Role of Mathematical Modeling in Integrating Data Science, Computational Thinking, and AI within K-12 Mathematics Learning: Japanese Classroom Practice with Grade 7 Students

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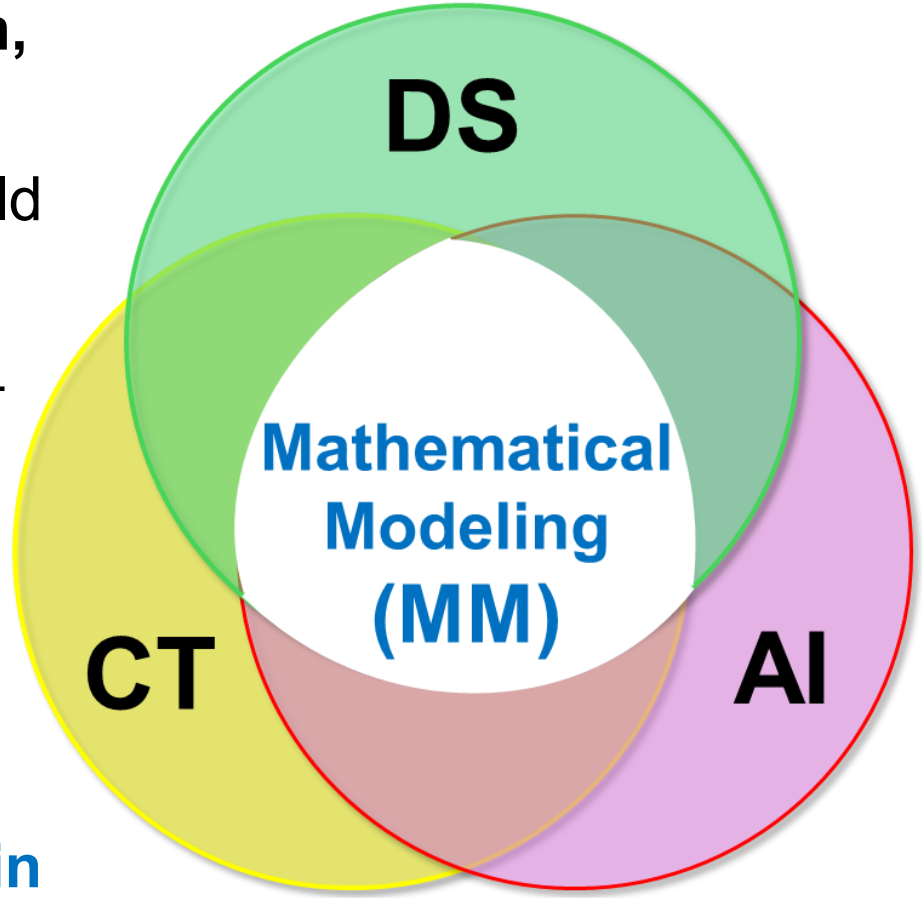
Why focus on mathematical modeling (MM)?

- **MM** is **a scientific process** **involving the generation, evaluation, and revision of mathematical models** that represent mathematical structures within real-world phenomena to describe, explain, and predict them (COMAP & SIAM, 2019; Lesh & Zawojewski, 2007; Niss et al., 2007).
- **MM** is **interdisciplinary** practice and can be regarded as **a boundary object** of data science (**DS**), computational thinking (**CT**), and **AI** (Ang, 2021; Biehler et al., 2025; Kawakami & Spooner, 2025).
- **MM** is now incorporated into **mathematics curricula in many countries** including **Japan**.

