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Using Shishi-odoshi as a Tool for Visualizing the Core Concepts in Disaster Science Education

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Abstract

From the perspective of civilian control of science and technology, citizens need to overcome various epistemological barriers that hinder the development of scientific literacy, which are caused by shared beliefs based on oversimplified models inherent in academic fields. To achieve this, structuring science education based on reliable fundamental scientific laws and a microscopic perspective and reducing discrepancies between the four fields (physics, chemistry, biology, and Earth science) are needed. However, the current secondary science curriculum does not adequately address the transport phenomena of mass, heat, and momentum that connect the four fields. Although the "disaster triangle (matter, energy, and motion)" proposed as a core conceptual device for disaster science education is expected to function as a tool for comprehensively understanding the mechanisms of climate change and fire extinguishing, the concept is too abstract. This study develops disaster model teaching materials that allow students to visually grasp the connections between the three core concepts of mass, heat, and momentum. Focusing on the "shishi-odoshi" used to explain the mechanism of landslides, a literature review was conducted to assess its versatility as a disaster model. The "shishi-odoshi" has been used to explain the mechanisms of various phenomena from the perspective of the balance between the functions that maintain the initial state and those that change the state. An observational experiment using the "shishi-odoshi" was developed for students to learn that the threshold for transitions between states is governed by the interaction between the system and the environment. Furthermore, an observation experiment on convective heat transfer that focuses on the momentum of heated water rising was developed.

Keywords: *Disaster Science Education, Core Concepts, Momentum, Feedback, Climate Change, Fire Safety*

1. Introduction

From the perspective of civilian control of science and technology, citizens need to overcome various epistemological barriers that hinder the development of scientific literacy, which are caused by shared beliefs based on oversimplified models inherent in academic fields [1].

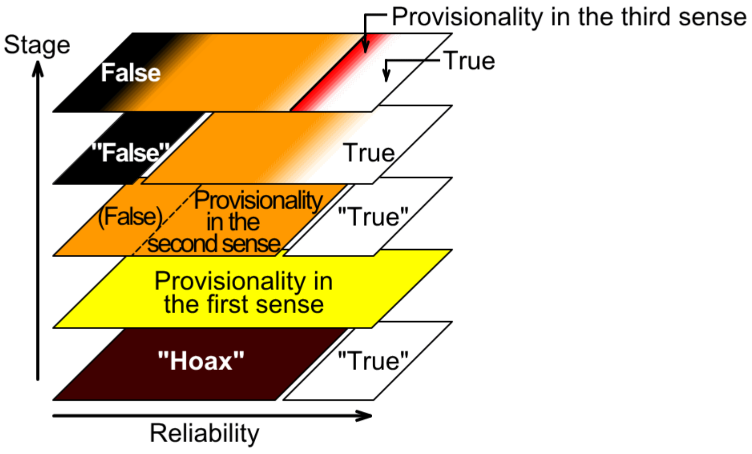


Fig.1. Stages in the Concept of Provisionality of Scientific Knowledge [2]

Stages in the concept of provisionality of scientific knowledge are illustrated in Fig. 1 [2]. "Hoax" in the bottom layer indicates such provisionality at the stage of primitive understanding of choosing either one way or the other. To solve problems in the modern society, citizens need to learn the nature of science to be able to share responsibility on "the provisionality in the third sense" that emerges due to approvals by various authorities including science textbooks, international organizations, and experts. To achieve this, structuring science education based on reliable fundamental scientific laws and a microscopic perspective and reducing discrepancies between the four fields (physics, chemistry, biology, and Earth science) are needed (Fig. 2).

