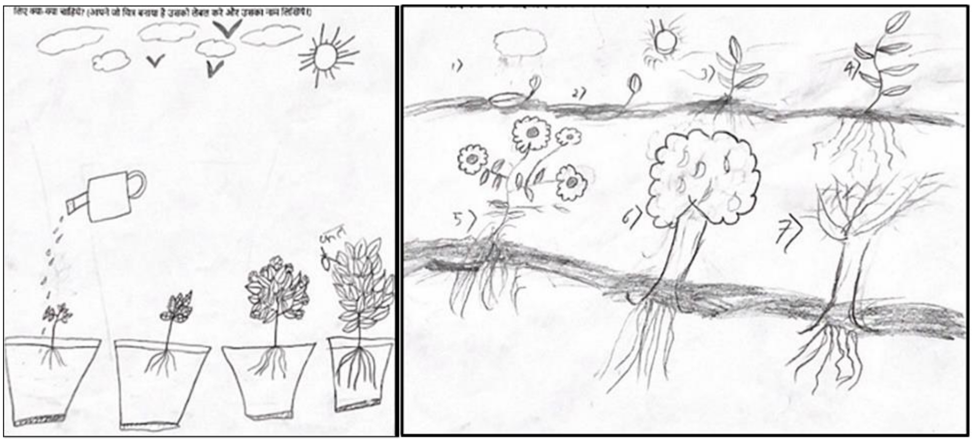
Drawing 2: Drawings by a Grade 5 student showing that chillies (fruits) grow directly from the seed.

***Table 1**: Students' misconceptions and difficulties elicited by analyzing the pre-tests (drawing and interviews)*

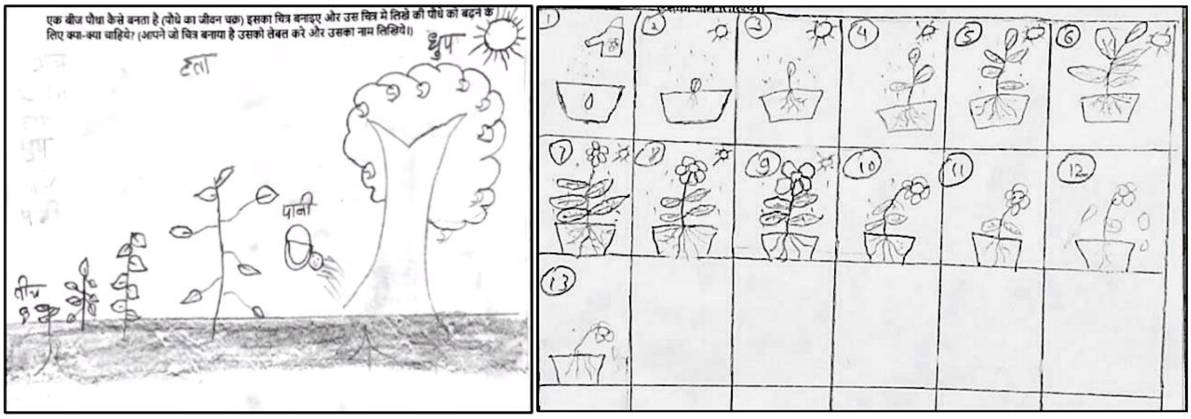
Sr. No.	Students' misconceptions and difficulties	Source of identification
1	Plants do not need air for growth.	Drawing and interview
2	Water is the only component that provides nutrients to the plants.	Drawing and interview
3	Leaves do not prepare food; the plants get food from water.	Interview
4	Roots take only water and not nutrients from the soil.	Interview
5	Flowers develop into leaves and stems.	Interview
6	Flowers are present for aesthetic purposes.	Interview
7	The plant does not grow old or die and stays alive forever if it gets water, sunlight, and nutrients.	Drawing and interview
8	Roots are not necessarily attached to the plants.	Interview
9	Not aware of the origin of seeds and fruits.	Interview
10	Seeds are dead.	Interview
11	Seeds are present throughout the plant's life cycle, and roots grow around them in the soil.	Drawing and interview

Misconceptions

The findings through the pre-tests revealed the misconceptions among the students, as seen in Table 1. The interviews helped the researcher understand the reason behind the misconceptions the students have; it was due to their prior experiences or observations, usually, something they have experienced at home or observed in their surroundings, like the frequent watering of the plants, seeing a plant or tree at the same place, never seen a flower develop into a fruit, or buying seeds from markets, this makes them believe that plants only need water for growth, they do not die, not aware of the origin of fruits and seeds come from the market, respectively.



Drawing 3 ***: (Left) Drawing by a Grade 3 student showing that flowers develop to fruits; (Right) Drawing by Grade 3 student showing that seeds germinate, the plants bear flowers then fruits and eventually die***



Drawing 4 ***: (Left) Drawing by a 12 years old girl in Grade 5 showing that seeds germinate, the plants bear fruits.; (Right) Drawing by a 11 year old girl in Grade 5 showing that seeds germinate to bear flowers and eventually die***

Interventions

The sessions exposed the students to participating in collaborative learning for the first time in their school life by working in groups. The disorder, discomfort and confusion from the first session started to turn into comfortability in working in groups, dividing work based on the students' strengths to solve problems and filling the observation worksheets of the first two activities. The activities promoted conceptual understanding. The findings suggest that such a pedagogical approach is crucial in addressing misconceptions that may persist despite traditional lecture-based instruction (as evidenced by the misconceptions held by both Grade 3 and Grade 5 students despite their different levels of prior exposure).

Post-tests

The pretest drawing question was repeated for the post-test. The post-test drawings showed a better understanding of the plant growth process. The earlier drawings showed seeds throughout plant growth and roots growing from around the seed in the soil. However, the students corrected their previous conceptions and had no seeds as the plants grew as seen in the drawings below. In Drawings 3 and 4, Right, the

Table 2 : Students' understanding of the role of air, water and sun (sunlight) in plant life cycle: comparison of pre-test and post-test results in grades 3 and 5 (based on drawings and interviews)

Grade	Test	Mode of test	Water	Sun	Sun and water	Sun, water and air
3	Pre-test	Drawing	7	4	17	-
		Interview	1	-	4	5
	Post-test	Drawing	-	-	17	9
		Interview	-	-	-	10
5	Pre-test	Drawing	2	12	9	-
		Interview	-	-	1	9
	Post-test	Drawing	-	-	7	13
		Interview	-	-	-	10

student drew the entire process from seeds in soil to germination till the process ends at a tree and eventually dies. The students also showed a flowering stage as seen in Drawing 3, Left. The students also drew and indicated air, water, and sun, (Drawing 4, Left) which helps in the process of growth.

The students overall showed more detailed and elaborate drawings of the plant growth cycle as a life process. They also indicated the presence of sunlight, water and air in their drawings and/or answered correctly in the interviews conducted.

B. Thematic analysis

Thematic analysis focused on understanding different parts of plants and the growth process. By combining drawings with interviews, the research provided deeper insights into students' misconceptions and their reasoning. Several themes came out including:

a) Understanding plant life cycle

After the sessions, students' drawings and interviews demonstrated a clearer understanding of plant life cycle. They corrected earlier conception was of roots being sometimes conceptions such as skipping germination, flowering and death stage (Drawings 3 and 4).

b) Role of seeds and roots

Students showed an evolving understanding on the role of seeds and roots. While the earlier detached and seeds being dead but still present through the life cycle. Post-tests showed they better understood that seeds germinate at the start and roots anchor and nourish the plant.

c) Recognition of Basic Plants growth needs

The students also demonstrated a better understanding of the role of air, water and sunlight in the growth process indicated in the post-test drawings and interviews (Table 2). In Grade 3 pre-test drawings, 17 students depicted both "sun and water" as essential factors for plant growth, but none included "sun, water, and air" together. Post-test drawings showed an increase, with 17 students recognizing "sun and water" and 9 students acknowledging the complete set of factors ("sun, water, and air"). The interviews followed a similar pattern, with only 5 students mentioning all three factors in the pre-test, compared to all students selecting the correct option in the post-test.

For Grade 5, the pre-test results showed 12 students identifying "sun" as a key growth factor, while 9 students mentioned "sun and water," but none included air. In the post-test, the number of students identifying "sun, water, and air" increased to 13 in their drawings and all 10 students in the interviews, suggesting that activity 2 significantly improved their understanding of the role of these elements in plant growth.

d) Role of Flowers and fruits

Students initially considered flowers as ornamental, often skipping the flowering stage before fruit formation. Post-intervention, they understood that flowers are crucial for fruit development. Fruits later bear seeds and when the seeds are sowed and basic needs are given, they may grow into healthy plants/trees (activity 1 and 2). This again grows through the cycle and later dies due to natural or man-made causes (activity 3).

e) Influence of real-life observations

Misconceptions were often based on daily experiences, like watering plants or buying seeds. Post-tests showed students integrating more scientifically accurate concepts along-side these experiences.

f) Similarities in reasoning

It was also found that although misconceptions are individual constructs of the students, everyone has different perspectives and applies different logic. However, those logics are still similar due to similar age factors and cultural backgrounds (Wadhwa e*t al*., 2020). As seen misconceptions often arose from prior experiences shaped by interactions with their environment, family, society, and textbooks.

***Grades 3 and 5: differences and similarities*[1]**

Distinctions were made between the Grade 3 and Grade 5 students, with the latter having received formal instruction on the topic, unlike the Grade 3 students, for whom this topic was skipped due to time constraints (as informed by the teacher in charge). This formal exposure resulted in more detailed and elaborate post-test drawings (Drawings 3 and 4) and interview responses from Grade 5 students, reflecting a comparatively better understanding. However, despite this formal instruction, many Grade 5 students still held misconceptions about the topic, indicating areas where further clarification was needed.

Effectiveness of collaborative learning inculcated through hands-on Constructivist Pedagogical Approach

The hands-on Constructivist Pedagogical Approach, proved effective in addressing misconceptions. The approach facilitated conceptual change, promoting plausible explanations grounded in scientific principles. Collaborative learning played a vital role, as students

[1] Although the study did not initially aim to focus on grade 5 students, as explained in the sample selection, the researchers engaged with them, which allowed for an analysis of their prior understanding. These students had been exposed to the topic through traditional teaching methods, such as lectures and the chalk-and board approach.

collaborated in group activities, complementing each other's strengths and discussing observations (Çil, 2015).

CONCLUSION AND IMPLICATIONS

The study focused on diagnosing and remediating elementary students' misconceptions about plant growth through drawing and hands-on constructivist pedagogy. Drawing proved effective in eliciting students' ideas and revealing misconceptions (Kara, 2007; Köse, 2008). Interviews provided further insight into students' reasoning behind their drawings and identified sources of misconceptions such as personal experiences, textbooks, and peer influence. To address these, a constructivist approach emphasized hands-on activities, collaborative learning, and open discussions. The pedagogical approach involving hands-on activities helped the students to interact with the plants and led to conceptual change (Çil, 2015). While changing deeply ingrained beliefs takes time, initiatives like this demonstrate the potential for meaningful learning experiences.

The tools used to carry out the suggested activities are not complex and expensive; these activities can be implemented easily in regular courses. The activities implemented span 12 days; in a regular school setting, due to time constraints, teachers might find it challenging to carry out; however, due to the nature of the activities, the teachers can conduct other course sessions during the waiting/gap period. Drawing to identify misconceptions can collaborate with art sessions to work on other concepts (Lampert, 2014).

Implications include the importance of early intervention to address misconceptions and the effectiveness of hands-on constructivist methods in promoting conceptual understanding. This underscores the need for educational strategies prioritizing critical thinking and exploration to enrich students' learning journeys.

Limitations of the study

The multiple-choice test used in the pre- and post-test interviews we used limits student explanations (Smith and Tanner, 2010), hindering our study's ability to inform pedagogy. Nonetheless, the identified misconceptions remain valuable for educators and warrant further analysis (Fuchs and Arsenault, 2018). The study was limited to 50 students from grades 3 and 5, with interviews of only 20 students, and was conducted in a single school. Challenges included a mixed-grade classroom, student absenteeism, varying ages, and the inability to assess post-break retention due to time constraints. However, the findings can be applied to similar settings.

ACKNOWLEDGEMENTS

We thank the administrative officer for granting permission to conduct this research. We are grateful to the school principal, Mrs. Lalita Gulati, and teacher, Mrs. Ujwala Baba Kadam, who guided and supported us. We thank the school authorities, staff and students for volunteering for the study. We are grateful to the faculty and staff of Homi Bhabha Centre For Science Education - TIFR, Mumbai, India and Tata Institute of Social Sciences, Mumbai, India for their valuable insights and institutional support. We are grateful to our family and friends for their unwavering encouragement. We are grateful for comments from the anonymous reviewers, which have improved the quality of the manuscript. We have no conflicts of interest. We acknowledge the support of the Government of India, Department of Atomic Energy, under Project Identification No. RTI4001.

REFERENCES

Balbharati (2022) *Environmental Studies - Standard Three (First)*. Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune.

Barman, C. R., Stein, M., McNair, S., and Barman, N. S. (2006) Students' ideas about plants and plant growth. *The American Biology Teacher* **68**(2): 73–79. https://www.jstor.org/stable/4451935

Bawingan, P. A., Montevirgen Jr., E. M., Canuto, P. P. L., Lucas, L. E., and Pumaras, J. C. (2024) Plant identification mobile apps: Users' difficulties and impressions. *Asian Journal of Biology Education* **16**: 15–21. https://doi.org/10.57443/ajbe.16.0_15

Bruner, J. S. (1961) The act of discovery. *Harvard Educational Review* **31**: 21–32.

Carey, S. (1987) *Conceptual change in childhood* (1st MIT paperback ed.). MIT Press.

Çil, E. (2015) Integrating botany with chemistry and art to improve elementary school children's awareness of plants. *The American Biology Teacher* **77**(5): 348–355. https://doi.org/10.1525/abt.2015.77.5.5

Clark, J., and Baker, T. (2007) Collaborative learning in diverse groups: A New Zealand experience. In: *17th ISANA Inter-national Education Association Conference Procee-dings*. pp. 1–7.

Dewey, J. (1933) *How we think: A restatement of the relation of reflective thinking and the education process*. D.C. Heath and Co. Publishers.

Duit, R., and Treagust, D. F. (2003) Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education* **25**(6): 671–688. https://doi.org/10.1080/09500690305016

Duit, R., Treagust, D. F., and Widodo, A. (2013) Teaching science for conceptual change: Theory and practice. In: *International handbook of research on conceptual change*. pp. 487–503. Routledge.

Fazio, C., Battaglia, O. R., di Paola, B. and Adorno, D. P. (2015) Using cluster analysis to study the modeling abilities of engineering undergraduate students: A case study. In: Lavonen, J., Juuti, K., Lampiselkä, J., Uitto, A. and Hahl, K. (eds.) *Proceedings of ESERA 2015*. pp. 37–48. https://www.esera.org/esera-2015/

Fuchs, T. T., and Arsenault, M. (2018) Secondary biology misconceptions: Using 23 years of test data to inform pedagogy. In: *National Association of Biology Teachers Professional Development Conference*. pp. 1–16.

Goris, T. (2010) Students' misconceptions in science, technology, and engineering. In: *ASEE Illinois/Indiana Section Conference, January 2010*. pp. 1–16.

Kara, I. (2007) Revelation of general knowledge and misconceptions about Newton's law of motion by drawing method. *World Applied Sciences Journal* **2**(S): 770–778. https://idosi.org/wasj/wasj2(S)/10.pdf

Karpudewan, M., Zain, A. N. M., and Chandrasegaran, A. L. (2017) Introduction: Misconceptions in Science Education: An Overview. In: Karpudewan, M., Zain, A. N. M., and Chandrasegaran, A. L. (eds.) *Overcoming students' misconceptions in science: Strategies and perspectives from Malaysia*. pp. 1–5. Springer Nature. https://doi.org/10.1007/978-981-10-3437-4

Köse, S. (2008) Diagnosing student mis-conceptions: Using drawings as a research method. *World Applied Sciences Journal* **3**(2): 283–293.

http://idosi.org/wasj/wasj3(2)/20.pdf

Kural, M., and Kocakulah, M. S. (2016) Teaching for hot conceptual change: Towards a new model, beyond the cold and warm ones. *European Journal of Education Studies* **2**(8): 1–40. https://doi.org/10.5281/ZENODO.163535

Laeli, C. M. H., Gunarhadi, and Muzzazinah. (2020) Misconception of science learning in primary school students. *Advances in Social Science, Education and Humanities Research* **397** (3rd International Conference on Learning Innovation and Quality Education): 657–671. https://doi.org/10.2991/assehr.k.200129.083

Lampert, E. (2014) Biology myth-killers. *The American Biology Teacher* **76**(5): 350–351. https://doi.org/10.1525/abt.2014.76.5.10

Posner, G. J., Strike, K. A., Hewson, P. W., and Gertzog, W. A. (1982) Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education* **66**(2): 211–227. https://doi.org/10.1002/sce.3730660207

Ramadas, J. (1998) *Small science textbook class 3 (English)*. 96 pp. Homi Bhabha Centre for Science Education. https://smallscience.hbcse.tifr.res.in/the-books/class-3/

Smith, J. I., and Tanner, K. (2010) The problem of revealing how students think: Concept inventories and beyond. *CBE Life Sciences Education* **9**(1): 1–5. https://doi.org/10.1187/cbe.09-12-0094

Summers, M., and Volet, S. (2010) Group work does not necessarily equal collaborative learning: Evidence from observations and self-reports. *European Journal of Psychology of Education* **25**(4): 473–492. https://doi.org/10.1007/s10212-010-0026-5

Tolmie, A. K., Topping, K. J., Christie, D., Donaldson, C., Howe, C., Jessiman, E., Livingston, K., and Thurston, A. (2010) Social effects of collaborative learning in primary schools. *Learning and Instruction* **20**(3): 177–191. https://doi.org/10.1016/j.learninstruc.2009.01.005

Verma, P., and Choudhuri, R. (2022) A review of misconceptions in biology. *Journal of Emerging Technologies and Innovative Research* **9**(7): 166–178. https://www.jetir.org/papers/JETIR2207319.pdf

Vosniadou, S., and Skopeliti, I. (2017) Is it the Earth that turns or the Sun that goes behind the mountains? Students' misconceptions about the day/night cycle after reading a science text. *International Journal of Science Education* **39**(15): 2027–2051. https://doi.org/10.1080/09500693.2017.1361557

Vygotsky, L. (1986) *Thought and language*. The MIT Press. https://doi.org/10.1037/11193-000

Wadhwa, M., Nashier Gahlawat, I., and Chhikara, A. (2020) Understanding students' alternative conceptions: A mirror to their thinking. *Integrated Journal of Social Sciences* **7**(1): 9–13. http://www.pubs.iscience.in/journal/index.php/ijss/article/view/1113

Zangori, L., and Forbes, C. T. (2015) Exploring third-grade student model-based explanations about plant relationships within an eco-system. *International Journal of Science Education* **37**(18): 2942–2964. https://doi.org/10.1080/09500693.2015.1118772

WEBSITE

Read, J. R. (2004) *Children's misconceptions* *and conceptual change in science education.* http://acell.chem.usyd.edu.au/ConceptualChange.cfm <retrieved 06/04/2025>

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_15

Research Paper

Four teachers' classroom management approaches (CMA): A case study in the Philippines

Lea C. Garcia*

Faculty, University of the Philippines Rural High School
UPLB, CAS, College, Laguna, Phillipines

(Received: 20 October 2024; Accepted for publication : 22 April 2025)

This case study determined whether classroom management approaches (CMA) to teaching cell division and Mendelian genetics vary based on years of teaching. Specifically, comparisons among four Grade 8 teachers—two beginning teachers and two experienced teachers—were made with respect to facilitating skills, metacognitive techniques, and personality construct dimensions. Initial interviews documented the teachers' knowledge and ideas about cell division and Mendelian genetics, after which video recordings of the actual teaching sessions were done for 10 days. Follow-up interviews were also done for clarification. The transcribed interviews and observations were subjected to qualitative analysis. The findings indicate that one experienced teacher and two beginning teachers demonstrated stronger CMA than the remaining experienced teacher, who did not show much facilitating skills, demonstrated fewer metacognitive techniques, and failed to project a strong personality. With the results, CMA partially varies based on years of teaching. This teacher should be encouraged to retool and upgrade skills through training and workshops. This case study may serve as a basis for school heads' planning of programs for continuous professional development on classroom management. Likewise, it is recommended to take into account a greater population size as well as apply a specific statistical tool in the analysis.

Key words: *beginning teacher, classroom management approaches, experienced teacher, facilitating skills, metacognitive techniques, personality construct, professional development*

***Author for correspondence:** leureal@yahoo.com/lcgarcia@up.edu.ph

INTRODUCTION

The quality of the academic staff is one of the key criteria in implementing the K–12 curriculum, as explicitly stated by the Philippine Department of Education (DepEd) in its 2016 K–12 guidelines (Metila *et al*., 2016). Recently reformed educational policies aim to enhance the training quality of secondary schools to align with the rapid changes brought by global integration. School effectiveness has become a critical issue, requiring administrators to continually revisit and update their school's vision, mission, and core values to meet societal expectations (Duong, 2018). Factors such as an organized school environment, teacher instructional leadership, clearly defined objectives, high expectations for learning outcomes, and the nature of teachers' responses significantly influence student learning success (Nosrati and Nayernia, 2021).

According to Sandy *et al*. (2019), qualified teachers possess the necessary instructional and social skills to create an engaging, dynamic, and stimulating environment where students can perform at their best. Classroom management, which directly impacts students' future professional success, is the most critical factor in achieving this goal. It is widely recognized as one of the most essential teaching skills for delivering content effectively and is a key aspect of teachers' responsibilities (Huntly, 2008). Additionally, classroom management is frequently cited as one of the most challenging aspects of teaching (Kaufman and Moss, 2010; Peters, 2012; Ritter and Hancock, 2007).

Over the past few decades, the Philippine education system has undergone several reforms and policy changes. Despite these efforts, significant challenges persist in classroom instruction. These challenges are multifaceted, encompassing issues related to curriculum, infrastructure, student outcomes, learning resources, and teacher quality. Among these, teacher quality is considered the most critical disparity in classroom management. The Philippines faces a shortage of qualified teachers, particularly in rural and remote areas. Although the Department of Education (DepEd) has made efforts to improve teacher recruitment, the distribution of teachers remains uneven, with some regions experiencing higher student-teacher ratios (DepEd, 2003). While the DepEd has introduced various Continuous Professional Development (CPD) programs to equip teachers with essential teaching skills, funding remains insufficient, and the programs often fail to address the specific needs of teachers in the classroom. Additionally, many teachers, especially those in rural areas, report limited access to professional development opportunities.

This study, which was conducted between 2019 and 2020 remains relevant for several reasons. First, classroom management strategies serve as foundation to effective teaching and learning, and their principles often remain consistent over time, even as technologies and other emerging educational tools evolve. The findings of this study can serve as a benchmark for understanding how teachers adapt to diverse classroom environments, which is a timeless challenge in education. Additionally, the study may highlight specific strategies or approaches that have proven effective, providing valuable lessons for current and future educators. The COVID-19 pandemic, which began in early 2020, likely influenced teaching practices during the study period, making it a unique snapshot of how teachers adapted to unprecedented challenges. This historical context can inform how educators handle future disruptions or shifts in education. Furthermore, the study's focus on individual teachers' experiences offers a nuanced perspective that can inspire professional development and reflective practice among educators. Even in 2025, the findings can contribute to ongoing discussions about teacher training and support, particularly in areas like student engagement and behavior management. Lastly, the study's qualitative data can be compared with more recent research to identify trends or changes in classroom management practices over time, making it a valuable reference for researchers and policymakers. Thus, while the study was conducted several years ago, its relevance endures as it addresses universal aspects of teaching and learning.

Considering the gaps mentioned above, it was imperative to conduct this case study to determine how four teachers with different years of teaching experience demonstrate classroom management in the teaching of cell division and Mendelian genetics. The CMA approaches include facilitating skills, metacognitive techniques, and personality construct dimensions which were used previously in some studies (Alpay and Dilara, 2016).

MATERIALS AND METHODS

Context of the Study

The site of the study was in two (2) public high schools in Region IVA (CALABARZON), Philippines, denoted as School A and School B (to protect their anonymity). The study was conducted from January to March of AY 2019-2020, the year's final quarter. Both schools offer two (2) shifts, one in the morning and one in the afternoon. The morning session starts at 6:15 A.M. and ends at 12:30 P.M., while the afternoon session begins at 1:10 P.M. and ends at 6:30 P.M. Table 1 shows the profile of School A and School B.

In both schools, most of the faculty members in the Science Department are females. The profile of the teachers is given in Table 2.

Design of the Study and Case Selection

This case study involved four Grade 8 Science teachers from two public high schools in Laguna, Philippines. They were selected for an empirical investigation to examine differences in their classroom management approaches while teaching cell division and Mendelian genetics. With the assistance of the science coordinators from the selected schools, the teachers were identified and chosen based on their teaching

Table 1: Profile of School A and School B

School	Location	Population	Average Class Size	Number of Teachers
A	Upper Laguna, Philippines	4266	60-65	9
B	Lower Laguna, Philippines	4241	55-60	8

Table 2: Profile of the Four Teachers

Teacher Characteristics	Ace	Bes	Ces	Des
Course Graduated	BS Mathematics and Science Teaching (BSMST), major in Biology	BS Agricultural Education, major in Animal Science; also earned some units in MA Education, major in Educational Management	BS Secondary Education, major in General Science; also finished MA in Administration and Supervision	BS Secondary Education with specialization in Biological Sciences
School	A*	A*	B**	B**
Years of Teaching	3	19	10	3
Science Subject Taught	Science 8	Science 7 Science 8	Science 8	Science 8
Years of Teaching in Other Schools	3	1	1	3
Number of Teaching Seminars Attended	1	2	5	4

A* – from School 1
B** - from School 2

experience. Two teachers were selected from each school: one from the group of beginning teachers (0–5 years of experience) and the other from the group of experienced teachers (more than 5 years of experience).

Data Collection, Validation and Analysis

A form was used to collect data about each of the four teachers. Initial interviews were conducted to gather relevant information about their understanding of cell division and Mendelian genetics. Follow-up interviews were also done to clarify details. With the teachers' consent, 10 consecutive actual classroom observations were video recorded.

The recordings were transcribed and analyzed to identify and quantify instances where specific classroom management elements—namely, (1) facilitating skills, (2) metacognitive techniques, and (3) personality construct—were demonstrated by each teacher. Afterwards, each teacher was provided with a copy of the transcripts, with highlighted sections indicating the observed classroom management instances. The teachers were asked to verify the accuracy and correctness of the researcher's observations. Discrepancies were noted, reconsidered, and corrected before finalizing the data. The collected data were then submitted to a second reader for peer examination. The second reader was selected based on prior experience with case studies and familiarity with the research methodology. Collected before the pandemic lockdown in 2020, the data was then subjected to qualitative analysis.

Limitations of the Study

This study was limited to four cases—two beginning and two experienced teachers. With a small number of respondents, it was challenging to establish significant relationships within the collected data. Another limitation was the type of school (public school) from which the respondents were selected and where the study was conducted. Public schools are subject to government intervention, as they are owned, funded, and governed by the government, unlike private schools, which benefit from greater autonomy and less government interference. As a result, the study was conducted exclusively in public high schools, where the K–12 curriculum is strictly implemented.

RESULTS

Table 3 summarizes interview highlights and video observations of the four teachers, validated during their actual teaching. The teachers are Teacher Ace (beginning, School A), Teacher Bes (experienced, School A), Teacher Ces (experienced, School B), and Teacher Des (beginning, School B). The table covers the three CMA dimensions: facilitating skills, metacognitive techniques, and personality construct. Facilitating skills include the use of motivational activities, correcting misconceptions, and implementation of small group discussion or cooperative learning. Metacognitive techniques focused on preparing student-centered activities, conducting the planned learning activities, and preparing quizzes. Personality construct assessed specific personality traits and student connections.

Teachers Ace, Ces, and Des each had 21 instances, while Teacher Bes had only 8. Teacher Ace's instances were 8 (facilitating skills), 8 (metacognitive techniques), and 5 (personality construct). Teacher Ces had 6, 11, and 4, respectively. Teacher Des had 6, 10, and 5. Teacher Bes had 2, 3, and 3. The results show varying frequencies across dimensions.

DISCUSSION

Research findings (e.g., Koni and Krull,

Table 3-1: Interview Highlights and Classroom Observations on the Four Teachers

Interview with the Teachers	**Classroom Observations**		
	Classroom Management Approaches		
	Facilitating Skills (FS)	**Metacognitive Techniques (MT)**	**Personality Construct (PC)**
T. Ace **On FS** • Used motivational activities (e.g., sharing personal experiences, family pictures) • Corrected misconceptions through re-discussion • Employed group discussions **On MT** • Valued student-centered activities for exploring concepts • Followed textbook activities. • Gave quizzes **On PC** • Approachable teacher	**Use of Motivational Activities** • **Confirmed**: Motivated students to link bathing to cell division, leading to understanding the nucleus as the control center • **Confirmed**: Had students observe each other's traits to introduce genetics (modified activity) • Motivated students to answer Activity 2 on the board • Prepared a board work on Mendel's 7 traits, with volunteers correcting group answers • Used a fill-in-the-blank visual aid on dihybrid cross to engage students **Correcting Misconceptions** • **Confirmed:** Corrected the misconception of chromosomes being mistaken for DNA • **Confirmed:** Clarified homozygous vs. heterozygous **Use of Cooperative Learning/SGD** Confirmed: Employed in discussions	**Setting Up Student-Centered Activities (All Confirmed)** • Retaught to correct chromosome role misconceptions using examples • Reviewed and clarified homozygous vs. heterozygous through re-discussion • Used small group discussions for mitosis stages • Prepared genetics problem-solving tasks for independent work. • Created a board work on inheritance traits, with peer checking. • Posted a fill-in-the-blank dihybrid cross activity for student participation **Planned Learning Activity (Confirmed but Not All)** Assigned students to perform Act 2, 4, and 5 independently **Quiz (Confirmed)** Gave 2 quizzes: comparing mitosis & meiosis; differentiating genetics terms	**Personality Traits** • Calmly subdued disruptive students by asking questions • Showed sensitivity to students' needs • Focused on assessing individual student performance. **Ability to Maintain Strong Connections** • Conducted student-centered group discussions • Used forms of representations
	8 instances	**8 instances**	**5 instances= 21**
T. Bes **On FC** • Corrects misconceptions	**Correcting Misconceptions** **Confirmed:** Clarified	**Setting Up Student-Centered Activities (All Confirmed)**	**Personality Traits** Created a passive, teacher-centered

(Table 3-2: Interview Highlights and Classroom Observations on the Four Teachers)

• Uses group discussions for teaching cell division and genetics **On MT** • Values student-centered activities for exploring concepts • Follows textbook activities • Gives quizzes **On PC** • Less approachable; appears naïve and unconfident	homozygous and heterozygous traits using a handout **Use of Cooperative Learning/Small Group Discussion** **Confirmed:** Used in discussions	• Used group discussions with cut-outs to analyze mitosis stages • Prepared board work on inheritance traits with peer checking **Planned Learning Activity (Confirmed but Not All)** Assigned Activities 2 and 4 to develop critical and analytical thinking	environment: silent during recitation but noisy during discussions **Ability to Maintain Strong Connections** • Used models, pictures • Used a SMART TV for a cell cycle video
	2 instances	**3 instances**	**2 instances = 8**
T. Ces **On FS** • Uses motivational activities: sharing personal experiences and family pictures • Adds storytelling for CD and role-playing for genetics. • Corrects misconceptions via post-experiments • Employs SGD **On MT** • Valued student-centered activities for exploring concepts • Followed textbook activities • Gave quizzes **On Personality Construct** Loud, approachable, jolly, and easy to work with	**Use of Motivational Activities** • Used colored visors to clarify phenotypes and genotypes. • Confirmed: Storytelling to explain nucleus functions. • Used a "SpongeBob" icebreaker to energize the class. • Confirmed: Role-playing to introduce Mendelian genetics. **Correcting Misconceptions** **Confirmed:** Clarified ribosome (not nucleus) functions for protein synthesis through repeated questioning. **Use of Cooperative Learning/Small Group Discussion** **Confirmed:** Employed in discussions	**Setting Up Student-Centered Activities (All Confirmed)** • Corrected ribosome role misconception through reteaching • Used group discussions for mitosis • Prepared independent problem-solving tasks in genetics • Conducted role-playing for Mendel's pea experiment. • Assigned independent work on Bikini Bottom Genetics • Drew mitosis stages creatively based on a video. • Conducted a mitosis experiment with critical questioning • Used storytelling to answer questions on cell parts. • Reviewed to clarify nucleus functions. **Planned Learning Activity (All Confirmed)**	**Specific Personality Traits** • jolly, very easy to deal with and had a happy face, which made the students very interested to listen during the discussion ▪ with a good personality, which made the students comfortable **Ability to maintain strong connections with the students** ● did student-centered group discussions used forms of representations

(Table 3-3: Interview Highlights and Classroom Observations on the Four Teachers)

		Assigned all five learning activities to develop critical and analytical thinking. **Quiz (Confirmed)** Gave one quiz comparing mitosis and meiosis, answered independently.	
	6 instances	**11 instances**	**4 instances = 21**
T. Des On FS • Used motivational activities: sharing personal experiences (e.g., bathing) and family pictures • Corrected misconceptions using a textbook • Employed group discussions for teaching cell division and genetics **On MT** • Valued student-centered activities for exploring concepts • Followed textbook activities • Gave quizzes **On PC** Very approachable, easy to work with, and cheerful	**Use of Motivational Activities** • Used a DNA & Life Cycle video to introduce chromosomes & cell division (CD) • **Confirmed:** Asked to compare family traits using pictures to introduce genetics • Used a hand activity/mnemonic for mitosis stages **Correcting Misconceptions** • **Confirmed:** Clarified sex cells for meiosis, & body cells for mitosis • **Confirmed**: Explained chromosome movement during CD • **Confirmed:** Used a blood cell analogy to explain the cell cycle **Use of CL/Small Group Discussion: Confirmed**	**Setting Up Student-Centered Activities (All Confirmed)** • Corrected misconceptions through reteaching • Rediscussed blood cells to highlight CD importance • Used SGD for (1) mitosis and (2) inheritance of traits. • Assigned independent problem-solving in genetics • Conducted genetics drills & trivia for critical thinking **Planned Learning Activity (Confirmed but Not All)** Assigned Activities 2, 3, 4, & 5 for critical and analytical thinking **2 Quizzes (Confirmed)**	**Specific Personality Traits** • Cheerful demeanor, making students comfortable • Encouraged students to explain family traits confidently • Soft-spoken, maintaining a quiet and attentive class **Ability to Maintain Strong Connections** • Conducted student-centered group discussions • Used models, pictures, visual aids, and personal illustrations
	6 instances	**10 instances**	**5 instances = 21**

2018; Sánchez, 2019; Shohani *et al*., 2015) show that experienced teachers (5+ years of experience) and beginning teachers (less than 5 years) manage classrooms differently. While beginning teachers apply to educators who are either new to the teaching field or have been doing it for less than 5 years or those with little or no prior teaching experience, experienced teachers are those with at least five years of classroom management experience (Martin, Yin, and Mayall, 2006; Tsui, 2003, 2005; Woest, 2018). Experienced teachers adapt lessons and engage students effectively, while beginning teachers often adopt directive approaches but are more interactive and tolerant. Findings can help school administrators and teacher educators evaluate professional development programs and improve classroom management training. Below are the beginning and experienced teachers' differences on the three (3) CMA dimensions.

On Facilitating Skills Dimension

Use of Motivational Activities

Teachers Ace, Ces, and Des used motivational activities, such as sharing personal experiences (e.g., cleaning up the body) and family pictures, to teach cell division and Mendelian genetics. In addition, Teacher Ces highlighted storytelling and role-playing.

Teacher Ace guided students to reflect on their knowledge, helping them construct the concept of the nucleus as the control center based on the obtained knowledge that cleaning up the body means cell division. Both Teachers Ace and Des used family pictures to discuss inherited traits, enabling students to understand inheritance. These facilitating skills, supported by Walker and Leary (2009), align with the constructivist approach, where knowledge is built through experiences and reflection (Minner *et al*., 2010). Real-life connections, as noted by Alstad-Davies (2019), enhance engagement and reduce classroom management challenges. McKimm and Morris (2009) emphasize the teacher's role as a facilitator, guiding discussions and encouraging active participation to foster deeper learning.

During the storytelling of Teacher Ces, students focused on the story and answered guide questions, enhancing critical thinking (McKillop, 2005). Barker and Gower (2010) noted that storytelling improves attention and decision-making, while Donaldson (2016) highlighted its role in simplifying complex situations. For role-playing, Teacher Ces asked her students to wear colored visors to visualize genetic crosses for clarifying genotypes and phenotypes. Ruiz-Ezquerro (2021) found that role-playing energizes learning and engages students, making it a valuable experience. Omrod (2014) opined that such activities motivate and sustain student behavior, keeping them focused and active.

These three (3) teachers included additional motivational activities in their actual teaching, which all facilitated student learning, namely, (1) a board work on identifying the seven (7) contrasting traits used by Mendel and, (2) a fill-in-the-blank visual aid on the board on dihybrid cross by Teacher Ace; (3) role-playing activity on Mendel, (4) a group's icebreaker presentation about "Sponge Bob" by Teacher Ces; (5) a short video clip about DNA and life cycle, and (5) a pneumonic or hand exercise on the stages of mitosis by Teacher Des. In discussing cell division and Mendelian genetics, Teacher Bes used a lecture-style approach rather than a motivational activity.

Correcting Misconceptions

Interviews and classroom observations revealed that teachers correct misconceptions to facilitate learning. For example, Teacher Ace clarified the role of chromosomes versus DNA in cell division when a student confused the two. Students also participated, such as correcting the meaning of "homozygous," which the teacher then clarified. Sothayapetch *et al*. (2013) and Lucariello and Naff (2020) emphasize that correcting misconceptions is crucial, as they hinder learning and are often deeply rooted. Teachers must identify and address misconceptions promptly to foster meaningful discussions and understanding. Teacher Ces corrected the misconception that ribosomes, not the nucleus, function in protein production, repeatedly questioning students to ensure understanding. Savion (2009) notes that naïve theories—initial beliefs formed before formal education—are hard to change, making it essential for teachers to address them. Teacher Ces adjusts her approach when many misconceptions arise, previously using visual aids and listing corrected misconceptions for students to copy. This year, however, fewer misconceptions were identified. Teacher Des was the only teacher observed using a textbook to correct misconceptions. For example, she clarified that sex cells undergo meiosis, not mitosis, after a student's incorrect answer. She also addressed errors in a mitosis video, explaining the correct chromosome behavior. Additionally, she corrected misconceptions about human blood cells and plant cells through re-discussion. Bensley and Lilienfeld (2015) and Hughes and Kaplan (2013) emphasize that misconceptions, if not corrected, lead to systematic errors, hinder new learning, and are often deeply ingrained and resistant to standard instruction.

Teacher Bes used a handout to clarify the meaning of homozygous and heterozygous traits. She stated in the post-interview that she creates a handout that summarizes the concepts if she is unable to address misconceptions immediately because of time constraints and a school activity.

Use of Small Group Discussion/Cooperative Learning

All teachers reported using small group discussions or cooperative learning, which was evident in their teaching. This student-centered approach encourages inquiry-based questions, motivates students, and helps them realize their potential. Teachers act as facilitators, guiding discussions while students exchange ideas and collaborate on tasks. In this classroom technique, students discuss issues, as supervised by the teacher; thus, the teacher plays the role of facilitator (Bakhtiyar *et al*., 2003).

For example, Teacher Ace had students discuss mitosis stages, with groups producing outputs based on shared knowledge. Hamann *et al*. (2010) and Reddy (2015) highlight that group work enhances learning, productivity, and idea-sharing, leading to quality outcomes. Moreover, each member gets the opportunity to present their own ideas and suggestions, thus paving the way for new methods on how to complete the task properly (Jaques, 2003). Similar collaboration was observed during the genetics problem-solving activities.

Teacher Ces used group collaboration for activities like answering guide questions on cell parts and drawing mitosis stages. She facilitated learning by mediating, prompting, and asking questions to help students construct knowledge. She also assigned small group tasks, such as drawing mitosis stages, conducting activities (Activities 1, 2, 4 and 5), and solving genetics problems. Millis (2002) supports this approach, noting that cooperative learning, when well-directed, deepens students' understanding through structured problem-solving.

In Teacher Des' class, students actively participated in group activities, such as discussing genetics questionnaires and mitosis stages using cut-outs. She facilitated by encouraging independence and assisting groups in solving genetics problems. Webb (2009) notes that heterogeneous groups expose students to diverse perspectives, enhancing participation. Adhikari (2019) describes facilitation as a student-centered skill where teachers guide discussions, encourage collaboration, and help students determine their learning paths. Burgess *et al*. (2020) add that small group discussions deepen understanding, foster teamwork, and allow students to build knowledge collaboratively.