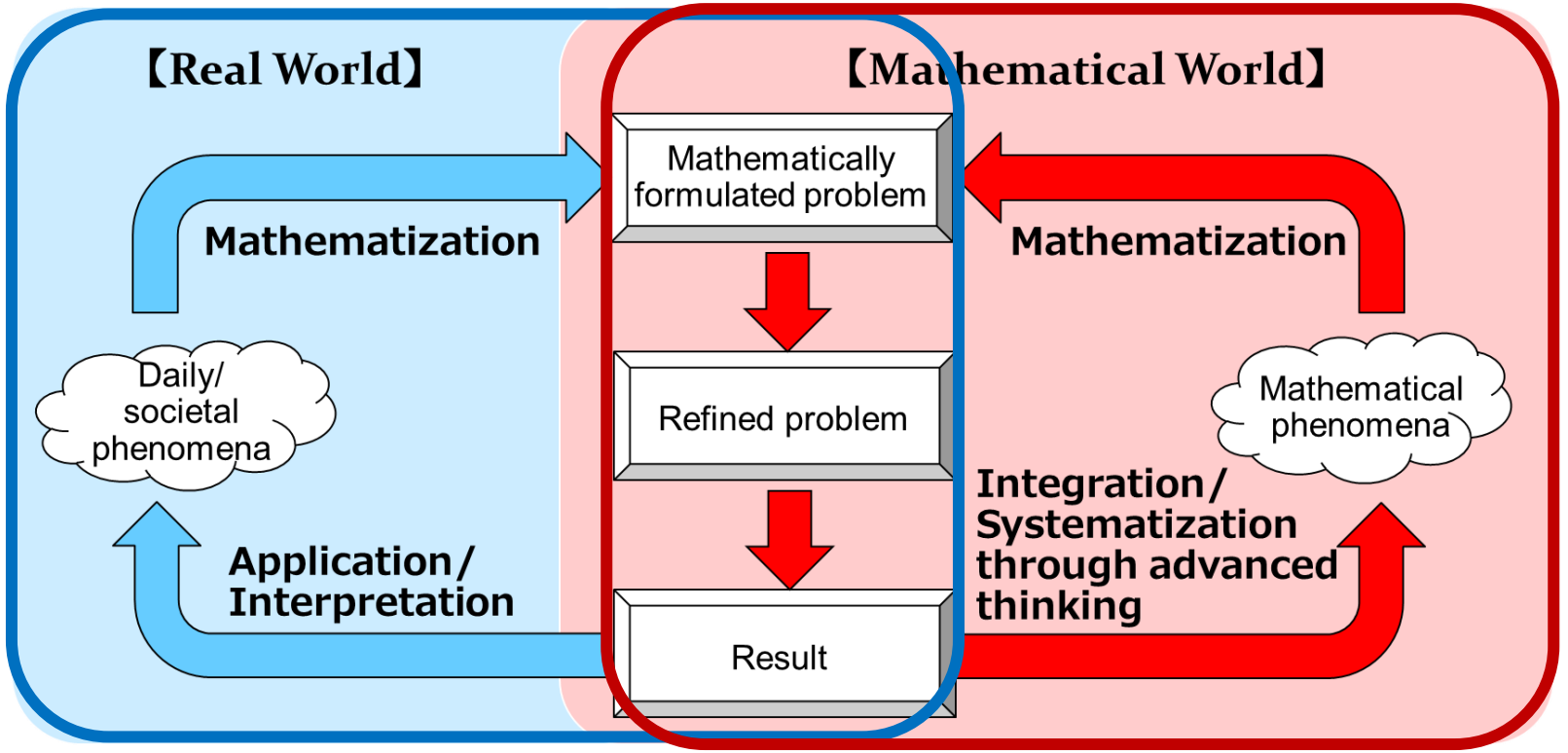


MM in mathematics national curriculum in Japan

- The current Japanese mathematics curriculum for elementary, lower secondary, and upper secondary schools emphasizes **MM** as a part of **"mathematical activities"** (Ministry of Education, Culture, Sports, Science and Technology [MEXT], 2018).

A model of "mathematical activities" (MEXT, 2018; English translation by Saeki, Kawakami, & Ikeda, 2025)

MM



Mathematical concept development

Example of Japanese MM lessons with an unplugged DS task

(DaMMS project, Grade 7)

- Task and activity design aligned with **the model of "mathematical activities"**.
- Part of "**da**ta, **m**odels, and **m**odeling in **S**TEAM" (**DaMMS**) research project (JSPS KAKENHI No. JP25K00852) led by Kawakami.
- Implemented as **a collaborative professional development program** between a math **teacher** and a math education **researcher**.