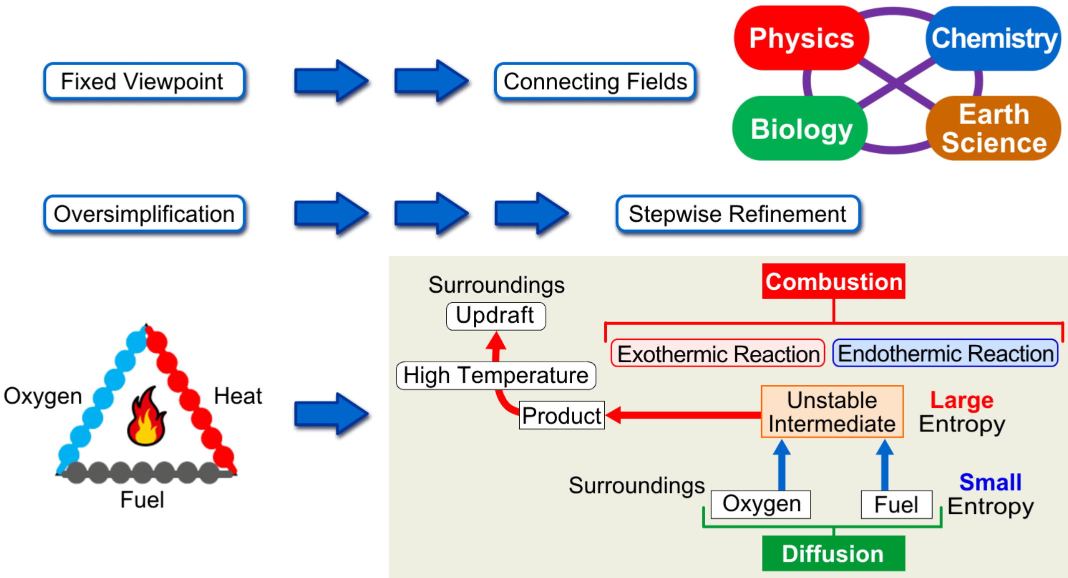


Fig.2. Connecting the Four Fields and Structuring Science Education [2]

However, in the current secondary science curriculum, the transport phenomena of mass, heat, and momentum that connect the four fields are not adequately addressed. Although the "disaster triangle (matter, energy, and motion)" [3] proposed as a core conceptual device for disaster science education was expected to function as a tool for comprehensively understanding the mechanisms of climate change and fire extinguishing [4], the concept is too abstract.

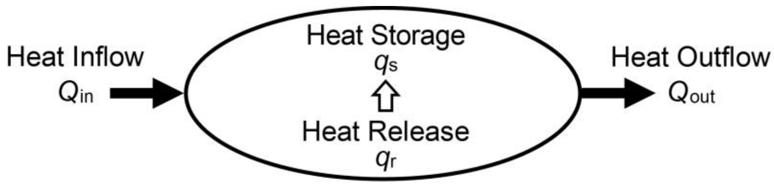


Fig.3. Heat Balance Diagram for the Earth's Atmospheric System in the Anthropocene [5]

Fig. 3 presents the heat balance diagram for the Earth's atmospheric system in the Anthropocene created by integrating the anthropogenic "heat release" and resulting latent "heat storage" included in the current curricula for physics and chemistry with the "Earth's heat balance" included in the curriculum for Earth science [5]. A teaching strategy has been proposed [5] whereby students apply the relationship between the system and the surrounding illustrated in Fig. 3 to directly observable specific systems, and refine the models by adding transport processes involving the core concepts not presented in Fig. 3, thus encouraging students' interest in the fundamental scientific laws and a microscopic perspective.
Following the proposal [5], this study developed disaster model teaching materials that enable students to visually grasp the relationship between the systems and surroundings and the connections between the three core concepts of mass, heat, and momentum.

2. Development of Observational Experiment Using Shishi-odoshi

2.1 Method

As an example of a specific model used to explain the mechanisms of complex disasters, we focused on the "shishi-odoshi" [6], which is used to explain the mechanisms of landslides [7], ignition [8, 9], and flame extinction [10-12]. A literature review assessed the versatility of the "shishi-odoshi" as a disaster model. Specifically, we input the search keyword “shishi-odoshi” into the National Diet Library Search, and extracted the materials related to the mechanisms of phenomena from the hits. Using the materials available among these, the similarities and differences between the mechanisms of the phenomena described and that of the shishi-odoshi (Fig. 4) were analyzed, and how the shishi-odoshi is specifically used to explain the mechanisms of phenomena was grasped.

(a) The tube begins to move. (b) Water begins to flow out. (c) The tube begins to return.