Finally, in Teacher Bes' classroom teaching, a small group discussion was implemented to perform an activity to compare mitosis with meiosis. However, there was limited facilitation, as the teacher just told the groups to discuss the stages of mitosis using cut-outs she provided and required a representative of each group to present the group's output in front. In most of her classes, she was always in front, dominating the discussion, making the discussion teacher-centred.

On Metacognitive Techniques Dimension

Interviews revealed that all teachers value metacognitive techniques in teaching. Classroom observations showed that both beginning teachers (Ace and Des) and one experienced teacher (Ces) frequently used student-centered metacognitive techniques involving planning, monitoring, and organizing learning. The other experienced teacher (Bes) used fewer metacognitive techniques. The metacognitive techniques considered were the setting up of student-centered activities to strengthen critical thinking skills, conducting planned learning activities and preparing quizzes.

Setting up student-centered activities to strengthen critical thinking skills

All teachers recognize the importance of student-centered activities, enabling students to explore cell division and Mendelian genetics independently. This reflects metacognition—awareness and regulation of cognitive processes (Meichenbaum, 1985).

Teachers Ace, Ces, and Des implemented student-centered activities, corrected misconceptions through reteaching, used group discussions and problem-solving tasks to enhance critical thinking. These approaches also encouraged curiosity, reflection, and deeper understanding. In addition, Teacher Ace used board work and fill-in-the-blank activities; Teacher Ces employed role-playing, storytelling, illustrations, experiments, and reviews, and Teacher Des utilized rediscussions, board drills, trivia questions, and reviews. All these activities were done to foster reflective and analytical thinking. Meichenbaum (1985) emphasizes that student-centered activities help teachers apply problem-solving strategies, reflect on outcomes, and adjust approaches, fostering independent and critical thinking in students.

Teacher Bes, though favoring lectures, used fill-in-the-blank activities and group discussions but often missed key concepts and struggled with time management, limiting her ability to monitor student learning. Unlike the others, she displayed frustration during teaching, reflecting inconsistent use of metacognitive techniques.

Conducting the Planned Learning Activities

Formative assessment (FA) is one of the most effective ways to introduce metacognition into the classroom. When teachers design and implement FA, they not only enhance their own awareness but also model the mental habits that support learning for their students. When these habits become embedded in the routines of teaching and learning, they transform the classroom culture (McCoy, 2020). As indicated in the interviews and confirmed through classroom observations, the implementation of planned learning activities varies among teachers, as shown in Table 4.

The students were required to complete five learning activities based on the textbook. Teacher Ces was the only one whose students finished all tasks during her actual teaching. Teacher Des' students completed Activities 2, 3, 4, and 5; Teacher Ace's students completed Activities 2, 4, and 5; and Teacher Bes' students completed only Activities 2 and 4. These

Table 4. Types of Planned Activities Carried out by the Teachers

Activity No.	Title of the Activity	Teacher Ace	Teacher Bes	Teacher Ces	Teacher Des
1	Observing Mitosis			√	
2	Comparing Mitosis and Meiosis	√	√	√	√
3	Tossing Coins and Probability			√	√
4	Comparing Genotypic and Phenotypic Ratios for a typical Mendelian trait	√	√	√	√
5	Filling up the Punnett Square for a Dihybrid Cross	√		√	√

activities involved metacognition, as students monitored their own learning while completing them. This aligns with Lin's (2001) definition of metacognition as the ability to "understand and monitor one's own thoughts and the assumptions and implications of one's activities." In other words, "thinking about one's thinking" refers to students' awareness of their own thought processes as they engage in specific tasks.

In the post-interview, Teachers Ace, Bes, and Des explained that they were unable to complete all the learning activities due to time constraints, interruptions from school events, and a lack of facilities, such as insufficient microscopes.

Preparing Quizzes

This is another formative assessment that teachers need to prepare. One experienced teacher, Ces, gave only one quiz (on comparing mitosis and meiosis), while the two beginning teachers, Ace and Des, prepared two quizzes each (Ace's quizzes focused on comparing mitosis and meiosis and differentiating genetics concepts, while Des' quizzes covered mitosis and the comparison of mitosis and meiosis). Teacher Bes, the other experienced teacher, did not prepare any quizzes. Instead, she used activities as replacements, citing their science coordinator's approval to use activities in place of tests.

In all these quizzes, the students demonstrated awareness of how to answer the questions by critically inquiring (asking questions and seeking clarifications) from their teachers. As observed, the students applied various metacognitive skills while answering from their seats. According to Rickey and Stacy (2000), metacognition is a form of self-regulated learning, which "refers to the processes used to plan, monitor, and assess one's understanding and performance." As the students developed critical thinking skills through completing different metacognitive activities, they became more aware of their own learning. This supports Brame's (2016) assertion that metacognition involves "a critical awareness of one's thinking and learning, as well as oneself as a thinker and learner."

With the documentation of strong scores achieved by students in various metacognitive activities, Nilson (2013) appears to be correct, as the author cited several studies showing that students who engage in metacognitive exercises perform better on exams, produce higher-quality written or designed work, and demonstrate improved problem-solving skills. Additionally, the students worked independently on every task they completed, a finding supported by Ambrose *et al*. (2010), who noted that metacognition enhances students' self-efficacy and independent agency, both of which boost their motivation to learn.

On Personality Construct Dimension

The two elements of the teachers' personality construct dimension are specific personality qualities and the ability to maintain strong connections with the students. During the initial interview and first meeting, initial impressions about the teachers were documented, namely, (1) the students seemed to be very much at ease with Teacher Ace, since she is an approachable teacher; (2) Teacher Bes appeared naïve and unconfident, and she was not always approachable; (3) Teachers Ces and Des were both approachable, easy to work with, and cheerful; and (4) additional impressions on Teacher Ces include her being jolly and with a loud voice. Observations during the teacher' actual teaching are indicated below.

Specific Personality Qualities

Ibad (2018) reported that the roots of the teacher personality construct arose out of Skinner's Behavioural Theory that relates to teaching, which spotlights the behaviours of teachers, rendering them as effective or ineffective.

As observed during their classroom teaching, the specific personality qualities of the beginning teachers (Ace and Des) as well as one experienced teacher (Ces) helped them teach cell division and Mendelian genetics quite easily. It was noted that Bes, the other experienced teacher, had very few specific personality qualities.

Teachers Ace and Des demonstrated strong personalities and effective classroom management by providing clear limits and high standards (e.g., reminding the students to do better, pacifying the noise to understand the lesson) as emphasized by Egeberg and Price (2021). Teacher Ace showed sensitivity to students' needs, consistently motivating underperforming students and tracking their progress through quiz results. Her positive demeanor made students feel comfortable, even when encouraging them to improve. Similarly, Teacher Des managed noise by engaging students in activities, like explaining inherited traits using family pictures. Her calm reminders kept students focused and eager to learn. Both teachers set clear expectations and fostered a supportive learning environment.

The lively voice and cheerful demeanor of Teacher Ces captivated students during activities like storytelling about cell parts, using mitosis cut-outs, and role-playing Gregor Mendel's work. Her enthusiasm and care created a comfortable learning environment, making complex topics like cell division and genetics easier to grasp and boost student motivation. Shulman and Shulman (2004) noted that a teacher's good personality fosters student interaction and engagement. With all the observations on the good personality of the three teachers that motivated and stimulated the students to learn, Dost and Hafshejani (2017) may be correct as they found out that a teacher's personality is a vital criterion that could affect a student's learning.

Finally, as observed, Teacher Bes' students were noisy during her discussions, leading to visible confusion on their faces. She created a passive, teacher-centered environment—passive because students remained silent during recitation but noisy during discussions, and teacher-centered because Teacher Bes relied on the traditional lecture-style method, as the class did not actively participate or share their ideas.

Ability to maintain strong connections with the students

In their actual teaching, the beginning teachers (Ace and Des) and one experienced teacher (Ces) maintained strong connections with the students as they discussed the concepts of cell division and Mendelian genetics in different approaches.

Teacher Ace fostered class interaction through group discussions, letting students present their learning while she provided feedback. For example, during mitosis discussions, students actively shared ideas, and Teacher Ace guided them by reacting to their descriptions. Similarly, Teacher Des encouraged active participation in genetics problem-solving, frequently checking and commenting on students' work. Teacher Ces also promoted student-centered learning through activities like drawing mitosis stages, solving genetics problems, storytelling, and role-playing, where students shared ideas and received feedback. These interactions built strong teacher-student connections. Syafitri (2023) and Hamann *et al*. (2010) support that group work enhances problem-solving, critical thinking, and knowledge sharing, as students learn from each other's ideas. The authors also said that teachers play a key role in maintaining these connections and facilitating collaborative learning.

Eilam and Gilbert (2014) emphasize that visual presentations enhance engagement, connection, and motivation in science learning. Teacher Ace used models and pictures to discuss mitosis, asking inquiry-based questions like, "How do you describe chromosomes in mitosis?" which encouraged critical thinking and active participation. She also used personal illustrations and textual visual aids to explain Mendel's experiment, fostering creative thinking. Mannan (2005) supports that these forms of representation help clarify, establish, correlate, and coordinate accurate concepts. Similarly, Teacher Des used models, pictures, and personal illustrations to clarify concepts like cytokinesis and genetics, making lessons engaging and interactive. Teacher Ces employed models, pictures, and a Venn diagram to compare mitosis and meiosis, stimulating student thinking and discussion. Evagorou *et al.* (2015) and Jägerskog (2020) highlight that visuals help teachers explain complex phenomena and enable students to absorb information quickly, strengthening connections and participation.

Teacher Bes' use of limited group activities in her actual teaching failed to provide many instances of maintaining strong connections with the students, though she was able to use pictures and models of mitosis. However, in all these activities, the discussion was teacher-centred.

CONCLUSIONS AND RECOMMENDATION OF THE STUDY

The findings of this case study reveal notable differences in the frequency of CMA among the four participating teachers. Two beginning teachers and one experienced teacher demonstrated a higher number of instances of CMA compared to another experienced teacher who exhibited the fewer number of instances. This suggests that the frequency and application of CMA may not solely depend on teaching experience but could also be influenced by such factors as facilitating skills, metacognitive techniques and personality construct. The three teachers' proactive use of management strategies may reflect their reliance on structured approaches to establish control and maintain order in the classroom. On the other hand, the one experienced teacher with fewer instances might employ more subtle or implicit management techniques, leveraging their expertise to prevent issues before they arise. Alternatively, this teacher may prioritize relationship-building and student autonomy, reducing the need for frequent interventions. These results highlight the complexity of classroom management and underscore the importance of context, individual teaching philosophies, and professional development in shaping effective practices. Future research could explore the underlying reasons for these differences and their impact on student outcomes, providing deeper insights into the dynamics of classroom management across varying levels of experience.

Since some issues were identified even in a small population, teacher educators should be responsible for strengthening and maintaining continuous teacher mentoring, which can have long-term advantages. Through mentoring, one has the chance to talk about teaching in a private setting while receiving advice. As they inspire, develop, learn, and grow together, the mentor-mentee connection can benefit both parties. Creating a mentoring culture is crucial to success in long-term teaching. The findings may also serve as an important basis for educators and school administrators to modify teacher preparation programs and provide better support during the first years of teaching of pre-service teachers. Moreover, innovative, and interesting professional development programs for new and experienced teachers are needed to help teachers build their long-term competence and confidence as educators. Additionally, in-service teacher training programs should focus on increasing teachers' cognitive awareness.

Finally, it is recommended to consider a larger population size to allow for specific statistical testing. This is necessary to achieve a representative population distribution and to be regarded as representative of the groups of people for whom results will be generalized.

ACKNOWLEDGEMENTS

The author would like to acknowledge the different school heads for allowing the teachers to participate in the study. Likewise, the author would like to acknowledge the head teacher at each school for helping the researcher in arranging the schedule of the interview with the teachers.

REFERENCES

Adhikari, B. R. (2019) Use of peer observation for self-enhancement. *Journal of NELTA Gandaki* **2**: 1–11. https://doi.org/10.3126/jong.v2i0.26599

Alpay, E., and Dilara, C. (2016) The changes in experienced teachers' understanding towards classroom management. *Universal Journal of Educational Research* **4**(1): 144-150. https://doi.org/10.13189/ujer.2016.040118

Ambrose, S.A., Bridges, M.W., DiPietro, M., Lovett, M.C., Norman, M.K., and Mayer, R.E. (2010) *How learning works: seven research-based principles for smart teaching.* Jossey-Bass, San Francisco.

Bakhtiyar Nasrabadi, H. A. and Norouzi, R. A. (2003) *New educational methods in the third millennium.* Sama Cultural Institute Publications, Qom, Iran.

Bandura, A. (1997) *Self-efficacy: The exercise of control*. W.H. Freeman, New York.

Barker, R. T. and Gower, K. (2010) Strategic application of storytelling in organizations. *Journal of Business Communication* **47**(3): 295–312.

Bensley, D. A., and Lilienfeld, S. O. (2015) What is a psychological misconception? Moving toward an empirical answer. *Teaching of Psychology* **42**(4): 282–292.

Brame, C. J. (2016) Effective educational videos: Principles and guidelines for maximizing student learning from video content. *CBE Life Sciences Education* **15**(4): 6. https://doi.org/10.1187/cbe.16-03-0125

Burgess, A., van Diggele, C., Roberts, C. and Mellis, C. (2020) Facilitating small group learning in the health professions. *BMC Medical Education* **20**(2): 1–6. https://doi.org/10.1186/s12909-020-02282-3

Dost, E. N. and Hafshejani, N. K. (2017) The impact of teachers' personality on senior high school EFL learners' general English achievement. *International Journal of English Literature and Social Sciences* **2**(3): 77–93. https://dx.doi.org/10.24001/ijels.2.3.9

Duong, M. T., Pullmann, M. D. and Buntain-Ricklefs, J. (2019) Brief teacher training improves student behavior and student-teacher relationships in middle school. *School Psychol* **34**(2): 212–221. https://doi.org/10.1037/spq0000296

Egeberg, H., McConney, A. and Price, A. (2021) Teachers' views on effective classroom management: a mixed-methods investigation in Western Australian high schools. *Educational Research for Policy and Practice* **20**: 107–124. http://dx.doi.org/10.1007/s10671-020-09270-w

Eilam, B. and Gilbert, J. K. (2014) *Science teachers' use of visual representations*. Springer International Publishing, Cham, Switzerland.

Evagorou, M., Erduran, S. and Mantyla, T. (2015) The role of visual representations in scientific practices: from conceptual understanding and knowledge generation to 'seeing' how science works. *International Journal of STEM Education* **2**: 11 https://doi.org/10.1186/s40594-015-0024-x

Hamann, K., Pollock, P. H. and Wilson, B. M. (2010) Comparing the benefits of small group and large-class discussions. *APSA 2010 Teaching and Learning Conference Pape* <downloaded on June 1, 2020, from https://ssrn.com/abstract=1544620 or http://dx.doi.org/10.2139/ssrn.1544620>

Hughes, S., Lyddy, F. and Kaplan, R. (2013) The impact of language and response format on student endorsement of psychological misconceptions. *Teaching of Psychology* **40**(1): 31–37.

Huntly, H. (2008) Teachers' work: Beginning teachers' conceptions of competence. *The Australian Educational Researcher* **35**(1), 125–145. http://dx.doi.org/10.1007/BF03216878

Ibad, F. (2018) Personality and ability traits of Teachers: student perceptions. *Journal of Education and Educational Development* **5**(2): 162–177.

Jaques, D. (2003) ABC learning and teaching in medicine: Teaching small groups. *BMJ* **326**: 492. http://www.bmj.com/cgi/content/full/326/7387/492

Jägerskog, A.-S. (2020) Using visual representations to enhance students' understanding of causal relationships in price. *Scandinavian Journal of Educational Research* **65**: 986–1003. https://doi.org/10.1080/00313831.2020.1788146

Kafman, D. and Moss, D. M. (2010) A new look at pre-service teachers' conceptions of classroom management and organization: Uncovering complexity and dissonance. *The Teacher Educator* **45**(2): 118–136. https://doi.org/10.1080/08878731003623669

Koni, I. and Krull, E. (2018) Differences in novice and experienced teachers' perceptions of planning activities in terms of primary instructional tasks. *Teacher Development* **22**(4): 464–480. https://doi.org/10.1080/13664530.2018.1442876

Lin, X. (2001) Designing metacognitive activities. *Educational Technology Research and Development* **49**(2): 23–39. https://doi.org/10.1007/BF02504926

Martin, N. K., Yin, Z. and Mayall, H. (2006, February) Classroom management training, teaching experience and gender: Do these variables impact teachers' attitudes and beliefs toward classroom management style? Paper presented at the Annual Conference of the Southwest Educational Research Association, Austin, TX. ERIC database.

<downloaded on July 18, 2020, from https://files.eric.ed.gov/fulltext/ED494050.pdf>

McCoy-Bryant, L. (2020) Classroom management to support active middle level classrooms. *Journal of Education and Learning* **6**(4): 201–206. https://doi.org/10.11591/edulearn.v6i4.163

McKimm, J. and Morris, C. (2009) Small group teaching. *British Journal of Hospital Medicine* **70**(11): 654–657. https://doi.org/10.12968/hmed.2009.70.11.45059

McKillop, C. (2005) *Storytelling grows up: Using storytelling as a reflective too in higher education.* Paper Presented at the Scottish Educational Research Association Conference, 24–26 November 2005, Perth, Scotland. <downloaded on January 5, 2019, from https://www.researchgate.net/publication/241745262_Storytelling_grows_up_Using_storytelling_as_a_reflective_tool_in_higher_education>

Mannan, A. (2005) *Modern Education: Audio-visual aids.* Anmol Publications, New Delhi, India.

Meichenbaum, D. (1985) Teaching thinking: A cognitive-behavioural perspective. In: Chipman, S. F., Segal, J. W. and Glaser, R. (eds.) *Thinking and learning skills, Vol. 2: Research and open questions*, pp. 407–426. Lawrence Erlbaum Associates, Hillsdale, NJ.

Millis, B. (2002) Enhancing learning – and more – through cooperative learning. *IDEA Paper* No. 38. <accessed: August 3, 2021, https://ideacontent.blob.core.windows.net/content/sites/2/2020/01/IDEA_Paper_38.pdf>

Minner, D. D., Levy, A. J. and Century, J. (2010) Inquiry-based science instruction - what is it and does it matter? Results from a research synthesis year 1984 to 2002. *Journal of Research in Science Teaching* **47** (4): 474–496. https://doi.org/10.1002/tea.20347

Metila, R., Pradilla, L. and Williams, A. (2016) The challenge of implementing mother tongue education in linguistically diverse contexts: The case of the Philippines. *The Asia-Pacific Education Researcher* **25**: 781–789. https://doi.org/10.1007/s40299-016-0310-5

Nilson, L. B. (2013) *Creating self-regulated learners: Strategies to strengthen students' self-awareness and learning skills*. Stylus, Sterling, VA. <downloaded on August 1, 2020 from https://www.taylorfrancis.com/books/mono/10.4324/9781003443803/creating-self-regulated-learners-linda-nilson-barry-zimmerman>

Ormrod, J. (2014) How motivation affects learning. In motivation and achievement. <downloaded on March 24, 2020, from http://www.education.com/reference/article/motivation affects learning behavior/>

Peters, J. H. (2012) Are they ready? Final year pre-service teachers' learning about managing student behavior. *Australian Journal of Teacher Education* **37**(9): 18–42. http://dx.doi.org/10.14221/ajte.2012v37n9.2

Rickey, D. and Stacy, A. M. (2000) The role of metacognition in learning chemistry. *Journal of Chemical Education* **77**(7): 915–920. https://doi.org/10.1021/ed077p915.

Ritter, J. and Hancock, D. (2007) Exploring the relationship between certifications sources, experience levels, and classroom management orientations of classroom teachers. *Teaching and Teacher Education* **23**: 1206–1216. https://doi.org/10.1016/j.tate.2006.04.013

Ruiz-Ezquerro, A. (2021) Rollings dice and learning: Using role-playing games as pedagogy tools. *Journal of Campus Activities Practice and Scholarship* **3**(1): 50-56. https://doi.org/10.52499/2021022

Sánchez, S. A. C. (2019) Classroom management and novice language teachers: Friend or foe? *HOW* **26**(1): 177–199. https://doi.org/10.19183/how.26.1.463

Sandy, L., Sudirman, W. and Lalu, M. (2019) Investigating English teachers' self-efficacy in developing classroom management style. *Advances in Social Science, Education and Humanities Research* **253**: 144–148. https://doi.org/10.2991/aes-18.2019.34

Savion, L. (2009) Clinging to discredited beliefs: The larger cognitive story. *Journal of the Scholarship of Teaching and Learning* **9**: 81–92.

Shohini, S., Azizifar, A., Gowhary, H. and Jamalinesari, A. (2015) The relationship between novice and experienced teachers' self-efficacy for personal teaching and external influences. *Social and Behavioral Sciences* **185**: 446–452. https://doi.org/10.1016/j.sbspro.2015.03.357

Shulman, L. S and Shulman, J. H. (2004) How and what teachers learn: a shifting perspective. *Journal of Curriculum Studies* **36**(2): 257–271. https://doi.org/10.1080/0022027032000148298

Sothayapetch, P., Lavonen, J. and Juuti, K. (2013) Primary school teachers' interviews regarding Pedagogical Content Knowledge (PCK) and General Pedagogical Knowledge (GPK). *European Journal of Science and Mathematics Education* **1**(2): 84–105.

Syafitri, W. (2023) Learning experiences in small group discussion in the third semester of English education students. *Journal of Languages and Language Teaching* **11**(2): 27–38. https://doi.org/10.33394/jollt.v11i1.6339

Tsui, A. B. (2003) Understanding expertise in teaching: Case studies of ESL teachers. Cambridge University Press, New York.

Tsui, A. B. (2005) Expertise in teaching: Perspectives and issues. In K. Johnson (Ed.), Expertise in second language learning and teaching (pp. 167–189). New York: Palgrave Macmillan. <downloaded on March 10, 2020, from https://link.springer.com/chapter/10.1057/9780230523470_9>

Walker, A. and Leary, H. (2009) A problem-based learning meta-analysis: differences across problem types, implementation types, disciplines, and assessment levels. *The Interdisciplinary Journal of Problem-based Learning* **3**(1): 12–43. http://dx.doi.org/10.7771/1541-5015.1061

Webb, N. M. (2010) The teacher's role in promoting collaborative dialogue in the classroom. *Educational Psychology* **79**(1): 1–8. https://doi.org/10.1348/000709908X380772

Woest, Y. (2018) Beginner teachers' experiences of transdisciplinary demands of a school curriculum. *The Journal for Trans-disciplinary Research in Southern Africa* **14**(2): 488. https://doi.org/10.4102/td.v14i2.488

WEBSITE

Alstad-Davies, C. (2019) *How to use real-life connections in the classroom to increase engagement.* https://resumes-for-teachers.com/blog/interview-questions/excellent-teachers-use-real-life-connections-in-the-classroom/ <accessed: April 15, 2020>

Department of Education Website. Primer on Inquiry-based instruction. www.deped.gov.ph <accessed: August 20, 2020>

Donaldson, R. (2016) Storytelling for problem solving and better decision making. NetIKXBlog. https://netikx.wordpress.com/2016/04/02/storytelling-for-problem- solving-better-decision-making/ <accessed: July 24, 2020>

Lucariello, J. and Naff, D. (2020) How do I get my students over their alternative conceptions (Misconceptions) for Learning? Removing barriers to aid in the development of the student. https://www.apa.org/education/k12/

misconceptions <accessed: January 19, 2020>

Reddy, C. (2015) Top 16 Advantages and Disadvantages of Working in a Group. https://content.wisestep.com/top-advantages-and-disadvantages-of-working-in-a-group/> <accessed: July 3, 2020>

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_33

Practical Report

Enhancing the design, delivery, evaluation, and learning transfer of hands-on taxidermy training

John O. de la Cruz*
Leyte Samar Heritage Center, University of the Philippines Tacloban College, Phillipines

(Received: 6 June 2025; Accepted for publication : 30 June 2025)

Taxidermy plays an enabling role in advancing research and supporting formal and informal education. This study provides recommendations for improving the design, delivery, and evaluation of taxidermy training and learning transfer based on an assessment of a hands-on taxidermy training offered as a public service by the University of the Philippines Tacloban College and the National Museum of the Philippines. Using Kirkpatrick's four levels of assessment, this study evaluated the implementation of the training and the extent of learning transfer by measuring the participants' knowledge retention and behavioral changes two years after the training in February 2020. The findings indicate that participants were generally satisfied with the training and acquired valuable knowledge and skills. Enhancing program design, delivery, and participant engagement, strengthening monitoring and assessment methods, and integrating structured post-training activities would help reinforce learning transfer. Addressing these areas will enable future training programs to foster a more effective learning environment and encourage more individuals to pursue taxidermy either as a practical learning experience, a full-time hobby, or a career. As demonstrated in this study, incorporating taxidermy as a supplement to laboratory activities, even though it is not part of the curriculum or standard instruction in Biology courses, can provide students with practical learning experiences that may benefit their future careers and enhance their appreciation of both science and the arts, as taxidermy involves both scientific and artistic skills.

Key words: *evaluation, extension, Kirkpatrick's model, public service, taxidermy, training*

***Author for correspondence:** jodelacruz3@up.edu.ph

INTRODUCTION

Taxidermy is the general term used to describe the various methods and techniques of collecting, skinning, preserving, stuffing, and mounting animal skins and other body parts over artificial structures to create lifelike impressions (Péquignot, 2006). This process is typically applied to vertebrate specimens, which are valuable for exhibitions, natural history collections, and scientific research (Das et al., 2025; Kabir and Hawkeswood, 2020). Taxidermy has also been recognized as an effective tool for enhancing instruction and enriching learning experiences in laboratory and classroom settings (Pimm, 1986). Moreover, taxidermy is also considered an art (Tikkanen, see website list) because it involves meticulous craftsmanship and an aesthetic appreciation for the lifelike presentation of the animal, which blends scientific accuracy with creative expression (Das et al., 2024; Kabir et al., 2021). Whether pursued as a hobby or profession, taxidermy requires the development of a specialized set of knowledge, attitudes, and skills (Fairooz et al., 2024). American naturalist Charles Johnson

Maynard (1883) emphasized that to become a proficient taxidermist, one must exercise utmost care, patience, and perseverance, combined with regular practice.

There are multiple ways to acquire taxidermy knowledge and skills. With the accessibility of digital learning resources, interested individuals can engage with online courses, instructional videos, e-books, and other materials to grasp the fundamentals of taxidermy. However, hands-on training remains the most effective method for developing both technical proficiency and creative problem-solving skills in taxidermy. Some countries provide taxidermy services but require licenses and permits. In the US, accredited colleges and trade schools offer taxidermy certificate and diploma programs, typically completed within two weeks to 12 months, depending on the program's rigor and scope (Best Accredited Colleges; Lone Star State School of Taxidermy, see website list). In the Philippines, taxidermy training is primarily conducted as an extension or public service program by higher education institutions (HEIs) and museums. These training sessions usually run for at least five days and are organized upon request.

As far as the scholarly literature is concerned, no study to date has examined how taxidermy training fosters cognitive and creative processes among learners or its effectiveness in facilitating learning transfer. This study fills in this gap by examining participant feedback, learning outcomes, and behavioral changes resulting from a hands-on taxidermy training (HTT) organized by a university in partnership with a national museum in the Philippines. The study aims to provide recommendations for improving the design, delivery, and evaluation of taxidermy training, as well as learning transfer among trainees. The insights generated from this study can serve as a basis for other HEIs and museums interested in offering similar training programs, ensuring that taxidermy education cultivates creativity and craftsmanship, and improves problem-solving and critical thinking skills. Furthermore, this study contributes to the limited literature on taxidermy and adds to the growing body of scholarly work on training evaluation using Kirkpatrick's model.

MATERIALS AND METHODS

Hands-on taxidermy training (HTT)

On 26 February 2020, the University of the Philippines Tacloban College (UPTC), through the Leyte Samar Heritage Center (LSHC), and the National Museum of the Philippines (NMP) organized an HTT in Tacloban City, Eastern Visayas, Philippines. This extension and public service activity aimed to increase the number of taxidermists in Eastern Visayas by providing participants with fundamental knowledge and a practical learning experience in taxidermy. The training formed part of the program of activities for the NMP's mobile museum boxes exhibit titled "Conserving the Natural History of the Visayas Region", which was displayed at the LSHC from 6–26 February 2020. Participation in the training was free of charge. The eight-hour training was structured with an introductory lecture that covered the fundamentals of taxidermy, followed by a practical learning exercise and a post-activity evaluation. During the practical exercises, participants were divided into groups of 10 to perform a taxidermy of a pigeon using the solid foam model method. Each group received their taxidermy materials and kits to ensure they had the necessary tools for the task. A total of 113 BS Biology students from UPTC (52) and Leyte Normal University (61), all at least 18 years old at the time, participated in the event.

Kirkpatrick's model

This study employs Kirkpatrick's model to evaluate the effectiveness of training programs, which consists of four hierarchical levels: reactions (Level 1), learning (Level 2), behavior (Level 3), and results (Level 4) (Kirkpatrick and Kirkpatrick, 2006). Kirkpatrick's model is widely used in assessing human resource development in business organizations (Alsalamah and Callinan, 2021) and educational programs (Bates, 2004), particularly in medicine and healthcare (Clark et al., 2013; Gunderman and Chan, 2015; Heydari et al., 2019). This study extends the application of the model to an HTT offered as a collaborative public service activity by an HEI and a museum.

Level 1 (Reactions): Participant satisfaction evaluation design

Evaluation at this level measures the trainees' satisfaction with the resource persons' performance and the overall delivery of the training (Kirkpatrick and Kirkpatrick, 2006), which is typically assessed through self-reports that reflect the participants' affective and attitudinal responses (Appannah et al., 2017). For the HTT, the organizers used the post-activity evaluation sheets that UPTC employs as a standardized assessment tool designed to measure client satisfaction for training and extension activities. The instrument allows participants to omit their names, which offers a degree of anonymity (Bess et al., 2004). The post-activity evaluation form consists of two main sections: a 5-point Likert scale rating and a comments and suggestions section. In the rating section, participants evaluated the flow and duration of activities, the relevance and timeliness of topics, the resource persons' performance, and their overall experience using the following scale: Excellent (5), Very Good (4), Good (3), Fair (2), and Poor (1). Since Likert scale responses are measured at the ordinal level, the mode, the most frequently occurring rating, was used to determine the average score for each component. The second section of the instrument collected qualitative feedback on the event's implementation and suggestions for improving similar activities in the future. Only fully completed evaluation sheets were included in the analysis. Moreover, the organizers and resource persons held a post-training meeting to discuss the challenges, weaknesses, and areas for improvement, as well as effective practices and procedures.

Level 2 (Learning): Knowledge assessment via criterion-referenced testing

Level 2 assesses the extent to which the participants had enhanced their knowledge, developed skills, or changed attitudes as a result of the capacity-building activity. This study primarily evaluated the cognitive-based learning, which refers to knowledge gained from the training, including verbal knowledge and strategies (Kraiger et al., 1993). No practical performance test or skill-based assessment was conducted due to financial constraints and COVID-19-related public health and safety protocols at the time. To assess the learning outcomes, a multiple-choice questionnaire was used (Burton, 2001; Oermann and Gaberson, 2019). The test followed a criterion-referenced interpretation of scores and consisted of 10 questions, each with one correct option and two distractors (Appendix A). The quiz was designed to assess both factual knowledge and the application of concepts learned (Horvat et al., 2014) during the training. Respondents were considered to have demonstrated mastery by correctly answering at least 70% (seven out of ten) of the questions. Using the conventional number-right scoring method (Bereby-Meyer et al., 2002), each correct answer was assigned a value of 1, while blank and incorrect answers were given a value of 0. The sum of correct responses determined the test score for each participant. Those who scored seven or higher were considered to have mastered the test, while those who scored below the cutoff were classified as non-masters. The quiz was administered as a time-constrained Google Quiz Form, which allowed each respondent a single attempt to complete the test within 15 minutes. A major concern with multiple-choice tests is that examinees can answer correctly by guessing (Choppin, 1988; Frary, 1988), which introduces a random factor that reduces test reliability and validity (Bereby-Meyer et al., 2002; Burton, 2001; Kubinger et al., 2010; Prihoda et al., 2006). To mitigate this issue, the raw scores were adjusted using the formula:

$$\text{Eq. 1} \qquad Adjusted\ score = R - \frac{W}{C-1}$$

where R is the number of correct answers, W is the number of incorrect answers, and C is the number of answer choices per item (Miller et al., 2008). The average difference between raw and adjusted scores was calculated, and a paired t-test was conducted using MS Excel to determine whether there was a significant difference between the mean raw and corrected scores.

Level 3 (Behavior): Post-training follow-up survey design

Level 3 examines the degree to which participants apply what they have learned in practice, demonstrating behavioral changes resulting from the training. This level of evaluation is typically conducted at least three months after the training to assess whether the knowledge and skills acquired have been transferred to the workplace (Kirkpatrick and Kirkpatrick, 2006), or in this case, applied in school work. This timeframe allows the participants sufficient opportunity to practice and refine their learning (Kirkpatrick and Kirkpatrick, 2006). Given this rationale, the follow-up online survey for this study was conducted on 26 January 2022, 24 months after the training, to provide the participants with more than enough time to apply the knowledge and skills gained from HTT. Online surveys have become the dominant mode for qualitative research (Braun et al., 2020; Toepoel, 2017), particularly during the COVID-19 pandemic (Onat Kocabıyık, 2021), as they offer significant time and cost savings (Lefever et al., 2007). In the online survey, the respondents were asked to enumerate the knowledge and skills they gained from the training, and to indicate their level of eagerness to apply these skills in school work (e.g., class project, laboratory exercises) or other settings (e.g., personal hobby or career). Those who applied their learning were asked to indicate their level of success (very successful, somewhat successful, or not successful) and to identify the factors contributing to their success. To validate the students' responses, the instructors who accompanied them during the training were asked to provide a general assessment of their performance in applying taxidermy skills and knowledge, particularly since the students were required to perform laboratory exercises and submit a class project on taxidermy after the training. Moreover, the student respondents were asked whether they intended to pursue taxidermy as a hobby, career, or both. If they expressed interest in continuing taxidermy, they were asked to specify the supplementary materials or activities they would find helpful. Finally, the respondents and their instructors were asked to provide suggestions for overcoming the challenges that hindered their progress in taxidermy. Qualitative data from these evaluation activities were processed and analyzed using thematic analysis (Braun and Clark, 2006; Braun et al., 2020).

Level 4 (Results): Institutional performance review

The fourth level of Kirkpatrick's model evaluates the organizational impact of the training by assessing its effects on performance, development, and overall benefits (Kaufman et al., 1996; Kirkpatrick, 1967). Moreover, this level examines how the training contributes to or influences the achievement of institutional goals (Ulum, 2015). In this study, the Results criterion assessed how the HTT supported UPTC in fulfilling its institutional objectives related to extension and public service. To measure the immediate impact, the study reviewed and analyzed the Office Performance and Commitment Review (OPCR) of LSHC, UPTC's extension and public service center and the primary organizer of the training, from January to June 2020. From the NMP's perspective, the training was part of its broader program of activities for the traveling exhibit, aimed at providing educational opportunities related to museum work, specifically taxidermy, to complement the exhibit and engage the academic community. Level 4 sought to determine how the HTT contributed to both the host university's extension and public service goals and the museum's programmatic objectives. Furthermore, findings from this analysis, along with the results from Levels 1 to 3, were used to assess the broader organizational impact of the training, particularly in informing the design, implementation, and evaluation of future taxidermy capacity-building initiatives.

Ethical considerations

Research ethics clearance was obtained from the University of the Philippines Visayas Research Ethics Board before the conduct of the surveys. In compliance with the Philippine Data Privacy Act and other ethical considerations, all the data generated from the study are treated with the utmost confidentiality and anonymity. Invitations and free and prior informed consent (FPIC) forms, including an information sheet, were sent to the individual email addresses of all training participants to assess levels 2 and 3. The information sheet outlined the study's objectives, methods, respondents' roles, data processing and analysis, storage plans, data usage, and potential risks and benefits. Only those who voluntarily signed the FPIC were considered respondents for Levels 2 and 3. Participants retained the right to refuse or withdraw from the surveys at any time. The survey posed only minimal risk. The primary inconvenience experienced by respondents was the time required to complete the quiz and survey. To compensate for this, each respondent received a mobile internet load worth Php50.00 (USD 0.89) upon completing both assessments. The instructors and two student respondents declined to accept the mobile load.

RESULTS

Level 1 (Reactions): Participant satisfaction with training delivery

Out of the 113 accomplished post-activity evaluation sheets, 108 (95.6%) contained complete ratings on the Likert scale. The modal score indicated that the majority of participants rated all components of the training as Excellent (5), except for the length of activities, which received an average modal rating of Very Good (4) (Table 1). During the post-mortem discussion, the organizers identified several challenges encountered during the implementation of the training, which aligns with those reported by the instructors and student participants. One participant effectively summarized the outcomes of both the

Table 1. Summary of the HTT participants' comments regarding the implementation of the training and their suggestions to further improve the design and delivery of the said public service

Component (*Average rating*)	**Comments**	**Suggestions**
Organization and flow of activities (*5, Excellent*)	Too many participants have shown up for the training and it led to crowding and a shortage of training kits. On the other hand, the organizers were kind enough to provide all the needed materials for the workshop during the training. (5)	Reduce the number of participants per batch, and divide them into smaller groups (e.g. groups with three to five members) for more focused learning. (7)
	The venue was not appropriate for the training. (2)	Find an appropriate venue (e.g. zoo laboratory, wet laboratory) with enough space, tables, chairs, and other important facilities. (5)
	No lunch was served to the participants (2)	Provide lunch to the participants in addition to the morning and afternoon snacks. (2)
Length of activities (*4, Very good*)	The number of hours allocated for the training was not enough. (3)	Increase the training hours enough to cover at least two to three days for better learning. (2)
	The event followed the prescribed program of activities on time. (2)	Start the program on time as much as possible. (1)
Relevance and timeliness of topics (*5, Excellent*)	The training was very relevant and useful to BS Biology students. (3)	Conduct a similar training using other specimens, like marine creatures. (2)
	In the local scene, the training will help promote taxidermy both as a process and an art. (4)	
Resource persons (*5, Excellent*)	The resource persons were knowledgeable, approachable, and cheerful, making the training a fun-filled learning experience. (8)	Provide the resource persons with enough space and a better projector set for better work demonstration. (1)
Overall evaluation (*5, Excellent*)	HTT was very informative, and it was a great public service from which the participants enjoyed and learned so much. (22)	Training kits, materials, equipment, venue, and important facilities must be prepared and in order before and during the event. (3)
		Prepare extra training kits in case a large number of participants show up. (3)
		Make the public service an annual event. (2)
		Before the event, inform the participants of what to wear and what to bring. (1)

post-activity evaluation survey and the post-mortem analysis:

"Overall, the training was successful. As one of the participants, I was able to do the hands-on taxidermy in our group. But, I noticed that since there were many participants, only a few per group were participating and there was little time for some students who wanted to try

the different processes. Because of that, not all were given enough time to experience the taxidermy process. I think it will be better if the activity was done by pair so that each student can focus on each process and experience. If the same large number of participants is needed, it can be a 2-3-day activity. In addition, it would be best if the participants were all in a laboratory gown, or any comfortable clothes to move freely while doing the taxidermy."

To address such concerns, the organizers suggested implementing a participant cutoff and introducing a registration fee to cover meals, kits, and other logistical costs. Other suggestions include conducting the training in laboratory settings equipped with essential facilities.

Level 2 (Learning): Knowledge acquisition based on adjusted quiz scores

Only 49 (43%) out of the 113 training participants took the online quiz. Table 2 shows the raw test scores and the adjusted test scores of the takers. The average difference between the raw and corrected test scores was approximately 0.73. The paired t-test further revealed a significant difference between the means of the raw and adjusted scores, as the p-value (6.553×10^{-12}) was lower than the significance level ($\alpha = 0.05$). This finding suggests that, without correctly guessing answers, the participants would have obtained significantly lower test scores, leading to a reduced passing rate. Table 3 presents the descriptive statistics for both the raw and adjusted test scores.