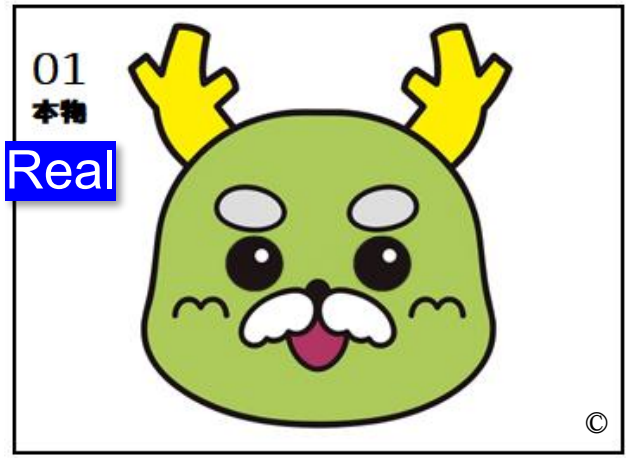
- **Purpose:** Provide age-appropriate **data-based MM experiences** in **"an unplugged machine-learning context"** (e.g., Fleischer & Biehler, 2025; Podworney et al., 2025; Lindner et al., 2019).
- **Participants:** A **Grade 7 class** in Japan, comprising students aged 12 to 13 (n = 34).
- **Duration:** Five 50-minute lessons in mathematics classrooms.

Unplugged image classification task (DaMMS project, Grade 7)

Recently, several characters have been introduced that are similar to our school mascot. This has raised questions about whether it is real or fake and has sparked a debate.

Therefore, we are asking you to develop and represent a classification method using image cards, which will convince others.