Fig.4. A Shishi-odoshi Found in Tonogayato Garden [13]

The analysis results were used to design the observational experiment using a mini shishi-odoshi in which students are expected to recognize the mechanisms of disasters as “state changes” and to explore the conditions at which such change of the shishi-odoshi occurs. The main bamboo tube and the two supports on the left and right were made from cut pieces of white bamboo (natural bamboo) sold for use as plant supports (approximately 20 mm in outer diameter). Holes were then drilled in both the main tube and the supports to pass a bamboo skewer through, and a mini shishi-odoshi was assembled. To help students understand that the threshold at which transitions between states occur is governed by interactions between the system and the environment, we developed an observational experiment in which clay weights are attached to the main tube of the mini shishi-odoshi and changes in its movement are observed [13].

In addition, to make grasping the effect of the flow of water inside the tube on the motion of the tube itself easier, we developed a supplementary observational experiment in which resin bullets flow inside transparent containers, similar to the water flow inside the bamboo tube of a shishi-odoshi [14]. The bottoms of two transparent cylindrical plastic containers were glued together, and holes for a bamboo skewer were drilled near the bottom of one of these. Resin bullets were placed inside each container, and the containers were attached to the support of the mini shishi-odoshi. When the tip of the lower container was slightly lifted, the bullets flowed and the containers were flipped upside down, as captured on video camera.

2.2 Results and Discussion

The literature in which the shishi-odoshi is used to explain the mechanisms of various complex phenomena, including disasters, is summarized in Table 1 [14]. In all cases, the transitions between two states were likened to the movement of a shishi-odoshi, such as non-collapse/collapse [7], non-combustion/combustion [8-12], non-eruption/eruption [15], wakefulness/sleep [16], and non-swallowing/swallowing [17]. The analysis revealed that the “shishi-odoshi” has been used to explain the mechanisms of various phenomena from the shared perspective of the balance between the functions that maintain the initial state and those that change the state.

Table 1. Literature Mentioning Shishi-odoshi in Explaining the Mechanisms of Phenomena [14]

Phenomenon	Matter and/or energy flowing into and out of the system	Reference
(Shishi-odoshi)	Water	[13]
Landslide	Soil	[7]
Ignition of combustibles	Heat	[8, 9]
Extinction of a candle flame	Heat	[10-12]
Volcanic eruption	Magma	[15]
Sleep	Sleep pressure	[16]
Swallowing	Food	[17]

Figs. 5 and 6 illustrate the responses of a mini shishi-odoshi attached with a clay weight of 3 grams, when water is dripped onto the opening of the tube “slowly without momentum,” using a graduated pipette. When the weight was attached to the tube on the opposite side from the opening across the fulcrum (rear), the weight demonstrated the function of maintaining the initial state (Fig. 5). The tube did not start moving until almost full of water, and even if it did start moving, the rotational speed and angular momentum did not increase, and it would quickly return to its original state once a small amount of water had flowed out. Conversely, when the weight was attached on the same side with the opening (front), the weight demonstrated the function of changing the state (Fig. 6). The tube began to rotate while there was still space inside the tube, and the water that had accumulated inside flowed toward the tip, thereby increasing the rotational speed due to the synergistic effect of the weight and water. This process, in which the consequences of initial changes promote further change, known as “positive feedback,” is crucial for understanding the mechanisms of climate change and fire spread.

(a) Tube begins to move. (b) Water begins to flow out. (c) Tube begins to return.

Fig.5. Shishi-odoshi Tube Motion (Weight Position: 9 cm Rear; Dripped Water Volume: 11.5 ml) [13]

(a) Tube begins to move. (b) Water begins to flow out. (c) Tube begins to return.

Fig.6. Shishi-odoshi Tube Motion (Weight Position: 5 cm Front; Dripped Water Volume: 6.5 ml) [13]

The response of a transparent shishi-odoshi-like experimental device containing resin bullets, when the tip of the lower container was lifted slightly and “slowly without momentum” is illustrated in Fig. 7 [14]. The shishi-odoshi-like movement was reproduced using transparent containers and granular bullets, and the video footage was then played back in slow motion, thereby making observation of the “positive feedback” involved in the rapid state change process easier.