Table 2. Distribution frequency of the raw and adjusted test scores of the HTT participants who took the online quiz

Score	Raw Test Score (%)	Corrected Test Score (%)	Interpretation
10	10 (*20.4%*)	10 (*20.4%*)	Passed/Masters
9	19 (*38.8%*)	0	Passed/Masters
8.5	0	19 (*38.8%*)	Passed/Masters
8	14 (*28.6%*)	0	Passed/Masters
7	3 (*6.1%*)	14 (*28.6%*)	Passed/Masters
6	3 (*6.1%*)	0	Failed/Non-masters
5.5	0	3 (*6.1%*)	Failed/Non-masters
4	0	3 (*6.1%*)	Failed/Non-masters
Total	49 (*100%*)	49 (*100%*)	

Table 3. Descriptive statistics of the raw scores and corrected scores of those who took the online quiz for the HTT

	Mean	Median	Mode	SE	Variance	Range	Minimum	Maximum
Raw Score	8.61	9	9	±0.15	1.08	4	6	10
Adjusted Score	7.92	8.5	8.5	±0.23	1.61	6	4	10

Level 3 (Behavior): Enthusiasm, knowledge and skills application

The same group of respondents from Level 2 participated in the Level 3 evaluation. Their responses indicated that the knowledge and skills acquired during the training included stuffing the skin using the solid foam method (47), the proper way of euthanizing a bird (46), preserving the skin and other body parts (45), mounting the specimen (44), caping or fleshing the specimen (38), legal and ethical aspects of taxidermy (1), and understanding the level of skill required to preserve a specimen (1). When asked about their enthusiasm, 28 respondents (57.1%) were somewhat eager, 19 (38.8%) were very eager, and two (4.1%) were not eager to use their acquired taxidermy skills. Regarding future aspirations, 18 respondents (36.7%) expressed interest in pursuing taxidermy as a hobby, eight (16.3%) aimed to become professional taxidermists, and 13 (26.5%) wanted to engage in taxidermy both as a hobby and a career. On the other hand, 10 respondents (20.4%) had no interest in continuing taxidermy in any capacity. All respondents who wished to pursue taxidermy further indicated that they would need both formal training in a taxidermy program and hands-on experience through an internship in museums or HEIs.

All four academic instructors (A, B, C, and D) who accompanied their students during the training provided an overall assessment of class performance, which included the quiz, class projects, and laboratory exercises. Figure 1 presents two sets of histograms: one showing the distribution of instructors' general assessments of the students' success in applying taxidermy knowledge and skills, and the other presenting the distribution of students' self-reported ratings of their application of these skills in both schoolwork and other settings (i.e., hobby). Instructor C noted, "*The students who actively participated in the hands-on activity were successful in applying their taxidermy learnings, whereas those who only observed and listened were less successful*." Despite variations in performance, the training positively influenced the students' attitudes and behaviors toward taxidermy as Instructor D observed, "*They became more motivated to apply different principles and techniques in taxidermy to various animals and specimens. The training also helped them*

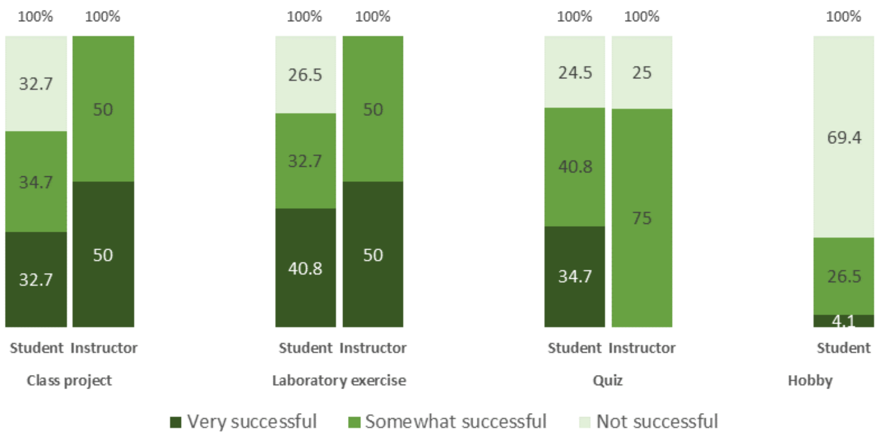


Figure 1. Comparison of instructors' assessments and students' self-reported ratings on the success of applying taxidermy knowledge and skills in schoolwork and other setting (hobby)

develop patience and a greater appreciation for their surroundings."

Several key factors contributed to the successful application of hands-on training. The most frequently mentioned factor was the knowledge and skills gained from the training (37) and guidance from course instructors (29). Other critical factors identified were the availability of necessary resources and materials (42) and access to an appropriate venue (21), such as a school laboratory or a dedicated workspace at home. Finally, personal motivation and interest (13) emerged as an important factor, with some students stating that their genuine enthusiasm for the craft encouraged them to continue practicing and improving their skills. At the same time, the participants identified several challenges. The most frequently cited challenge was the lack of chemicals, supplies, and materials (31), followed by the fact that taxidermy was not required in their coursework (28). In addition, the lack of an appropriate venue (27), the absence of specimens (27), the lack of confidence (21), and insufficient taxidermy skills (15) made independent practice difficult. The lack of guidance from instructors (13) and limited correspondence with trainers (12) further contributed to their struggles. Moreover, some participants found taxidermy to be time-consuming and laborious (11), while others cited external factors such as the lockdown during the COVID-19 pandemic (1) and the limited time available, particularly for beginners (1), as additional barriers. To address these challenges, the respondents suggested several solutions. Many recommended providing taxidermy individual kits, including manuals and tools, that participants could take home after the training (45), as well as offering incentives, such as prizes, for participants who performed well during the workshop (20). They also emphasized the need for a dedicated platform for continued correspondence between participants and trainers after the training (22) and the importance of establishing a network of taxidermists (29). Some participants reiterated their recommendations from the post-activity evaluation, which included increasing the number of training hours (39), securing an appropriate venue for the training (38), limiting the number of participants (26), and inviting additional taxidermy experts as resource persons (24). Meanwhile, the instructors underscored the importance of engaging in more hands-on training focused on techniques specific to different types of animals.

Level 4 (Results): Contribution to institutional and programmatic objectives

Based on the approved ratings for the OPCR from January to June 2020, the HTT significantly contributed to the Center's achievement of its target under the strategic initiative of enhancing the university's public service and engagement, supporting the broader institutional goal of contributing to national development. Within this initiative, key performance indicators focus on community involvement, which include metrics such as (1) the number of extension/public service activities conducted in collaboration with regional public service and civic engagement networks, and (2) the number of beneficiaries served. Initially, LSHC set a target of two public service activities, with at least a total of 70 participants. Through HTT, the Center exceeded its targets, achieving an average rating of 4.67 (Outstanding) for each metric before the end of the rating period. In grading the OPCR, public service activities were first rated by the project leader and later validated by the immediate supervisor (Center Director) based on three criteria: quality/effectiveness, efficiency, and timeliness, using the rating scale prescribed by the Civil Service Commission of the Philippines. Simultaneously, the HTT also contributed to the NMP's programmatic objectives as part of its exhibit. By incorporating the HTT into the exhibit's programming, the museum sought not only to promote a deeper understanding of taxidermy as a museum practice but also to foster a greater appreciation for specimen preservation and conservation. Furthermore, the actual number of participants exceeded the museum's target of 20. Despite receiving very satisfactory ratings, positive feedback, and a noticeable impact on the learning and behavior of participants, the organizers must carefully consider the comments and suggestions from the trainees to further refine the design, delivery, and evaluation of the training, as well as to enhance the learning transfer among participants.

DISCUSSION

Effectiveness of the HTT implementation

The Kirkpatrick's evaluation framework demonstrated that the HTT was effective in achieving its main goal of imparting fundamental knowledge and skills in taxidermy, which participants were able to apply and retain over time. In terms of training design, delivery, and evaluation, the results from the post-activity evaluation indicated that the training received excellent ratings and generally positive feedback despite some critical remarks. Level 1 findings support that efficiency of training delivery, perceived usefulness, and trainer performance influence participant satisfaction (Giangreco et al., 2009; Lee and Pershing, 2002; Morris, 1984; North et al., 2001; Towler and Dipboye, 2001). However, some participants expressed dis-appointment with the length of the training, wishing for a longer duration, which impacted their perception of the training's efficiency. Addressing the duration of the training and ensuring an appropriate time frame would likely enhance both the efficiency and effectiveness of the program, ultimately improving learning outcomes (Axtell et al., 1997; Kejela and Tiruneh, 2022). In addition, the post-evaluation survey revealed that trainees were highly engaged in providing feedback, openly identifying weaknesses in the HTT, and suggesting improvements. This active participation suggests that the survey effectively captured candid responses, particularly due to the anonymity of the submissions, which allowed participants to voice their perspectives without hesitation (Bess et al., 2004). The high level of engagement and constructive feedback underscores the value of incorporating structured feedback mechanisms into future training programs, as these mechanisms are vital for refining instructional methods and enhancing the overall learning experience.

Learning and application

Learning transfer is shaped by three primary elements: training design and delivery, individual trainee characteristics (e.g., motivation and self-efficacy), and the workplace environment (Baldwin and Ford, 1988; Bell et al., 2017; Blume et al., 2010; Martin, 2010; Sahoo and Mishra, 2019). At the learning (Level 2) and application (Level 3) stages, the hands-on component of the HTT enabled participants to develop essential taxidermy skills. However, the retention and application of these skills are contingent upon follow-up activities and reinforcement (Kondratjew and Kahrens, 2019), such as quizzes, laboratory exercises, and projects. This finding aligns with previous observations where trainees who actively engaged in post-training activities exhibited higher knowledge retention (Martin, 2010), a trend also reflected in some HTT participants.

Individual trainee characteristics, such as self-efficacy, also play a critical role in learning transfer. Participants who rated themselves as very successful in applying their taxidermy knowledge likely demonstrated high self-efficacy, a trait closely linked to greater motivation and achievement (Chiaburu and Marinova, 2005). However, it is important to note that some trainees may have overestimated their proficiency, a phenomenon consistent with the Dunning-Kruger effect, where individuals with limited skills tend to overrate their capabilities (Kruger and Dunning, 1999). This nuanced aspect highlights the need for realistic self-assessment and ongoing guidance during and after the training.

Furthermore, the workplace environment significantly influences the application of acquired skills. Supportive academic settings, access to proper materials, and opportunities for hands-on practice are essential for successful learning transfer (Martin, 2010; Tracey et al., 2001). As demonstrated in similar studies (Burke and Hutchins, 2007; Lim and Morris, 2006; Rouiller and Goldstein, 1993), the effectiveness of HTT relied on the availability of necessary materials, such as chemicals and laboratory equipment, as well as instructor support and curriculum integration within trainees' home institutions. In addition, structured follow-up activities, including projects and quizzes, further reinforced the learning transfer process (Kondratjew and Kahrens, 2019; Xie and Derakhshan, 2021), as indicated by the post-HTT surveys. To enhance skill application in real-world settings, it is recommended that institutions strengthen workplace support by ensuring access to necessary materials, establishing structured mentorship programs, and integrating taxidermy more fully into existing curriculum or coursework. Moreover, future training programs should incorporate structured post-training activities, such as project-based learning and periodic assessments, to sustain trainees' interest, improve knowledge retention, and facilitate practical application. Multiple assessment strategies are needed to determine whether the learning targets (i.e., objectives, outcomes, or competencies) were achieved (Brookhart and Nitko, 2008). Addressing these challenges could foster a more engaging and effective training environment, ultimately supporting the achievement of the training goals (Csikszentmihalyi, 2013; Sawyer, 2011).

In terms of learning evaluation, the HTT used a multiple-choice questionnaire, which is adaptable for assessing a wide range of content and learning outcomes at the levels of recall, comprehension, application, and analysis (Burton et al., 1991; Oermann and Gaberson, 2009). However, there is a need to improve the design and content of test items. Limited response options in the current quiz may have increased the likelihood of guessing correct answers (Jin et al., 2022; Zimmerman and Williams, 2003), as suggested by the significantly lower adjusted scores. Enhancing the construction, selection of options, administration, scoring, and analysis of test items will provide a clearer understanding of participants' learning and performance (Brookhart and Nitko, 2008; Rouse, 2011; Royal and Stockdale, 2017). In turn, these improvements can help enhance the training module, the associated assessment tools, and follow-up activities.

Institutional impact of HTT

Regarding the broader impact of training on institutional goals, HEIs and museums invest substantial resources into extension and public service programs. However, these initiatives are often not assessed for long-term effectiveness, leading to a gap in the literature on their sustained impact (Llenares and Deocaris, 2018; Sermona et al., 2020). Some organizations may not view long-term training evaluation as a priority, while others lack the capacity to conduct comprehensive assessments (Kirkpatrick and Kirkpatrick, 2006). Despite challenges in implementation, the HTT made a meaningful contribution to the museum's and the host institution's extension service objectives. Aligning with Kirkpatrick's framework, the training successfully enabled participants to acquire and apply taxidermy skills, fulfilling its primary objective. Moreover, the participants' ability to retain and implement these skills in their respective institutions and communities highlights the effectiveness of the HTT as a skill-building initiative and underscores the potential long-term impact of such programs on both institutional and participant outcomes.

CONCLUSION

Taxidermy plays an enabling role in both formal and informal learning environments, such as schools and museums. Given the global decline in the number of taxidermists, it is essential to expand and enhance taxidermy training programs to meet the needs of potential practitioners. The application of Kirkpatrick's evaluation model yielded valuable insights into the organization, implementation, monitoring, and assessment of the HTT as an informal educational activity. Based on participant reactions, learning outcomes, behavioral changes, and the training's contribution to the museum's and university's institutional goals, the HTT can be considered a successful initiative. The success of HTT underscores several key considerations for future training programs. First, it highlights the importance of structured training design and hands-on learning in skills development. Second, it emphasizes the need for continuous institutional support, including access to materials, mentorship, and follow-up activities, to reinforce learning transfer. Finally, it demonstrates the necessity of systematic evaluation and long-term tracking of training outcomes. To improve participant engagement and knowledge transfer, extension and public service providers in HEIs and museums can adopt the recommendations from this study, refine training methodologies, and consider integrating taxidermy into coursework, especially in Biology or Museum management majors. Moreover, future programs should focus on strengthening key elements such as training design, individual learner characteristics, and workplace support. These factors are integral to creating a learning environment that not only fosters attitude and skills development but also encourages individuals to pursue expertise in taxidermy. However, caution must be exercised in interpreting the results of this study due to its limitations. As the HTT was conducted as a short public service activity, further research is needed to examine the impact of extended training programs, such as diploma and certificate courses, as well as longitudinal assessments. Addressing these limitations in future studies can provide institutions with valuable data on knowledge retention and skill application over time, ensuring that future extension initiatives are optimized for sustained impact and effectiveness.

ACKNOWLEDGMENT

Sincere gratitude is extended to Prof. Patricia B. Arinto, Dr. Erlinda Castro-Palaganas, Dr. Shigeki Mayama, and the journal's reviewers for their valuable insights and guidance in the development and refinement of this article. Appreciation is also given to Dr. Stephen Q. Lagarde, Mr. John Laurence M. Laurente, Mr. Jeremy B. Romero, Mr. Reynaldo N. Macarayon, Ms. Ma. Odezsa T. Cabral, Ms. Melchona Ann A. Dy, the UPTC Division of Natural Sciences and Mathematics, all those who helped organize the HTT, as well as the instructors and students who participated in the training and this study. Special thanks are extended to the NMP and Mr. John Micheal M. Galindon and Mr. Eddie Codino, who served as HTT resource persons. This scholarly work was supported by the Office of the Vice President for Public Affairs – Padayon Public Service Office of the University of the Philippines System through the 3rd Public Service Writing Fellowship.

DISCLOSURE STATEMENT

The author reports there are no competing interests to declare.

DATA AVAILABILITY STATEMENT

The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, supporting data is not available.

REFERENCES

Alsalamah, A., and Callinan, C. (2021). Adaptation of Kirkpatrick's four-level model of training criteria to evaluate training programs for head teachers. *Education Sciences* **11** (3): 116.

Appannah, A., Meyer, C., Ogrin, R., McMillan, S., Barrett, E. and Browning, C. (2017) Diversity training for the community aged care workers: A conceptual framework for evaluation. *Evaluation and Program Planning* **63**:74–81.

Axtell, C. M., Maitlis, S. and Yearta, S. K. (1997) Predicting immediate and longer-term transfer of training. *Personnel Review* **26** (3): 201–213.

Baldwin, T. and Ford, J. K. (1988) Transfer of training: A review and directions for future research. *Personnel Psychology* **41** (1): 63–105.

Bates, R. (2004) A critical analysis of evaluation practice: The Kirkpatrick model and the principle of beneficence. *Evaluation and Program Planning* **27** (3): 341–348.

Bell, B. S., Tannenbaum, S. I., Ford, J. K., Noe, R. A. and Kraiger, K. (2017) 100 years of training and development research: What we know and where we should go. *The Journal of Applied Psychology* **102** (3): 305–323.

Bereby-Meyer, Y., Meyer, J., and Flascher, O. M. (2002) Prospect theory analysis of guessing in multiple choice tests. *Journal of Behavioral Decision Making* **15** (4): 313–327.

Bess, G., King, M., and LeMaster, P. L. (2004) Process evaluation: How it works. *Indian and Alaska Native Mental Health Research (Online)* **11** (2): 109–120.

Blume, B. D., Ford, J. K., Baldwin, T. T., and Huang, J. L. (2010) Transfer of training: A meta-analytic review. *Journal of Management* **36** (4): 1065–1105.

Braun, V., and Clark, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology* **3** (2): 77–101.

Braun, V., Clark, V., Boulton, E., Davey, L. and McEvoy, C. (2020) The online survey as a qualitative research tool. *International Journal of Social Research Methodology* **24** (6): 641–654.

Brookhart, S. M., and Nitko, A. J. (2008) *Assessment and grading in classrooms*. Pearson Education, Upper Saddle River. New Jersey.

Burke, L. A., and Hutchins, H. M. (2007) Training transfer: An integrative literature review. *Human Resource Development Review* **6** (3): 263–296.

Burton, R. F. (2001) Quantifying the effects of chance in multiple choice and true/false tests: Question selection and guessing of answers. *Assessment & Evaluation in Higher Education* **26** (1): 41–50.

Burton, S. J., Sudweeks, R. R., Merrill, P. F., and Wood, B. (1991) *How to prepare better multiple-choice test items: guidelines for university faculty*. Brigham Young University Testing Services. Provo.

Chiaburu, D. S., and Marinova, S. V. (2005) What predicts skill transfer? An exploratory study of goal orientation, training self-efficacy, and organizational supports. *International Journal of Training and Development* **9** (2): 110–123

Choppin, B. H. 1988. Correction for guessing. *In*: Keeves, J. P. (ed) *Educational Research, Methodology, and Measurement: An International Handbook*, pp. 384–86. Pergamon Press, Oxford.

Clark, C. M., Ahten, S. M., and Macy, R. (2013) Using problem-based learning scenarios to prepare nursing students to address incivility. *Clinical Simulation in Nursing* **9** (3): e75–83.

Csikszentmihalyi, M. (2013) *Creativity: Flow and the Psychology of Discovery and Invention.* Reprint. Harper Perennial. New York.

Das, M. R., Kabir, A., and Rana, J. (2024) Reptilian taxidermy in the Jamuna Bridge Regional Museum of Bangladesh. *Global Scientific and Academic Research Journal of Multidisciplinary Studies* **3** (12): 190–193.

Das, M. R., Kabir, A., and Zaman, T. (2025) Taxidermy: the art of preserving life beyond death. *Global Scientific and Academic Research Journal of Multidisciplinary Studies* **4** (3): 10–12.

Fairooz, F., Islam, M. A., Haither, N., Das, M. R., and Uddin, M. A. (2024) Preservation of natural history and biodiversity of Bangladesh: effort of Bangladesh National Museum. *American Journal of Pure and Applied Biosciences* **6** (4): 133–151.

Frary, R. B. (1988) Formula scoring of multiple-choice tests (Correction for guessing). *Educational Measurement: Issues and Practice* **7** (2): 33–38.

Giangreco, A., Sebastiano, A. and Peccei, R. (2009) Trainees' reactions to training: An analysis of the factors affecting overall satisfaction with training. *The International Journal of Human Resource Management* **20** (1): 96–111.

Gunderman, R. B., and Chan, S. (2015) Kirkpatrick's evaluation of educational programs and its relevance to academic radiology. *Academic Radiology* **22** (10): 1323–1325.

Heydari, M. R., Taghva, F., Amini, M., and Delavari, S. (2019). Using Kirkpatrick's model to measure the effect of a new teaching and learning methods workshop for health care staff. *BMC Research Notes* **12** (1): 1–5.

Horvat, L., Horey, D., Romios, P., and Kis-Rigo, J. (2014) Cultural competence education for health professionals. *The Cochrane Database of Systematic Reviews* 2014 (5): CD009405.

Jin, Y., Siu, L., and Huang, X. (2022) Exploring the impact of random guessing in distractor analysis. *Journal of Educational Measurement* **59** (1): 43–61.

Kabir, A., and Hawkeswood, T. J. (2020) A review on wildlife taxidermy: preservation for conservation. *Calodema* **845**: 1–8.

Kabir, A., Das, M. R., and Hawkeswood, T. J. (2021) A study on the theoretical concepts of quality mammalian taxidermy: clues for conservation. *Calodema* **854**: 1–10.

Kaufman, R., Keller, J. and Watkins, R. (1996) What works and what doesn't: Evaluation beyond Kirkpatrick. *Performance + Instruction* **35**: 8–12.

Kejela, S., and Tiruneh, A. G. (2022) Determinants of satisfaction and self-perceived proficiency of trainees in surgical residency programs at a single institution. *BMC Medical Education* **22**:473.

Kirkpatrick, D. L. (1967). Evaluation of training. In: Craig, R. L., and Bittel, L. R. (eds) *Training and Development Handbook*, pp. 87–112. McGraw-Hill, NY, USA.

Kirkpatrick, D. L., and Kirkpatrick, J. D. (2006) *Evaluating Training Programs: The Four Levels*. 3rd ed. Berrett-Koehler Publishers, Inc., San Francisco, California, USA.

Kirkpatrick, J., and Kirkpatrick, W. K. (2009) *The Kirkpatrick Four Levels: A Fresh Look after 50 Years 1959-2009*. The Kirkpatrick partners, Newnan, Georgia, USA.

Kondratjew, H., and Kahrens, M. (2019) Leveraging experiential learning training through spaced learning. *Marion* **11** (1): 30–52.

Kraiger, K, J. K. Ford, and Salas, E. (1993) Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. *Journal of Applied Psychology* **78** (2): 311–328.

Kruger, J., and Dunning, D. (1999) Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self assessments. *Journal of Personal and Social Psychology* **77** (6): 1121–1134.

Kubinger, K. D., Holocher-Ertl, S., Reif, M., Hohensinn, C., and Frebort, M. (2010) On minimizing guessing effects on multiple-choice items: Superiority of a two solutions and three distractors item format to a one solution and five distractors item format. *International Journal of Selection and Assessment* **18** (1): 111–115.

Lee, S. H., and Pershing, J. A. (2002) Dimensions and design criteria for developing training reactions evaluations. *Human Resources Development International* **5** (2): 175–197.

Lefever, S., Dal, M., and Matthíasdóttir, Á. (2007) Online data collection in academic research: Advantages and limitations. *British Journal of Educational Technology* **38** (4): 574–582. .

Lim, D. H., and Morris, M. L. (2006) Influence of trainee characteristics, instructional satisfaction, and organizational climate on perceived learning and training transfer. *Human Resource Development Quarterly* **17** (1): 85–115.

Llenares, I. I., and Deocaris, C. C. (2018) Measuring the impact of an academe community extension program in the Philippines." *Malaysian Journal of Learning and Instruction* **15** (1): 35–55.

Martin, H. J. (2010) Improving training impact through effective follow-up: Techniques and their application. *Journal of Management Development* **29** (6): 520–534.

Maynard, C. J. (1883) *Manual of Taxidermy: A Complete Guide in Collecting and Preserving Birds and Mammals*. S.E. Cassino & Company, Boston, Massachusettes, USA.

Miller, M. D., Linn, R. L., and Gronlund, N. E. (2008) *Measurement and Assessment in Teaching*. 10th ed. Pearson College Div. Upper Saddle River, N. J.

Morris, M. (1984). The evaluation of training. *Industrial and Commercial Training* **16** (2): 9–16.

North, R. F. J., Strain, D. M. and Abbott, L. (2001) Training teachers in computer-based management information systems. *Journal of Computed Assisted Learning* **16** (1): 27–40.

Oermann, M. H., and Gaberson, K. B. (2019) *Evaluation and Testing in Nursing Education*. 6th ed. Springer Publishing Company. New

York.

Onat Kocabıyık, O. (2021) Social media usage experiences of young adults during the COVID-19 pandemic through social cognitive approach to uses and gratifications. *International Journal of Technology in Education and Science* **5** (3): 447–462.

Péquignot, A. (2006) The history of taxidermy: Clues for preservation. *Collections: A Journal for Museum and Archives Professionals* **2** (3): 245–255.

Pimm, J. W. (1986) Using taxidermy as a science motivator. *The American Biology Teacher* 48 (7): 422–424.

Prihoda, T. J., Pinckard, R. N.., McMahan, C. A., and Jones, A. C. (2006) Correcting for guessing increases validity in multiple-choice examinations in an oral and maxillofacial pathology course. *Journal of Dental Education* **70** (4): 378–386.

Rouiller, J. Z., and Goldstein, I. L. (1993) The relationship between organizational transfer climate and positive transfer of training. *Human Resource Development Quarterly* **4** (4): 377–390.

Rouse, D. N. (2011) Employing Kirkpatrick's evaluation framework to determine the effective-ness of health information management courses and programs. *Perspectives in Health Information Management*, **8** (Spring): 1c.

Royal, K. D., and Stockdale, M. R. (2017) The impact of 3-option responses to multiple-choice questions on guessing strategies and cut score determinations. *Journal of Advances in Medical Education & Professionalism* **5** (2): 84–89.

Sahoo, M., and Mishra, S. (2019) Effects of trainee characteristics, training attitudes and training need analysis on motivation to transfer training. *Management Research Review* **42** (2): 215–238.

Sawyer, R. K. (2011) *Structure and Improvisation in Creative Teaching*. Cambridge University Press.

Sermona, N. L. D., Talili, I. N., Enguito, R. C., and Salvador, M. F. (2020) Implementation of extension services in select state uni-versities and colleges in the Philippines. *Science International-Lahore* **32** (6): 609–614.

Toepoel, V. (2017). Online survey design. *In*: Fielding, N. G., Lee, R. M. and Blank, G. (eds) *The SAGE Handbook of Online Research Methods*, 2nd ed., pp. 184–202. Sage.

Towler, A. J., and Dipboye. R. L. (2001) Effects of trainer expressiveness, organization, and trainee goal orientation on training outcomes. *The Journal of Applied Psychology* **86** (4): 664–73.

Tracey, J. B., Hinkin, T. R., Tannenbaum, S., and Mathieu, J. E. (2001) The influence of individual characteristics and the work environment on varying levels of training outcomes. *Human Resources Development Quarterly* **12** (1): 5–22.

Ulum, Ö. G. (2015) Program evaluation through Kirkpatrick's framework. *Pacific Business Review International* **8** (1): 106–11.

Xie, F., and Derakhshan, A. (2021) A conceptual review of positive teacher interpersonal communication behaviors in the instructional context. *Frontiers in Psychology* **12**: 708490.

Zimmerman, D. W., and Williams, R. H. (2003) A new look at the influence of guessing on the reliability of multiple-choice tests. *Applied Psychological Measurement* **27** (5): 357–371.

WEBSITE

Best Accredited Colleges. Schools with Taxidermy Programs: How to Choose. https://bestaccreditedcolleges.org/articles/schools-with-taxidermy-programs-how-to-choose.html

<accessed: 13/08/2022>

Lone Star State School of Taxidermy. Course Descriptions. https://www.texastaxidermyschool.com/course-descriptions/#:~:text=Taxidermy%206%20Week%20course%20(240%20Hours)&text=The%20Taxidermy%206%20Week%20course,novelty%20items%2C%20and%20bird%20mounts <accessed: 13/08/2022>

Tikkanen, A. Taxidermy. Britannica. https://www.britannica.com/science/taxidermy <accessed: 20/02/2025>

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_50

Research Paper

Fostering Students' Awareness and Attitudes toward River Environments: Development of a Diatom-Based Educational Program

Shigeki Mayama[1,2]*, Kengo Satomi[1], Kazhuhiro Katoh[3], Balasubramanian Karthick[4], Mathew L. Julius[5], Hiroshi Omori[6], Megumi Saito-Kato[7]

[1]*Tokyo Gakugei University, Japan*
[2]*Tokyo Diatomology Lab, Japan*
[3]*The Open University of Japan*
[4]*Agharkar Research Institute, India*
[5]*St. Cloud State University, U.S.A.*
[6]*The University of Tokyo, Japan*
[7]*The National Museum of Nature and Science, Tokyo*

(Received: 27 March 2025; Accepted for publication : 1 June 2025)

This study examined changes in students' awareness of river environments and the formation of their behavioral attitudes through a diatom-based educational program implemented in secondary schools in India, Japan, and the United States. The program used past and present diatom specimens, river photographs, and the SimRiver simulator to help students understand the relationship between human activities and river water quality. Text mining analysis, using TWINSPAN and Correspondence Analysis, revealed a significant increase in environmental awareness among students after the lessons. The qualitative analysis of students' responses revealed distinct patterns in their behavioral attitudes. In the Indian groups, a relatively high proportion of students exhibited autonomous and action-oriented attitudes. In contrast, Japanese students frequently showed concern for environmental issues, but their responses often reflected other-dependent thinking. Students in the U.S. group offered fewer behavior-related responses, which may be attributed to the favorable local environment, the geographical disconnect between the lesson materials and the students' everyday surroundings, and the generally shorter nature of their written responses. The program demonstrated its effectiveness in raising students' environmental awareness and supporting the development of attitudes toward action. Furthermore, incorporating historical and international comparisons appeared to promote the transition from awareness to action among students. These findings suggest that such lesson programs may serve as valuable contributions to education for Sustainable Development Goal 6 (SDG 6).

Key words: *cross-cultural comparison, diatoms, environmental education, SDG 6, river environment, SimRiver, student awareness and attitude*

***Author for correspondence:** mayama@u-gakugei.ac.jp

INTRODUCTION

Water pollution and sanitation issues are crucial challenges that should be addressed through international collaboration, as advocated by Sustainable Development Goal 6 (SDG 6) (UN-Water, 2023). Raising people's awareness and shaping attitudes toward the water environment is a fundamental factor in solving these problems. The SDG 6 Global Acceleration Framework (UN-Water, 2020) emphasizes the integration of water and sanitation education into school curricula and public outreach programs to facilitate behavioral change related to water conservation and pollution reduction.

There are various hands-on environmental education programs that emphasize the importance of water, implemented both locally (Bae *et al*., 2011; Fu and Komatsu, 2024; Miyao *et al*., 2007; Wongchantra *et al*., 2022; Jeevitnadi, *see Websites*) and globally (Project WET, *see Websites*; Project WILD, *see Websites*). These programs are often conducted as workshops that include fieldwork, games, discussions, etc., primarily as extracurricular activities. Participants in such hands-on programs can observe water in situ, but it is difficult for them to directly understand the causal relationships behind changes in the water environment.

Many Japanese junior high school science and senior high school biology textbooks introduce methods for assessing river water quality using aquatic invertebrates as bioindicators, and/or chemical test kits. This is rooted in the context of Japan's water quality improvement history, where rivers became severely polluted during the period of rapid economic growth in the 1960s but gradually improved following the enactment of the Water Pollution Control Law in 1971. During this process, the former Environment Agency and the Ministry of Construction (now the Ministry of the Environment and the Ministry of Land, Infrastructure, Transport and Tourism) took the initiative in promoting citizen-led water quality assessments using aquatic bioindicators in rivers across the country (Ministry of the Environment, *see Websites*). The students who participated in the program could learn about the water quality of the surveyed sites based on the environmental adaptations of the observed organisms. However, it was difficult for them to understand the causal relationships behind how the water environment came into being. Thus, they found it challenging to model their observations and grasp the conceptual framework of the relationship between human activities and their resulting impacts on the aquatic ecosystem.

Meanwhile, to help students understand changes in the water environment, computer simulation programs such as Leaf Pack Network Simulation (*see Websites*), River City (Ketelhut *et al*., 2010a), EcoMUVE (Ketelhut *et al*., 2010b), and SimRiver (Mayama *et al*., 2011; Hoffer *et al*., 2011; Lee *et al*., 2011; Lobo *et al*., 2014) have been developed. With these programs, students can learn about water quality changes and the resulting shifts in aquatic organisms. Generally, since changes in the water environment occur over long periods, it is difficult for students to experimentally observe these processes within the limited duration of school education. However, learning through simulators enables students to model causal relationships by formulating hypotheses and testing them through repeated simulations in a short time. Additionally, collecting and processing data statistically, including numerical analysis and graphing, helps students develop their ability to logically explain the relationship between environmental changes and aquatic organisms, as well as predict future environmental changes. However, one challenge of simulation-based learning is that it often lacks a tangible connection to the real world, making it difficult for students to fully comprehend its relevance to real-world environmental issues (Mayama *et al*., 2008; Hamed and Aljanazrah, 2020).

SimRiver, which we developed, is an online simulator designed to help students visually understand the relationship between human activities and river water quality through diatoms (Katoh *et al*., 2004). Diatoms are a fundamental producer in the aquatic ecosystem, responsible for generating approximately 20 to 25% of global photosynthesis, and their name appears in all junior high school science textbooks in Japan. The interface of SimRiver is graphically designed to allow for easy operation. By adjusting environmental factors, users can generate different water conditions, and the corresponding virtual diatom community images are produced based on the given water quality. This simulation program is based on 20 years of accumulated data on water quality and diatom communities that we have collected and analyzed from real rivers (Kobayasi and Mayama, 1989; Mayama, 1999; Satomi *et al*., 2018). As a result, learners can observe virtual diatom communities as high-quality images, similar to actual diatom samples collected from rivers. With the incorporation of gaming elements, students can actively engage in repeated simulations, naturally acquiring an understanding of the concept of anthropogenic environmental disturbance.

Unlike aquatic invertebrates, which are commonly used as other bioindicators for water quality assessment, diatom specimens do not deteriorate even over centuries because their cells are encased in a glass-like silica shell. Kosakai and Mayama (2015) developed a learning program that combined observations of diatom specimens collected from the same river in the past and present, photographs and a video of the river from both time periods, and a SimRiver simulation. This approach resulted in more realistic responses from students compared to using SimRiver alone, as well as opinions that led to actions for environmental improvement.

To clarify the educational effects contributing to SDG 6, this study implemented lessons in schools in India, Japan, and the United States, utilizing past and present diatom samples, river photographs, and SimRiver simulations. The study aimed to analyze changes in students' awareness of river environments and the formation of their attitudes, and to identify key characteristics of this transformation.

METHODOLOGY

Diatom samples and preparations

Past diatom samples used as learning materials were chosen from the collections of the National Museum of Nature and Science, Japan, the Academy of Natural Sciences of Drexel University, U.S.A., and the Agharkar Research Institute, India. These samples were carefully selected to allow for clear comparison with the present diatom assemblages from the same rivers. Additionally, the present samples were collected from the exact same locations as the past samples (Table 1).

The samples were heated in a water bath with sulfuric acid containing potassium dichromate for one hour, then rinsed with pure water several times (Mayama, 1993). The suspension containing diatom frustules was dropped onto a cover slip, dried, and then embedded in Mount Media (Fuji Film Wako Pure Chemical, Osaka), a commercial product equivalent to Pleurax (Brown, 1997). Next, the samples were observed under an Axioskop microscope (Zeiss, Oberkochen) equipped with a 63× oil immersion objective lens (N.A. = 1.25).

Images were captured using a DP71 digital camera (Olympus, Tokyo). Subsequently, multiple images were stitched together to create a wide-field composite image. This process was performed for samples from all three countries (Figure 1). For each sample, the original microscope slide along with 99 duplicate specimens has been

Table 1. Diatom samples used in this educational project

1	Date	Site	Collector	Source
RM-001847	May 1982	Tama River, Tokyo, Japan	Shigeki Mayama	The National Museum of Nature and Sciences, Japan
GC3525A	Aug. 1948	Lititz Run, Pennsylvania, U.S.A	Ruth Patrick	The Academy of Natural Science of Drexel Univ. U.S.A.
Sr. 4	Mar. 1945	Borivali Stream, Mumbai, India	Hemendrakumar Prithivraj Gandhi	Agharkar Research Institute, Pune, India
M-2133	Aug. 2017	Tama River, Tokyo, Japan	Kengo Satomi	Original, housed at Tokyo Diatomology Lab
M-2339	Aug. 2018	Litiz Run, Pennsylvania, U.S.A	Matthew L. Julius	Original, housed at Tokyo Diatomology Lab
M-2340	Apr. 2017	Borivali Stream, Mumbai, India	Karthick Balasubramanian	Original, housed at Tokyo Diatomology Lab

deposited in the National Museum of Nature and Science, Japan, where they are accessible to third parties upon request.

Characteristics of the Specimens and Social Conditions of the River Basin at the Time of Collection

The site where the Japanese diatom specimens were collected was a site where a large amount of untreated domestic wastewater flowed in the past. In the diatom community collected at that time, *Nitzschia palea*, a species classified as a pollution-tolerant diatom (Mayama, 1999), was dominant. The Saprobic Index calculated from the community was 3.7, indicating severe pollution in the water body (Satomi *et al*., 2018). In contrast, a recent diatom sample collected from the same site indicated good water quality (Saprobic Index = 1.07), demonstrating significant environmental improvement.

The site where the American samples were collected was a small town, but in the past, the river was severely polluted due to wastewater discharge from a chocolate factory located by the river, as well as other industrial facilities (Patrick, 1949; Blankenbiller, 2009). The species composition of the diatom community at that time was similar to that of past samples from Japan. However, a recent sample contained a diverse range of species, reflecting improved environmental conditions.

The river basins where past samples were collected in Japan and the U.S. are now equipped with sewer systems and sewage treatment plants. However, at the time when the past specimens were collected, the sewage treatment system in these areas was still underdeveloped. The species compositions of the past diatom communities clearly reflected the social conditions of those times.

In contrast, the past Indian diatom community consisted mainly of species indicative of good water quality, similar to those found in present-day Japanese rivers. However, the present Indian specimen was dominated by *Nitzschia palea*,

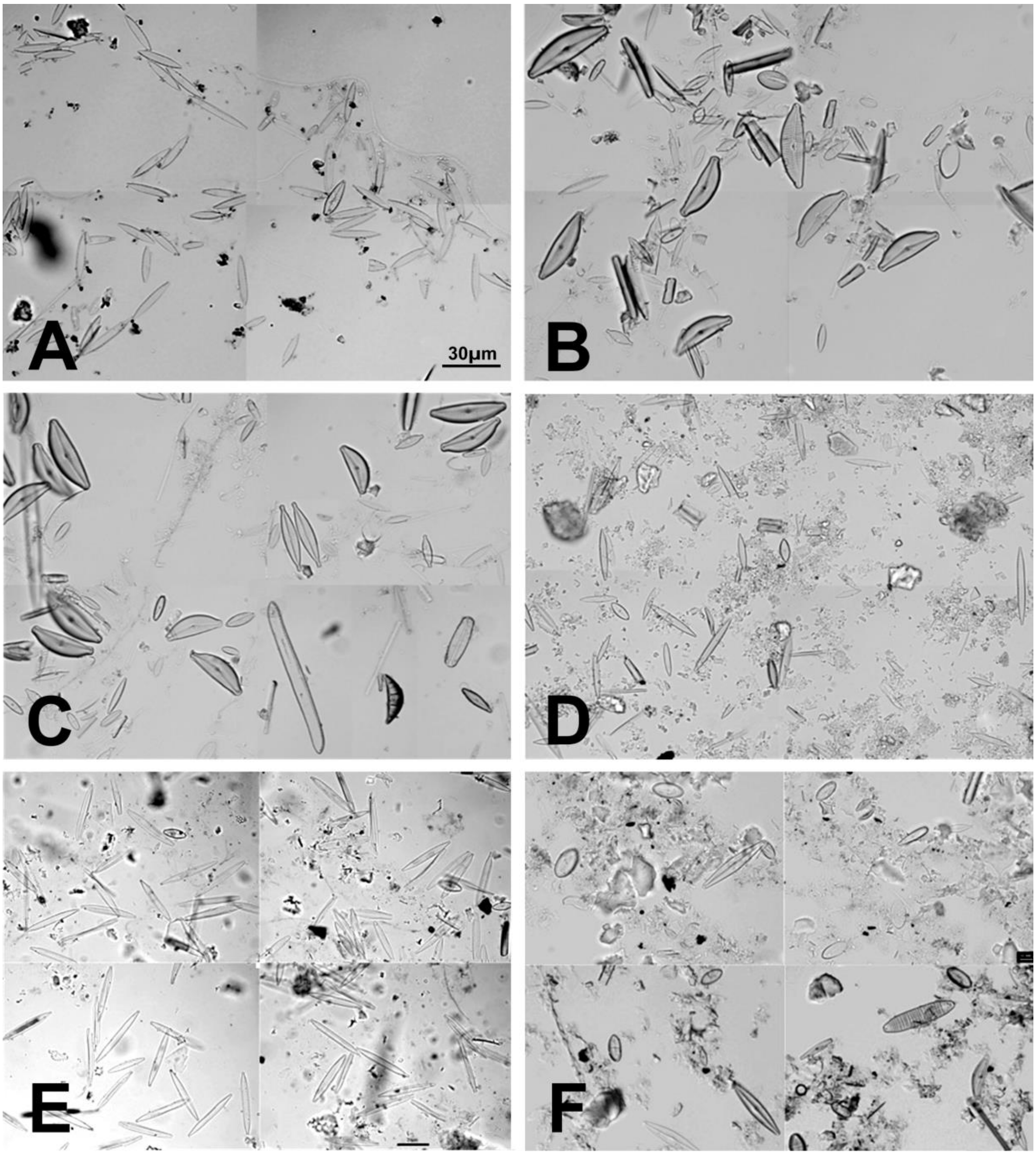


Figure 1. Photographs of diatom specimens

A and B were collected from the Tama River in Tokyo, Japan, in 1982 and 2017, respectively. C and D were collected from the Borivali Stream in Mumbai, India, in 1945 and 2017, respectively. E and F were collected from Lititz Run in Pennsylvania, U.S.A., in 1945 and 2018, respectively. The diatom communities in A, D, and E are composed exclusively of pollution-tolerant diatoms, whereas B, C, and F exhibit a diverse species composition, including pollution-sensitive species.

exhibiting a species composition similar to that of past samples from Japan and the U.S.