Junior high school mascot

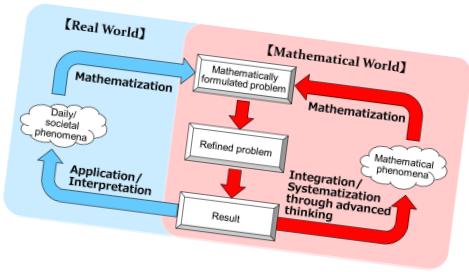


Real

…

Fake

…



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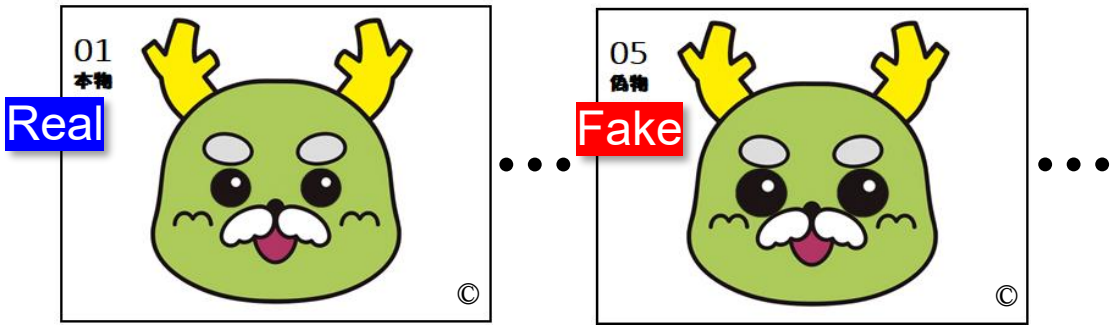
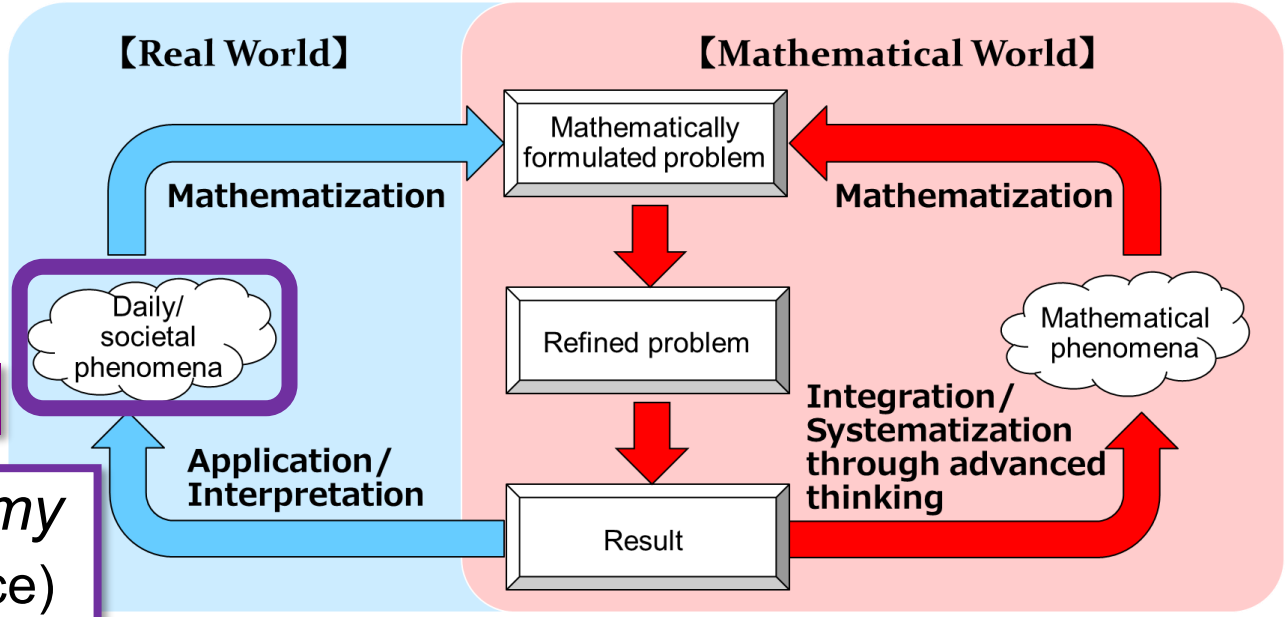


Daily/societal phenomena

"I often incorporate daily phenomena into my regular math lessons" (The teacher's utterance)



MEXT (2018)

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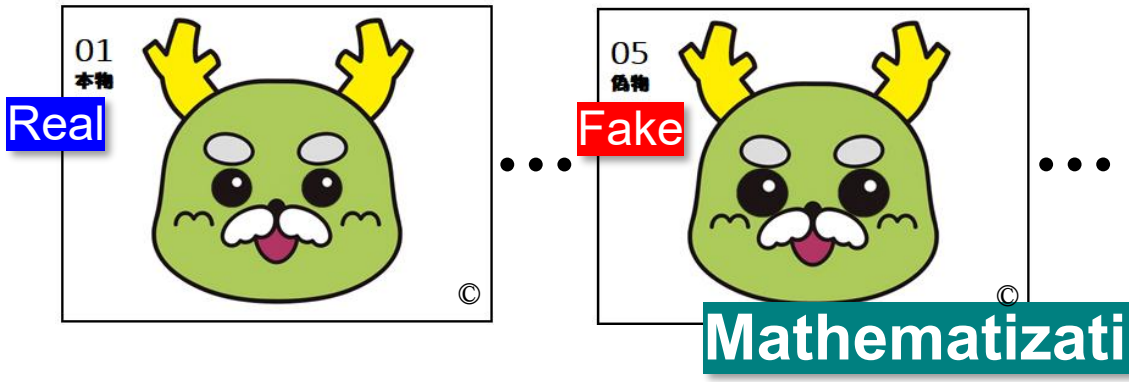