(a) Lift the bottom to start moving. (b) Bullets inside flow. (c) Bullets keep flowing inside.

Fig.7. Movement of the Transparent Shishi-odoshi-like Experimental Device [14]

3. Observation Experiment on Convective Heat Transfer Focusing on the Momentum of Water

In the observation experiment using the mechanism of shishi-odoshi, the connection between mass and momentum was visually grasped. Next, to visually grasp that between heat and momentum, and as a starting point for systematically incorporating transport phenomena into the school science curriculum, we developed an observation experiment on convective heat transfer that focuses on the momentum of heated water rising.

3.1 Method

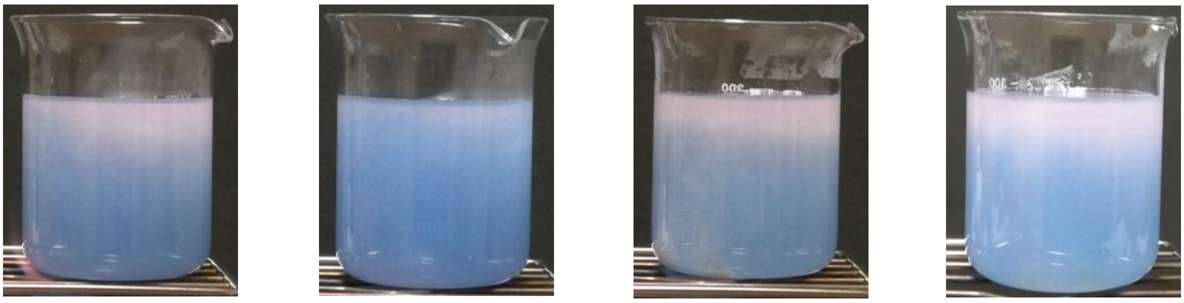
Following the teaching method for radiative heat transfer [18], the basic theory describing the motion of water in natural convective heat transfer was expressed as a set of simple propositions by utilizing science textbooks and fluid mechanics books.
To help students understand these propositions, observation experiments on convective heat transfer in water were conducted, in which the momentum of heated water rising was changed through varying the power of a gas burner or viscosity using familiar materials. After trial and error, 300 ml of water or 150 ml of water + 150 ml of laundry starch, 2 ml of thermochromic ink, and 2 drops of silver paint were put into a 300ml beaker, which was then heated on a science gas stove. The changes in color inside the beaker were recorded with a video camera.

3.2 Results and Discussion

A set of propositions that express the basic theory of the motion of objects and water relevant to the observation experiments of convective heat transfer are presented in Table 2. Propositions 2 and 3 express the conservation of the momentum of a fluid and the equation of motion of a fluid, respectively; neither is included in the current secondary science curriculum. Observation experiments on convective heat transfer conducted in science classes are based solely on Proposition 1, which leads to confusion regarding the distinction between water movement and heat transfer. To solve this problem, an understanding of viscous (frictional) forces is necessary.

Table 2. Propositions Expressing the Fundamental Theory on the Motion of Objects and Fluids

No.	Proposition	Reference
0	Sum of the momentum (= Mass × Velocity) of multiple objects exerting forces on each other remains constant if no external forces are acting (or if the sum is 0 even if an external force is acting).	[19]
1	When water is heated, its volume increases, and it is subjected to a vertical upward force (buoyancy).	[20] [21]
2	Because fluids are subject to pressure forces that vary depending on the location, the momentum of a fluid is expressed as the sum of "Mass × Velocity" and "Pressure × Cross-sectional area," and this sum is kept constant.	[22]
3	Force acting on a fluid is expressed as the sum of pressure, viscous force (frictional force), and external force.	[22]



(1) Large flame; 90 sec (2) Small flame; 6 min. (3) Large flame; 90 sec (4) Small flame; 6 min.
(a) 300 ml of water (b) 150 ml of water + 150 ml of laundry starch
Fig.8. Changes in Color Inside the Beaker in the Natural Convection Observation Experiment