Present-day Indian society is experiencing severe water pollution due to rapid population growth and an underdeveloped sewage system in urban areas. However, diatom analysis suggests that, before national independence, the river basins were well-preserved in a rich natural environment, as neither rapid urbanization nor industrialization had yet developed.

Digital Learning Resources

There are fewer photographs and videos of polluted rivers compared to clean ones. Even fewer exist for the past. In this study, images of polluted rivers were obtained from the DiatomProject webpage that we developed, which includes historical and contemporary photos and videos of polluted rivers from around the world (*see Websites*), as well as a video produced by NHK for School (The Polluted Tama River, *see Websites*).

For clean rivers, we also used recent photographs taken in Japan and the U.S. by the authors, while for India, we used a 19th-century photograph of the Yamuna River from the Old Indian Photos archive (*see Websites*).

The ecosystem simulator SimRiver (*see Websites*), which models the relationship between human activities, river water quality, and diatom communities, has been updated annually based on user feedback. In this study, we used version 6 of the program.

Schools and Students

Lessons were conducted between October 2017 and September 2018 at a national high school in Tokyo, Japan, a private secondary school in Bangalore, India, where English was used as the medium of instruction, a public secondary school in Bangalore, India, where Kannada was used, a private secondary school in Pune, India, where Marathi was used, and two public high schools near St. Cloud, Minnesota, USA.

The number of students who participated in the lessons was as follows: 108 in Japan (Grade 10), 112 in the English-medium school in India (Grades 8 and 9), 127 in the Kannada-medium school in India (Grades 8 to 10), 122 in the Marathi-medium school in India (Grades 8 to 10), 34 in one U.S. high school (Grade 10), and 60 in the other U.S. high school (Grade 10). Although the number of students in the two U.S. high schools was relatively small, their backgrounds and feedback were similar. Therefore, the data from both schools were combined for analysis as a single group of 94 students.

From this point forward, the schools will be referred to as JP for the school in Japan, IE for the English-medium school in India, IK for the Kannada-medium school in India, IM for the Marathi-medium school in India, and US for the schools in the U.S.

Lesson implementations and analyses

The lesson program, the flow of which is outlined in Table 2, lasted for two class periods or an equivalent duration at each school. The order in which diatom specimens were introduced differed in each country; specimens collected from that country, both past and present, were shown first, followed by specimens from other countries for comparison. Some of the authors instructed the students in the classes. In Japan, the lessons were conducted in Japanese. In the U.S. and at the IE school in India, they were conducted in English. In the IK and IM schools, the authors' English instructions were translated into Kannada and Marathi, respectively, by local collaborators.

Before and after the lessons, students were asked the same question: "What do you think about river environments now?" and provided open-ended descriptive answers. The responses were analyzed using text mining methods. Prior to the analysis, answers written in languages other than English were translated into English. Each response was first subjected to morphological analysis, and the words contained in the responses were extracted using the freeware KH Coder 3 (*see Websitest*) by Higuchi (2016; 2017).

Table 2. Lesson flow for two class periods

Duration (min)	Activity
First period	
10	**Pre-survey:** Students provide descriptive answers.
8	**Questioning:** Asking students how they can determine past river water quality. **Introduction:** Explanation of what diatoms are.
17	**Observation:** Students observe two diatom specimens without being informed whether they are from the past or present. **Discussion:** Analyzing the characteristics of the specimens using a diatom shape guide (Appendix 1). **Comparison:** Introducing photographs of the same river taken in the past and present. **Concept Introduction:** Explanation of diatoms as bioindicators.
25	**Explanation:** Demonstration of how to operate SimRiver.
Second period	
20	**Simulation Activity:** Students manipulate environmental settings to generate virtual diatom specimens that resemble the two real specimens, to understand the river basin environment at the time the real specimens were collected. **Presentation:** Students present their simulation results and share their findings.
15	**Discussion:** Determining the time period when the two real specimens were collected. **Comparison:** Introduction of real diatom specimens collected from other countries, along with photographs from the past and present. **Questioning:** Asking students to determine the time period when each specimen was collected.
10	**Post-survey:** Students provide descriptive answers.
5	**Discussion:** Reflection on global river environments.

Based on the results, a matrix was created in which each row represented a student's response and each column represented a word. This matrix was analyzed using TWINSPAN (Hill, 1979), which classified both responses and words into distinct groups. TWINSPAN is a hierarchical clustering method for multivariate data that combines an ordinal structure derived from a procedure similar to the first axis of Correspondence Analysis with subsequent binary classification guided by the selection of indicator species—substituted by indicator words in this study. For further details on TWINSPAN, see Appendix 2. The same matrix was also used for Correspondence Analysis to determine the ordering of the responses.

TWINSPAN and Correspondence Analysis were conducted using PC-ORD (Wild Blueberry

Media LLC, Corvallis, USA) and KH Coder 3, respectively. In the qualitative analysis of students' responses, statistical testing was conducted using the two-proportion z-test with Python's statsmodels package, and multiple comparisons were adjusted using the Benjamini–Hochberg False Discovery Rate (FDR) correction. For the detailed conditions and program settings used in both analyses, see Appendices 3–5.

RESULTS AND DISCUSSION

Changes in students' awareness

A matrix composed of student's responses and the words they described was classified using TWINSPAN, resulting in nine response groups (R1 to R9) and eight corresponding groups of words labeled as Human & Pollution, Cause of Pollution and Ecosystem e.t.c. (Figures 2). In the pre-survey, students in all school groups (US, IE, IM, IK) except for the JP group were predominantly classified into R3, which included words from the groups labeled as Current Situation, Human & Pollution, and Causes of Pollution, indicating anthropogenic contamination of rivers, such as garbage. However, the frequency of each word in these groups varied among countries. For example, in Human & Pollution group "clean", "polluted" and "human" were more frequently used by Indian students, "country" and "pollution" were more frequently described by American students, and "flow," "time," "increase," "small," and "use" were used without bias by students from any particular country.

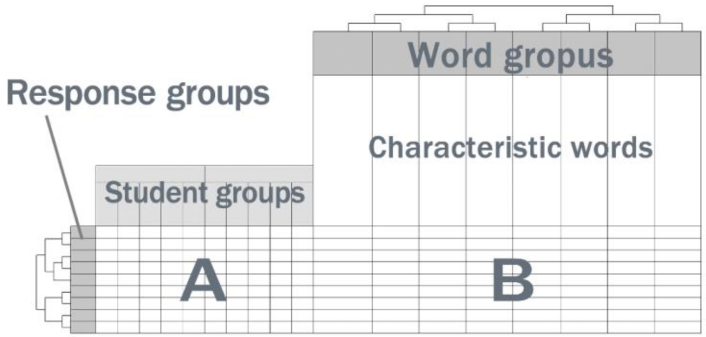
Following R3, R4 (more prevalent response in the US and IM) and R5 (more prevalent in the US and IK) were also notable. The students in the R4 mentioned only anthropogenic pollution, whereas those in the R5 also referred to the environment.

In the post-survey, however, the number of responses classified into R3 decreased. Conversely, the number of students classified into R2, which frequently included words from the groups labeled as International/Over-time Comparison and Improvement, Current Situation, and Human & Pollution, increased the most. This suggests that students began to develop ideas for improving river conditions through international and/or temporal comparisons. In the JP school, the proportion of students classified into R2 was already the highest in the pre-survey (30.1%) and increased significantly to 80.7% in the post-survey.

The frequency of word usage in the International/Over-time Comparison and Improvement group varied significantly by country, indicating differences in students' perspectives on improvement.

In the post-survey, the total proportion of students who described any of R1 to R5 exceeded 97% in all student groups except for the US, demonstrating a significant increase in awareness of water pollution. On the other hand, the proportion of US students describing these responses was 87.7%, which, although relatively high, was lower compared to students from Japan and India. This may be attributed to the relatively well-preserved natural environment around their schools.

The correspondence analysis plot (Figure 3) illustrates the distribution patterns of the vocabulary used in students' descriptive responses and the relationships between those words and the student groups who provided them. This analysis was conducted using the same response × word matrix as TWINSPAN; however, unlike TWINSPAN, which focuses on classification, correspondence analysis visualizes how each group's awareness changed relatively before and after the lesson within a shared semantic space.



	Pre-survey (%)					Post-survey (%)					International/ Over-Time Comparison & Improvement	Current Situation	Human & Pollution	Causes of Pollution	Earth & Environment	Daily Life & Nature	Ecosystem	Life & Aquatic Environment
	JP	US	IE	IM	IK	JP	US	IE	IM	IK	example, activity (J), concern, reason, relation, various, change (J), foam, **India (I)**, awarenes (U), quality (J), same, situation, treatment (U), development (J), diatom, Germany, improvement, **Japan (I), past (I)**, technology (J)	opinion, **present (I)**, problem, world	**clean (I)**, flow, country (U), **polluted (I), pollution (U)**, time, **human (I)**, increase, small, use	basin (U), chemical, day, factory, sewage, free, disease (I), plastic, domestic (I), **garbage**, industry, waste	earth, **environment**, precious, city, sea	beautiful (I), tree, clothes, purpose, drinking (I), **animal**, dengerous (I), fishing, place, **plant**, nature, organism (J)	care, **house (J)**, different, **ecosystem, important (J)**, natural, future, pure	influence, **life (U)**, pond (I), useful, **fish (I)(U)**
R1	8.7	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0							●	
R2	30.1	7.9	7.3	3.3	4.9	80.7	56.2	66.7	55.4	80.7	●	●	●					
R3	23.3	25.6	27.7	49.6	41.0	4.6	15.1	17.1	29.8	4.6		●	●	●				
R4	13.6	20.6	11.9	33.1	9.0	9.2	2.7	9.0	9.1	9.2			●					
R5	13.6	22.2	12.8	5.0	26.2	3.7	13.7	4.5	3.3	3.7			●		●			
R6	0.0	9.5	11.9	6.6	10.7	0.9	1.4	0.9	1.7	0.9						●		
R7	0.0	7.9	11.9	0.8	2.5	0.0	6.8	0.0	0.8	0.0							●	●
R8	4.9	6.3	15.6	1.7	4.9	0.0	4.1	1.8	0.0	0.0								●
R9	5.8	0.0	0.0	0.0	0.8	0.9	0.0	0.0	0.0	0.9							●	

Figure 2. Relationship between Student Response Groups and Word Groups Classified by TWINSPAN

This figure is divided into two main regions. Region A (left) shows the proportions of each student group that were classified into each response group before and after the lesson. Region B (right) illustrates the associations between response groups and word groups. Within each word group, frequently used words are shown in bold. Words that were characteristically used in only one country are marked with (J) for Japan, (US) for the United States, and (I) for India. Each word group is labeled for clarity. Labels related to river pollution are shown with a dark blue background, while those not directly related are shown with a brown background. Region B also uses black dots to indicate strong associations between response groups and word groups. The dendrograms at the top and left represent the hierarchical clustering of the response groups and word groups, respectively. Number of students (pre-/post-survey): JP (103/109), US (63/73), IE (109/111), IM (121/121), IK (122/126).

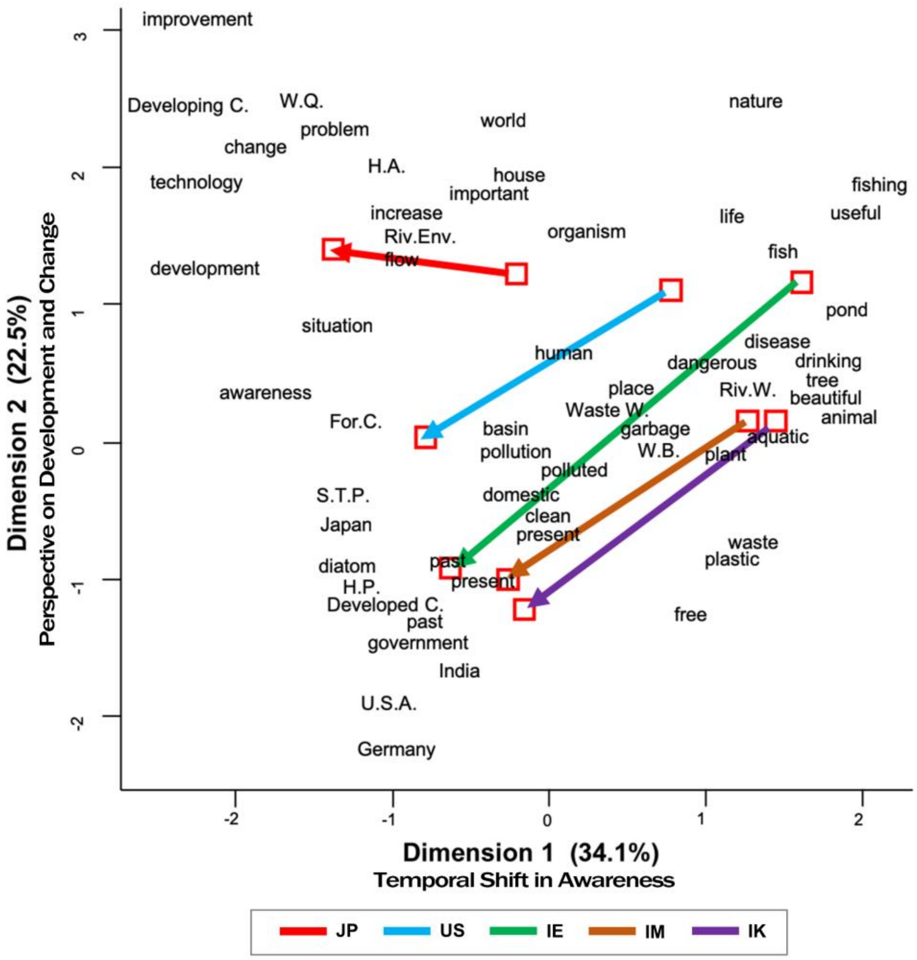


Figure 3. Correspondence analysis of student responses before and after the lesson

Each red square represents the centroid of a student group's responses at each time point (pre- and post-survey), and arrows indicate shifts in awareness. The plot is based on the same response × word matrix used in the TWINSPAN analysis. Percentages in parentheses represent the variance explained by each axis.

Abbreviations: Developing C. = developing countries; Developed C. = developed countries; For. C. = foreign countries; W.Q. = water quality; H.A. = human activity; S.T.P. = sewage treatment plant; H.P. = human population; Waste W. = wastewater; W.B. = water bodies; Riv. Env. = river environment; Riv. W. = river water.

Dimension 1 represents the temporal change in students' awareness, from pre-survey responses (right) to post-survey responses (left), reflecting the conceptual shift induced by the lesson. Dimension 2 reflects students' orientation toward development and change. The upper area contains words related to improvement, technology, and abstract social concepts, while the lower area includes country names and institutional or present/past-oriented terms. Red squares represent the average positions (centroids) of each group, while the arrows indicate the direction and magnitude of conceptual shifts resulting from the lesson.

Only words that appeared at least 25 times were included in the analysis, and for visualization purposes, the 60 words with the highest chi-square values were selected (Appendix 5). As such, the results reflect the most distinctive awareness patterns associated with each country. Words that appeared frequently both before and after the lesson—particularly those related to river pollution—were concentrated near the origin of the two axes. Words located near each group's centroid are considered to reflect awareness tendencies characteristic of that group.

Although students expressed a wide range of ideas in their free responses, the TWINSPAN analysis showed that river pollution was a common awareness across all school groups, both before and after the lesson. However, the associations and contexts of that awareness differed by country.

As summarized in Table 3, the words that characterized student groups before and after the lesson varied considerably, clearly reflecting group-specific transformations in awareness. For example, Indian students initially expressed concrete, everyday-life-related concerns, such as the use of river water or associated health risks. After the lesson, their responses included terms related to comparisons across time and between countries, indicating a broader and more reflective awareness. Japanese students, by contrast, initially expressed their awareness of rivers using abstract concepts and words associated with their personal living environment, such as house. After the lesson, they began using terms related to social improvement and development, such as development and water quality. American students initially showed awareness of the natural environment through words such as life and fish, but after the lesson, they used terms suggesting increased global awareness and concrete solutions, such as foreign countries, awareness, and sewage treatment plant. Examples of how these keywords were used in actual student responses can be found in Appendix 6.

The correspondence analysis also revealed that the three Indian groups—IE, IK, and IM—showed remarkably similar directional shifts in awareness despite differences in location, school type (public/private), and instructional language. These results suggest that the changes in students' awareness brought about by the lesson may be fairly generalizable within India. In contrast, whether the distinctive changes observed among students in Japan and the United States are generalizable remains uncertain and requires verification through more extensive comparative studies.

Formation of attitudes

While TWINSPAN and Correspondence Analysis primarily identified students' awareness toward river environments—especially in the post-survey—as underlying their attitudes, we further analyzed students' behavioral aspects of attitude through a conventional method: interpreting

Table 3. Key characteristics of students' awareness transformation before and after the lesson, by country

	Pre-survey	Post-survey
India	disease, drinking, dangerous, fish	clean, human, India, Japan, past, present, pollution
Japan	organisms, human, important, house	activity, change, development, technology, water quality
U.S.A	fish, life, organisms	awareness, foreign countries, pollution, sewage treatment plant

and classifying their descriptive responses.

In the post-survey, students' responses included not only descriptions of learning content but also opinions expressing their desire to improve river environments. Such behavior-related descriptions were observed in approximately 60–70% of students in the JP, IE, IM, and IK groups, respectively (Table 4).

Furthermore, students' opinions regarding behavioral attitudes were categorized into two types: those they could not carry out themselves and those they could. The former included actions that governments or companies can take, such as providing international aid, constructing sewage treatment plants, enacting laws and regulations, and developing technology. Some of these actions were also partially reflected as group-characterizing words in the TWINSPAN and Correspondence Analysis results (Figures 2 and 3). This category also included non-autonomous, other-dependent thinking, exemplified by statements like "People should do X" or "I expect X to happen," which may become feasible in the future. This type of thinking was observed in nearly half of the students in the JP, IE, IM, and IK groups. The latter category reflected autonomous, action-oriented thinking, exemplified by not throwing garbage into rivers, advising friends and family against improper waste disposal, and participating in river clean-up activities. While fewer in number compared to the former category, such responses were more frequent in the Indian groups (11–22%) than in the Japanese group (3.7%). Although fewer students in the US group expressed opinions related to behavioral attitudes, those who did often demonstrated autonomous thinking, and the proportion (11%) did not differ significantly from that of the Indian groups (Table 4).

The responses of Indian students reflect an internal motivation shaped by their learning and daily exposure to polluted rivers. In contrast, the limited number of autonomous responses from JP students may be related to the absence of polluted rivers in their residential environment.

As for the US group, the lack of opinions on improving river environments may be attributed not only to the relatively good condition of their local environment, but also to the fact that the visual and biological records of polluted rivers shown during the lesson were from regions different from where they live. Additionally, their responses were generally shorter compared to those of other groups, which may have limited the expression of such opinions. Nevertheless, the fact that more US students expressed

Table 4. Types and frequency of students' attitudes in the post-survey

	Student groups (%)				
	JP	US	IE	IM	IK
Answers with opinions on improving river environments*	**63**	20.3	**66.7**	**66.1**	**72.2**
Non-autonomous and other-dependent thinking*	**59.3**	8.6	**49.5**	**52.1**	**50**
Autonomous and action-oriented thinking with specificity**	3.7	**11.4**	**17.1**	**14**	**22.2**
Answers without opinions on improving river environments*	**37**	79.7	**33.3**	**33.9**	**27.8**
Number of students	108	79	111	121	126

* Significant differences were found between US and all other groups (p < 0.00001).
** Significant differences were found between JP and all other groups, with p-values ranging from < 0.05 to < 0.001.
Values in bold indicate groups that showed no significant differences from each other in multiple comparisons.

autonomous thinking than those in the JP group—and at a frequency not significantly different from that of the Indian groups—may suggest the influence of cultural factors, such as the tendency among Japanese people to be less assertive.

Educational implications and global context

In the context of educational contributions to SDG 6, raising students' awareness of river environments constitutes the first step, while fostering attitudes toward action represents the second. The survey questions were deliberately kept simple to avoid leading respondents toward particular answers through the wording, thereby ensuring that the responses reflect students' own thoughts rather than external influences.

The high frequency of responses expressing students' attitudes toward improving river environments in the JP and Indian groups suggests that the lesson design functioned effectively for these students. In contrast, the results from the US group indicate a need to reconsider the post-lesson activities and instructional materials provided for them.

As noted at the beginning of this paper, a variety of educational activities related to river water have been implemented worldwide. In addition, many countries have provided Official Development Assistance (ODA) to developing nations. However, as indicated in the SDG Progress Report (United Nations Statistics Division, 2024), efforts to address water pollution in developing countries remain insufficient.

Historically, improvements in water quality in many countries have been preceded by heightened public awareness in response to critical environmental conditions. This was followed by governmental and municipal efforts, including the enactment of laws and regulations and the construction of wastewater treatment systems (Bate, 2019; Hartig, 2010; Hill, 2019; JICA, 2022).

When students in developed countries learn about the historical conditions of their own river environments and the processes through which improvements were achieved, and engage in dialogue with students in developing countries about the outcomes and behavioral attitudes involved, such interactions may contribute to the global resolution of water-related issues. Collaborating with local researchers and educators to develop more effective instructional methods and learning environments for this purpose remains an important area for future research. Furthermore, differences in students' awareness and attitudes may also be influenced by the educational environments in which they are situated. Therefore, identifying the reasons behind these differences will require multifaceted investigation from various perspectives.

CONCLUSION

In this study, we implemented lessons in secondary schools in India, Japan, and the United States using past and present diatom specimens, river photographs, and the SimRiver simulation. These lessons aimed to enhance students' awareness of river environments and support the development of action-oriented attitudes. TWINSPAN and Correspondence Analysis revealed that students' awareness shifted significantly after the lessons.

In addition, qualitative analysis of students' descriptive responses showed that a relatively high proportion of students in the three Indian groups expressed autonomous and action-oriented attitudes toward improving river environments. In contrast, many students in the Japanese group demonstrated other-dependent thinking, although concern for environmental action was still frequently observed.

Students in the United States expressed fewer opinions related to behavior, which may be attributed to their relatively well-preserved local environments, the geographical distance between the lesson materials and their lived context, and the generally shorter nature of their responses. These findings suggest that students' environmental awareness and the expression of their attitudes are influenced by the social and cultural contexts of their respective countries.

This lesson program was designed as an educational contribution to SDG 6 to raise students' environmental awareness and support the formation of autonomous and practical attitudes. Its effectiveness was partially confirmed. In particular, the incorporation of comparisons between past and present conditions, as well as international perspectives, may have contributed to the development of students' awareness into attitudes and actions.

Moving forward, further development of this lesson model and its application to diverse educational settings will require collaboration with educators and researchers across countries and regions. Interactive learning among students from different cultural backgrounds may also help foster a sense of responsibility toward global environmental issues.

ACKNOWLEDGEMENTS

The authors would like to thank M. Uchiyama, M. Olson, J. Dammann, M. A. Khan, S. Reddy, and L. Krishnamurthy for their support in arranging the class activities. We are also grateful to B. Alakananda and N. Wadmare for their assistance with translations, as well as to M. Potapova for providing information on historical American specimens. This work was supported by JSPS KAKENHI Grant Number 23K02759, 19K03113 and 16K01011.

REFERENCES

Bae, H.-S., Choi, D. S. and Kim, Y. R. (2011) The effects of urban stream ecological experience program on the environmental sensitivity of elementary school students. *Korean Journal of Environmental Education* **24**: 66–75.

Bate, D. (2019) *The death of the Delaware River*. WHYY. https://whyy.org/articles/the-death-of-the-delaware-river/ <accessed: March 21, 2025>

Blankenbiller, K. (2009) *Images of America. Lititz.* Arcadia Publishing, Charleston, U.S.A.

Brown, P. A. (1997) A review of techniques used in the preparation, curation and conservation of microscope slides at the Natural History Museum, London. *The Biology Curator* **10** Special Supplement: 1–34.

Fu, S.-P. and Komatsu, H. (2024) Evaluating the impact of place-based education: insights from a river environmental program in Taiwan. *Journal of International Cooperation in Education* **26**: 153–170.

Gauch, Jr. H. G. and Whittaker, R. H. (1981) Hierarchical classification of community data. *Journal of Ecology* 69: 537–557.

Hamed, G. and Aljanazrah, A. (2020) The effectiveness of using virtual experiments on students' learning in the general physics lab. *Journal of Information Technology Education: Research* **19**: 977–996.

Hartig, J. H. (2010) *Burning river. Revival of four urban-industrial rivers that caught on fire.* Multi-Science Publishing Co Ltd., Brentwood, UK.

Higuchi, K. (2016) A two-step approach to quantitative content analysis: KH Coder tutorial using Anne of Green Gables (Part I). *Ritsumeikan Social Sciences Review* **52**(3): 77-91. https://www.ritsumei.ac.jp/file.jsp?id=325881

Higuchi, K. (2017) A two-step approach to quantitative content analysis: KH Coder Tutorial using Anne of Green Gables (Part II). *Ritsumeikan social sciences review* **53**(1): 137-147. https://www.ritsumei.ac.jp/file.jsp?id=346128

Hill, L. (2019) *The Chicago River. A natural and unnatural history.* Southern Illinois University Press, Carbondale, U.S.A.

Hill, M. O. (1979) *TWINSPAN—a FORTRAN program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Ecology and Systematics, Cornell University, Ithaca, New York. https://www.researchgate.net/publication/240311310_TWINSPAN-A_Fortran_Program_for_Arranging_Multivariate_Data_in_an_Ordered_Two-way_Table_by_Classification_of_The_Individuals_and_Attributes#full-text <accessed: March 21, 2025>

Hoffer, J., Mayama, S., Lingle, K., Conroy, K., and Julius, M. (2011) SimRiver, environmental modeling software for the secondary science classroom. *Science Scope* **34**(5): 29-33.

JAICA (2022) *Japan's experience in water resources management.* Japan International Cooperation Agency. https://openjicareport.jica.go.jp/pdf/1000047167.pdf <accessed: March 21, 2025>

Katoh, A, Mayama, S., Ohmori, H. and Seino, S. (2004) Construction of "SimRiver": a simulation program for river epilithic diatom assemblage composition. *Japnese Journal of Educational Technology* **28**: 217–226.

Kobayasi, H. and Mayama, S. (1989) Evaluation of river water quality by diatoms. *Korean Journal of Phycology* **4**: 121–133.

Kosakai, K. and Mayama, S. (2015) Environmental education in high school for understanding river environment changing over long periods of time: A class activity using preserved diatom slides, simulation software and video images of an old river. *Bulletin of Tokyo Gakugei University. Division of Natural Sciences* **67**: 33–34.

Ketelhut, D. J. K., Clarke, J. and Nelson, B. C. (2010a) The development of River City, a multi-user virtual environment-based scientific inquiry curriculum: Historical and design evolutions. *In*: Jacobson, M. J. and Reimann, P. (eds.) *Design for Learning Environments of the Future. International Perspectives from the learning sciences,* pp. 89-111. Springer Science + Business Media. Berlin, Germany.

Ketelhut, D. J. K., Nelson, B. C., Clarke, J. and Dede, C. (2010b) A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Education Technology* **41**: 56–68.

Lee, J. H., Cheong, C., Kwon, N. J., Kim, Y. J., Park, H. G., Mayama, S., Katoh, K. and Omori, H. (2011) Trial of educational computer simulation software 'SimRiver' for assessment of river water quality for environmental education in schools. *Environmental Education, Korea* **24**(1): 40–48.

Lobo, E. A., Wetzel, C. E., Schuch, M. and Ector, L. (2014) *Diatomáceas epilíticas como indicadores da qualidade da água em sistemas lóticos subtropicais e temperados brasileiros*. EDUNISC, Santa Cruz do Sul, Brazil.

Masuda, Y., Katoh, K., Murakami, A. and Watanabe, S. (2001) A study on urban open space for environmental education based on questionnaires to teachers. *Journal of The Japanese Institute of Landscape Architecture* **64**: 627–631.

Mayama, S. (1993) *Eunotia sparsistriata* sp. nov., a moss diatom from Mikura Island, Japan.

Nova Hedwigia Beiheft **106**: 143–150.

Mayama, S. (1999) Taxonomic revisions to the differentiating diatom groups for water quality evaluation and some comments for taxa with new designations. *Diatom* **15**: 1–9.

Mayama, S., Katoh, K.., Ohmori, H., Seino, S., Kokubuda, K., and Oshikata, K. (2008) Trial and evaluation of "SimRiver": Educational simulation software for assessment of river water quality using diatoms. *Japanese Journal of Biology Education* **48:** 10–20.

Mayama, S., Katoh, K., Omori, H., Seino, S., Osaki, H., Julius, M., Lee, J. H., Cheong, C., Lobo, E. A.., Witkowski, A., Srivibool, R., Muangphra, P., Jahn, R., Kulikovskiy, M.., Hamilton, P. B., Gao, Y. H., and Ector, L. (2011) Progress toward the construction of an international web-based educational system featuring improved "SimRiver" for understanding of river environments. *Asian Journal of Biology Education* **5:** 2–14.

Miyao, H., Kamata, T., Yoshino, H. and Tsuji, M. (2007) Support for environmental learning using rivers as a theme. *Comprehensive Report of the River Environment Research Institute* **13**: 1–11.

Patrick, R. (1949) A proposed biological measure of stream conditions, based on a survey of the Conestoga Basin, Lancaster County, Pennsylvania. *Proceedings of the academy of Natural Sciences of Philadelphia* **101**: 277–341.

Satomi, K., Mayama, S. and Saito-Kato, M. (2018) Water quality change indicated by past and present diatom samples collected from Tama River: Basic research toward the development of educational program for understanding relationship between human activity and river environment change using diatoms. *Bulletin of Tokyo Gakugei University. Division of Natural Science* **70**: 31–53.

UN-Water (2023) *The Sustainable Development Goal 6 Synthesis Report on Water and Sanitation Global Acceleration Framework.* UN-Water. https://www.unwater.org/sites/default/files/2023-08/UN-Water_SDG6_SynthesisReport_2023.pdf <accessed: March 21, 2025>

UN-Water (2020) *The Sustainable Development Goal 6* Global Acceleration Framework https://www.unwater.org/sites/default/files/app/uploads/2020/07/Global-Acceleration-Framework.pdf <accessed: March 21, 2025>

United Nation Statistics Division (2024) SDG Report 2024 Goal 6. https://unstats.un.org/sdgs/report/2024/Goal-06/ <accessed: March 21, 2025>

Wongchantra, P., Ongon, S, Junkaew, L. and Sookngam, K. (2020) The effect of environmental education learning for enhancing rivers management in northeast Thailand. *Journal of Educational Issues* **8**: 152–173.

WEBSITES

DiatomProject https://www2.u-gakugei.ac.jp/~diatom/index.html <accessed: June 19, 2025>

Jeevitnadi https://www.jeevitnadi.org/ <accessed: June 19, 2025>

KH Coder 3 https://khcoder.net/en/ <accessed: June 19, 2025>

Leaf Pack Network Simulation https://leafpacknetwork.org/virtual-stream-study/ <accessed: June 19, 2025>

Ministry of the Environment. Revision of the Simple Water Quality Survey Method by Aquatic Organisms - Unification of Survey Methods of the Environment Agency and the Ministry of Construction-. https://www.env.go.jp/press/943.html?utm_source=chatgpt.com <accessed: June 19, 2025>

NHK for School. The Polluted Tama River

https://www2.nhk.or.jp/school/watch/clip/?das_id=D0005311065_00000 <accessed: June 19, 2025>

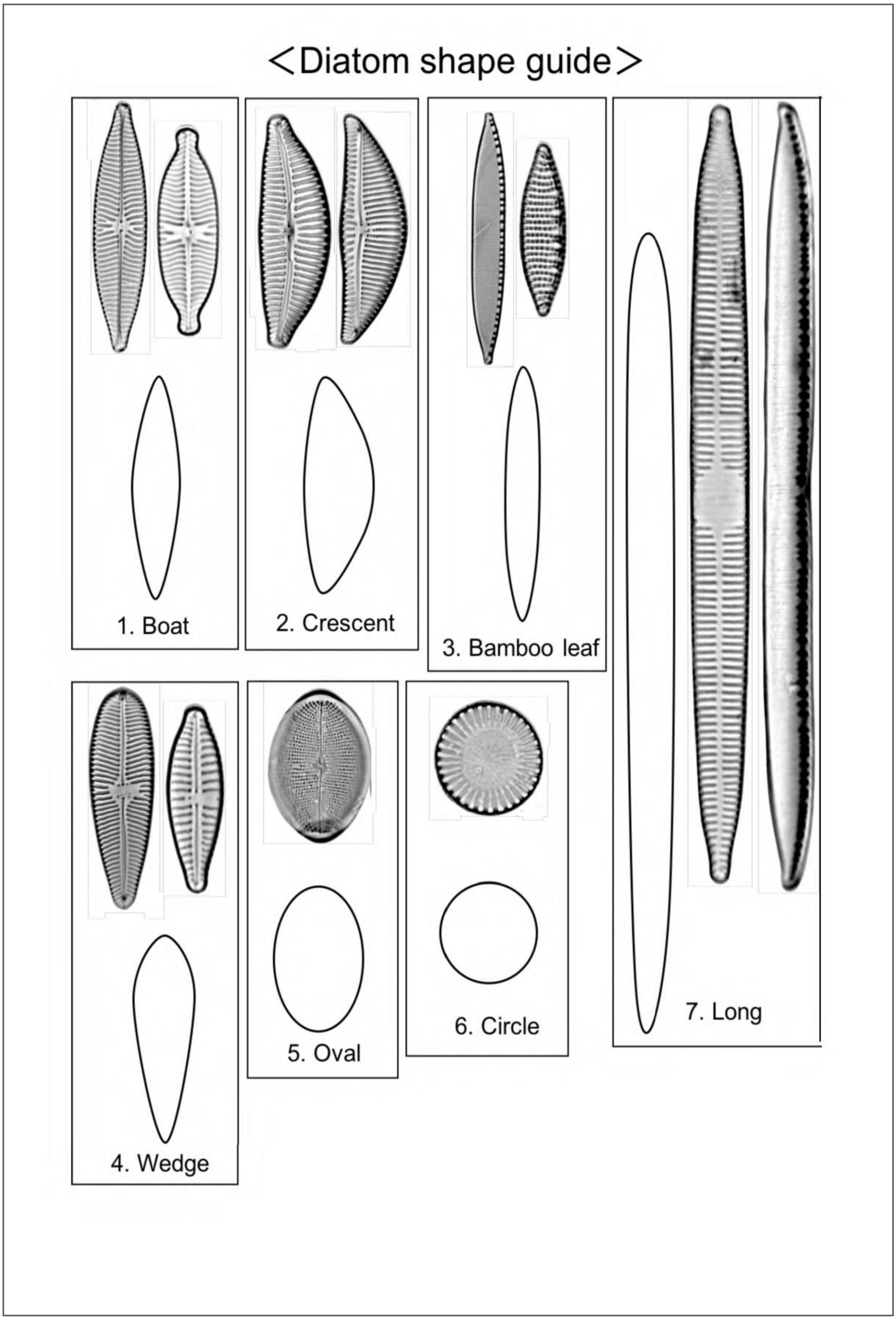
Project WET https://www.projectwet.org/<accessed: June 19, 2025>

Project WILD https://www.fishwildlife.org/projectwild <accessed: June 19, 2025>

SimRiver http://lbm.ab.a.u-tokyo.ac.jp/%7Eomori/srhtml/diatom.htm <accessed: June 19, 2025>

Yamuna River from the Old Indian Photos https://www.oldindianphotos.in/2016/01/the-railway-bridge-on-river-yamuna.html <accessed: June 19, 2025>

Appendix 1. Diatom shape guide



Appendix 2: TWINSPAN

TWINSPAN (Two-Way Indicator Species Analysis) is a binary hierarchical classification method originally developed by Hill (1979) for the purpose of analyzing community structures in ecology. This method is characterized by the combination of an axis extraction procedure similar to Correspondence Analysis to capture the ordinal structure of the data, and binary classification based on the occurrence patterns of indicator species. Gauch and Whittaker (1981) systematically evaluated the validity of TWINSPAN through comparisons with other hierarchical classification techniques.

In TWINSPAN, a species × sample matrix is first subjected to an ordination procedure (not a full Correspondence Analysis, but a comparable method internally implemented in TWINSPAN) to extract an underlying gradient structure among the samples. Based on this structure, the samples are divided into two groups, and representative indicator species are then selected for each group. Indicator species are defined as those that frequently appear in one group but rarely in the other, thereby characterizing the ecological features of each group. This division and selection of indicator species are applied recursively, resulting in a binary tree hierarchical structure. The algorithm offers both classification and ordination capabilities and is practical due to its relatively low computational demands, making it suitable for large datasets.

Application in Educational Survey Analysis

This method is not limited to ecology but has also been applied to open-ended questionnaire analysis in the field of education. For example, Masuda *et al*. (2001) applied TWINSPAN to teachers' written responses regarding urban green spaces, classifying the responses based on lexical occurrence patterns and extracting indicator words. In educational applications, each written response is treated as a sample, and nouns, adjectives, and other selected parts of speech extracted through morphological analysis are regarded as species. A frequency matrix of words × responses is then constructed, to which TWINSPAN is applied. This allows for the hierarchical classification of written responses according to tendencies in word usage.

Furthermore, TWINSPAN's classification originates from a potential structure extracted through correspondence analysis-like processing based on vocabulary appearance frequency. That is, by numerically arranging responses (samples) according to their vocabulary distribution patterns and then classifying them into two groups along this arrangement, differences in the substantive direction of the descriptions can be visualized. During classification, words that characteristically appear in each group are extracted as "indicator words." These words, analogous to indicator species in ecology, can be interpreted as keywords that symbolize distinctive awareness or cognitive frameworks within each group. Thus, TWINSPAN can serve as an effective tool for statistically and semantically capturing the structural diversity embedded in open-ended survey responses.

Appendix 3. List of synonyms used for analysis

Words described by students	Converted word for analysis
dirty, bad, worse, not clean, unclean	polluted
good, not polluted, better, neat, fresh	clean
other countries, another country	foreign countries
sewage channel, sewage system, drainage system	sewage treatment plant
older days, before, previous days, 1960's	past
dust, trash	garbage
vanish	disappear
nowadays, now, today, modern, 2010's	Present
spoil, contaminate,	pollute
ill, sick	disease
harmful, hazardous, unsafe	dangerous
conserve, maintain	preserve
household	domestic
living things, creature	organisms
condition	situation
my country, our country	Japan (for Japanese students), India (for Indian students), U.S.A. (for American students)

Appendix 4. Selection of Words used for TWINSPAN and Correspondence Analysis

Parts of Speech	
Noun, pronoun, freign words, adjective.	
Extracted compounds	**Excluded words**
alien species, class activity, COD, developed countries, developing countries, foreign countries, high economic growth, human activity, human population, native species, river environment, river water, Saprobic Index, sewage treatment plant, SimRiver, U.S.A., waste water, water bodies, water pollution, water quality.	able, anything, area, do, due, etc, few, Get, glad, have, kind, less, lot, make, many, more, most, much, other, river, such, thing, think, thought, want, Water, way, work, year.

Appendix 5. Program setting

PC-ORD	KH-Coder
Filter words by Term Frequency: Min. TF = 20 Cut levels: 0.0000 Minimum group size for division = 5 Maximum number of indicators per division = 5 Maximum number of species in final table = 200 Maximum level of divisions = 6	Filter words by Term Frequency: Min. TF = 25 Filter words by Document Frequency: Min. DF = 1 Document Unit: Sentence Filter words by chi-square value: Top 60

Appendix 6. Selected Qualitative Responses from Pre- and Post-Surveys on River Environments.

This appendix presents selected qualitative responses from students in India, Japan, and the U.S.A. to the question “What do you think about the river environment?” These responses were collected before and after the lesson and show considerable variation in both length and style of expression. The examples were chosen because they reflect characteristic words commonly used in each student group (Table 3) and were incorporated into subsequent analyses such as TWINSPAN and Correspondence analysis.