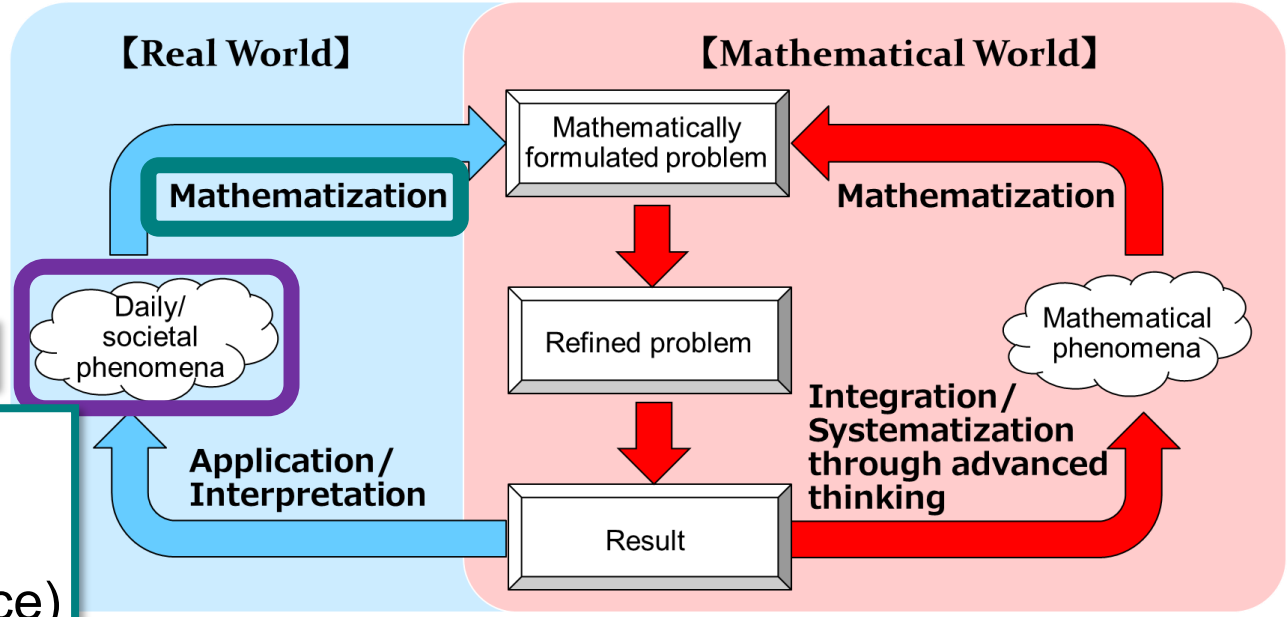

"As data are provided in my statistics lessons, generating numbers or data from nowhere is attractive" (The teacher's utterance)

MEXT (2018)

Unplugged image classification task (DaMMS project, Grade 7)