Fig. 8 shows the changes in color inside the beaker filled with water (Fig. 8(a)) or the mixture of water and laundry starch (Fig. 8(b)), both mixed with 2 ml of thermochromic ink and 2 drops of silver paint, being heated on a science gas stove. The stove flame is located approximately 45° from the front of the beaker toward the left side of the images. When water was heated with a large flame, a pink-colored high-temperature layer developed quickly (Fig. 8(1)), whereas when heated with a small flame, the contribution of thermal diffusion was greater than the development of the high-temperature layer (Fig. 8(2)).
When laundry starch was added to increase the viscosity and the mixture was heated with a large flame, the penetration of the upward flow into the high-temperature layer (Fig. 8(1)), which was observed when water was heated with a large flame, did not occur (Fig. 8(3)). When laundry starch was added to increase the viscosity and heated over a small flame, a clear high-temperature layer

was observed (Fig. 8(4)), which was not observed when water was heated over a small flame (Fig. 8(2)).
The experimental equipment used for observing thermal convection made precise adjustment of the flame size and the heated area difficult. Therefore, careful observation of the experimental footage was necessary to determine the effects of viscosity and heating power on convection behavior. Improvements to the experimental method are desirable so that differences in results due to experimental conditions are easier to distinguish. Furthermore, using large amounts of laundry starch places a significant burden on the environment. Improvements to reduce the environmental impact are also desirable.

4. Conclusions and Future Work

To enhance structuring of science education and reduce discrepancies between the four fields (physics, chemistry, biology, and Earth science), we developed disaster model teaching materials for students to visually capture the connections between the three core concepts of mass, heat, and momentum.
Focusing on the “shishi-odoshi,” which was used to explain the mechanism of landslides, we assessed its versatility as a disaster model. The “shishi-odoshi” was an effective tool as a model to explain the mechanisms of various phenomena from the perspective of the balance between the functions that maintain the initial state and those that change the state. An observation experiment using the “state change” of a “shishi-odoshi” was developed for students to learn that the threshold for transitions between states is governed by the interaction between the system and the environment.
Furthermore, as a starting point for systematically incorporating transport phenomena, including the momentum of fluids which is not currently covered in secondary science, into the science curriculum, we developed an observation experiment on convective heat transfer, focusing on the momentum of rising water as it is heated.
As a next step, teaching strategies need to be developed to help students model the observation experiments conducted in this study from the perspective of the relationship between the system and surroundings. Then, through refining the model by adding transport processes that involve the core concepts of disaster science, we hope students’ interest in the fundamental scientific laws and microscopic perspectives will increase.

Notes

This paper is a reorganization of the content presented in [13] and [14], with significant additions and revisions.

REFERENCES

[1] Nomura Y. (2025) “Proposal for Earth Science Education Considering Human-Generated Heat Release in the Anthropocene,” JSSE Research Report, 40(1), 51-56.
[2] Nomura Y. (2026) “Exploring How Transport Phenomena are Addressed in the Four Fields of School Science,” JSSE Research Report, 40(4), 43-46 (in Japanese).
[3] Nomura Y. (2019) “Disaster Triangle: A Conceptual Device for Implementing Comprehensive and Continuous Disaster Education into School Science,” Japan Geoscience Union Meeting 2019, G01-P07.
https://researchmap.jp/NOMURA_Yuko/presentations/11744744?lang=en
(accessed 2026.03.08).
[4] Nomura Y. (2024) “Potential Adverse Effects of Insufficient Explanation of Greenhouse Gases in Science Education on Fire Safety Education,” JSSE Research Report, 39(1), 41-46.
[5] Nomura Y. (2025) “Designing a High School Science Curriculum in the Context of the Anthropocene for a Required Subject Integrating the Four Fields,” JSSE Research Report, 40(3), 41-44 (in Japanese).
[6] Cerwén G. (2019) “Listening to Japanese Gardens: An Autoethnographic Study on the Soundscape Action Design Tool,” Int. J. Environ. Res. Public Health, 16, 4648.
doi:10.3390/ijerph16234648
[7] Kyoto University (2016) “Shamen dosō no hattatsu to hōkai o ‘shishi-odoshi’ kara kangaeru: Sanchi saigai kagaku no saizensen [Considering the Development and Collapse of Slope Soil

Layers from the Perspective of 'Shishi-odoshi': The Forefront of Mountain Disaster Science]" (in Japanese).
https://www.kyoto-u.ac.jp/sites/default/files/embed/jaresearchresearch_results2016documents161025_101.pdf (accessed 2026.03.08).