	Pre-survey	**Post-survey**
India	When we observe the current situation, we see that diseases are spreading in India. We need to change this situation. A plan must be developed to minimize the spread of such diseases. Rivers are a primary source of drinking water. To reduce disease, we must keep our rivers clean.	Water is essential for all organisms. Water pollution is increasing due to the growth of the human population, and rivers in India are more polluted than those in other countries. In developed countries like Japan, rivers were more polluted in the past, but now they have become cleaner thanks to the construction of sewage treatment plants. In contrast, rivers in India were clean in the past, but are now polluted due to many changes. As a result, organisms in the river, such as fish, are decreasing. Therefore, to control this pollution, we should build sewage treatment plants.
	Rivers are polluted now, and fish are dying. If we play or swim in the rivers, the pollution can cause diseases in us.	We should protect rivers by avoiding the dumping of waste, plastics, and waste oils into them. Humans should change their attitude toward cleanliness. In the past, rivers in India were kept clean, and no waste was thrown into them. However, with increasing pollution, rivers have become contaminated and are no longer suitable for drinking. Similarly, in Japan, rivers were polluted in the past, but now people understand the importance of keeping rivers clean. If we continue to dump waste into rivers, the animals, plants, and other organisms living in the water will be harmed. That is why everyone says we should protect our rivers.
	The present situation is that all rivers are polluted. The water in the rivers is also contaminated. It contains many dangerous chemicals and gases that are harmful to us. This water is unsafe for drinking. Due to the addition of garbage, these water bodies have become polluted, and as a result, the number of fish has decreased. If this situation continues for a few more years, all living organisms may eventually disappear.	India had clean rivers in the past, but now they are becoming polluted due to increased water pollution and the growing human population near rivers. In the past, Japan, the U.S.A., and Germany faced similar problems. Now, developed countries have recognized the importance of clean rivers, and by enforcing strict laws and maintaining cleanliness, they have managed to improve river conditions. Similarly, we too can clean our rivers and keep them beautiful.
	At present, rivers are more polluted because we are destroying them. I like to play in the river. In the past, river water was clean and safe to drink, but now we cannot drink it because it is polluted. Also, we can no longer catch fish, crabs, and other aquatic creatures.	It is possible to clean river water by finding new solutions and conducting experiments. Developed countries like Japan and the U.S.A. have made efforts to clean their rivers and have been successful. They have stopped dumping garbage and releasing waste into rivers. They have also raised awareness about the importance of rivers, especially for people living in cities near them. In the past, all rivers in India were clean, but now they are polluted. Similarly, rivers in Japan were once heavily polluted, but the current situation is improving.
Japan	When I was a child, I often caught crayfish in a small river near my grandparents' house and watched the flowing water. That river had the clean water I long for, but such rivers are rare in Tokyo or Saitama. More people should care about water quality.	The river conditions in Japan during its period of rapid economic growth and in developing countries today are similar. However, past experiences have improved the river conditions in Japan, and we must develop technologies to keep the river environment clean. As a way to understand the river environment, organisms such as diatoms are useful and very interesting. Through this

		class activity, students will learn that human activities and the river environment are closely related in a practical way.
	Due to changes brought by human activity and development, river ecosystems have changed, but I do not have a real sense of it myself.	The river environment has changed dramatically from the past to the present. Most of these changes are due to human activity. Humans have created a large amount of polluted water, and the river environment has become contaminated almost without our realizing it. Humans need to understand the river environment better than any other species. We also have the technology to improve it. Japan has succeeded in making its rivers cleaner, and this effort should be extended to other countries as well.
	Rivers are unique and host many different and diverse organisms. Studying all the rivers would be almost overwhelming.	Through the class activities, I learned that human activity is a major factor affecting water quality. Humans use energy to obtain water and build advanced sewage treatment plants and water purification facilities. While humans affect water, water also has a greater impact on the Earth. The water that connects humans to the Earth must continue to be conserved.
	Rivers usually don’t have a strong connection to my daily life, but the Kanda River is near my house. Upstream near the highway, the water is polluted ? we can’t see the bottom and it smells bad. I wonder what its original condition was. Clean water supports many organisms, but people pollute it, and that saddens me.	Rivers are originally natural resources, and humans have respected nature. People used to clean rivers, go fishing, and appreciate nature’s life. However, due to development, humans have become foolish. They pollute rivers with domestic wastewater, kill fish, and harm themselves. Currently, developed countries have a sense of crisis and are trying to restore river environments to their original state through technology and effort. We can keep rivers clean through our daily activities. However, developing countries are becoming polluted like the rivers in developed countries’ past. It is important for developed countries to cooperate with others to clean rivers.
U.S.A.	A lot of rivers are becoming overcrowded with both visitors and fishermen, so humans tend to leave garbage, harm fish, and litter the shores. As a result, the fish population is decreasing, especially the smaller ones. Rivers need to be kept clean.	I was surprised to learn that many rivers today, such as those in the U.S.A. and Japan, have cleaner water quality than in the past. I think rivers in developing countries like India still have very polluted water, and countries in similar situations should take action to change this. I believe making such changes would improve the quality of life in many developing countries.
	I think rivers are cool because there are plenty of different kinds of fish and other types of wildlife in and around them.	I think that rivers are still quite polluted, and obviously, some places are cleaner than others. The biggest threat to clean and safe water is humans, so areas with many people are usually more polluted.
	I think rivers are really great habitats for fish and other organisms. I believe we need to work on reducing the pollution we are putting into our rivers.	Rivers today are improving in quality due to greater awareness and better sewage treatment facilities. I think we should continue to raise awareness.
	I like to go to rivers and see God’s glorious creation. There are so many insects and animals that live around rivers. Sometimes, if the river is clean enough, fish can swim through it. Some rivers are polluted, which is very sad because rivers provide so much for us—transportation, wildlife, and more.	I think rivers still need a lot of work, and we can help by advancing technology and funding research on sewage treatment and filtration for rivers and streams. I believe that India and the Philippines need to improve their filtration technology to preserve their streams.

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_72

Practical Report

A Possible Student Biology Research Project: Investigating Historical Mammal Species Loss as an Indicator of Biodiversity Decline

Robert Wallis*

Federation University Australia

(Received: 15 July 2025; Accepted for publication : 5 August 2025)

Many parts of secondary and tertiary biology curricula in Australia have opportunities for students to undertake research. Biodiversity loss is a major concern to the environmental health of planet Earth and forms parts of the secondary school science subjects, and also biology courses at universities. Here I describe a potential student research project that investigates the loss of biodiversity. It is illustrated by a case study in loss of mammal species in a region of Victoria, Australia. The investigation involved searching books and reports written in the 19th Century after European settlement of Victoria that include reference to mammals that once lived in the south-west of the State. Sources were searched detailing past and present distributions of mammals. As well, newspapers (especially regional ones) were searched for mentions of mammals in the same time period. Finally, articles on sub-fossil (Holocene) deposits that contain mammalian remains in the region were accessed. The technique could be applied to any flora or fauna group and the causes of extirpation could be investigated. The case study is an example of a biology research project for senior secondary or tertiary students to carry out in their own locality.

Key words: *biodiversity decline, historical records, mammal extirpation, student research*

***Author for correspondence:** r.wallis@federation.edu.au

INTRODUCTION

Inquiry and research form an important component in Australia's school curricula. For example, one of the aims of the Victorian Science Levels F-10 Version 2.0 is "an understanding of scientific inquiry and the ability to use a range of scientific inquiry practices" (Victorian Curriculum and Assessment Authority, VCAA, 2025a – see websites list). Similarly, an aim of the Biology curriculum at senior secondary schools is to develop a range of inquiry skills (VCAA, 2022a – see websites list). Research projects are common in university biology degrees and are often used as preparation for students wishing to enter an honours year in which most of the assessment is through a research project.

In this paper I use loss of biodiversity as a case study topic for a possible secondary science and tertiary biology research project. The loss of biodiversity is examined specifically in Science Levels 9 and 10 of the Victorian Curriculum F – 10 (VCAA, 2025b – see websites list) and in two subjects of the senior secondary (VCE) curriculum Environmental Science (VCAA, 2022b – see websites list) and Outdoor and Environmental Studies (VCAA, 2024 – see websites list). This case study could be used in these secondary school subjects and in biology at university.

Maintaining biodiversity is an international, national, state and local government priority. UN's Sustainable Development Goal 15 (Life on Land) has a specific target (number 5) that the extinction of threatened species and overall biodiversity loss will be halted. In Australia, the National Biodiversity Strategy and Action Plan (Commonwealth of Australia, 2024) has two pertinent aims: to conserve and restore biodiversity and to mainstream biodiversity considerations into decision-making. Australia was also one of 188 countries to adopt the Kumming-Montreal Global Biodiversity Framework. The Victorian State government is committed to stopping the decline of native plants and animals and improving the state's natural environment through its "Protecting Victoria's Environment – Biodiversity 2037" plan (Department of Energy, Environment and Climate Action, 2025). At my local government level, the City of Warrnambool also has a policy Green Warrnambool that states "we will increase the number of indigenous plant and animal species in the municipality and ensure that none become extinct" (City of Warrnambool City Council, undated).

Largely because of Australia's geographic isolation, 87% of Australian mammal species are endemic – they are found naturally nowhere else in the world. During the last ice age, between 40,000 and 50,000 years ago, a wave of extinction of the Australian megafauna occurred in which 90% of large mammals, birds and reptiles were lost. Possible reasons for this extinction have included a changed climate (Hocknull *et al.*2020), overhunting by Indigenous communities (Turney *et al.,* 2008; van der Kaars *et al.*, 2017) and habitat change caused by Indigenous humans' use of fire (Bird *et al,* 2013).

After European settlement of Australia in the late 18th Century, there occurred another wave of extinction of mammals, many being in what is known as the critical weight range of 55g to 5.5.kg (Ritchie, 2022). Some 38 species (and seven sub-species) of mammals have become extinct in this wave of species loss and another 52 species are listed as critically endangered. Habitat loss, introduced carnivores such as the Red Fox (*Vulpes vulpes*) and Cat (*Felis catus*) and for at least two species of marsupial, hunting by European settlers are believed to be the principal causes. Other causes have been introduced herbivores such as European Rabbits (*Oryctolagus cuniculus*), cattle grazing and disease. Very recently there has been a "third" wave of extinctions, especially in northern Australia (Fitzsimons *et al.,* 2010) where invasion by introduced Cane Toads (*Rhinella marina*) is an additional threatening process to small and medium-sized mammals.

Here I describe a case study that involves the use of historical records of mammals in the south-west of Victoria, Australia, to chart local extinctions over time and thus provide an indication of biodiversity loss in the region. I believe the techniques could be applied elsewhere to help biology/ environmental studies/ science students investigate the loss of species and in appreciating the changes in environment since historical records were kept. The methods can be adapted for studying any flora or fauna group in a student's locality.

MATERIALS AND METHODS

Four main sources of historical information were used to ascertain the mammalian fauna that previously existed in south-west Victoria, Australia, especially around Warrnambool the region's largest city.

1. Books written by residents or visitors to the region in the 19th Century.

The first permanent settlement in Victoria was in south-west Victoria in Portland Bay in

1834. Six years later, the town of Portland was surveyed. In 1840 the town of Warrnambool was surveyed and lots were sold; Warrnambool was formally established as a town in 1855. Thus, I sought books, letters and reports from early European settlers and visitors to the region in the latter half of the 19th Century. One famous book that was referred to by many subsequent authors was written by the first manager of the Bank of Australasia branch in Warrnambool, Samuel Hannaford (1860). Fortunately, this book was republished in1981. Another book that was recommended to me by local historians was that by Dawson (1881). Searching library holdings using terms like "Warrnambool", "history", "19th Century" and "fauna" yielded others that proved valuable, especially those by a visitor to the region Bonwick (1858) and a local newspaper editor Osburne (1980).

Unfortunately, Indigenous communities kept no written records of fauna although verbal stories have been handed down through many generations and some early European settlers carefully documented what they were told by Aboriginals (e.g. Dawson, 1881).

2. Newspaper reports that mention mammals in the area.

Many national and state newspapers have been digitised by the National Library of Australia (see website list) in a database called Trove, but unfortunately, only a few regional newspapers can be searched electronically. Using Trove, I entered key words such as "mammals" and "south-west Victoria" and specified a time period before 1st of January 1900. Often, I had to enter key words that described particular species that I suspected had once been present in the region, such as "wombat" or "native cat". Sometimes a Melbourne-based newspaper referenced an article in one of Warrnambool's newspapers. I then used the microfilm holdings in the Warrnambool City Library to locate the article that had been mentioned in the local newspaper to gather more detail.

The *Portland Guardian and Normanby General Advertiser* was first produced on August 20, 1842, and is generally regarded as Victoria's first newspaper. Warrnambool's newspapers began in 1849. There were 16 different titles coming out of Warrnambool in the 19th Century.

Wallis (2023) contains reports in books and newspapers relevant to mammals living in the south-west Victoria in the 19th Century.

3. Sources that have mammal past and present distribution lists

There are several books (e.g. Menkhorst, 1995; Baker and Gynther, 2013) and web sites (Atlas of Living Australia, undated; Victorian Biodiversity Atlas, 2025 – see websites list) that have past and present Australian mammal distribution maps.

4. Subfossils

Subfossils are the remains of organisms that existed from about 12,000 years ago to present day. In south-west Victoria we have been fortunate for reports of mammal fossils present in a series of caves and middens researched by Wakefield (1964). Some of the caves have been called "death traps" as animals fell into chasms on the ground surface. Others were once feeding sites for owls or marsupial carnivores. Other subfossil sites are in kitchen middens of Indigenous communities – these are cooking and feeding sites where the food remains often accumulated into large deposits. Some middens are quite recent and suggest a fauna that lived at the time of European settlement of south-west Victoria.

RESULTS

Using the four sources (methods) above, the following mammals that once lived in the local area (south-west Victoria) that are no longer found there were determined.

***Common or Bare-nosed Wombat* (*Vombatus ursinus*)**

Samuel Hannaford lived in Warrnambool for two years after moving there in 1854 to take up a bank manager's role. He visited Warrnambool several times later and in 1860 published his book on natural history of the western Victorian coast (Hannaford, 1860). One mammal he found living on the Warrnambool coast was the Bare-nosed Wombat, a large burrowing marsupial. Climbing a steep hill in the town, Hannaford noted the large number of burrows of what he described as the uncouth wombat. He also met a citizen who had hand-reared pouch-young of killed wombats. Two years earlier, Bonwick (1858) also wrote on wombats but rather disparagingly: "The sand which lies on the limestone and under the soil…is a famous resort for the Wombats. These pig headed, pig bodied and pig sized marsupials are fat, chubby sort of creatures, keeping very bad hours, for they sport at night, but afford a delicious supper for the Blacks, and not despicable to the palate of Whites" (Bonwick, 1858, p. 65). Dawson (1881) also noted that wombats were a favoured food of Indigenous communities.

There were also several newspaper articles that mentioned wombats living in the 19th Century in and around Warrnambool (Wallis and O'Callaghan, 2018). Wombat sub-fossils have also been found in seven sites in western Victoria, including some quite recent Aboriginal middens (Wakefield, 1964).

The last known living wombat in Warrnambool was found in 1954 (Wallis and O'Callaghan, 2018). Causes for the extirpation of wombats could have been urbanisation and eradication by farmers because they were considered a pest.

***Quolls* (*Dasyurus* spp.)**

Two species of dasyurid carnivorous marsupials once lived in the 19th Century Warrnambool district (Wallis, 2021). Evidence for the presence of these attractive species comes from all four categories of sources – books and reports, newspaper articles, past and present distribution maps and sub-fossils.

The Eastern Quoll (*D. viverrinus*) – historically called the native cat – no longer lives in the wild on the Australian mainland. The Spot-tail Quoll (*D. maculatus*) survives but in very low numbers. Both species regularly raided chicken coops and were shot, poisoned and hunted by landholders. Only when quoll numbers had plunged did authorities realise their value in preying on European Rabbits that were causing so much environmental damage. It is also believed that a toxoplasmosis-like disease affected quolls (and many other dasyurid marsupials) in the late 1800s and early 1900s.

Quolls have been found in midden deposits as sub-fossils in Warrnambool (Wakefield, 1964).

***Bandicoots* (*Perameles* spp., *Isoodon obesulus*)**

Bandicoots are cat-sized marsupial omnivores with pointed snouts. Three species have been found in sub-fossils in south-west Victoria but only one persists and in very low numbers today. None exist near Warrnambool. The three species were all reported in books by Hannaford (*op. cit.*) and Dawson (*op. cit.*) and in a few newspapers.

***Toolache Wallaby* (*Notamacropus greyi*)**

The marsupials described above all still live elsewhere in Australia; they have thus become locally extinct or extirpated in south-west Victoria. However, the Toolache Wallaby that once dwelt in grasslands and wetlands in the region, is now totally extinct. This graceful and most attractive wallaby proved a good quarry for English settlers who were starved of species to hunt on horseback; while habitat change and the draining of wetlands certainly caused a decline in

Toolache numbers, hunting had a major effect as well (Menkhorst, 1995).

Wakefield (1964) found bones of Toolache Wallaby specimens in middens very close to Warrnambool as well in another cave fossil site 100km from Warrnambool. There have been no historical reports of this species in books or newspapers, but the distribution data indicate the wallaby once lived in the far south-west Victoria (Menkhorst, 1995).

***White-footed Rabbit-rat* (*Conilurus albipes*)**

The White-footed Rabbit-rat (*Conilurus albipes*) was an attractive, large, native rodent that was once widespread throughout Eastern Australia and is now sadly extinct. The species is one of four so called tree-rats of which three species remain in northern Australia. The term 'tree-rat' is derived from their habit of resting during the day in tree hollows and in fallen limbs.

This rat became extinct only 30 years after it was described by English settlers. It may have been preyed on by cats (it became extinct before foxes and rabbits became widespread in Australia) but the most compelling hypothesis could be the species' association with yam daisies (*Microseris* spp.). Yam daisies have underground tubers that *Conilurus* ate and which Indigenous communities farmed. As Indigenous peoples were driven off their lands, so too did the yams decline and the rats that depended on them became extinct (Wallis, 2024).

There have been no sub-fossils or mentions of *Conilurus* in newspapers or by visitors to Warrnambool in the 19th Century. However, sub-fossils have been found some 100km west and north-east of Warrnambool and yam daisies occurred near Warrnambool. I have speculated that suitable habitat for *Conilurus* (and the yams) was abundant in the south-west and thus surmised this beautiful rodent may well have once lived there (Wallis, 2022).

***Dingo* (*Canis lupus dingo*)**

Dingoes are thought to have entered Australia about 4,000 years, introduced by Indonesian seafarers but they are still considered native mammals (Menkhorst and Knight, 2001). The Dingo is a subspecies of dog. There are many reports of Dingoes in newspapers from Trove searches. Almost all the pre-1900 articles were about their status as pests and how they preyed on sheep. Pure Dingoes are no longer found in south-west Victoria. There have been no Dingo remains found as sub-fossils in the region.

Other sub-fossil species

Many mammals listed by Wakefield as sub-fossils no longer live in Victoria. These include the Tasmanian Devil (*Sarcophilus harrisii*), Thylacine (*Thylacinus cynocephalus*) – now extinct, and two small macropodids, a pademelon and a bettong. However, some of these species were lost well before Europeans settled in the area. Thus, presence as sub-fossils is the only indication of the species' prior existence in south-west Victoria. Investigating the possible reasons for the loss of these species would be a worthwhile research question for students.

RECOMMENDATIONS

In this paper I have described how evidence of mammal species that once lived in an area can be sought. I believe this methodology could be used in the biology classroom by students investigating the decline in biodiversity in their local area. Many newspapers have now been digitised and can be searched for species records and reports with search criteria including time periods and location. Local libraries often have books on historical natural history. Students could also search international conservation sites, such as the IUCN Red List of Threatened Species (IUCN, 2025 - see website list) for data on relevant species but I found sufficient detail in the listed sources. Finally, sub-fossil records could be searched for relevant species in the appropriate localities. Students undertaking research into lost fauna or flora from their area could search research web sites such as Google Scholar and key in "subfossils" and their region to see if there are relevant published works available. As well, state and national museums may well have displays and records of local subfossils.

ACKNOWLEDGEMENT

I am indebted to Dr. Nobuyasu Katayama of the Tokyo Institute of Biology Education for his extremely valuable and constructive suggestions about earlier versions of this paper.

REFERENCES

Baker, A. and Gynther, I. (2013) *Strahan's Mammals of Australia*. New Holland, Wahroonga.

Bird, M. I., Hutley, L. B., Lawes, M. J., Lloyd, J., Luly, J., Ridd, P. V., Roberts, R. G., Ulm S. and Wurster, C. M. (2013) Humans, megafauna and environmental change in tropical Australia. *Journal of Quaternary Science* **28:** 439–452. http://dx.doi.org/10.1002/jqs.2639 <retrieved 12/08/2025>

Bonwick, J. (1858) *Western Victoria. Its Geography, Geology and Social Condition. The Narrative of an Educational Tour in 1857.* Thomas Brown, Geelong.

City of Warrnambool (undated) Green Warrnambool. https://www.warrnambool.vic.gov.au/sites/warrnambool.vic.gov.au/files/documents/warrnambool/environment/Green%20Warrnambool%20FINAL%20adopted%203%20September%202018.pdf <retrieved 25/06/2025>.

Commonwealth of Australia. Australia's Strategy for Nature 2024-2030 (2024) Australia's National Biodiversity Strategy and Action Plan. https://www.dcceew.gov.au/sites/default/files/documents/australias-strategy-for-nature-2024-2030.pdf <retrieved: 25/06/2025>.

Dawson, J. (1881) *The Languages and Customs of Several Tribes of Aborigines in the Western District of Victoria, Australia.* George Robertson, Melbourne. (Reissued in 2009 by Cambridge University Press, Cambridge, United Kingdom).

Department of Energy, Environment and Climate Action (2025) Biodiversity 2037 Progress Report. https://www.environment.vic.gov.au/biodiversity/biodiversity-progress-report <retrieved 01/07/2025>.

Fitzsimons, J., Legge, S., Traill, B. and Woinarski, J. (2010) Into oblivion? The disappearing mammals of northern Australia. *The Nature Conservancy*. https://www.natureaustralia.org.au/content/dam/tnc/nature/en/documents/australia/Into-Oblivion.pdf <retrieved: 19/06/2025>.

Hannaford, S. (1860). *Sea and River-side Rambles in Victoria; being a handbook for those seeking recreation during the summer months.* Blundell & Co., Melbourne.

Hocknull, S. A., Lewis, R., Arnold, L. J., Pietsch, T., Joannes-Boyau, R., Price, G. J., Moss, P., Wood, R., Dosseto, A., Louys, J, Olley, J. and Lawrence, R. A. (2020) Extinction of eastern Sahul megafauna coincides with sustained environmental deterioration. *Nature Communications* **11,** 2250. DOI: 10.1038/s41467-020-15785-w. https://www.nature.com/articles/s41467-020-15785-w

Menkhorst, P (1995) *Mammals of Victoria. Distribution, Ecology and Conservation*. Oxford University Press, Melbourne.

Menkhorst, P. and Knight, F. (2001). *A Field Guide to the Mammals of Australia.* Oxford University Press, Melbourne.

Osburne, R. (1980) *The History of Warrnambool, Capital of the Western Ports of Victoria from 1847.* Pinson, Lindsay and Madden, Warrnambool). Facsimile edition of 1887 edition.

Ritchie, E. (2022). 'Gut-wrenching and infuriating': why Australia is the world leader in mammal extinctions, and what to do about it. *The Conversation* 19/10/2022 https://theconversation.com/gut-wrenching-and-infuriating-why-australia-is-the-world-leader-in-mammal-extinctions-and-what-to-do-about-it-192173.

Turney, C. S. M., Flannery, T. F., Roberts, R. G., Reid, C., Fifield, L. K., Higham, T. F. G., Jacobs, Z., Kemp, N., Colhoun, E. A., Kalin, R. M. and Ogle, N. (2008) Late-surviving megafauna in Tasmania, Australia, implicate human involvement in their extinction. *Proceedings of the National Academy of Sciences* **105:** 12150–12153. https://doi.org/10.1073/pnas.0801360105

van der Kaars, S., Miller, G. H., Turney, C. S. M., Cook, E. J., Nurnberg, D., Scgonfeld, J. Kershaw, A. P. and Lehman, S. J. (2017) Humans rather than climate the primary cause of Pleistocene megafaunal extinction in Australia. *Nature Communications* **8:** 14142. DOI: 10.1038/ncomms14142 https://www.nature.com/articles/ncomms14142.

Wakefield, N. A. (1964) Recent mammalian sub-fossils of the basalt plains of Victoria. *Proceedings of the Royal Society of Victoria* **77:** 419–425. https://www.biodiversitylibrary.org/page/57434068#page/505/mode/1up <retrieved 12/08/2025>

Wallis, R. (2021) Historical reports of quolls in Victoria's south-west. *The Victorian Naturalist* **138:** 78–85. https://www.Biodiversitylibrary.org/item/331070#page/14/mode/1up <retrieved 12/08/2025>

Wallis, R. (2022) Was the beautiful Rabbit-rat ever in the Warrnambool District? *Warnimble* **56**(3): 8–10. https://nla.gov.au/nla.obj-3212479174/view.

Wallis, R. (2023) *Natural History in the 19th Century Warrnambool District.* Warrnambool & District Historical Society, Warrnambool.

Wallis, R. (2024) James Dawson's muurang and yaakar. *The Victorian Naturalist* **141**, 17– 20.

Wallis, R. and O'Callaghan, E. (2018) Historical reports of Common (Bare-nosed) Wombats in Warrnambool, Victoria. *The Victorian Naturalist* **135:** 178–180. https://www.biodiversitylibrary.org/item/312580#page/22/mode/1up <retrieved 12/08/2025>

WEBSITES

Atlas of Living Australia https://bie.ala.org.au/species/https://biodiversity.org.au/afd/taxa/e9e7db31-04df-41fb-bd8d-e0b0f3c332d6 <retrieved 30/06/2025>.

International Union for Conservation of Nature and Natural Resources, IUCN (2025) The IUCN Red List of Threatened Species. Version 2025-1. https://www.iucnredlist.org/ <retrieved 30/06/2025>.

National Library of Australia. Trove. https://trove.nla.gov.au/ <retrieved 20/06/2025>.

Victorian Biodiversity Atlas (2025) https://vba.biodiversity.vic.gov.au/vba/#/ <retrieved 30/06/2025>.

Victorian Curriculum and Assessment Authority, VCAA (2022a) Victorian Certificate of Education, Biology, Study Design. https://www.vcaa.vic.edu.au/curriculum/vce-curriculum/vce-study-designs/biology/biology <retrieved 06/07/2025>.

Victorian Curriculum and Assessment Authority, VCAA (2022b) Victorian Certificate of Education, Environmental Science, Study Design. https://www.vcaa.vic.edu.au/

curriculum/vce-curriculum/vce-study-designs/environmental-science/environmental-science <retrieved 06/07/ 2025>.

Victorian Curriculum and Assessment Authority, VCAA (2024) Victorian Certificate of Education, Outdoor and Environmental Studies, Study Design. https://www.vcaa.vic.edu.au/curriculum/vce-curriculum/vce-study-designs/outdoor-and-environmental-studies/outdoor-and-environmental-studies <retrieved 06/07/2025>.

Victorian Curriculum and Assessment Authority, VCAA (2025a) The Victorian Curriculum F–10 Version 2.0, Science, Introduction. https://f10.vcaa.vic.edu.au/learning-areas/science/introduction <retrieved 01/07/2025>.

Victorian Curriculum and Assessment Authority, VCAA (2025b) The Victorian Curriculum F–10 Version 2.0, Science, Content descriptions – Levels 9 and 10. https://f10.vcaa.vic.edu.au/learning-areas/science/curriculum#VC2S10U05 <retrieved 06/07/ 2025>.

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_80

Practical Report

The Effects of an Informal Online Science Program on Young Children's Scientific Thinking and Understanding of Genes

Shinobu Arai[1)*], Manabu Sumida[2)]

[1)] *Nakamura Gakuen University*
[2)] *Ehime University*

(Received: 29 April 2025; Accepted for publication : 21 August 2025)

This study reports on the content and results of an online science program related to genes conducted with 22 children, aged 4–8 years, attending Japan's Ehime University Kids Academia. Scientific reasoning abilities are present from early childhood, and it has been shown that young children can form evidence-based hypotheses during exploratory play. Therefore, we developed a science course on the theme of "gene", with activities designed to explore the peculiarities of its structure and formulate hypotheses about its functions. The instructor lectured on genes and living organisms. The children then considered why genes have a helical structure while examining a genetic craft model. They inquired about the function of genes that enable Tibetans to live in high mountains with limited oxygen. Half of the children attempted to use their existing knowledge to provide a scientific explanation for their ability to survive. Furthermore, after completing the online science program, some children were able to apply their knowledge of the function of "gene" to explain other tasks as well. This case study demonstrates that young children can think critically and formulate hypotheses about advanced scientific concepts, such as "gene", through simple online science activities.

Key words: *early childhood science education, gene, hypothesis, thinking, online science program*

***Author for correspondence:** arai_s@nakamura-u.ac.jp

INTRODUCTION

Early science education in early childhood fosters curiosity and inquisitiveness, serving as a foundation for future science learning (Spektor-Levy *et al*., 2013). Children who have a strong curiosity about how things work or are skilled in a particular academic field are not satisfied with the formal educational program, the same play equipment and activities as their peers and are more likely to be influenced by the understanding and support of adults close to them, such as acquiring more advanced knowledge from books or the Internet or participating in informal classes (Kahn, 2023).

At Ehime University Kids Academia in Japan, where face-to-face science activities were previously conducted, an online science program using the Zoom videoconferencing platform was implemented in 2020 due to COVID–19–related social distancing constraints. During the pandemic, an online science program was conducted to focus on medicine, aiming to cultivate scientific and medical thinking among children and help them resist misinformation related to COVID-19 (Sumida and Kurata, 2023). Through these activities, the advantages of efficiency, convenience, and the potential of online science programs were demonstrated. The program also highlighted the benefits of allowing children living far away to participate, as regional differences and teacher expertise have been identified as challenges in early science education for gifted children (Kahn, 2023). Thus, the shift to online science programs—unexpectedly accelerated by the COVID-19 pandemic—ensured educational continuity and opened new avenues for innovation in science education.

Among the many scientific topics that can be explored in online science program, genetics has become especially relevant in the post-COVID-19 world. Gene-targeted bioengineering, which has been applied in the development of COVID-19 vaccines, exerts significant influence across a wide range of fields, including agriculture, medicine, and environmental science. Given the ethical implications inherent in this domain, there is a growing consensus on the importance of providing educational opportunities for younger generations to develop foundational understandings of genetics (Strawhacker, 2020). In response to this need, recent efforts have developed educational tools such as CRISPEE, a bioengineering toy specifically designed for early childhood learners (Verish *et al.*, 2018). Nevertheless, for children with a high level of scientific curiosity, introducing gene-related concepts—now increasingly relevant in contemporary life—can further stimulate their interest and engagement in science.

In this context, we developed and implemented a new online science program for young children that focused on the theme of "gene" and aimed to support scientific thinking and hypothesis generation. Children's scientific reasoning abilities and understanding of scientific knowledge have traditionally been considered limited by their difficulty in making a fundamental distinction between theories or hypotheses and evidence (Kuhn, 2010). However, recent research suggests that even young children can engage in conceptual reasoning and apply prior knowledge effectively (Skene *et al.*, 2022). For instance, Walker *et al*. (2017) demonstrated that five-year-olds can generate hypotheses based on prior knowledge. Furthermore, Köksal-Tuncer and Sodian (2018) showed that children aged 3 to 6 years demonstrated verbal argumentation competence in scientific reasoning tasks using a blicket detector paradigm that was entirely novel to them. These findings suggest that young children can utilize existing knowledge and build upon it. Based on this, we hypothesized that if young children become interested in genetics and actively engage in acquiring new knowledge, they may also be capable of applying that knowledge to think critically and formulate their hypotheses.

Purpose of the Present Study

We implemented a new online science program in which young children engaged in simple hands-on activities at home to explore the theme of "*gene*". The study aimed to evaluate an informal online science program on the theme of genes for children in terms of the following two points.

1. Are children able to engage in thinking and hypothesis setting using the "gene" knowledge presented in the lecture?
2. Did their interest in genes increase, and are they able to apply "gene" concepts to explain phenomena beyond the context of the online science program?

METHODS

The online science program was conducted for young children registered in the Ehime University Kids Academia. Ehime University Kids Academia was established in 2010 as an informal science education program designed to engage young children in science (Sumida, 2015). This unique science program is meant for children, allowing them to explore their interests and think critically for themselves. Currently, approximately 240 children from Japan and abroad are registered in the program (as of 2025.06.20, https://kids-academia.com/).

Participants

This study included children aged 4 to 8 years who were registered at Ehime University Kids Academia. Notification of this study's activities was sent to the parents of registered children via e-mail to encourage participation. Participants included 22 Japanese children from various regions of the country. Permission was obtained from the children's parents to use photographs of them during the activities, their speech, and other information in the study. The parents agreed that this scientific activity constitutes participation in research and that they will receive no remuneration for their participation. They also promised confidentiality to all participants.

Online Science Program Design

The online science program was conducted in Japanese as a 60-minute program in 2022. The scientific activities conducted in this study lasted for 45 minutes (Table 1). A genetic craft model kit (http://x2.gmobb.jp/sfa1/index. htm) was sent to the participants' homes in advance (Figure 1), and they were asked to make the model in advance. Parents were allowed to support their children with the gene craft activity as needed. The activity was conducted in five steps (Table 1). In Steps 1, 3, and 4, the instructor's lecture introduced the concept of genes to the children. In Steps 2 and 5, the children were asked to think independently and formulate hypotheses through a thinking activity. The lecturer for this science activity was the author, Arai, who specializes in molecular biology and has studied the mechanisms of gene regulation in skeletal and cardiac muscles.

In Step 0, the lecturer described the kind of

Table 1. Thinking and Hypothesis Setting Activity on the Theme of Genes

Step	Time mm:ss	Theme	Method	Contents
0	02:30	Introduction		Meet the instructors
1	01:15	What is a gene?	Lecture	The teacher explains what genes are using slides
2	07:10	Let's consider the features of gene structure.	Thinking (free talking)	Learn about genes by using a model of a gene Consider why it has a helical structure
3	03:30	We can easily obtain gene information!	Lecture	Introduction to HPs where genetic information can be acquired
4	03:30	What did Svante Pääbo discover?	Lecture	Explain what hypotheses can be considered by knowing the gene sequence.
5	01:10	Hypothesis about the function of genes	Explanation of the problem	Tibetans can live in high mountains
	03:00		Thinking time	What is the function of genes that only Tibetans have?
	10:00		Announcement	Presentation of hypotheses
	03:20		Answer description	Description of the genes that Tibetan people have
	09:00	Ending	Question time	
Total	44:25			

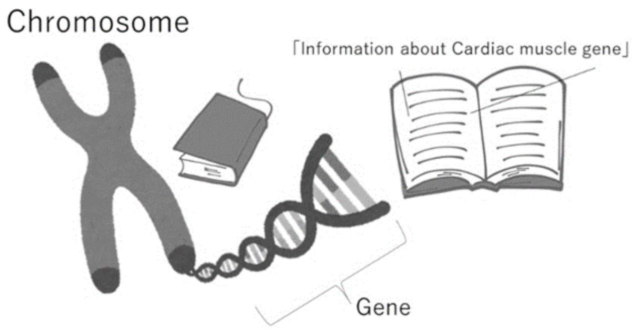


Figure 1. Slide in Step1

This figure shows English translations of slides originally written in Japanese.

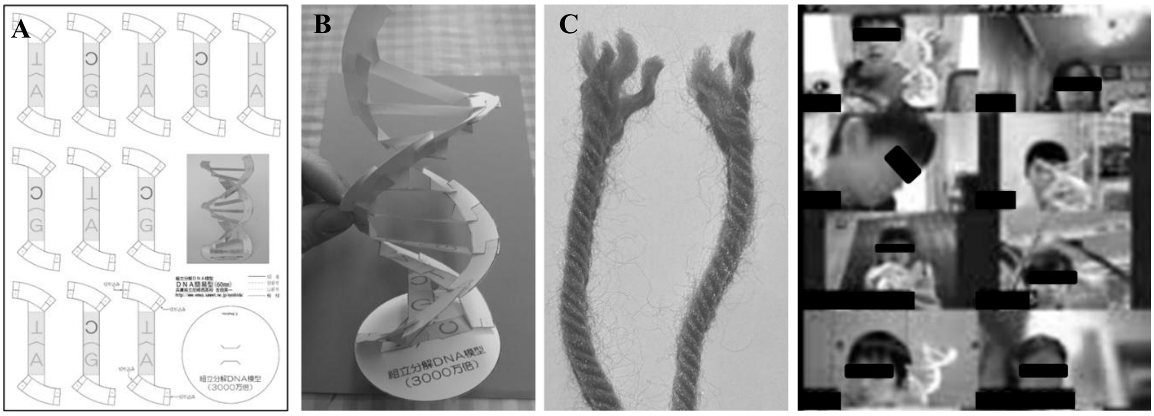


Figure2. Thinking About Gene Structure by Using Gene Craft

A. Gene craft (http://x2.gmobb.jp/sfa1/index.htm), B. Completed gene craft, C. wool yarns in a helical structure, D. Children thought about the structure of genes by using gene craft.

research she had been doing. She briefly explained the relationship between gene dysfunction and heart failure. To help children understand the concept of heart muscle deterioration, the cells that make up the heart were explained using the metaphor of a puzzle. It was then explained that when certain genes within those cells stop functioning, some of the puzzle pieces fall out, leading to impaired heart function.

In Step 1, the lecturer explained what genes are. She compared a cell to a piece of a puzzle and explained that a gene is one of the pieces that make up an organism, and that the gene serves as the blueprint for the organism, using a book as an analogy. She further explained that the gene, which serves as the blueprint for an organism, is a huge volume of information written with four letters (ATGC) and has a helical structure (Figure 1).

In Step 2, the children were asked to think and freely discuss why genes have a helical structure by comparing their own gene craft model and wool yarns bundled in a helical structure (Figure 2).

In Step 3, for children interested in genetic information, we informed them that genetic information is available free of charge from the National Center for Biotechnology Information (NCBI: https://www.ncbi.nlm.nih.gov/). Given that the NCBI website is available only in English, it poses accessibility challenges for children.

Accordingly, rather than instructing them on how to use the site, we conveyed the idea that NCBI offers free access to comprehensive genetic information.

In Step 4, we explained the evolutionary process that can be revealed by understanding genetic information, using the example of Svante Pääbo, who was awarded the Nobel Prize in 2022 for decoding Neanderthal genes. This discovery revealed that Neanderthal genes are present in the genes of Homo sapiens (Figure 3-A).

In Step 5, as an activity to support the understanding that humans possess different traits depending on their living environments—

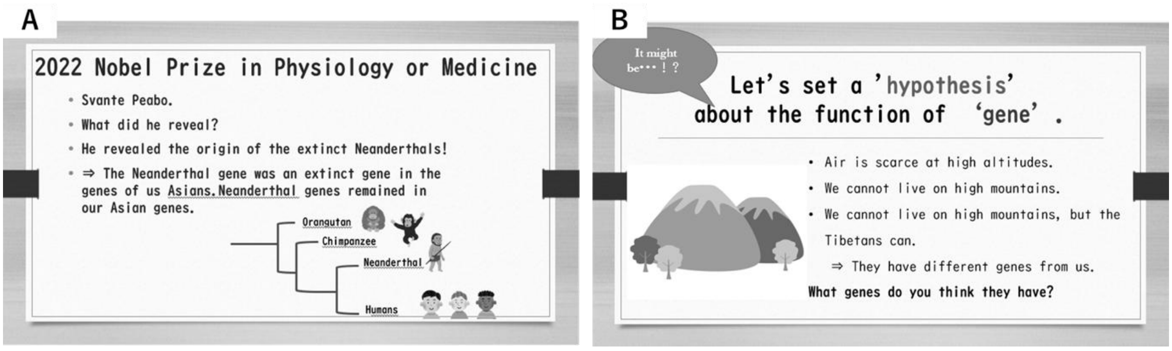


Figure 3. Slides in Step (4) and Step (5)

This figure shows English translations of slides originally written in Japanese.

Table 2. The list of 22 young children

Code	Grade	Interests
C-1	K1	Insects
C-2	K1	National Flag (Certification Level 1)
C-3	K2	Origami
C-4	K2	Insects
C-5	K3	History (especially Toyotomi Hideyoshi), Stars
C-6	K3	Language (Chinese, Japanese, Kanji)
C-7	K3	Cars (Investigation of windshield wipers)
C-8	K3	Elements (especially P), Minerals
C-9	K3	Cells, Human Body, Planaria
C-10	K3	Tag
C-11	G1	The beginning of time, Universe (dark matter), Reading (1,000 books so far)
C-12	G1	Space, Weather, SDGs
C-13	G2	Languages, Scientists
C-14	G2	Slime molds, Neanderthals, Bears
C-15	G2	Reading (600 books per year)
C-16	G2	Origami
C-17	G2	Reading (700 books per year)
C-18	G2	Electricity
C-19	G2	Money
C-20	G2	Snake venom, Elements, English, Slime molds, History
C-21	G3	Animals
C-22	G3	Silkworms, Space

traits that are determined by gene function—we used Tibetans living in high-altitude regions as a case example. The children were asked the question, “What genes allow Tibetans to live in high mountains where oxygen is scarce?” and they formulated their hypotheses (Figure 3-B). In response to this question, after the children had stated their hypotheses about the function of genes, the researcher explained the scientifically established function of the gene found in Tibetans and described why it is suited for living at high altitudes (Simonson *et al*., 2010).