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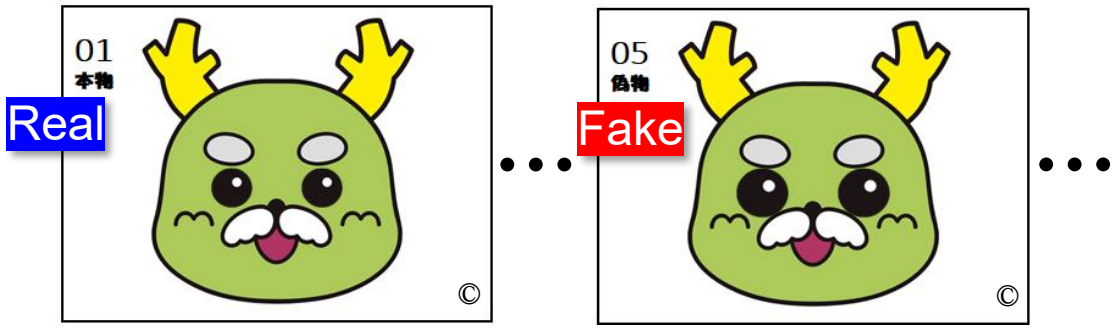
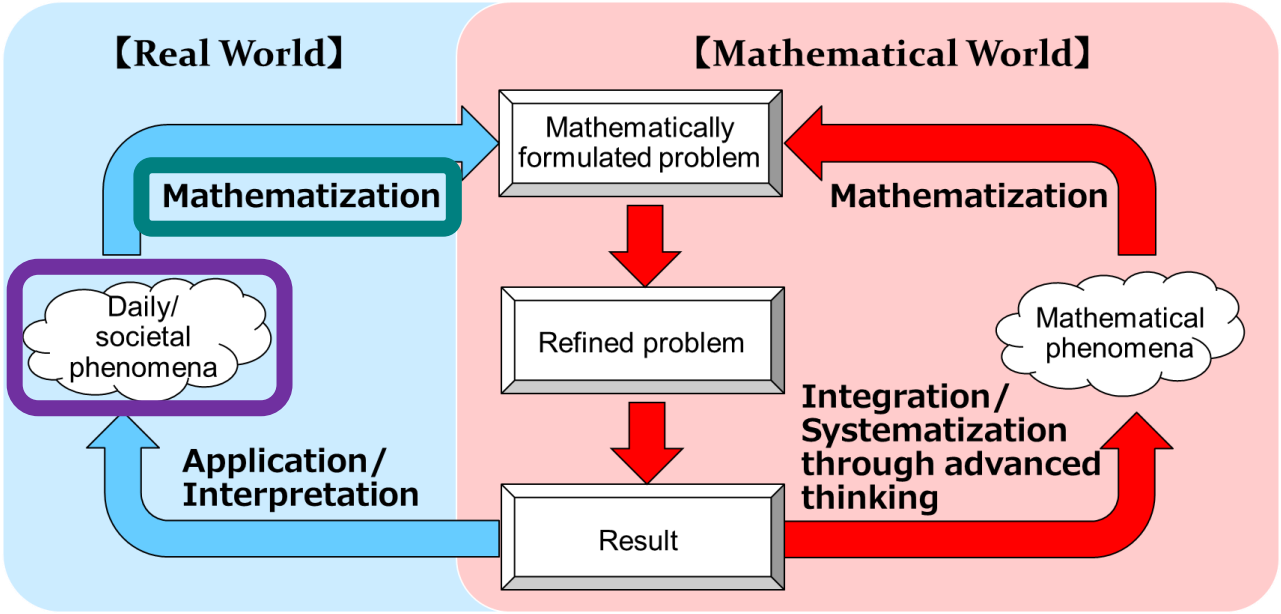
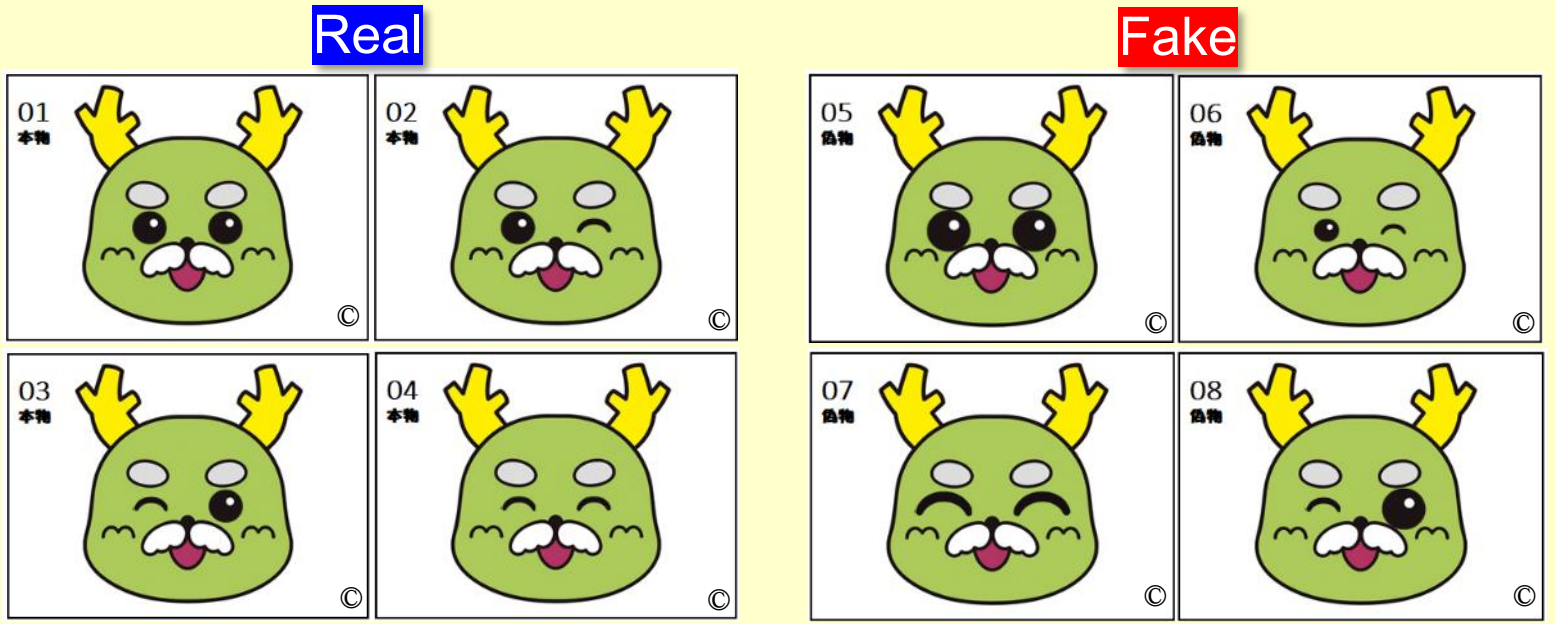