[8] Nomura Y. (2020) "Development of Education Materials for Understanding Ignition of Solid Combustibles," JSSE Research Report, 35(1), 29-32 (in Japanese).

[9] National Research Institute of Fire and Disaster (2020) "Jikken eizō: Shishi-odoshi no ugoki o, kurabete miyou! [Experimental Video: Let's Compare the Movements of the Shishi-odoshi!]." https://nrifd.fdma.go.jp/public_info/kids/files/drawing_paper2.html (accessed 2026.03.09).

[10] Nomura Y. (2021) "Development of Education Materials for Understanding Extinction of Flames," JSSE Research Report, 35(5), 33-38 (in Japanese).

[11] National Research Institute of Fire and Disaster (2023) "Jikken eizō: Sagatta 'shishi-odoshi' ni mizu o sosogu to? [Experimental Video: What Happens If You Pour Water onto a Tilted 'Shishi-odoshi'?]."
https://nrifd.fdma.go.jp/public_info/kids/p6_combustion/review/files/candle_flame2.html (accessed 2026.03.09).

[12] National Research Institute of Fire and Disaster (2023) "Jikken eizō: 'Shishi-odoshi' to rōsoku no hi o kurabete miyou! [Experimental Video: Let's compare the 'shishi-odoshi' with a candle flame!]."
https://nrifd.fdma.go.jp/public_info/kids/p6_combustion/review/files/candle_flame3.html (accessed 2026.03.09).

[13] Nomura Y. (2025) "6 Gatsu no kagaku asobi bunka-kai: Shishi-odoshi kara manabu koto: Mini shishi-odoshi o tsukurou [June Science Play Workshop: Learning from Shishi-odoshi: Let's Make a Mini Shishi-odoshi]," Kodomo to kagaku yomi mono [Children and Science Books], Newsletter of the Japanese Society of Science Books for Children, No. 554, 10-14 (in Japanese).

[14] Nomura Y. (2025) "Shishi-odoshi no shikumi o katsuyō shita saigai moderu kyōzai no sakusei [Developing Disaster Model Teaching Materials Using the Mechanism of Shishi-odoshi]," the material distributed at the venue of the 75th National Conference of Society of Japan Science Teaching (revised August 28, 2025 version) (in Japanese).
https://researchmap.jp/NOMURA_Yuko/works/50938928?lang=en
(accessed 2026.03.08).

[15] Mannen K. (2022) "Fujisan wa itsu funka suru no ka? Kazan no shikumi to sono fushigi [When will Mount Fuji Erupt? Mechanisms of Volcanoes and Their Mysteries]," Chikumashobo (in Japanese).

[16] Yanagisawa M. (Supervisor) (2023) "Nyūton chō zukai Shinsho: Saikyō ni omoshiroi suimin [Newton's Super Illustrated New Book: The Most Interesting Sleep]," Newton Press (in Japanese).

[17] Sakai T. (Supervisor) (2023) "Nyūton kagaku no gakkō shirīzu: Jintai no gakkō [Newton Science School Series: Human Body School]," Newton Press (in Japanese).

[18] Hiraku N. & Tonishi S. (2025) "Teaching Method to Develop the Prior Understanding Necessary to Formulate a Hypothesis for Investigating the Relationship between Solar Altitude and Temperature," JSSE Research Report, 40(2), 209-212 (in Japanese).

[19] Miura N. et al. (2021) "Kaitei butsuri [Revised Physics]," Tokyo Shoseki (in Japanese).

[20] Arima A. et al. (2021) "Tanoshī rika 4-nen [Fun Science 4th Grade]," Dainippon Tosho (in Japanese).

[21] Miura N. et al. (2021) "Kaitei shinpen butsuri kiso [Revised New Edition Physics Basics]," Tokyo Shoseki (in Japanese).

[22] Kubota N. (2007) "Tokoton yasashī ryūtai rikigaku no hon [Thoroughly Easy Book on Fluid Mechanics]," Nikkan Kogyo Shimbun (in Japanese).