Data analysis

The activities were recorded by Zoom's recording function, and the speech was extracted from the data. The children are labeled C-1 through C-22. The grades of the labeled children are presented in Table 2. As shown in Table 2, each child is interested in a variety of things, not just science.

Parent feedback, including their child's behavior and response, was surveyed using a questionnaire sent to their parents (using the Google Forms survey instrument software). The questions used in this study are shown in Table 3. The response rate of the questionnaire was 82% (18/22).

The questions in Table 3 were administered by the parents. Specifically, for items such as "Understanding of the program content" and "Interest in genes and transfer of knowledge to other tasks after the online science program," the parents asked their children the questions. They entered the children's responses on their behalf. This approach was intended to reduce stress and help the young children respond more comfortably and naturally, without feeling nervous.

RESULTS

As background of “familiarity with genes before the activity”, more than half of the participating children (Q1-1, 59%, 13 out of 22) indicated that they had heard the word

Table 3. Contents of the Post-Program Questionnaire Administered to Parents

Item
Q1. Familiarity with genes before the activity
Q1-1. Had your child heard the word “gene” before today’s session? (Selected from the following: already familiarity with it, first time learning about it)
Q1-2. If your child had heard the word before, how much did they already know about the topic covered by the guest teacher? (Selected from the following: *Knew everything*, *Knew a little*, *Knew very little*, *Knew nothing at all*)
Q2. Understanding of the program content
Q2-1. How well did your child seem to understand the content of the guest teacher’s lecture on genes? (Selected from the following: *Understood everything*, *Understood a little*, *Understood very little*, *Did not understand anything at all*)
Q2-2. If there were any parts of the lecture that your child found difficult to understand, please describe them. (Free-text)
Q3. Interest in genes and the transfer of knowledge to other tasks after the online science program
Q3-1. Did your child seem motivated to learn more or explore today’s topic further? (Selected from the following: *Very positive*, *Somewhat positive*, *Somewhat negative*, *Very negative*)
Q3-2. If your child showed a strong interest, what kinds of things did they say they wanted to learn more about? (Free text)
Q3-3. Please ask your child the following questions and tell us how they responded. Also, ask them why they gave that answer (*e.g*., “Why do you think so?”).
Q3-3-1. Do you think rice has genes? (Free text)
Q3-3-2. Why do you think some people have blond hair? (Free text)

"*gene*" before. Among them, only one child, C-9 (K3), reported full knowledge of the term (selected "Knew everything" in response to Q1–2). Four children—C-5 (K3), C-11 (G1), C-13 (G2), and C-14 (G2)—answered that they had some prior knowledge (selected "Knew a little" in response to Q1–2). Building on the above, this study aims to clarify the following two aspects regarding the online science program for these children.

Result 1: The scientific thinking and hypothesis in the online science program

In Step 1, the lecture explained that "genes are the blueprints that shape organisms and contain a great deal of information for life" and "genetic information is folded and stored in cells" (Figure 1), comparing them to books.

In Step 2, the children were asked to consider why genes have a helical structure, and they actively shared their ideas (Figure 4). In their comments, the children focused on the fact that the genes shown in Step 1 were information, and they thought that the helical structure might be used to read the information. The children discussed genes from the perspective of reading them as information, using expressions such as "to read," "to write down the genetic information," and "read books about genes" (Figure 4). However, since the helical structure is a physical property that depends on stability, the children were asked to compare the structure of wool yarn, which had been prepared in advance as a familiar object, with the genetic model. As a result, C-18(G2) said, "It is hard to break!" The children noticed the stability of the model. This child's comment seemed to convince all the children of the properties of the helical structure. Among the four children who spoke here, three of them (C-9, 14, and 18) had heard the word "gene" before, and only C-9 fully understood the content of the lecture.

In Step 4, before the introduction, there was one Grade 2 child who knew about Svante Pääbo (Table 2, C-14; this child was very interested in Neanderthals and had expert knowledge about their characteristics and why they became extinct). The gene sequence allowed us to formulate a new hypothesis about racial characteristics (the hypothesis that Neanderthal genes are retained in Asians and that Asians may have genes that lead to why there are fewer severe cases of new coronaviruses compared to Europeans (Zeberg and Pääbo, 2020).

In Step 5, children hypothesized the function of the gene. Specifically, Tibetans can live in high mountains where oxygen is scarce (Simonson *et al.* 2010), whereas we cannot live in high mountains due to the scarcity of oxygen. The children were told that this is because Tibetans have a gene with a characteristic that we do not have, and they were asked to hypothesize about the function of the gene (Figure 3). The children were given 3

T: Why are genes twirling (genes)?
C-14(G2): Because it's a double helix!
~quieten down (inactive)~.
T: Then, why is it twirling for?
C-14(G2): To make it easier to read...?
C-9(K3): To write down the genetic information...?
C-20(G2): Is it because it's easier for someone who read books about genes to read this shape...?
T: Then, can you think of any other reason to compare it with the shape of the yarn?
C-20(G2): If gene makes it like a string, what good will it do・・・・?
C-18(G2): It is hard to break! It's stable!!!!

***Figure 4*. Children's Statement in Thinking**

Note. T = Teacher; C-x = Children; () = Grade.

minutes to think about their hypotheses and were instructed to write them down on the provided paper. The children then presented their hypotheses. The children freely made hypotheses using the various knowledge they had. The C-14(G2), who is interested in Neanderthals, associated their short stature with a difference between apes, and hypothesized that Tibetans are also short and use less oxygen. Children who knew more about the human body and its need for oxygen hypothesized that the Tibetans would be able to convert less air into oxygen in their bodies, or that they would not need oxygen in the first place. In response to the mention of oxygen during the presentation of hypotheses, C-9(K3) explained about mitochondria that produce energy from oxygen. This suggests that children not only have knowledge but also can use it to explain their hypotheses scientifically (Figure 5). Twelve children expressed their own opinions on the hypothesis in question. Among them, only four children (Figure 5; C-22, C-18, C-12, and C-17) formulated their hypotheses about the function of genes. Another child was able to draw based on their existing knowledge—such as the function of human lungs or body constitution—to support their statements. Interestingly, some children generated new hypotheses or shared their knowledge after listening to the ideas proposed by others. For instance, C-20 (G2) initially stated, "I think their body is now strong enough not to run out of oxygen." However, after hearing the opinions of other children, this child formulated a new hypothesis by incorporating personal knowledge about temperature changes in high-altitude areas and air pollution in urban environments. Furthermore, in response to the knowledge shared by C-20 (G2) and C-9 (K3), C-9 (K3) said, "I have something to add," and went on to explain the relationship between living organisms and oxygen, specifically noting that mitochondria were incorporated during the evolutionary process. Among the 12 children who spoke here, 9 of them (C-9, 10, 11, 12, 14, 15, 17, 18, and 22) had heard the word "gene" before.

An analysis of their statements supported their hypothesis, which was based on underlying knowledge, including aspects such as "Gene

C-20(G2): I think their body is now strong enough not to run out of oxygen.
C-15(G2): I think that they are healthy even with less air, less oxygen.
C-22(G3): Their genes make more oxygen-carrying red blood cells.
C-11(G1): I think their lungs evolved to withstand less air.
C-18(G2): Genes capable of withstanding thin air.
C-21(G3): A bit like C-r1, but I think I'm able to breathe tiny oxygen.
C-14(G2): I think they were short like a Neanderthal.
C-10(K3): They can live with less oxygen.
C-12(G1): I think it's a gene that can change all the air into oxygen in the body, even if it's little air.
C-20(G2): Two new hypotheses came up, and I wanted to mention them. I thought that since the temperature of high mountains drops by one degree per 100 meters, once warmed up, the insulating skin would be fine, just as it is fine in cold weather. I think they have that kind of gene. Also, the air in cities is polluted with chemicals from the emissions of various factories, but forests are different, so I think they must be less susceptible to air pollution.
C-9(K3):I have an addition. I believe that humans didn't need oxygen in the past, but other animals did, and they took that into humans, and that's how they became mitochondria."
C-17(G2):There may be different genes besides A, C, T, and G. One of them may be special. I don't need oxygen; I have a kind of oxygen suction machine in my body that allows me to breathe air from far away.
C-5(K3): Maybe they have big lungs or something?

Figure 5. Children's Statements in Hypothesis Setting

Note. T = Teacher; C = Children; () = Grade.

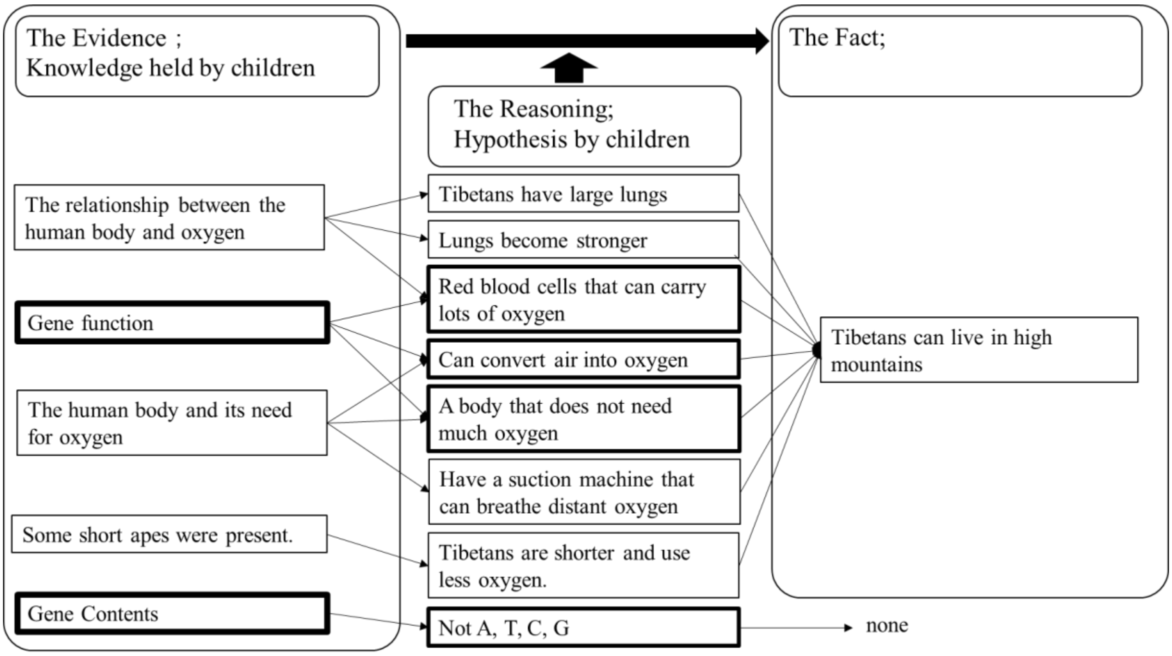


Figure 6. Children's Constructing Explanations in Science

Bold rectangular boxes represent explanations connected to genes, while arrows indicate the associated content.

Table 4. Children's recognition about their understanding of the content of the lecture on genes (Q2-1).

Grade	*N*	Understood everything	Understood a little	Understand very little	Did not understand at all	Unanswered
K-1	2				1	1
K-2	2		1	1		
K-3	6	1	3	1	1	
G-1	2	1	1			
G-2	8	2	3	1		2
G-3	2		1			1
Total	22	4 (18.2%)	9 (36.4%)	3 (9.1%)	2 (13.6%)	4 (22%)

Function", "The relationship between the human body and oxygen", "The human body and its need for oxygen" and "Some short apes were present" (Figure 6).

Result 2: The effects of the online science program on children's understanding of "gene"

The results of "Understanding of the program content" showed that 54.6% (12/22) of the children demonstrated a partial understanding of the lecture on genetics (Table 4). Half of the children understood (13/22, 54.6%). However, five children did not understand (5/22, 22.7%).

After the online science program, we tested whether the children could provide explanations using the knowledge of genes as information about living organisms, which we lectured on in this research activity. The questions "Do you think there is a gene in rice? (Q3-3-1)" and "Why do you think some people have golden hair? (Q3-3-2)" were designed to assess the children's understanding of two concepts: that all living organisms have genes, and that genes serve as a blueprint for the characteristics of living organisms,

Table 5. Explanations as genes with respect to organisms and species

Code	UPC	Do you think there is a gene in rice? (Q3-3-1)	Why do you think some people have golden hair? (Q3-3-2)
C-1(K1)	1	None	None
C-3(K2)	2	No (shaking one's head）	I don't know.
C-4(K2)	3	I think not.	None
C-5(K3)	3	I think **yes**. Because rice is also made from genes.	I don't know, but it's possible that someone with black hair could **suddenly mutate.** There's also a possibility, however small, that someone with albinism could be born.
C-6(K3)	2	I think no. Because they are found in living things.	I wondered if it depended on where you were born. But Japanese people have black hair no matter where they are born... I wondered why.
C-7(K3)	1	I think no. Because rice is food.	Because their hair is blonde (because it's hair) (I'm writing the person's words exactly as they said them).
C-8(K3)	3	I think **yes**. Living things cannot take shape without a blueprint. Food is originally alive.	Because blueprint is gold, the reason is that there must be a reason why people with golden hair were more likely to survive in their environment. Just as animals change color to attract mates, it makes them more noticeable and easier to attract mates.
C-9(K3)	4	I think **yes**. Rice originally comes from rice plants, which are plants. Plants have DNA inside their cells.	It's because everyone's **genes are different**. It may be related to the difference between adenine and thymine, coming after cytosine and guanine instead of guanine and cytosine.
C-10(K3)	3	none	none
C-11(G1)	4	I think **yes**. Because rice is alive. Because plants are alive.	Because they have **genes that make their hair golden**. To attract females. If they don't attract females, they can't reproduce.
C-12(G1)	3	I think **yes**. The answer was that it depends on the type of rice. The reason is that there are many different types of rice, such as brown rice, mixed grain rice, mochi rice, Himehikari, and Himenrin. The color, shape, size, and weight of the grains are all different. Mochi rice is softer and stickier. That's why it's different, I think.	I saw it in an encyclopedia, but I forgot. Each strand of hair has genes, and maybe it's because the **genes are different**.
C-13(G2)	3	I think **yes**. Food also decays, which means that living things are living things, and living things have genes because they use the components of food.	I think it's because of **genetic factors** or because of the influence of substances in the mother's womb.
C-14(G2)	4	I think **yes**. It is a plant that grows from seed to seedling and then to rice.	Because I have the **golden gene.**
C-15(G2)	3	I think **yes**. There are various types and origins of rice.	Because they're foreigners, maybe it's because their **genes are different** from those of Japanese people.
C-16(G2)	2	No (shaking one's head）	I don't know.
C-17(G2)	3	I think **yes**. I had read about genetically modified wheat in a book.	I think it's a **special mutation** from when humans were originally particles.
C-18(G2)	4	I think **yes**. Fruits have genes, so I think that cooking them means they have genes.	The pigment in their hair is different. That's because their **genetic information is different.**
C-22(G3)	3	I think **yes**. Since it is a plant, I think it has genes. I'm unsure if the genes remain after being heated.	It's because people with less pigment were born in places where there isn't much sunlight.

UPC; Understanding of the program content (Q2-1, 4: Understood everything, 3: Understood a little, 2: Understood very little, 1: Did not understand anything at all) respectively. The relationship between the responses to these questions and the children's under-standing of the online science program is shown in Table 5. Based on the results (Table 5), children who demonstrated an under-standing that rice possesses genes were able to provide scientifically accurate explanations. For example, participant C-8 (K3) stated, "Living things cannot take shape without a blueprint." Similarly, regarding the idea that genetic information determines the traits of organisms, some children offered appropriate explanations such as, "Because they have genes that make their hair golden." Moreover, children who reported a high level of comprehension of the lecture—categorized as "*Understood everything*" or "*Understood a little*," were able to provide accurate explanations concerning genes. Table 6, which summarizes the relationship between lecture comprehension and the accuracy of responses, indicates that in the online science program focusing on "*gene*," the level of understanding of the lecture had a significant influence on children's ability to correctly explain genetic concepts.

In Table 3, "Did your child seem motivated to learn more or explore today's topic further? (Q3-1)" 50% (11/22) of the children were "*Very positive*" or "*Somewhat positive*" (Table 7, Figure 7). Of these 11 children, the parents of 10 provided responses to the free-text question(Q3-2): "If your child showed a strong interest, what kinds of things did they say they wanted to learn more about?" Two parents described their child's (C-4, 18) behavior after the activity, noting that their child read illustrated books or texts about genes. Five children expressed specific questions to their parents about the nature of genes, such as: "when genes are produced in babies"(C-11), "how genes increase when cells increase" (C-12), "characteristics of genes"(C-10, 15) and "how genes are produced" (C-13). Three children related their interest in genes to other areas of personal curiosity, saying things like: "the genetic differences between dinosaurs and birds"(C-22), "evolution from sexual reproduction to loss of sexual differentiation"(C-9) and "the genetic differences between species (interested in the reasons why Neanderthals became extinct)"(C-14). Thus, most of the children, regardless of age, were not only interested in gaining new knowledge about genes through the activities of

Table 6. Relationship between question accuracy and lecture comprehension

Understanding of the online science program lecture	Understood everything	Understood a little	Understood very little	Did not understand anything at all
Rice Gene Availability	4/4 (100%)	8/9 (89%)	0/3 (0%)	0/2 (0%)
Relation to gene function as a race	4/4 (100%)	6/9 (67%)	0/3 (0%)	0/2 (0%)

Table 7. Children's Active Research of Genes After the Lecture

Grade	*N*	Very active	Rather active	Rather inactive	Not positive at all	Unanswered
K-1	2			1		1
K-2	2		1		1	
K-3	6	2	1	2	1	
G-1	2	1	1			
G-2	8	3	1	1	1	2
G-3	2		1			1
Total	22	6 (27.3%)	5 (22.7%)	4 (18.2%)	3 (13.6%)	4 (22.7%)

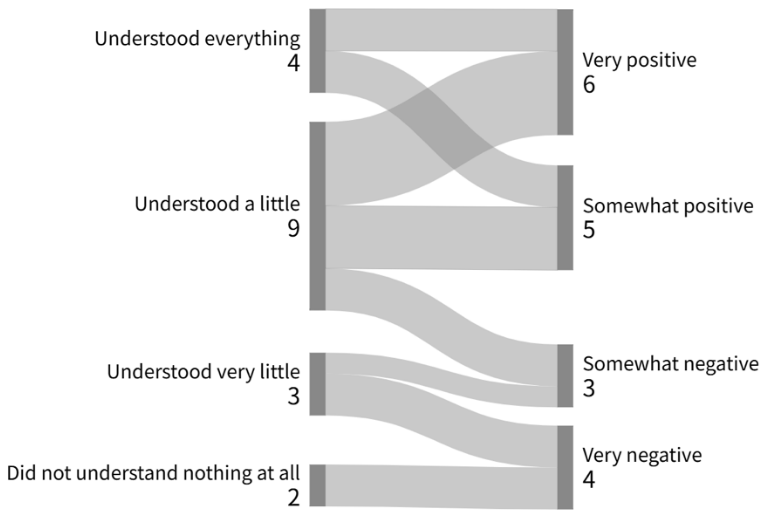


Figure 7. Understanding of the Lecture and Post-Program Curiosity about Genes

The left side shows the level of understanding of the lecture, and the right side shows the level of curiosity about genes after the Online Science Program (Table 3). The numbers indicate the number of participants who selected each response option. A Sankey diagram was created using Sankey MATIC (https://sankeymatic.com/).

this study but were also curious about the questions that arose during the activities. However, when examining this result concerning the level of understanding of the lecture, it was found that children with low comprehension did not show increased curiosity about genes after the online science program (Figure 7). Among the five children who learned about genes for the first time during this program, only one responded as "*Somewhat positive*", while the others showed similar trends of "*Somewhat negative*" or "*Negative*".

DISCUSSION

This paper aimed to examine whether children can actively engage in thinking through participation in an informal online science program focused on the topic of "*gene*". Based on children's verbal responses during the online science program and the results of the post-program parent questionnaire, the following findings emerged:

1. Young children were able to discuss the characteristics and functions of "*gene*" using their knowledge during the online science program.
2. The program stimulated children's curiosity and interest in learning about "*gene*".
3. However, both outcomes were significantly influenced by the children's level of understanding of the lecture.

Considering that formal education on genetics typically begins in junior high school, this difficulty may be inevitable. Nevertheless, for some children with an interest in the topic "*gene*", the program enabled them to understand genetic concepts—normally taught at the secondary level—and to connect that understanding to real-life examples such as differences in rice varieties or human populations (Table5). Today, bio-engineering plays a significant role in the fields of medicine and food that surround us, and the outcomes of the online science program presented in this study may serve as a valuable new learning resource for introducing the concept of "*gene*" from an early childhood perspective. This suggests that informal learning may hold meaningful value. Below, we summarize the outcomes of using "*gene*" as a discussion topic in the online science program and outline challenges to be addressed in the future.

A belief and hypothesis in science is a theoretical explanation of what can be proved or disproved to clarify phenomena under assumed knowledge and conditions (Okasha, 2002). Therefore, explaining hypothetical reasoning theoretically is one of the most important skills for science, and is also incorporated into problem-solving learning in elementary school education in Japan (Ministry of Education, Culture, Sports, Science and Technology, 2018). Additionally, the method of setting up hypotheses, which requires a certain level of skill to set up as a theoretical explanation, has recently been studied in Japanese elementary school education to foster the ability to construct arguments (Tanaka *et. al.*, 2021). However, since previous arguments suggest that even preschool children can use their prior knowledge to generate hypotheses (Köksal-Tuncer and Sodian, 2018), in this study, we conducted an online science activity to formulate hypotheses about the structure and function of "*gene*" for young children. As a result, the children were able to explain their hypotheses by drawing on their knowledge of events they had not previously encountered. After the online science program, children who understood the lecture and actively participated in discussions began to develop new questions based on their interests—such as the evolution of dinosaurs—from a genetic perspective. Some children also expressed a desire to learn more specific details about the nature of genes. These observations suggest that the online science program, with "*gene*" as its central theme, enabled children to encounter genetic concepts for the first time or to deepen their understanding, while stimulating their thinking. Therefore, it can be regarded as a highly valuable educational experience. Additionally, activities involving thinking and hypothesis setting could be easily and effectively adapted to online activities.

In recent years, efforts to develop educational policies for children with specific talents have been gradually advancing in Japan. These children attend public schools like their peers, but their advanced abilities often leave them feeling unchallenged and bored with regular school lessons. One way to support them is by providing opportunities for deeper exploration and learning beyond the classroom. In this context, it may be important that each child has expertise in a field in which they excel and that the teacher empathizes with their comments, finding value in them. In the activities conducted in this study, some children had scientific knowledge that the teacher did not know and who spoke up (*e.g.*, why Neanderthals became extinct). The lecture showed respect for the child's statement, and the child seemed to experience a sense of self-affirmation. In the online science program studied, there were instances when children unexpectedly demonstrated their expertise in topics unrelated to the activity content. It seemed that they wanted to share their knowledge with others rather than just behaving selfishly—that is, children not only acquire specialized knowledge through their interests, but they also need a place to express the desire to share their knowledge with others. In this sense, compared to face-to-face activities in which children from only a specific region participate, online activities provide a place where children with similar interests can gather and discuss on a national scale, stimulating not only their self-esteem but also their awareness of the existence of others who have greater knowledge than they do.

However, the most critical issue identified in this activity was that the effects described above were not observed in children who were unable to understand the lecture on "gene". Previous studies on science education programs have also reported that a certain number of children may struggle to grasp the content presented (e.g., Hong and Diamond, 2012). This may point to the inherent limitations of designing lectures that are fully comprehensible to all children. Our findings suggest that prior understanding of genes was associated with a higher level of comprehension during the lecture. Therefore, one possible approach to address this issue is to conduct a pre-assessment and recruit participants based on their existing knowledge of the topic.

This study did have some limitations. This study focused on an online science program themed around "genes"; however, no comparison was made with face-to-face activities. It is conceivable that face-to-face interaction may have yielded different levels of comprehension and engagement. Furthermore, the participants in this study were children registered with the Kids Academia program, which may limit the generalizability of the findings. Whether an online science program on the topic of genes can be broadly applied remains uncertain. These limitations underscore the need for future research that incorporates in-person implementations and involves a broader range of children.

AUTHOR NOTE

This paper was partly presented at the PECERA Conference in Bali, July 2023.

ETHICS STATEMENT

In this study, it has been determined that ethical approval is not required. The focus of this research involves anonymizing and de-identifying speech data to prevent the identification of individuals, thus ensuring adequate protection of the participants' privacy. Additionally, consent has been obtained from guardians, and appropriate ethical procedures have been followed in conducting the research. Therefore, it has been concluded that ethical approval is unnecessary for this study.

ACKNOWLEDGEMENT

We would like to thank Dr. Yuri Onishi for organizing the online conference for this study. We would also like to thank the children and their parents who participated in this scientific activity.

AUTHOR CONTRIBUTIONS

A.S and S.M: Conceptualization, writing, and methodology. A.S: Data collecting, data analysis, review, and editing. S.M: supervision.

DECLARATION OF INTEREST

We have no conflicts of interest to disclose.

ROLE OF THE FUNDING SOURCE

This work was supported by JSPS KAKENHI Grant Number 22K02969.

DATA TRANSPARENCY STATEMENT

Participants are informed that their responses will only be used for the purposes of this study. Therefore, the data set will be used by the authors to use the content of the responses for the purposes of this study only. In this study, certain illustrations (Figure 1, 3) have been sourced from free materials available at (https://www.irasutoya.com/), and are being used in accordance with their respective copyright information and usage conditions. The use of the Gene craft (Figure 2, http://x2.gmobb.jp/sfa1/index.htm) has been permitted by its inventor, Mr. Eiichi Yoshida.

REFERENCES

Akerson, V. L., Weiland, I., and Fouad, K. E. (2015) Children's ideas about life science concepts. In: Trundle, K. C. and Saçkes, M. (eds.) *Research in early childhood science education,* pp. 99–123. Springer, Dordrecht, Netherland.

Fleer, M., and Hardy, T. (1993) How can we find out what 3 and 4 year olds think? New approaches to eliciting very young children's understandings in science. *Research in Science Education* **23**: 68–76.

Hong, S. Y., and Diamond, K. E. (2012) Two approaches to teaching young children science concepts, vocabulary, and scientific problem-solving skills. *Early Childhood Research Quarterly* **27**(2): 295–305. https://doi.org/10.1016/j.ecresq.2011.09.006

Kahn, S. (2023) Special needs and talents in science learning. In: Norman, G. L., Dana, L. Z., and Judith, S. L. (eds.) *Handbook of research on science education, Volume III,* pp. 325–358. Routledge, Abingdon, U.K.

Köksal-Tuncer, Ö., and Sodian, B. (2018) The development of scientific reasoning: Hypothesis testing and argumentation from evidence in young children. *Cognitive development* **48:** 135–145. https://doi.org/10.1016/j.cogdev.2018.06.011

Kuhn, D. (2010) What is scientific thinking and how does it develop? In: Goswami, U. (ed.) *The Wiley-Blackwell handbook of childhood cognitive development*, pp. 497-523.

Ministry of Education, Culture, Sports, Science and Technology (2018) *Course of Study for Elementary School: Science.* <Retrieved on August 14, 2025, from https://www.mext.go.jp/content/20220405-mxt_kyoiku02-000005241_003.pdf>

Okasha, S. (2002) *Philosophy of science: A very short introduction* (2nd ed.). Oxford University Press, Oxford, U.K.

Osborne, R., and Freyberg, P. (1985) *Learning in science: The implications of children's science.* Heinemann, Auckland, N.Z.

Siry, C., Trundle, K. C., and Saçkes, M. (2023) Science education during the early childhood years: Research themes and future directions. In: Norman, G. L., Dana, L. Z., and Judith, S. L. (eds.) *Handbook of research on science education*, *Volume 3*, pp. 499–527. Routledge, Abingdon, U.K.

Simonson, T. S., Yang, Y., Huff, C. D., Yun, H., Qin, G., Witherspoon, D. J., Bai, Z., Lorenzo, F. R., Xing, J., Jorde, L. B., Prchal, J. T., and Ge, R. (2010) Genetic evidence for high-altitude adaptation in Tibet. *Science* **329** (5987): 72–75. https://doi.org/10.1126/science.1189406

Skene, K., O'Farrelly, M. C., Byrne, M. E., Kirby, N., Stevens, C. E., and Ramchandani, G. P. (2022) Can guidance during play enhance children's learning and development in educational contexts? A systematic review and meta-analysis. *Child Development* **93**(4): 1162–1180. https://doi.org/10.1111/cdev.13730

Spektor-Levy, O., Baruch, Y. K., and Mevarech, Z. (2013) Science and Scientific Curiosity in Pre-school—The teacher's point of view. *International Journal of Science Education* **35**(13): 2226–2253. https://doi.org/10.1080/09500693.2011.631608

Strawhacker, A. L. (2020) *Biodesign education in early childhood: A design-research study of the tangible CRISPEE technology and learning intervention.* Doctoral dissertation, Tufts University, MA, U.S.A.

Sumida, M. (2015) Kids science academy: Talent development in STEM from the early childhood years. In: Khine, M. S. (ed.) *Science education in East Asia: Pedagogical innovations and research-informed practices*. pp. 269–295. Springer, Dordrecht, Netherlands. https://doi.org/10.1007/978-3-319-16390-1_10

Sumida, M., and Fukada, S. (2005) Young children's high competence in science and its implications for improving the Japanese science curriculum. *Journal of Science Education in Japan* **29**(2): 99–109. https://doi.org/10.14935/jssej.29.99

Sumida, M., and Kurata, M. (2023) Personally and collaboratively enriching science teaching and learning for all. *International Journal of Curriculum Development and Practice* **25**(2): 27–39. https://doi.org/10.18993/jcrdaen.25.2_27

Tanaka, T., Kamiyama, S., Yamamoto, T., and Yamaguchi, E. (2021) Preliminary study on the relationship between children's ability to self-access arguments and their argument skills: A case study on "objects and weights" in third-grade elementary school introducing argumentation with claims-evidence-reasoning. *Journal of Research in Science Education* **62**(1): 119–131. https://doi.org/10.11639/sjst.sp20005

Verish, C., Strawhacker, A., Bers, M., and Shaer, O. (2018) CRISPEE: a tangible gene editing platform for early childhood. In: *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*, pp. 101–107.

Walker, C. M., Lombrozo, T., Williams, J. J., Rafferty, A. N., and Gopnik, A. (2017) Explaining constraints causal learning in childhood. *Child Development* **88**(1): 229–246. https://doi.org/10.1111/cdev.12590

Zeberg, H., and Pääbo, S. (2020) The major genetic risk factor for severe COVID-19 is inherited from Neanderthals. *Nature* **587**: 610–612. https://doi.org/10.1038/s41586-020-2818-3

Asian Journal of Biology Education, 2025
https://doi.org/10.57443/ajbe.17.0_96

Country report

Biodiversity-related Content Currently Taught in Upper Secondary Biology in Japan: Endangered Species and Invasive Alien Species in Basic Biology Textbooks

Nobuyasu Katayama*⁾
Tokyo Institute of Biology Education, Japan

(Received: 11 July 2025; Accepted for publication: 27 September 2025)

This study aimed to investigate how native and alien organisms, particularly endangered and invasive alien species, are treated in relation to biodiversity and its conservation in Basic Biology courses at Japanese upper secondary schools. To this end, the current Japanese Upper Secondary School National Curriculum Standard (USS-NCS), its Guidelines and currently used Basic Biology textbooks were examined. The current USS-NCS does not address the treatment of native and alien organisms like its predecessor, but its Guidelines cite the introduction of alien species as an example of anthropogenic disturbances and recommend that its adverse effects on native organisms be explained in Basic Biology course. In all ten Basic Biology textbooks surveyed, the terms "native organisms", "endangered species", "Red List", and "alien organisms" were found in the sections related to biodiversity and its conservation. In addition, some terms related to them, such as "endemic species", "rare species", "Red Data Book", "the IUCN Red List of Threatened Species", "the Invasive Alien Species (IAS) Act", and "designated invasive alien species (DIAS) under the IAS Act", were found in more than half of these textbooks. However, some textbooks were lacking a sufficient explanation of some of these terms. Some textbooks also were lacking the explanation of the measures to conserve native organisms and those to combat the deleterious impacts of invasive alien species. Among organisms appearing in the sections related to biodiversity and its conservation of these textbooks, 71 species (55 animals, 15 plants and one protist) were extinct or endangered ones in Japan though some of them were not clearly mentioned as endangered ones. There was almost no mention of extinct or endangered species overseas, probably because the Basic Biology course focuses on ecosystem problems within Japan. There were 52 species (38 animals and 14 plants) of DIAS and "invasive alien species that require control measures" found in the ten textbooks. Some of them also were not clearly stated as these kinds of alien species. The number of extinct or endangered native species and invasive alien species in Japan appearing in each textbook varied widely, ranging from nine to 31 and from two to 33, respectively. Description of "alien species of domestic origin" was found in only three textbooks and description of "species native to Japan as invasive alien species overseas" was found in only two textbooks. The results of the survey of current Basic Biology textbooks indicate that emphasis is placed on the treatment of invasive alien species, reflecting the descriptions in the USS-NCS Guidelines. There were also many cases where terms were not sufficiently defined or explained, and some essential information on native and alien organisms was lacking. Although an increase in endangered species is not the only indication of a decline in biodiversity in an ecosystem, it would be good to have more description of the protection and conservation of native species. As an example of biodiversity conservation, textbooks should stress that properly managed eco-

systems, such as SATOYAMA (countryside forests) and wetlands, have a high level of biodiversity.
Keywords: Basic Biology, biodiversity conservation, endangered species, invasive alien species, Japan, textbook survey, upper secondary biology
***Author for correspondence:** *katayama@u-gakugei.ac.jp*

INTRODUCTION

Since biodiversity conservation is one of the significant challenges facing modern society (Biodiversity Center of Japan, undated, see website list; Stockholm Resilience Centre, undated, see website list), it has been pointed out that it is an important topic not only in environmental education (Numata, 1990; Ubukata, 2011; Navarro-Perez and Tidball, 2012) but also in biology education in schools (Heavenlin *et al.*, 2015; Shoji and Nagashima, 2015; Børresen *et al*., 2022). To find out what topics related to biodiversity and its conservation are being taught in Japanese upper secondary biology classes, we have been conducting a survey of the current Upper Secondary Schools National Curriculum Standard (USS-NCS), its Guidelines, and Basic Biology and Advanced Biology textbooks currently in use. We have already reported on the results of an investigation of how terms related to biodiversity and its conservation are used in these materials (Katayama and Nakamichi, 2024).

When teaching biodiversity and its conservation, it seems important which organisms are to be considered. Research on organisms as teaching materials for biodiversity and its conservation in Japan seems to have focused more on alien organisms than on native organisms. For example, Higa has conducted a series of studies on the use of alien organisms, particularly invasive ones, in school biology education, and reported that the previous USS-NCS published in 2009 did not mention alien organisms, although its Guidelines made such a mention (Higa, 2019). Indeed, the previous USS-NCS Guidelines recommended that “in Basic Biology, students be made aware that anthropogenic disturbance of ecosystems through the introduction of alien species can lead to a loss of biodiversity, and in Advanced Biology, such disturbance can lead to the extinction of local populations” (Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT>, 2009b, p. 80 and p.92). As a result, topics related to alien organisms were included in all Basic Biology and Advanced Biology textbooks used until the 2021 academic year (Higa, 2019). He also conducted research on the same topic on the current USS-NCS published in 2018 and its Guidelines published in 2021, reporting that while the current USS-NCS also does not mention alien organisms, its Guidelines do include the term (Higa, 2024). The current USS-NCS Guidelines recommend the same for Basic Biology as the previous Guidelines (MEXT, 2021, p. 125), but do not mention alien species for Advanced Biology. However, some topics related to alien organisms are still included in all currently used Advanced Biology textbooks as well as Basic Biology textbooks (Higa, 2024).

In addition, in secondary education in Japan, there has been considerable research on the development of educational strategies, materials, and experiments to teach about invasive alien organisms (Ohshika *et al.*, 2007; Suzue, 2007; Kisakibaru, 2012; Sakuraba *et al.*, 2013; Doi and Hayashi, 2015; Ito *et al*., 2015; Mori, *et al*., 2017; Higa, 2018; Kato, 2018; Wada, 2019; Sasaki *et al*., 2020; Kurabayashi *et al*., 2021; Shimabe and Imai, 2021, 2022), as well as on students' perceptions of invasive alien species and the threats they pose (Yamanoi *et al*., 2016a;

Murase and Kato, 2020;). Meanwhile, there have been only a few reports on the use of native organisms, particularly endangered species, in upper secondary biology classes (Hayakawa, 2006; Fuse, 2015a; Sakuraba *et al.*, 2013; Umezawa and Tsunoda, 2022) and environmental education for upper secondary students (Fukata *et al*., 2018).

Kato (2011) investigated what kinds of organisms, that included alien species as well those species in need of conservation, were listed and how their use in upper secondary school biology textbooks changed over time between 1947 and 1999. After Kato's work, there have been two reports on what kinds of organisms are considered in Basic Biology textbooks which conformed to the previous USS-NCS published in 2009. Sakuraba *et al.* (2013) investigated what kinds of organisms appear in the section "Ecosystem Balance and Conservation" of nine Basic Biology textbooks published in 2011 or 2012 and reported that numbers of different types of organisms, that are listed in each textbook, ranged 11 to 60. As will be described later, the names of organisms that appear in the textbooks sometimes may not be species names, but their survey results included some unclear information about this. Doi and Hayashi (2015) also investigated what kinds of organisms are listed in three Basic Biology textbooks published in 2012 (three of the textbooks examined by Sakuraba *et al*., 2013) and reported that these textbooks included 49 alien species, 19 of which were invasive alien species. However, it is unclear whether these organisms were mentioned in relation to biodiversity and its conservation, or whether they were clearly stated as alien species in these Basic Biology textbooks.

Considering the shortcomings of these two previous studies, I surveyed currently used upper secondary biology textbooks to examine how native and alien organisms are treated in relation to biodiversity and its conservation. The survey was conducted on both Basic Biology and Advanced Biology textbooks, but since the survey results were deemed too extensive to report in a single paper, the survey results for Advanced Biology textbooks will be reported separately. Although the treatment of alien organisms in the previous and current USS-NCS and their Guidelines has already been investigated and reported by Higa (2019 and 2024), this time it was investigated again together with how native organisms are treated in these materials. When compiling the survey data, it was sometimes difficult to determine whether the species mentioned in the textbooks were native to Japan or not, so this paper focuses on which endangered native species and invasive alien species are mentioned and how they are treated in the sections on biodiversity and its conservation.

MATERIALS AND METHODS

Materials Surveyed

PDF files of the previous USS-NCS (MEXT, 2009a) and its Guidelines (MEXT, 2009b), as well as the current USS-NCS (MEXT, 2018) and its Guidelines (MEXT, 2021), were downloaded from the MEXT website. Ten Basic Biology textbooks published in 2022 (See the list in "BASIC BIOLOGY TEXTBOOKS SURVEYED") were used for textbook survey. Details of these textbooks have been provided by our previous report (Katayama and Nakamichi, 2024). As in the previous paper, each textbook will be referenced by number in this paper.

Data Collection

Terms related to native and alien organisms that are mentioned in relation to the topics of biodiversity and its conservation in these textbooks were collected, and how these terms are defined and explained was investigated. Some Basic Biology textbooks provide English translations for key terms, but other terms are written in Japanese. Thus, these terms were translated into English and synonymous terms were defined for their discrimination (See Appendix 1). The English translations and definitions of terms were mainly based on those in a document provided by the Ministry of the Environment Japan <MOE> (MOE, 2004a), the *Act on the Prevention of Adverse Ecological Impacts Caused by Designated Invasive Alien Species* (*Invasive Alien Species Act* in short; abbreviated as the *IAS Act*) enacted in 2004 and amended in 2014 (MOE, 2014), and the *Environmental Glossary* provide by the Environmental Innovation Information Center <EIC> (EIC Net, undated, see website list). The terms collected in this study were not necessarily just single words or compound nouns. Some textbooks use expressions like "an organism which is rare" instead of the compound noun "rare species." In such cases, it was determined that the term "rare species" would be used.

The names of organisms that appear in the unit "Diversity of Organisms, and Ecosystems" of Basic Biology textbooks were collected as organisms used to explain content related to biodiversity and its conservation.

Data Analysis

The method for analysing the descriptions of terms and topics related to native and alien organisms in textbooks was based on Higa (2019). I considered not only whether the definition or explanation of each term is provided, but also whether the definition is clear and the explanation is sufficient. In some cases, I had to make my subjective judgement as to the clarity of the definition of term and the sufficiency of the explanation of term.

To determine whether the organisms are extinct or endangered native species, the Red List compiled in 2020 under the *Act on Conservation of Endangered Species of Wild Fauna and Flora* (commonly known as the "*Species Conservation Law*," enacted in 1992) by the MOE (abbreviated as the *MOE Red List 2020*; MOE, 2020) was used. Local governments and NGOs in Japan also compile their own Red Lists, which may include species that are not listed in the *MOE Red List 2020*, but these were not referred to in this study. For endangered species overseas, the *Red List of Threatened Species* provided by the International Union for Conservation of Nature and Natural Resources <IUCN> (abbreviated as the *IUCN Red List*; IUCN, undated, see website list) was referenced. For organisms that were thought to be alien species in Japan, the *List of Alien Species that May Cause Damage to Japan's Ecosystems* (abbreviated as the *LIST*; MOE, 2015; see Appendix 1 for details) and the *List of Regulated Living Organisms under the Invasive Alien Species Act* (MOE, 2024) were referenced to determine whether they fell into any of the categories of invasive alien species in Japan.

Generally, in textbooks surveyed, each species is shown by its standard domestic name written in Japanese. However, it could sometimes be difficult to determine whether the Japanese name listed refers to a species or a genus or family. For example, TANAGO is the name of a Japanese native fish species *Acheilognathus melanogastera* which belongs to the subfamily Acheilognathinae, but the name is also used as a general name for fish in this subfamily. When the name of an organism presented was not a species name but a taxonomic group (*e.g.* genus), if a species belonging to that taxonomic group is designated as an endangered species or an invasive alien species, the organism was considered to be also designated.

Notation of Organisms' Names

In this paper, when writing the name of an organism for the first time, the scientific name will be written, followed by the common English name in parentheses, unless the Japanese name written in the textbook is not the species name. If the organism is endemic to Japan and does not have a common English name, the scientific name is followed by the standard Japanese name in upper case in parentheses. From then on, either the common English name or the standard Japanese name is given. The scientific name and common English name of each organism were primarily based on the *MOE Red List 2020*, the *List of Regulated Organisms under the IAS Act* (MOE, 2024), and the *IUCN Red List*.

RESULTS

Description of Native and Alien Organisms in Current USS-NCS and Its Guidelines

It was found that the current USS-NCS make no reference to either native or alien organisms; this also applied to the previous USS-NCS. However, its Guidelines contain statements related to alien organisms for the "Ecosystem Balance and Conservation" section of the unit "Diversity of Organisms, and Ecosystems" of Basic Biology, namely, “To show how anthropogenic disturbance can damage the diversity of organisms, present materials, for example, showing the ecology of alien fish such as the largemouth bass and the changes in the number of native fish species and populations after their introduction, so that students can recognize how the introduction of alien organisms has affected the number of species and populations of native organisms (MEXT, 2021, p. 125)” which is almost identical to its predecessor (MEXT, 2009b, p. 80; see INTRODUCTION section). As such, in the current USS-NCS Guidelines, the terms native and alien organisms (species) were found. The introduction of alien organisms is cited as an example of anthropogenic disturbance and even the name of *Micropterus salmoides* (largemouth bass) is mentioned. However, regarding native organisms, it is only stated that they are being affected by introduced alien species, and there is no mention of native species that are at risk of extinction at all. In the current USS-NCS Guidelines, this unit is the only one that mentions the names of specific organisms other than humans, and in addition to the largemouth bass, the names of starfish, *Enhydra lutris* (sea otter), and sea urchin also appear.

Terms Related to Native Organisms and Endangered Species Found in Textbooks

The current Basic Biology textbooks include some terms related to native organisms with their definitions or explanations mainly in the chapter "Ecosystems and Their Conservation" of the unit "Diversity of Organisms, and Ecosystems" (Table 1). All textbooks include the term <u>native organisms</u> (or <u>native species</u>) - from now on, every term found in the textbooks will be underlined -, seven list it in their indexes, and four treat it as a key term. Five textbooks include the term <u>endemic species</u>, and one includes the term <u>primeval species</u>, both of which are used in conjunction with the term <u>native organisms</u>. Textbook #5 lists both terms along with <u>native organisms</u> in its index. Five textbooks include the term <u>rare species</u>, and one of them (Textbook #9) lists it in its index. However, explanations or definitions of each term are often missing or insufficient, making the differences in the definitions of each term unclear.

All textbooks include the term <u>endangered species</u>, and eight treat it as a key term. However, most textbooks only provide a brief explanation of endangered species and do not provide categories for endangered species (near threatened, NT; vulnerable, VU; endangered, EN; critically endangered, CR). All textbooks except Textbook #4, mention the terms <u>Red List</u> and <u>Red Data Book</u>, most of them list both terms in their indexes, and

Table 1: Terms related to native organisms and their explanations in Basic Biology textbooks

Term or Explanation	Basic Biology textbook surveyed									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
"Native organisms"	●	●	◎	●	◎	●	◎	○	○	○
Explanation of native organisms	○	○	△	○	○	○	○	△		○
"Endemic species"	○			○	◎	○		○		
Explanation of endemic species	○				○	○		○		
"Primeval species"					◎					
Explanation of primeval species										
"Rare species"	○	○						○	◎	○
Explanation of rare species									○	
"Endangered species"	○	○	●	●	●	●	●	●	●	●
Explanation of endangered species	○	○	○	○	○	○	○	○	○	○
"Red List"	◎	◎	◎	●	◎	○	◎	◎	●	○
Explanation of Red List	○		○	○	○	○	○	△	○	○
"Red Data Book"	◎	◎	◎		◎	○	◎	◎	●	○
Explanation of Red Data Book	○	○	○		○	○	○	○	○	○
Categories of endangered species	○	○	○							
Measures to conserve or to preserve native organisms	○	○	○	△		○			○	○
"IUCN Red List of Threatened Species"	○	○		○			○	○		
Explanation of the IUCN Red List of Threatened Species	○			△						

○: found in the text, ◎: listed in the index, ●: treated as a key term,△: presented in the text, but insufficient

Textbook #9 treats both as key terms. Textbook #4 treats the term Red List as a key term but lack the term Red Data Book. In most textbooks, measures for the protection and/or conservation of native species are only briefly discussed in relation to countermeasures against invasive alien species or environmental assessments. Although not shown in Table 1, Textbook #9 mentions the Species Conservation Law, provides some explanations, and lists it in its index.

Five textbooks mention the term IUCN Red List as a global list of endangered species or indicate the existence of such a list, but only one (Textbook #1) provides a sufficient explanation of it. Even that textbook does not mention the IUCN categories of extinct and endangered species (EX, EW, CR, EN, VU, NT) that are used worldwide.

Japanese Endangered Species Found in Textbooks

The total number of extinct and endangered species native to Japan listed in the unit "Diversity of Organisms, and Ecosystems" in ten Basic Biology textbooks was 71, including 55 animals, 15 plants, and one protist (Appendix 2). However, since no textbook mentions some of them as extinct or endangered in their sections, the number of textbooks which clearly state that each species is endangered is shown in parentheses in Appendix 2. There were 14 species that are designated as endangered (CR, EN, VU, NT) on the *MOE Red List 2020* but are not clearly stated as endangered in any textbooks: two mammal species, four bird species, three fish species, four insect species, and one plant species (Appendix 2, "0" in parentheses). In textbooks, they are introduced as keystone species such as the sea otter, which is also used to explain a phenomenon called indirect effects; organisms such as the giant water bug and the great purple emperor that inhabit SATOYAMA (countryside forests) areas; species such as HONMOROKO found in a survey of organisms inhabiting a certain place; organisms such as the little tern and the osprey involve in bioaccumulation. Textbook #9 mentions *Meimuna boninensis* (Ogasawara cicada) as an example of “populations of native species are decreasing due to the invasion of an alien species (the green anole).” This species was designated a National Natural Monument in 1970 under the *Law for the Protection of Cultural Properties* because it is endemic to the Ogasawara Islands (Biodiversity Center of Japan, undated, see website list) which consists of more than 30 islands in the Pacific Ocean, about 1,000 km south-southeast of Tokyo, but it is not listed on the *MOE Red List 2020*, so it was not included in the present tabulation.

Two mammal species (the Tsushima wildcat and the Amami rabbit) and four bird species (the Okinawa rail, the Japanese crest ibis, the rock ptarmigan, and the short-tailed albatross) are mentioned as endangered species in five or more textbooks. On the other hand, 20 animal species and 12 plant species are mentioned as endangered only in one textbook. Two textbooks (#3 and #10) list MARIMO, a protist which inhabits in Lake Akan in Hokkaido and was designated a National Natural Monument in 1952 (Agency for Cultural Affairs, Japan, undated, see website list), as an endangered species. The Japanese native endangered species listed in each textbook were not necessarily species at a high risk of extinction as ranked CR or EN (Appendix 2).

The number of Japanese native species listed on the *MOE Red List 2020* in each textbook varied considerably, ranging from nine to 31 (average 17). Among them, the species that are clearly indicated as extinct or endangered species in each textbook ranged from two to 24 (average 12). In every textbook, animal species appear more frequently than plant species, and in one textbook (#6), plant species are not mentioned at all (Table 2).

Endangered Species Outside of Japan Found in Textbooks

In the unit "Diversity of Organisms, and Ecosystems" many organisms that are not native to Ja-

Table 2: The number of extinct or endangered species native to Japan appearing in each Basic Biology textbook*

	Textbook									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Animals	10 (8)	8 (1)	14 (8)	17 (15)	18 (14)	12 (5)	26 (20)	14 (8)	17 (9)	16 (11)
Plants	4 (4)	1 (1)	2 (2)	1 (1)	1 (1)		5 (4)	1 (1)	2 (2)	3 (2)
Protist			1 (1)							1 (1)
Total	14 (12)	9 (2)	17 (11)	18 (16)	19 (15)	12 (5)	31 (24)	15 (9)	19(11)	20 (13)

*The number in parentheses indicates the number of species which is stated that the species is extinct or endangered.

pan were found. Among these organisms, 24 species or taxa were listed on the *IUCN Red List*. These were 19 mammal species or taxon, three bird species, one reptile taxon, and one plant species (Appendix 3). However, in textbooks, most of them are used to explain the world's biomes, and only the passenger pigeon and orangutans (there are three species listed on the *IUCN Red List*) are mentioned in relation to species extinction due to human activities: the former is introduced by two textbooks (#7 and #8) as an example of extinction due to hunting and the latter are introduced by three textbooks (#1, #2, and #4) as being at risk of extinction due to deforestation of tropical rainforests.

Terms Related to Alien organisms Found in Textbooks

All Basic Biology textbooks include the term alien organisms (alien species) in the main text, list it in their indexes, and treat it as a key term (Table 3). All textbooks explain that alien species are organisms which have been introduced artificially, whether intentionally or not, into non-native habitats. However, only four (#1, #2, #9, and #10) out of ten textbooks explain sufficiently how alien organisms generally are introduced or invade an ecosystem. Among them, only two textbooks (#9 and #10) further provide specific examples of invasive alien species and explanations of how they were brought into or invaded Japan. All textbooks explain that if an alien species invades and becomes established, it may have an adverse impact on the native ecosystem, but they provide only one or a few specific examples of such adverse effects. On the other hand, Textbook #4 describes that alien organisms do not necessarily give an adverse impact to human beings, indicating that there are a

Table 3: Terms related to alien organisms and their explanations in Basic Biology textbooks

Term or Explanation	Textbook surveyed									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
"Alien organisms (species)"	●	●	●	●	●	●	●	●	●	●
Explanation of alien organisms (species)	○	○	○	○	○	○	○	○	○	○
Routes/ history of introduction or invasion of alien organisms (species)	○	○	△						○	○
Effects of alien organisms (species)	○	○	△	○	○	○	○	○	○	○
Measures against invasive alien species in Japan		△	△	△	○	○	○	△	○	○
"Invasive Alien Species (IAS) Act"			○	○	○	○	○	△	◎	◎
"Invasive alien species"			◎						●	●
Explanation of invasive alien species			○						○	○
"Designated invasive alien species" under the IAS Act			◎	◎	◎	○	●	●	◎	◎
Explanation of designated invasive alien Species			○	○	○	○	○	○	○	○
Mention of domestic alien organisms	○					○			○	

○: found in the text, ◎: listed in the index, ●: treated as a key term, △: presented in the text, but insufficient lot of useful organisms, such as cultivated crops and livestock, among them. Regarding countermeasures against invasive alien species in Japan, nine textbooks discuss one or a few examples of invasive alien species control in Japan. The most representative examples are the eradication of two designated invasive alien species, the Small Indian mongoose and the largemouth bass. Eight textbooks refer to the existence of a law for preventing adverse impacts on ecosystems by alien species and explain the purpose of the law and some of the measures it provides, but one of them (textbook #8, △ mark in Table 3) does not mention the name of the law, *i.e.*, the IAS Act. Two of the remaining seven textbooks (#9 and #10) list the IAS Act in their indexes. These eight textbooks mention the term designated invasive alien species (DIAS) that is designated under the law, seven list it in their indexes, and two treat it as a key term. However, only three textbooks (#3, #9, and #10) include the term invasive alien organisms with an explanation, and list it in their indexes, and two (#9 and #10) treat it as a key term. Although the term alien species of domestic origin (from now on, the term "domestic alien organisms" will be used; see Appendix 1 for details) was not found in any of the textbooks, three textbooks (#1, #6, and #9) mention some adverse effects of domestic alien organisms. Textbook #9 states that alien organisms include not only species from overseas, but also native species from other parts of Japan.

Although not shown in Table 3, textbook #3 even mentions the List of Alien Species that May Cause Damage to Japan's Ecosystems (the *LIST*) and explain that, to help with countermeasures, the *LIST* classifies "invasive alien species that require control measures" as follows: those to be prevented from entering, those requiring emergency measures, and those requiring priority measures.

Invasive Alien Species Found in Textbooks

Among alien species that appear in the unit "Diversity of Organisms, and Ecosystems" in the surveyed textbooks, those designated as invasive alien species under the *IAS Act* (DIAS) or included in the *LIST* are shown in Appendix 4. Thirty-eight invasive alien animal species were found in these ten textbooks, the majority of which were DIAS, while only 14 invasive alien plant species were found, half of which were DIAS.

All invasive alien animals listed in Appendix 4 are mentioned as alien species in the textbooks. However, some textbooks list the names of invasive alien animals but do not state that they are DIAS or included in the *LIST*. For example, all textbooks mention the largemouth bass following the recommendation of the USS-NCS Guidelines (MEXT, 2021, p. 125), but only four of them note that this species is a DIAS. DIAS other than the largemouth bass found in five or more textbooks included two mammals (the small Indian mongoose and the raccoon), one reptile (the green anole), one fish species (the bluegill), and one insect species (the red imported fire ant). Textbook #8 specifically indicates that some invasive alien animal species, such as the red imported fire ant and the red-back widow spider, are harmful to human beings.

The seven designated invasive alien plant species shown in Appendix 4 are noted that they are DIAS in every textbook that includes them. Among them, four species, the water lettuce, the bur cucumber, the lance-leaved coreopsis and the golden glow, were found in multiple textbooks, but none were found in more than five textbooks. The other seven alien plant species in Appendix 4 are listed in the *LIST*, but, except for the cut-leaf evening primrose, the textbooks in which they were found do not mention that they are invasive alien plants that require control measures. Furthermore, the textbooks that include the Brazilian elodea, the common water hyacinth and the annual fleabane do not even mention that they are alien species (marked X in Appendix 4). In Textbook #1, *Ambrosia artemisiifolia* (ragweed) and *Conyza sumatrensis* (Sumatran fleabane) are given as examples of the plants that appear at the initial stages of secondary succession and explained that they are alien species. As discussed below, they were previously considered invasive alien species, but have now been delisted and are therefore not included in Appendix 4.

The number of invasive alien species found in each textbook varied considerably, ranging from two to 33, but the number of species which are clearly stated as invasive in each textbook was from zero to 31 (average 11). Every textbook lists more animal species than plant species, and in one textbook (#2) does not mention any alien plant species at all. This textbook and another textbook (#1) published by the same publisher do not state that, even though the alien species listed are DIAS, they are so (Table 4).

Regarding domestic alien organisms, only Textbook #1 and Textbook #6 respectively present a specific example: vegetation destruction caused by introduced goats in the isolated Ogasawara Islands and genetic disturbance of a local firefly population.

Textbook #3 describes that *Miscanthus sinensis* (Japanese silver grass or Chinese silver grass), *Pueraria montana* var. *lobata* (kudzu), and “the carp,” as Japanese species that have been introduced and become established in the USA. Textbook #9 also gives the kudzu as an example of invasive alien species in the USA.

DISCUSSION

Treatment of Native and Alien Organisms in Current USS-NCS

In the previous USS-NCS Guidelines, for the section "Ecosystem Balance and Its Conservation" in Basic Biology, it was stated that “students should be made to understand the importance of ecosystem conservation by showing examples of ecosystems that have been disturbed and biodiversity has changed due to human activities such as the introduction of alien species and deforestation” (MEXT, 2009b, p.80). The current USS-NCS Guidelines (MEXT, 2021, p. 125) state almost the same thing for the section "Ecosystem and Its Conservation" in Basic Biology. Furthermore, in both cases, the adverse effects of the introduction of alien species are explained using the largemouth bass as an example. However, there are only a few descriptions of native organisms, and no mention of endangered native species, which may have reflected a remarkable difference in the number of studies between on teaching invasive alien organisms versus teaching native organisms in secondary education (See INTRODUCTION section). Although the protection of a specific endangered species does not directly lead to the conservation of native ecosystems, the protection of native or-

Table 4: The number of invasive alien species appearing in each Basic Biology textbook*

	Textbook									
	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
Animals	2 (0)	2 (0)	10 (5)	21 (21)	4 (1)	4 (1)	27 (26)	3 (2)	8 (7)	7 (5)
Plants	2 (0)		3 (2)	6 (4)	1 (1)	1 (1)	6 (5)	1 (1)	1 (1)	2 (2)
Total	4 (0)	2 (0)	13 (7)	27 (25)	5 (2)	5 (2)	33 (31)	4 (3)	9 (8)	9 (7)

*The number in parentheses indicates the number of species which is stated that the species is designated invasive alien species under the IAS Act, or the species is invasive.

ganisms, especially endangered species, and the conservation of their environments need to be addressed in more detail in the USS-NCS Guidelines in relation to the conservation of native ecosystems.

Treatment of Native Organisms in Current Basic Biology Textbooks

Although not required by the current USS-NCS Guidelines, all Basic Biology textbooks contain descriptions of native organisms, including endangered species. However, reflecting the content of the USS-NCS Guidelines, the treatment of native organisms seems to be insufficient compared to alien organisms. First, native organisms are described somewhat less than alien organisms, with unclear definitions of the term. In addition, as pointed out in our previous paper (Katayama and Nakamichi, 2024), all ten textbooks list the term alien organisms (or alien species), which is the antonym of native organisms, in their indexes and treat it as a key term (Table 3), whereas textbooks list the term native organisms (or native species) in their indexes were seven and those treat it as a key term were only four (Table 1). Furthermore, in textbooks that use the synonymous terms, endemic species and primeval species, in addition to native organisms, the definitions of these terms are missing or unclear. Since the USS-NCS Guidelines request a reduction in the number of terms used in Basic Biology textbook (MEXT, 2021, p.127), it is necessary to consider the appropriateness of using such similar terms.

Since the extinction of species endemic to a certain region or an increase in the number of endangered species in that region signifies a decline in the region's biodiversity, the USS-NCS Guidelines require that species extinction should be mentioned in the unit "Diversity of Organisms, and Ecosystems" of Basic Biology (MEXT, 2021, p.124). In response, all ten textbooks include the term endangered species, and eight of them treat it as a key term. The total number of endangered native species that appear in the ten textbooks (Appendix 2) was larger than the total number of invasive alien species that appear in these textbooks (Appendix 4). In all textbooks except for textbooks #4 and #7, the number of endangered native species exceeded the number of invasive alien species (Tables 2 and 4). Furthermore, if endangered species overseas (Appendix 3) were included, the total number of endangered species appearing in the unit "Diversity of Organisms, and Ecosystems" in each textbook would be much higher. Judging solely from the number of species and taxa listed in each textbook, endangered species appear to be receiving more favourable treatment than invasive alien species, but many of the endangered species overseas are not clearly stated to be in danger of extinction. There was a difference between the average number of endangered native species (17) and the average number of those that are clearly stated as endangered (12). This is because a considerable number of endangered native species listed in each textbook are also not presented as examples of endangered species, such as the sea otter. The sea otter is included in all the textbooks (Appendix 2) because the USS-NCS Guidelines stated that “It is possible to touch on the indirect effect through the food chain by presenting data showing the population density of sea urchins and seaweeds in environments with and without sea otters as top predators” (MEXT, 2021, p. 125). In this way, and as is the case with the largemouth bass, when the curriculum guidelines provide a specific example, textbook authors and editors tend to prioritize incorporating it in their textbooks.

All textbooks point out that direct and indirect effects of various anthropogenic disturbances, such as habitat destruction and fragmentation due to land development and deforestation, as well as the introduction and invasion of invasive alien species, are factors that lead to the extinction of species and the increase in endangered species. On the other hand, there is a hypothesis that a certain degree of natural disturbance enhances biodiversity (this is called the "Intermediate Disturbance Hypothesis") and two textbooks (#5 and #6) mention this hypothesis (Katayama and Nakamichi, 2024), though the USS-NCS Guidelines do not mention it at all. Textbooks #1 and #2 state that some organisms require a certain degree of disturbance, and cite the thoroughwort and the MIZUAOI, which grow in floodplains, as examples of species that are at risk of extinction due to habitat loss caused by river flood control works. Furthermore, all textbooks except Textbook #8 explain the importance of human management, which is a kind of anthropogenic disturbance, for the conservation of biodiversity in SATOYAMA areas. SATOYAMA, in the narrow sense, refers to forests or hilly areas close to the living areas where people obtained firewood, thatch or organic fertiliser, *etc*. It has become known worldwide through the *SATOYAMA Initiative* (Doshita, 2015; The Satoyama Initiative, undated, see website list). Nowadays, SATOYAMA is defined more broadly as areas "located in the rural areas of Japan where agriculture, forestry and fisheries are the main industries. They are known as socio ecological production landscapes and seascapes. They consist of production ecosystems like secondary forests, farmlands, irrigation ponds, and grasslands as well as human settlements (MOE, 2022, p.2)." Five textbooks list some endemic species in SATOYAMA areas that are properly managed by humans, in addition to explaining that these areas are rich in biodiversity. Some of these endemic species are designated as endangered species, but unfortunately, most of them are not stated as endangered in these textbooks. Kominami *et al*. (2013) suggested that SATOYAMA could be useful as a teaching material for biodiversity education and developed an inquiry activity model by using tree distribution data from a SATOYAMA secondary forest (Kominami and Muramatsu, 2016; Kominami, 2022). In addition, many cases of using SATOYAMA areas for environmental education and outdoor education have been reported in Japan (*e.g.*, Fuse, 2015b; Shingai *et al.*, 2021). Such previous studies would be useful for developing materials for teaching about biodiversity and its conservation in biology education at the secondary level.

The endangered native species marked with a diamond (◆) in Appendix 2 have been designated as Special Natural Monuments (JATAFF, undated, see website list) under the *Law for the Protection of Cultural Properties* enacted in 1950. Some of them are occasionally featured in television programs, newspapers, and magazines, so students may be familiar with them. Therefore, it seems reasonable that the Amami rabbit, the Japanese crested ibis, the rock ptarmigan, and the short-tailed albatross are listed as endangered native species in more than half of ten textbooks. However, many other endangered species are rare ones that live in remote islands, mountainous districts, or other isolated areas, so they possibly are unfamiliar to students. Although some textbooks, such as textbook #3, seemed to give priority to extinct species and species with critically endangered (CR) or endangered (EN) levels, most other textbooks seemed to list endangered native species regardless of their threat level and the criteria for selection were unclear. Since biology textbooks are used by students nationwide, it may be difficult to select the best endangered native species to be included in the textbooks. However, it is desirable to give priority to species with a high risk of extinction, such as CR or EN in the *MOE Red List 2020* and, as Sakuraba *et al.* (2013) pointed out, to select species well-known among students as possible. In addition, consideration should be given to selecting representative species from each phylum.

Regarding the species to be introduced in the unit "Ecosystems and their Conservation," Sakuraba *et al.* (2013) and Fuse (2015a) suggested that it is appropriate to select species that inhabit in areas close to the students' living areas because such organisms are likely to attract students' interest and related reference materials will be easily available. Sakuraba *et al.* (2013) gave two fish species, *Acheilognathus typus* (ZENI-TANAGO, CR) and *Pungitius pungitius* Omono type (IBARA-TOYOMI, CR), and one bird species, the black woodpecker (VU), as specific examples from their residential area, Akita Prefecture. Hayakawa (2006) introduced the Tokyo salamander as a versatile biological teaching material for his biology classes in an upper secondary school located near Tokyo and stated that continued rearing of the salamander in schools would contribute to the protection of endangered species. However, only one textbook introduces this species as an endangered one, possibly because the distribution area of this species is extremely limited. In a recent research report on the use of endangered species in the Ryukyu Islands, the Amami rabbit, the Iri- omote wildcat, and the Okinawa rail, as teaching materials, Miyake (2024) pointed out that these endangered species are exposed to the threat of roadkill, the diversification and increase of predators and habitat destruction. Textbook #3 introduces the construction of underpass as a way to protect the Okinawa rail from roadkill. In the other studies on the development of teaching materials for biodiversity education so far, the native endangered species covered were fish such as the Tokyo bitterling (Fukata *et al.*, 2018) and the killifish (Umezawa and Tsunoda, 2022). Most of these studies are quite recent and may not have been referenced when the current textbooks were compiled. However, the black woodpecker and the Tokyo bitterling are introduced as an endangered species in two textbooks, the killifish in three, the Amami rabbit in four, and the Iriomote wildcat and the Okinawa rail in six each (Appendix 2). It is desirable that further research on the development of teaching materials like them will be conducted in the future and that the results will be used in biology textbooks.

Species that are endangered outside of Japan are not covered in most textbooks in relation to biodiversity and its conservation, perhaps because the topic is outside the scope of Basic Biology courses. Among the overseas organisms found in the unit "Diversity of Organisms, and Ecosystems" in textbooks, 24 species or taxa are listed on the *IUCN Red List* (Appendix 3), most of which are presented as representatives of the world's biomes. Therefore, they are not stated as endangered species, but it would have been better to at least state that. More than five textbooks use the Asian elephant, the European rabbit, the lion, and the reindeer for explaining the biome in which each of them habits. Possibly, they are familiar animals among upper secondary students. However, some of the other endangered species seem to be unfamiliar to the students. Is it appropriate to use such a rare and endangered species as a representative of a certain biome? Although it is not related to the objectives of present study, when compiling a textbook, careful consideration should be given to what species should be the representative species of each biome.

Treatment of Alien Organisms in Current Basic Biology Textbooks

Higa (2019) reported that several topics related to alien organisms were included in all previous Basic Biology textbooks which were used until the 2021 academic year. According to him, among the ten Basic Biology textbooks, nine explained alien organisms, seven discussed the history of their introduction or the route of invasion, ten explained their adverse impacts, eight described measures against them in Japan, and eight presented laws and regulations related to them.

As mentioned above, the current USS-NCS does not list the term "alien organisms," but its Guidelines recommend including the introduction of alien species as an example of anthropogenic disturbance (MEXT, 2021, p. 125). Following the recommendation of the USS-NCS Guidelines, and as already pointed out (Higa, 2024; Katayama and Nakamichi, 2024), all Basic Biology textbooks include the term alien organisms (or alien species) in the main text, list it in their indexes, and treat it as a key term (Table 3). All textbooks explain alien species and their adverse effects, nine explain the countermeasures against invasive alien species in Japan, and eight introduce the IAS Act and the DIAS under the Act. Up to this point, their contents are almost the same as previous Basic Biology textbooks, but while seven previous Basic Biology textbooks provided specific examples explaining the history of the introduction of invasive species and their routes of invasion (Higa, 2019), only four current textbooks include this topic (Table 3).

There is an issue with the use of terms related to alien organisms. The category DIAS is included in the category of invasive alien species, which are included in the category of alien species. However, among the ten textbooks, some only use two terms DIAS and alien species (Table 3). If students are to conduct an inquiry activity by using technique such as text mining and the creation of concept maps (Mori, *et al.*, 2017), then it is essential that the terminology is clearly and consistently applied.

Some of the invasive alien species listed in the textbooks are not necessarily exemplified as DIAS or species on the *LIST*. However, there was almost no difference between the average number of invasive alien species appearing in the textbooks and the average number of species clearly stated as DIAS. This is because, unlike the case of endangered native species (Table 2), most DIASs are described as such in all textbooks except for Textbooks #1 and #2 (Table 4). In terms of selecting invasive alien species, most textbooks seem to give priority to DIAS (Appendix 4). Even in this case, it is of course desirable to choose a species with which students are familiar. It is also desirable not to simply introduce the species with a photo, but to give some more information, such as its invention route, specific damage, and countermeasures, so that students can understand why the species is being used as an example in the textbook.

As mentioned in the INTRODUCTION, a considerable number of studies have been conducted so far on using alien organisms as teaching materials for biodiversity conservation in biology education at the secondary school level. Of these alien species, only largemouth bass, the bluegill, the Western mosquitofish, the signal crayfish, and the red swamp crayfish are included in current Basic Biology textbooks (Appendix 4). However, since the species specified as DIAS are prohibited from being kept or transferred without permission in Japan (MOE, 2014), it becomes very difficult to capture them, breed them at schools, and use live specimens as materials for experiments or dissection, *etc.* Although these organisms can be used for studying their ecology in their settled habitat (Kurabayashi *et al.*, 2021) and their distribution (Suzue, 2007; Shimabe and Imai, 2021), students can only learn about them in the classroom through photographs, published research reports, and other sources.

According to Doi (2020), in Japan, the red swamp crayfish was encouraged to be kept as a pet at elementary schools and was included in many Life Studies textbooks for first and second graders, with some textbooks even encouraging the release of the animal into the wild after being used. However, elementary school textbooks compiled and published after 2015, when this animal was designated as an "alien species that require urgent measures (KT)" on the *LIST*, have not treated it as a captive animal. The same as this animal species, the red-eared slider turtle was also included in the *LIST* in 2015. Kato (2018) conducted a survey on the keeping of red-eared slider turtles in schools in Shizuoka Prefecture during the period of 2015-2016, and reported that among the 733 schools that responded, 45 were keeping 86 red-eared slider turtles. In 2023, both species were designated as "conditionally designated alien species", meaning they cannot be imported, sold, distributed, or released into the wild without permission, but individuals currently being kept will be able to continue raising (MOE, 2023, see website list). So MEXT issued a notice to institutions, which manage and operate schools, to take sufficient care when handling the red swamp crayfish and the red-eared sliders turtle in schools so as not to deleteriously affect local natural environments and ecosystems (MEXT, 2023).

Other invasive alien species and taxa on the *LIST* also require careful handling; the MOE has asked invasive alien species on the *LIST* not to be introduced, released and spread (MOE, 2015b). However, although the Brazilian elodea is included in the *LIST* as an "invasive alien species that requires priority measures (JT, Appendix 4)", it is included in Basic Biology textbooks without any warning and is being used as experimental material in upper secondary school biology classes. Therefore, this plant is kept in many upper secondary school laboratories, but many biology teachers wonder if they are aware that this plant is on the *LIST* and must be handled with care (This plant, along with the common water hyacinth (JT), is still sold in many pet stores in Japan). *Xenopus laevis* (African clawed frog) is also in the *LIST* and designated as "alien species requiring comprehensive measures (ST)", but it also is included in Basic Biology textbooks without any warning, and it seems to be treated the same as the Brazilian elodea in many schools.

On the other hand, the ragweed and the Sumatran fleabane mentioned in Textbook #1 as alien species had been designated as "alien species that require control measures" under the *IAS Act*, but this designation was revoked when the *LIST* was compiled and published in 2015 (MOE, 2015a, p. 4), and they are no longer included in the *LIST* (MOE, 2015b).

The number of invasive alien species designated under the IA*S Act* and other laws is increasing yearly, and the classifications to which they belong are also changing or, as in the case of the ragweed and the Sumatran fleabane, the designation may be revoked. The treatment of invasive alien species in textbooks and biology lessons needs to change accordingly. The same goes for endangered species. Because compiling and revising textbooks takes a considerable amount of time, biology teachers are required to try to obtain the latest information on invasive alien species and endangered species rather than relying solely on textbooks.

As stated in Textbook #4, alien organisms are not necessarily invasive and do not necessarily give adverse effects on native ecosystems they settled or on human beings. However, since some alien animals, such as the raccoon which was raised as pets (MOE, 2016, p. 8), and alien plants, such as the lance-leaf tickseed which was cultivated in flower beds (MOE, 2013), were released or escaped and became invasive alien organisms, students need to learn that proper handling alien organisms is very important for the conservation of native ecosystems.

Treatment of Domestic Alien Species in Current Basic Biology Textbooks

Most textbooks explain that alien species (GAIRAI-SHU in Japanese) are organisms that have been brought from other regions by humans and have become established in areas where they were not originally distributed. However, most of these textbooks do not point out that the term "other regions" includes other areas in Japan. In recent years, some domestic alien species have caused problems in Japan, such as adversely affecting ecosystems into which they have invaded, causing genetic disturbance to local population and destroying vegetation (MOE, 2015a). Therefore, the *LIST* has included 20 animal species and ten plant species as domestic alien species that require measures (MOE, 2015b). Since most students are likely to interpret the word GAIRAI as foreign or overseas and cannot imagine domestic alien species, it is desirable for Basic Biology classes to mention this topic briefly. Doi and Hayashi (2015) reported that eight domestic alien species are found in three Basic Biology textbooks published in 2012 that they surveyed. However, Sakuraba *et al*. (2013) conducted a similar textbook survey that included the same textbooks earlier but did not report on the occurrence of domestic alien species at all, so it is unclear whether the eight species identified by Doi and Hayashi (2015) were presented as examples of domestic alien species in these textbooks. For the current Basic Biology textbooks, only three mention domestic alien organisms and their adverse effects. This is thought to be because there has been little research, except for Yamanoi *et al*. (2016b) and Sato *et al*. (2024), to date on introducing domestic alien species into school biology education. It is hoped that many research projects will be conducted to develop teaching materials on domestic alien species, and that the results will arouse students' interest. As an example, the HONMOROKO, an endemic species of Lake Biwa, the largest lake in Japan, which has been designated an endangered species (MOE, 2020) likely due to the invention of the alien predator, the bluegill (Shiga Prefecture, undated). However, the fish has been introduced into other lakes where it has become an invasive species (NIES, undated, see website list).

Treatment of Japanese Native Species that Have Become Invasive Alien Species Overseas in Current Basic Biology Textbooks

The problem of invasive alien organisms is not specific in Japan. But only two textbooks cover this issue, perhaps because the topic is outside the scope of Basic Biology courses. To prevent students from misunderstanding the word "alien species," it is advisable to mention native Japanese species that have spread overseas. Sakuraba *et al.* (2013) reported two Basic Biology textbooks published in 2012 dealt with this issue, both of which introduced the kudzu and *Undaria pinnatifida* (wakame), and one further introduced *Acanthogobius flavimanus* (yellow goby), *Asterias amurensis* (Northern Pacific sea star), *Fallopia japonica* (Japanese knotweed) and the Japanese silver grass. Among these organisms, the kudzu, the wakame, the Japanese knotweed and the Northern Pacific sea star have been listed on the *100 of the World's Worst Invasive Alien Species* (*ISSG List*; Lowe *et al.*, 2000).

The kudzu and the Japanese silver grass are still used in current Basic Biology textbooks as examples of invasive species from Japan. The kudzu seems to be a good example of the invasive alien species in the USA because it was "introduced into the United States at the 1876 Centennial Exposition in Philadelphia (Forseth and Innis, 2004, p. 401)." The Japanese knotweed, along with the Japanese silver grass, is introduced in Basic Biology textbooks as a pioneer species of primary succession, but since this plant species is included in the *ISSG List* mentioned above, it seems to be a better example than the Japanese silver grass. Another good example is the wakame, a popular edible seaweed in Japan that is considered "one of the world's worst invaders (South *et al.*, 2017)."

Textbook #3 mentions that "carp" from Japan has become an invasive alien organism in the USA, but this description seems to be a misquotation. *Cyprinus carpio* (common carp) is included in the *ISSG List* and is one of the worst invasive carp species (Asian carp) in that country. However, it was introduced from Europe, not Japan (Koel *et al.*, 2000, see website list). Furthermore, "in the United States, four species of non-native carp – bighead, silver, black and grass carp – are collectively called invasive carp" (Invasive Carp Regional Coordinating Committee, 2022). Therefore, the invasive carp in the USA refers exclusively to the following four fish species native to Asia: *Hypophthalmichthys nobilis* (bighead carp), *H. molitrix* (silver carp), *Mylopharyngodon piceus* (black carp), and *Ctenopharyngodon idella* (grass carp), with the first two species native to China, being of particular concern (New York Invasive Species Information, 2019, see website list). Instead of carp, *Popillia japonica* (Japanese beetle) may be a good example of a Japanese native animal species that has become an invasive species in the USA, because it "has become the most widespread and destructive insect pest of turf, landscapes, and nursery crops in the eastern United States (Potter and Held, 2002, p. 175)."

In addition to the topic of Japanese native species becoming invasive species in other countries, students will also be interested to learn about species that are endangered in their native habitats, but have become invasive species in other countries where they have been introduced, altering native ecosystems and causing social problems. For example, the European rabbit, in its native habitat (in the Iberian Peninsula), is classified as EN (endangered) on the *IUCN Red List* (IUCN, undated, see website list), but this species is included in the *ISSG List* and has become one of the worst pests in Australia where it was introduced (The National Museum of Australia, undated, see website list).

CONCLUDING REMARKS

In this study I investigated the current Japanese USS-NCS, its Guidelines and currently used Basic Biology textbooks to find out how native organisms and alien organisms are treated in relation to biodiversity and its conservation in Basic Biology courses at Japanese upper secondary schools. The USS-NCS Guidelines recommend that, in Basic Biology course, the introduction of alien species be explained as an example of anthropogenic disturbances, citing an invasive alien species. However, regarding native organisms, it is only stated that they are being affected by introduced alien species, and there is no mention of endangered native species. Most of the Basic Biology textbooks surveyed included nearly all key terms related to native and alien organisms, but some textbooks were missing important concepts or the definitions of key terms or provided incomplete explanations of key terms.

Extinct and endangered species native to Japan listed in the sections related to biodiversity and its conservation of these textbooks were 71 (55 animals, 15 plants and one protist), although some of them are not clearly indicated as endangered.

There was almost no mention of extinct or endangered species overseas. Invasive alien species that require measures such as DIAS listed in these textbooks were 52 species (38 animals and 14 plants), although some of them also are not clearly stated as they are such species. The number of extinct and endangered species native to Japan and invasive alien species in Japan listed varied greatly between textbooks. When using textbooks with fewer examples of endangered and invasive alien species, teachers need to provide additional information to students. Very few textbooks listed domestic alien species and Japanese native species that have become invasive overseas. These topics, however, are indispensable for students to understand what invasive alien species are.

In biology education at the upper secondary level, endangered species and their protection are one of the topics that students should learn. However, when learning about endangered species, students are expected not only to consider the protection of a particular endangered species, but also to think about ways to reduce the number of species facing extinction. Furthermore, from the perspective of biodiversity conservation, it is also necessary to think about ways to enhance biodiversity. This also leads to the conservation of natural environment, *i.e.*, ecosystem conservation, which is one of the goals of the curriculum guidelines as described below. To this end, it is important for teachers to have students think about how to conserve the habitats of native species, including endangered species, in their surroundings, using examples such as SATOYAMA and wetlands, which are rich in biodiversity.

The curriculum guidelines call for students to "understand the relationship between ecosystem balance and human disturbance, and recognize the importance of ecosystem conservation (MEXT, 2021, p.125)". An example of anthropogenic disturbance is the negative impact of artificially introduced alien species on native species, but students are not only required to consider measures to mitigate the negative impact of invasive alien species. Anthropogenic disturbance is not just the introduction of invasive species into a specific native ecosystem. Humans have anthropogenic impacts on ecosystems around the world through a variety of activities, including deforestation, land development, waste disposal, air and water pollution, and greenhouse gas emissions. These global environmental issues have led to a decline in biodiversity in many parts of the world, and Conservation International has designated these places as *Biodiversity Hotspots* (Conservation International, undated, see website list). Students must consider not only how to properly conserve the habitats of endangered native species, but also how to address various environmental issues to conserve global biodiversity.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Professor Robert Wallis of Federation University, Australia, who read the original paper and provided valuable suggestions for improving it. I also am grateful to my colleagues Dr. Hideo Kitano and Ms. Teiko Nakamichi, who provided useful advice during the preparation of the paper.

REFERENCES

<Note: The English titles of all Japanese research papers are quoted verbatim though there may be some grammatical errors or awkward parts.>

Biodiversity Center of Japan (Ministry of the Environment, Japan <MOE>) (undated) *Basic Act on Biodiversity* (Act No. 58 of 2008). https://www.biodic.go.jp/biodiversity/about/kihonhou/files/biodiversity.pdf

Børresen, S. T., Ulimboka, R., Nyahongo, J., Ranke, P. S., Skjaervø, G. R., and Røskaft, E. (2022) The role of education in biodiversity conservation: Can knowledge and understanding alter locals' views and attitudes towards ecosystem services? *Environmental Education Research* **29**(1): 148-163. https://doi.org/10.1080/13504622.2022.2117796

Doi, T. (2020) The history and current state of elementary school childrens' textbook descriptions regarding the management after breeding an alien species in living environmental studies: Focused on crayfish. Journal of Science Education in Japan 44(4): 375-383. (in Japanese with English abstract) https://doi.org/10.14935/jssej.44.375

Doi, T. and Hayashi, T. (2015) Analysis of textbooks describing alien species and changes in students' recognition through lessons: Aiming to further the development of environmental education in elementary school. *Journal of Science Education in Japan* **39**(3): 212-224. (in Japanese with English abstract) https://doi.org/10.14935/jssej.39.212

Doshita, M. (2015) The globalisation of symbolic concepts of nature: A case study of Satoyama. *The Bulletin, School of Global Studies, Tama University* **7**: 1-15. https://tama.repo.nii.ac.jp/records/259

Forseth, I. N. and Innis, A. F. (2004) Kudzu (*Pueraria montana*): History, physiology, and ecology combine to make a major ecosystem threat. *Critical Reviews in Plant Sciences* **23**: 401-413. https://doi.org/10.1080/07352680490505150

Fukata, Y., Kume, T. and Ueda, T. (2018) A practice research of environmental education using rare species Tokyo bitterling. *Bulletin of Education Practices, Faculty of Education, Utsunomiya University* **4**: 59-65. (in Japanese with English title) https://uuair.repo.nii.ac.jp/records/11143

Fuse, T. (2015a) Development of the teaching material using Japanese bee, *Apis cerana japonica* and verification on the effect of it: A case study of teaching ecosystem for consideration on local natural environment. *Japanese Journal of Biological Education* **56**(1): 11-20. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.56.1_11

Fuse, T. (2015b) A study on the forest environmental education practiced in upper secondary school science curriculum - An ESD trial using the rich forest environment in the Shiretoko Peninsula World Heritage Site -. *Japanese Journal of Environmental Education* **25**(2): 40-52. (in Japanese with English abstract) https://doi.org/10.5647/jsoee.25.2_40

Hayakawa, M. (2006) Utilization of Tokyo hynobiid salamander as a multipurpose material for high school biology class. *Japanese Journal of Biological Education* **46**(3): 145-154. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.46.3_145

Heavenlin, M., Christy, I. K., Gunasekaran, C., Rajkumar, V. and Chinnaraj, P. (2015) Biodiversity conservation education: An evaluation of effects on students' knowledge, perception and attitudes. *IJRD Journal of Biological Science* **1**(6): 15-25. https://www.ijrdo.org/index.php/bs/article/view/2353

Higa, T. (2018) A development of teaching material for sustainable society: The use of subject on alien organism in junior high school science class. *Bulletin of Faculty of Education University of the Ryukyus* **93**: 115-124. (in Japanese with English title) https://u-ryukyu.repo.nii.ac.jp/records/2010047

Higa, T. (2019) A study of textbooks' treatment of foreign invasive species: Based on authorized textbooks of living environment studies and science for elementary schools, and science for junior and senior high schools. *Journal of Science Education in Japan* **43**(4): 457-467. (in Japanese with English abstract) https://doi.org/10.14935/jssej.43.457

Higa, T. (2024) A study on alien species as teaching materials. *Bulletin of Department of Teacher Education Graduate School of Education University of the Ryukyus* **8**: 19-27. (in Japanese with English title) https://doi.org/10.24564/0002020297

Invasive Carp Regional Coordinating Committee (2022) *What to Do If You Think You Have Found an Invasive Carp.* https://icrcc.fws.gov/sites/carp/files/2023-12/Found-Invasive-Carp-Handout.pdf

Ito, T., Tanaka, K., Oda, Y. and Hosoya, K. (2015) The utilization of the black basses as anatomical experiment materials in environmental education program. *Memoirs of the Faculty of Agriculture of Kinki University* **48**: 50-58. (in Japanese with English abstract) https://kindai.repo.nii.ac.jp/records/5362

Katayama, N. and Nakamichi, T. (2024) Biodiversity-related content currently taught in upper secondary biology in Japan - Especially biodiversity-related terms found in textbooks. *Asian Journal of Biology Education* **16**: 54-73. https://doi.org/10.57443/ajbe.16.0_54

Kato, H. (2018) Research on the present situation of the red-eared turtle, *Trachemys scripta elegans*, kept at public schools in Shizuoka prefecture. *Bulletin of the Center for Educational Research and Teacher Development Shizuoka University* **28**: 121-124. (in Japanese with English title) https://doi.org/10.14945/00024667

Kato, M. (2011) A research on change of descriptions about “Conservation of Living Things” based on high school biology textbooks in Japan. *Japanese Journal of Biological Education* **52**(3): 96-111. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.52.3_96

Kisakibaru, Y. (2012) Experiment of the observation on the sperm in the apple snails. *Japanese Journal of Biological Education* **53**(1-2): 36-40. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.53.1-2_36

Kominami, Y. (2022) A model of inquiry activity in science by using tree distribution data in a Satoyama secondary forest. *Bulletin of the Center for Educational Research and Teacher Development Shizuoka University* **32**: 227-233. (in Japanese with English abstract) https://doi.org/10.14945/00028709

Kominami, Y., Hiraga, D., Kato, R. and Seto, K. (2013) Use of Satoyama as teaching materials for biodiversity education: Learning in species diversity and regulating services by tree census. *Studies in Subject Development* **1**: 173-182. (in Japanese with English abstract) http://hdl.handle.net/10297/7404

Kominami, Y. and Muramatsu, Y. (2016) A method for biodiversity education by using tree census data finding inquiry themes in making a forest diorama. *Studies in Subject Development* **4**: 81-88. (in Japanese with English abstract) http://hdl.handle.net/10297/9358

Kurabayashi, M., Fukaya, S., Takahashi, E. and Takemura, M. (2021) Class practice and control measures based on the specific alien organism “*Aromia bungii*”: Creation and utilization of Sakura damage map. *Japanese Journal of Biological Education* **63**(1): 10–21. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.63.1_10

Lowe, S., Browne, M., Boudjelas, S. and De Poorter, M. (2000) *100 of the World’s Worst Invasive Alien Species A selection from the Global Invasive Species Database*. The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN). https://portals.iucn.org/library/sites/library/files/documents/2000-126.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT> (2009a) *The Upper Secondary School National Curriculum Standards.* (In Japanese) https://www.mext.go.jp/component/a_menu/education/micro_detail/__icsFiles/afieldfile/2011/03/30/1304427_002.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT> (2009b) *Guidelines on the Upper Secondary School National Curriculum Standards, Science Subjects.* (In Japanese) https://www.mext.go.jp/component/a_menu/education/micro_detail/__icsFiles/afieldfile/2010/01/29/1282000_6.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT> (2018) *The Upper Secondary School National Curriculum Standards.* (in Japanese) https://www.mext.go.jp/content/20230120-mxt_kyoiku02-100002604_03.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT> (2021) *Guidelines on the Upper Secondary School National Curriculum Standards (2018 Revision), Science Subjects and Inquiry-Based Study of Science and Mathematics.* (in Japanese) https://www.mext.go.jp/content/20211102-mxt_kyoiku02-100002620_06.pdf

Ministry of Education, Culture, Sports, Science and Technology, Japan <MEXT> (2023) *Notice on the handling of American crayfish and red-eared sliders in schools.* (in Japanese) https://www.mext.go.jp/content/20240729-mxt_kyoiku01-100002611_002.pdf

Ministry of the Environment, Japan <MOE> (2004a) *Measures to be taken against invasive alien species in Japan.* https://www.env.go.jp/en/nature/as/040326.pdf

Ministry of the Environment, Japan <MOE> (2004b) *Basic policy for preventing adverse effects on ecosystems caused by invasive alien species (Cabinet decision as of October 15, 2004).* https://www.env.go.jp/content/900452912.pdf

Ministry of the Environment, Japan <MOE> (2013) *Coreopsis lanceolata is a "designated invasive alien species!"* (in Japanese) https://www.env.go.jp/nature/intro/4document/files/p_ookinkeigiku_zenkoku.pdf

Ministry of the Environment, Japan <MOE> (2014) *Invasive Alien Species Act (enacted in 2004 and amended in 2014).* https://www.env.go.jp/content/900452905.pdf

Ministry of the Environment, Japan <MOE> (2015a) *Basic Policy for Compiling a List of Alien Species that May Cause Damage to Japan's Ecosystems.* (in Japanese) https://www.env.go.jp/nature/intro/2outline/list/hosoku.pdf

Ministry of the Environment, Japan <MOE> (2015b) *The List of Alien Species that May Cause Damage to Japan's Ecosystems (The List of Invasive Alien Species for Preventing Ecosystem Damage).* (in Japanese) https://www.env.go.jp/nature/intro/2outline/list/list.pdf

Ministry of the Environment, Japan <MOE> (2016) *Raccoon Control Guide (How to Proceed with Planned Control), revised version.* (in Japanese) https://www.env.go.jp/nature/intro/3control/files/manual_racoon.pdf

Ministry of the Environment, Japan <MOE> (2020) *MOE Red List 2020.* (in Japanese) https://www.env.go.jp/content/900515981.pdf

Ministry of the Environment, Japan <MOE> (2022) *Satoyama in Japan - For Nature-based Solutions -.*

https://www.env.go.jp/nature/satoyama/pdf/satoyama2022E.pdf

Ministry of the Environment, Japan <MOE> (2024) *List of Regulated Living Organisms under the Invasive Alien Species Act.* https://www.env.go.jp/nature/intro/2outline/files/siteisyu_list_e3.pdf

Miyake, S. (2024) Exploring the theme of diversity conservation education: Causes and countermeasures for animal extinction in Japan. *JSSE Research Report* **38**(5): 37-42. (in Japanese with English title) https://doi.org/10.14935/jsser.38.5_37

Mori, K., Takahashi, D. and Kayano, A. (2017) A case study of the teaching method using invasive alien species as educational material in a junior high school science: Application of "coding" by text mining. *JSSE Research Report* **32**(1): 25-28. (in Japanese with English title) https://doi.org/10.14935/jsser.32.1_25

Murase, R. and Kato, H. (2020) Research on recognition status of adventive organism and class practice at junior high school. *Bulletin of the Center for Educational Research and Teacher Development Shizuoka University* **30**: 97-105. (in Japanese with English abstract) https://doi.org/10.14945/00027110

Navarro-Perez, M. and Tidball, K. G. (2012) Challenges of biodiversity education: A review of education strategies for biodiversity education. *International Electronic Journal of Environmental Education* **2**(1): 13-30. https://files.eric.ed.gov/fulltext/EJ1057485.pdf

Numata, M. (1990) Biodiversity as a basis of environmental education. *Shukutoku University Bulletin* **24**: 27-37. https://shukutoku.repo.nii.ac.jp/records/457

Ohshika, K., Sato T., Muko H., Takeshita S., and Ikeda H. (2007) The development and its features of teaching materials in dissection using alien species of fresh-water fishes. *Japanese Journal of Biological Education* **47**(4): 166-173. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.47.4_166

Potter, D. A. and Held, D. W. (2002) Biology and management of the Japanese beetle. *Annual Review of Entomology* **47**: 175-205. https://doi.org/10.1146/annurev.ento.47.091201.145153

Sakuraba, H., Matsuda, H., Akashi, K. and Ishii, T. (2013) Discussion in teaching of Tsunami, Satoyama and Biological experiments subjects in junior high school and/or high school. *Memoirs of Faculty of Education and Human Studies, Akita University: Educational science* **68**: 51-64. (in Japanese with English abstract) http://hdl.handle.net/10295/2092

Sasaki, H., Yamahashi, T., Iwata, E. (2020) Development of the teaching materials thinking about the origin of alien species *Lepomis macrochirus*. *Research Bulletin of Meisei University* **No. 2**: 97-103. (in Japanese with English title) https://meisei.repo.nii.ac.jp/records/2610

Sato, A., Sakurai, Y. and Kurihara, J. (2024) Development of teaching materials for students to make a decision based on the scientific evidences in junior high school science “nature and human” - A case study on the releasing commercial Medaka fish -. *Bulletin of Center for Educational Research and Practice, Gunma University* **41**: 63-72. (in Japanese with English title) http://hdl.handle.net/10087/0002000311

Shiga Prefecture (undated) Increase in alien fish and decline in crucian carp and HONMOROKO populations. (in Japanese) https://www.pref.shiga.lg.jp/file/attachment/5376161.pdf

Shimabe, H. and Imai, A. (2021) Examination of exotic plants as science education material in junior high school. *Annual Report of the Faculty of Education, Gifu University, Humanities and Social Sciences* **70**(1): 139-146. (in Japanese with English title) https://gifu-u.repo.nii.ac.jp/records/65138

Shimabe, H. and Imai, A. (2022) Development of science education curriculum for alien species in junior high school. *Research Bulletin, Information and Multimedia Center, Gifu University* **38**(1): 29-39. (in Japanese with English title) https://gifu-u.repo.nii.ac.jp/records/76314

Shingai, Y., Aori, R., Takeda, Y., Kobayashi, W., Kusunoki, F., Mizoguchi, H., Sugimoto, M., Funaoi, H., Yamaguchi, E. and Inagaki, S. (2021) Satoyama Management Game, A learning support system for acquiring problem solving skills in STEM education: An examination of the learning effect when dealing with multiple Satoyama. *Journal of Science Education in Japan* **45**(2): 112-127. (in Japanese with English abstract) https://doi.org/10.14935/jssej.45.112

Shoji, K. and Nagashima, Y. (2015) Biodiversity education for compulsory education. *Bulletin of Sendai Science Museum* **24**: 43-48. (in Japanese with English title) https://doi.org/10.24650/scsm.24.0_43

South, P. M., Floerl, O., Forrest, B. M. and Thomsen, M. S. (2017) A review of three decades of research on the invasive kelp *Undaria pinnatifida* in Australasia: An assessment of its success, impacts and status as one of the world's worst invaders. *Marine Environmental Research* **131**: 243-257. https://doi.org/10.1016/j.marenvres.2017.09.015

Suzue, T. (2007) School News 4: Nature observation classes and biology club activities at Akutagawa High School. *Japanese Journal of Ecology* **57**(3): 448-451. (in Japanese) https://doi.org/10.18960/seitai.57.3_448

Ubukata, H. (2011) Environmental education challenging the crises of biodiversity and ecosystems. *Kushiro Ronshu, - Journal of Hokkaido University of Education at Kushiro -* **43**: 77-85. (in Japanese with English title) https://doi.org/10.32150/00008443

Umezawa, K. and Tsunoda, H. (2022) Development of biodiversity teaching materials for high school biology. *Japanese Journal of Biological Education* **64**(1): 2–8. (in Japanese with English abstract) https://doi.org/10.24718/jjbe.64.1_2

Wada, K. (2019) Development and implementation of a learning program on "body structure" and "food chain" using alien fish: Dissection practice in conjunction with the Marine Education Pioneer School Program and alien fish eradication activities in lakes. *Meisei University KSC Annual Report* **2**: 79-92. (in Japanese) https://meisei.repo.nii.ac.jp/records/1666

Yamanoi, T., Watanabe, T. and Yatsu, J. (2016a) A preliminary survey on knowledge of alien species among high school and university students with special reference to differences in their knowledge of exotic animals and plants. *Hakuoh Journal of the Faculty of Education* **10**(1): 277-285. (in Japanese with English title) https://hakuoh.repo.nii.ac.jp/records/443

Yamanoi, T., Sato, C., Koya, Y. and Ohtsuki, H. (2016b) Development of a class for junior high school students to think about biodiversity conservation on the theme of Genji fireflies introduced from other areas of Japan. *Japanese Journal of Environmental Education* **25**(3): 75-85. (in Japanese with English abstract) https://doi.org/10.5647/jsoee.25.3_75

WEBSITES

Agency for Cultural Affairs, Japan (undated) Marimo in Lake Akan (*National Database of Designated Cultural Properties*). https://kunishitei.bunka.go.jp/heritage/detail/401/2 <accessed: 12/09/2025>

Biodiversity Center of Japan (Ministry of the Environment, Japan <MOE>) (undated) *'95 Survey of Familiar Organisms – Survey Results Final Version – (The Fifth Green Census).* https://www.biodic.go.jp/reports/5-2/n025.html < accessed: 12/09/2025>

Conservation International (undated) *Biodiversity Hotspots*. https://www.conservation.org/ priorities/biodiversity-hotspots <accessed: 12/09/2025>

International Union for Conservation of Nature and Natural Resources (IUCN) (undated) *IUCN Red List of Threatened Species*. https://www.iucnredlist.org/ <accessed: 12/09/2025>

ibid. (undated) European rabbit. https://www.iucnredlist.org/species/41291/170619657 < accessed: 12/09/2025>

Japan Association for Techno-innovation in Agriculture, Forestry and Fisheries <JATAFF> (undated) *Japan's Special Natural Monuments [Animals and Plants]*. https://www.jataff.or.jp/monument/ <accessed: 12/09/2025>

Koel, T. M., Irons, K. S. and Ratcliff, E. (2000) Asian carp invasion of the Upper Mississippi River System (Project Status Report: PSR2000-05). Upper Midwest Environmental Sciences Center. https://www.umesc.usgs.gov/reports_publications/psrs/psr_2000_05.html <accessed: 12/09/2025>

Ministry of the Environment, Japan <MOE> (2023) *Cabinet Decision to Designate the Red-eared Slider Turtle and the American Crayfish as Conditionally Designated Invasive Alien Species*. (in Japanese) https://www.env.go.jp/press/press_01039.html <accessed: 12/09/2025>

Ministry of the Environment, Japan <MOE> (undated) The Invasive Alien Species Act. *Glossary of Terms*. (in Japanese) https://www.env.go.jp/nature/intro/1law/yougo.html <accessed: 12/09/2025>

National Institute for Environmental Studies <NIES> (undated) HONMOROKO (*Gnathopogon caerulescens*). *Invasive Database*. (in Japanese) https://www.nies.go.jp/biodiversity/invasive/DB/detail/50560.html <accessed: 12/09/2025>

New York Invasive Species Information (2019) Asian carp. https://nyis.info/spec zies/asian-carp/#:~:text=In%20North%20America%2C%20the%20term,Chicago%20Sanitary%20and%20Ship%20Canal <accessed: 12/09/2025>

Oxford Reference (undated) Native species (Quick Reference). *A Dictionary of Environment and Conservation, 2nd ed.* https://www.oxfordreference.com/display/10.1093/oi/authority.20110803100224991 <accessed: 12/09/2025>

Stockholm Resilience Centre, Stockholm University (undated) *Planetary Boundaries, The nine planetary boundaries and their status.* https://www.stockholmresilience.org/research/planetary-boundaries.html <accessed: 12/09/2025>

The Environmental Innovation Information Center, EIC Net (undated) *Environmental Glossary.* (in Japanese) https://www.eic.or.jp/ecoterm/ <accessed: 12/09/2025>

The National Museum of Australia (undated) *Rabbits introduced*. https://www.nma.gov.au/defining-moments/resources/rabbits-introduced <accessed: 12/09/2025>

The Satoyama Initiative (undated) *What is "SEPLS"? Socio-ecological production landscapes and seascapes*. https://satoyamainitiative.org/concept/ <accessed: 12/09/2025>

BASIC BIOLOGY TEXTBOOKS SURVEYED

#1. Asashima, M. *et al.* (2022) Basic Biology. Tokyo Shoseki Co., Ltd.

#2. Asashima, M. *et al.* (2022) Basic Biology New Edition. Tokyo Shoseki Co., Ltd.

#3. Mogami, Y. *et al.* (2022) Basic Biology. Jikkyo Shuppan Co., Ltd.

#4. Mogami, Y. *et al.* (2022) Upper Secondary School Basic Biology. Jikkyo Shuppan Co., Ltd.

#5. Akasaka, K. *et al.* (2022) Upper Secondary School Basic Biology. Shinkoshuppansha Keirinkan Co, Ltd.

#6. Akasaka, K. *et al.* (2022) Basic Biology i Version. Shinkoshuppansha Keirinkan Co, Ltd.

#7. Shimada, M. *et al.* (2022) Upper Secondary School Basic Biology. Suken Shuppan Co., Ltd.

#8. Shimada, M. *et al.* (2022) Basic Biology New Edition. Suken Shuppan Co., Ltd.

#9. Yoshizato, K. *et al.* (2022) Upper Secondary School Basic Biology. Daiichi Gakushusha Corp.

#10. Yoshizato, K. *et al.* (2022) Upper Secondary School New Basic Biology. Daiichi Gakushusha Corp.

APPENDIXES

Appendix 1: Terminology and Definition

In the Basic Biology textbooks surveyed, both -SEIBUTSU (organism) and -SHU (species) are used, and in some cases the term -SHU is not used in its biological sense, *i.e.*, indicating each species. This paper uses the term "organism" when not referring to each biological species.

A native species is generally defined as, for example, “a species that is within its known natural range, and occurs naturally in a given area or habitat, as opposed to an introduced species or invasive species; it is also known as endemic species or indigenous species (Oxford Reference, undated, see the Website list).” However, because synonymous Japanese terms for native organisms appear in the textbooks surveyed, this paper uses different English terms to discriminate them (Table A-1), and their definitions are as follows: a native species is a species that has been in a particular area for a long time and still inhabits there today, rather than being introduced from elsewhere, *i.e.*, the term native species is roughly the same as primeval species. However, in Japan, forests that have grown naturally without human intervention are called GENSEI-RIN (primeval forests), and so a primeval species refers to a species living in natural environments (wild nature) that have had little or no human influence. An endemic species refers to “a species or subspecies whose distribution is restricted to a specific area, which can be considered at various levels such as country, prefecture, or region (EIC Net, undated, see website list).”

An endangered species refers to a species or subspecies listed on the *MOE Red List 2020* (MOE, 2020). The term also refers to a species or subspecies listed on the *IUCN Red List* (IUCN, undated, see website List).

An alien species refers to a species which has been introduced artificially, whether intentionally or not, into non-native habitats, in other words, an introduced species, an adventive species or an exotic species. The term invasive species is also often used to refer to non-native species, but to avoid confusion with invasive alien species defined below, this paper uses the word “invasive” only for invasive alien species. An invasive alien species refers to "an alien species which threatens biological diversity by bringing an adverse impact which could not arise under natural conditions (MOE, 2004a)." A designated invasive alien species (abbreviated as DIAS) refers to a species designated by Japanese government under the *IAS Act*.

Table A-1: English translations of terms related to native and alien organisms found in the unit "Diversity of Organisms, and Ecosystems" of Basic Biology textbooks

Japanese terms	English terms
SHU	species
SEIBUTSU	organism
ZAIRAI-NO (ZAIRAI-SHU)	native (native species)
KOYU-NO (KOYU-SHU)	endemic (endemic species)
GENSEI-NO (GENSEI-SHU)	primeval (primeval species)
KISHOH (KISHO-SHU)	rare (rare species)
ZETSUMETSU-KIGU-SHU	endangered species
GAIRAI-NO (GAIRAI-SHU)	alien (alien species)
GAIRAI-SEIBUTSU HOU	Act on the Prevention of Adverse Ecological Impacts Caused by Designated Invasive Alien Species (Invasive Alien Species Act / *IAS Act*)
SHINRYAKUTEKI GAIRAI-SHU	invasive alien species
TOKUTEI GAIRAI-SHU	designated invasive alien species (DIAS)

Since invasive alien organisms including DIAS are thought "to have adverse effects on ecosystems, human life and health, agriculture, forestry, fisheries, *etc.* (MOE, 2004b, 2014)," they have been including in the *List of Alien Species that May Cause Damage to Japan's Ecosystems* (abbreviated as the *LIST*). The *LIST* was compiled in 2015 by the MOE and the Ministry of Agriculture, Forestry and Fisheries to serve for countermeasures of invasive alien organisms following the *National Biodiversity Strategy 2012-2020*, which was approved by the Cabinet in September 2012. The *LIST* includes five categories of invasive alien species (Table A-2) which are "not only designated invasive alien species under the IAS Act, but also invasive alien organisms that cause or are likely to cause damage to Japan's ecosystems, *etc*. (MOE, 2015a)."

The classification "alien species of domestic origin (MOE, 2015a, p. 3)," is not included in the *LIST* categories, but the *LIST* does list species that fall into this category. An alien species of domestic origin or domestic alien species (Table A-2) refers to "a species that have a natural distribution range in Japan but have been introduced into other parts of the country beyond their natural distribution range (MOE, undated, see website list)."

Table A-2: English translations of "SEITAIKEI HIGAI-BOUSHI GAIRAI-SHU List" and the categories of invasive alien organisms in the list

Japanese terms	English terms
SEITAIKEI HIGAI-BOUSHI GAIRAI-SHU List	the List of Alien Species that May Cause Damage to Japan's Ecosystems (LIST)
SHNNYU YOBOU GAIRAI-SHU	alien species to be prevented from entering (SY)
TEICHAKU YOBOU GAIRAI-SHU	alien species requiring measures to prevent establish-

	ment (TY)
KINKYU TAISAKU GAIRAI-SHU	alien species requiring emergency measures (KT)
JUTEN TAISAKU GAIRAI-SHU	alien species requiring priority measures (JT)
SOGO TAISAKU GAIRAI-SHU	alien species requiring comprehensive measures (ST)
KOKUNA YURAI NO GAIRAI-SHU (KO-KUNAI GAIRAI-SHU)	alien species of domestic origin (domestic alien species)

Appendix 2: Species native to Japan, which are listed on the MOE Red List 2020, appearing in Basic Biology textbooks

	Species	MOE Category*	Number of textbooks listing**
Mammals	*Canis lupus hodophilax* (Japanese wolf)	EX	2 (2)
	Lutra lutra nippon / Lutra lutra whiteleyi (Japanese otter) ◆	EX	1 (1)
	Dugong dugon (dugong)	CR	3 (3)
	Enhydra lutris (sea otter)	CR	10 (0)
	Prionailurus bengalensis euptilurus (Tsushima wildcat)	CR	5 (5)
	Prionailurus bengalensis iriomotensis (Iriomote wildcat) ◆	CR	5 (4)
	Pteropus dasymallus daitoensis (Daito flying fox)	CR	1 (1)
	Zalophus japonicus (Japanese sea lion)	CR	1 (1)
	Pentalagus furnessi) (Amami rabbit) ◆	EN	6 (6)
	Sorex minutissimus hawkeri (Hawker's least shrew)	VU	1 (1)
	Mustela erminea (stoat)	NT	4 (4)
	Phoca vitulina (harbour seal)	NT	1 (0)
	Capricornis crispus (Japanese serow) ◆	LP***	4 (1)
Birds	*Ciconia boyciana* (Japanese white stork)	CR	3 (3)
	Gallirallus okinawae (Okinawa rail)	CR	6 (6)
	Ketupa blakistoni blakistoni (Blakiston's fish-owl)	CR	1 (1)
	Nipponia nippon (Japanese crested ibis) ◆	CR	6 (6)
	Aquila chrysaetos japonica (golden eagle)	EN	1 (1)
	Lagopus muta japonica (rock ptarmigan) ◆	EN	7 (5)
	Butastur indicus (grey-faced buzzard)	VU	2(0)
	Charadrius alexandrinus dealbatus (Kentish plover)	VU	1 (1)
	Dryocopus martius martius (black woodpecker)	VU	2 (1)
	Falco peregrinus japonensis (Japanese peregrine falcon)	VU	1 (1)
	Grus japonensis (red-crowned crane) ◆	VU	2 (2)
	Phoebastria albatrus (short-tailed albatross)	VU	5 (5)
	Sterna albifrons sinensis (little tern)	VU	2 (0)
	Accipiter gentilis fujiyamae (Northern goshawk)	NT	1 (0)
	Pandion haliaetus haliaetus (osprey)	NT	2 (0)
Reptiles	*Caretta caretta* (logger head turtle)	EN	4 (4)

	Eretmochelys imbricata (Hawksbill turtle)	EN	1 (1)
	Chelonia mydas mydas (green sea turtle)	VU	3 (2)
Amphibians	*Hynobius abei* (Abe's salamander)	CR	2 (2)
	Pelophylax porosus brevipodus (Nagoya daruma frog)	EN	1 (1)
	Andrias japonicus (Japanese giant salamander) ◆	VU	3 (3)
	Hynobius nebulosus (clouded salamander)	VU	1 (1)
	Hynobius tokyoensis (Tokyo salamander)	VU	1 (1)
Fish	*Oncorhynchus kawamurae* (black kokanee)	EW	1 (1)
	Gnathopogon caerulescens (HONMOROKO)	CR	2 (0)
	Pseudorasbora pumila (SHINAI top−mouth gudgeon)	CR	1 (1)
	Tanakia tanago (Tokyo bitterling)	CR	3 (2)
	Anguilla japonica (Japanese eel)	EN	3 (3)
	Lefua echigonia (HOTOKE loach)	EN	1 (1)
	Oryzias latipes / *Oryzias sakaizumii* (killifish)	VU	5 (3)
	Gymnogobius castaneus (JUZUKAKE goby)	NT	2 (0)
	Sarcocheilichthys variegatus variegatus (KAWAHIGAI)	NT	2 (0)
Insects	*Libellula Angelina* (BEKKO dragonfly)	CR	2 (2)
	Luciola owadai (Kumejima firefly)	CR	1 (1)
	Melitaea scotosia (HYOMON-MODOKI)	CR	2 (2)
	Cheirotonus jambar (Yanbaru long-armed scarab beetle)	EN	2 (2)
	Cybister chinensis (GENGORO water beetle)	VU	5 (4)
	Dorcus hopei binodulosus (giant stag beetle)	VU	1 (0)
	Kirkaldyia deyrolli (giant water bug)	VU	2 (0)
	Luehdorfia japonica (Japanese Luehdorfia)	VU	2 (0)
	Phengaris arionides takamukui (greater large blue)	NT	1 (1)
	Sasakia charonda charonda (great purple emperor)	NT	2 (0)
Plants	*Viola stoloniflora* (ORIDZURU violet)	EW	1 (1)
	Callianthemum miyabeanum (Hidaka-so)	CR	1 (1)
	Gentiana aquatica (HINA gentian)	CR	1 (1)
	Persicaria japonica var. *taitoinsularis* (DAITO SAKURATADE)	CR	1 (1)
	Polemonium kiushianum (HANASHINOBU)	CR	2 (2)
	Rhododendron boninense (MUNIN azalea)	CR	3 (3)
	Cypripedium marcanthos var. *rebunense* (Rebun Cypripedium)	EN	1 (1)
	Oxytropis megalantha (REBUN-SO)	EN	1 (1)
	Stellaria humifusa (saltmarsh starwort)	EN	1 (1)
	Echinops setifer (HIGOTAI)	VU	1 (1)
	Marsilea quadrifolia (DENJI-SO)	VU	1 (1)
	Sciaphila nana (HONGO-SO)	VU	2 (2)
	Xanthium strumarium (common cocklebur)	VU	1 (0)

	Eupatorium japonicum (thoroughwort)	NT	2 (1)
	Monochoria korsakowii (MIZUAOI)	NT	1 (1)
Protist	*Aegagropila linnaei* (MARIMO) ◆	CR/EN	2 (2)

* EX: extinct, EW: extinct in the wild, CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened.
** The number in parentheses indicates the number of textbooks which state that the species is extinct or endangered.
*** Some local populations are at risk of extinction (LP) in the MOE Red List 2020.
◆ Species that have been designated as Special Natural Monuments, Japan.

Appendix 3: Species non-native to Japan, that are listed on the IUCN Red List, appearing in Basic Biology textbooks

	Species / Taxon	IUCN Category*	Number of textbooks listing**
Mammals	*Pongo* spp. (orangutans)	CR	7 (3)
	Elephas maximus (Asian elephant)	EN	6
	Equus ferus przewalskii (Przewalski's wild horse)	EN	3
	Inia geoffrensis (Amazon river-dolphin)	EN	1
	Oryctolagus cuniculus (European rabbit)	EN	6
	Panthera tigris altaica (Siberian tiger)	EN	3
	P*anthera tigris tigris* (Bengal tiger)	EN	2
	Pan troglodytes (chimpanzee)	EN	1
	Rhinopithecus roxellana (golden snub-nosed monkey)	EN	1
	Acinonyx jubatus (cheetah)	VU	2
	Ailuropoda melanoleuca (giant panda)	VU	1
	Aonyx cinerea (Asian small-clawed otter)	VU	1
	Bison bison (American bison)	VU	3
	Giraffa camelopardalis (giraffe)	VU	3
	Panthera leo (lion)	VU	5
	Rangifer tarandus (reindeer)	VU	7
	Ursus maritimus (polar bear)	VU	3
	Ornithorhynchus anatinus (platypus)	NT	1
	Panthera onca (jaguar)	NT	3
Birds	*Ectopistes migratorius* (passenger pigeon)	EX	2 (2)
	Neophron percnopterus (Egyptian vulture)	EN	1
	Spheniscus humboldti (Humboldt penguin)	VU	1
Reptiles	Sea turtles	CR - VU	1
Plants	*Selaginella lepidophylla* (stone flower)	NT	1

* EX: extinct, CR: critically endangered, EN: endangered, VU: vulnerable, NT: near threatened.
** The number in parentheses indicates the number of textbooks which state that the species is extinct or endangered.

Appendix 4: Invasive alien species designated under the IAS Act* or listed on the LIST** appearing in Basic Biology textbooks

	Organisms	Category in the *IAS Act* or the *LIST****	Number of textbooks listing****
Mammals	*Callosciurus erythraeus* (Taiwan squirrel)	DIAS	1 (1)
	Erinaceus spp. (hedgehogs)	DIAS	1 (1)
	Herpestes auropunctata (small Indian mongoose) *****	DIAS	8 (4)
	Macaca cyclopis (Taiwan macaque)	DIAS	3 (3)
	Muntiacus reevesi (Reeves's muntjac)	DIAS	1 (1)
	Mustela vison (American mink)	DIAS	1 (1)
	Myocastor coypus (nutria)	DIAS	1 (1)
	Ondatra zibethicus (muskrat)	DIAS	1 (1)
	Procyon lotor (raccoon)	DIAS	8 (7)
	Trichosurus vulpecula (brushtail possum)	DIAS	1 (1)
Birds	*Garrulax canorus* (laughing thrushes)	DIAS	3 (3)
	Leiothrix lutea (red-billed mesia)	DIAS	1 (1)
	Pycnonotus cafer (red-vented bulbul)	DIAS	1 (1)
Reptiles	*Anolis carolinensis* (green anole)	DIAS	5 (3)
	Chelydra serpentina (snapping turtle)	DIAS	4 (4)
	Protobothrops mucrosquamatus (Taiwan pit vivers)	DIAS	2 (2)
Amphibians	*Bufo cognatus* (Great Plains toad)	DIAS	1 (1)
	Bufo marinus (cane toad)	DIAS	1 (1)
	Eleutherodactylus coqui (Puerto Rican coquí)	DIAS	1 (1)
	Rana catesbeiana (bullfrog)	DIAS	4 (3)
Fish	*Atractosteus spatula* (alligator gar)	DIAS	1 (1)
	Esox lucius (northern pike)	DIAS	1 (1)
	Gambusia affinis (Western mosquito fish)	DIAS	1 (0)
	Ictalurus punctatus (channel catfish)	DIAS	1 (1)
	Lepomis macrochirus (bluegill)	DIAS	6 (2)
	Micropterus dolomieu (smallmouth bass)	DIAS	1 (1)
	Micropterus salmoides (largemouth bass)	DIAS	10 (4)
	Siniperca chuatsi (Mandarin fish)	DIAS	1 (1)
Insects	*Bombus terrestris* (large earth bumblebee)	DIAS	3 (3)
	Linepithema humile (Argentine ant)	DIAS	1 (1)
	Propomacrus spp. (Propomacrus beetles)	DIAS	1 (1)
	Solenopsis invicta (red imported fire ant)	DIAS	5 (5)
Crustaceans	*Pacifastacus leniusculus* (signal crayfish)	DIAS	2 (2)
	Procambarus clarkii (red swamp crayfish)	KT	1 (0)
Spiders	*Latrodectus hasseltii* (red-back widow spider)	DIAS	2 (2)

Shellfish	*Dreissena polymorpha* (zebra mussel)	DIAS	1 (1)
	Limnoperna fortunei (golden mussel)	DIAS	1 (1)
	Achatina fulica (giant African snail)	JT	1 (0)
Plants	*Coreopsis lanceolata* (lance-leaf tickseed)	DIAS	3 (3)
	Gymnocoronis spilanthoides (Senegal tea plant)	DIAS	1 (1)
	Myriophyllum aquaticum (parrot feather)	DIAS	1 (1)
	Pistia stratiotes (water lettuce)	DIAS	4 (4)
	Rudbeckia laciniata (cut-leaf coneflower)	DIAS	2 (2)
	Sicyos angulatus (bur cucumber)	DIAS	4 (4)
	Veronica anagallis-aquatica (water speedwell)	DIAS	1 (1)
	Egeria densa (Brazilian elodea)	JT	X
	Eichhornia crassipes (common water hyacinth)	JT	X
	Taraxacum officinale (common dandelion)	JT	1 (0)
	Oenothera laciniata (cut-leaf evening primrose)	JT	1 (1)
	Solidago altissima (tall goldenrod)	JT	1 (0)
	*Erigeron annuu*s (annual fleabane)	ST	X
	Xanthium canadense (oriental cocklebur)	ST	1 (0)

* Invasive Alien Species Act
** The List of Alien Species that May Cause Damage to Japan's Ecosystems
*** DIAS: species that have been designated invasive alien species under the IAS Act, KT: alien species requiring urgent measures, JT: alien species requiring priority measures, ST: alien species requiring comprehensive measures
**** The number in parentheses indicates the number of textbooks that state that the species is DIAS or invasive alien species. X: No textbooks stated that this species is an alien species.
***** Some textbooks simply refer to it as a mongoose, but the description makes it clear that it is the small Indian mongoose, so I have included it here.

From the Editor-in-Chief

AJBE Vol. 17 brings together seven contributions that highlight both classroom-based practice and curriculum-level perspectives, covering topics such as conceptual change in elementary science, effective classroom management, experiential training programs, diatom-based river education, student research on biodiversity loss, informal online learning for young children, and the treatment of biodiversity issues in upper secondary school textbooks.

I sincerely thank the members of the editorial board as well as Dr. Takayuki Sato, Dr. Ashraful Kabir, Dr. Miyuki Kato, Dr. Shunji Takeshita, and Dr. Takashi Higa for their outstanding contributions to the peer review process over the last two years. Through their careful and constructive reviews, the academic standard of the journal has been greatly enhanced.

In order to make AJBE better known to a wider audience and to encourage the submission of high-quality manuscripts, we renewed the AJBE website this year. The new design places the Online First list on the top page and provides a modern navigation system that enables easy access to all previously published articles. In addition, information for authors has been reorganized and clearly presented, and the Instructions for Authors and the Research Ethics Guidelines are now located in readily accessible sections of the site.

We also created a new AJBE logo. The design combines motifs of growing plant leaves and dynamic animals, forming a shape reminiscent of a helical gene structure. A circular element representing the human head is placed at the top to symbolize education, while the overall form expresses the letter “A” for Asia, reflecting the regional identity of our association.

For articles published since July of this year, final manuscripts have been submitted to J-STAGE in XML format, enabling the full text to be displayed in HTML. This change has greatly increased the likelihood that articles will be discovered through internet searches, providing substantial benefits to authors. Moreover, the availability of full-text HTML allows readers to use browser-based translation functions to read English articles in other languages, thereby reducing the time required to understand the content.

Furthermore, the Editorial Board has decided to display Creative Commons licenses starting with AJBE Vol. 18. By clearly stating the copyright policy in advance, AJBE will move from a green open-access journal to a gold open-access journal.

Finally, I would like to express my sincere appreciation to all those who have contributed to these efforts to enhance the status of AJBE, and I look forward to receiving many high-quality submissions in the future. With the cooperation of many colleagues, we hope to continue enriching AJBE as a scholarly journal, and I invite all of you to join us in this endeavor.

Dr. Shigeki Mayama (mayama@u-gakugei.ac.jp)

The Asian Journal of Biology Education (AJBE) is published electronically by the AJBE Editing and Publishing Office for the Asian Association for Biology Education (AABE). The Journal is on the AABE website: https://aabe.sakura.ne.jp/ajbe/