"The ability to mathematize daily[/societal] phenomena has long been emphasized as a goal of mathematics education in Japan."
(MEXT, 2018, p. 25)

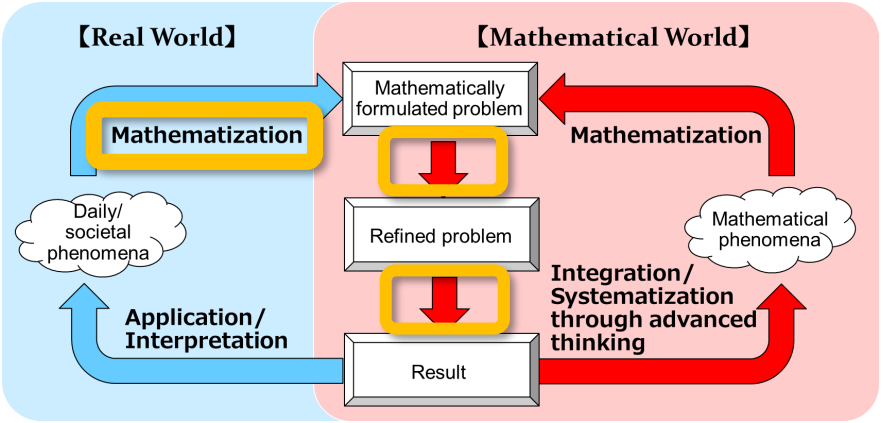


MEXT (2018)

MM activities of students (DaMMS project, Grade 7)



Variables set by the teacher:
Eye width (quantitative)
Eye opening/closing (qualitative)



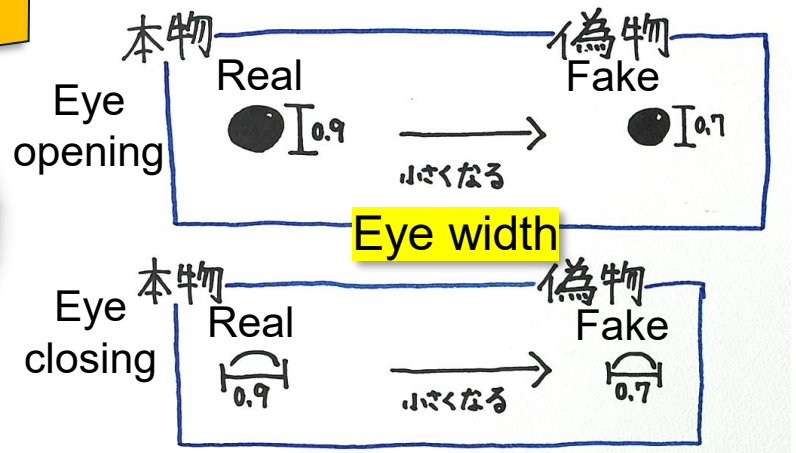
MEXT (2018)

Mathematization and processing

Generating and selecting variables

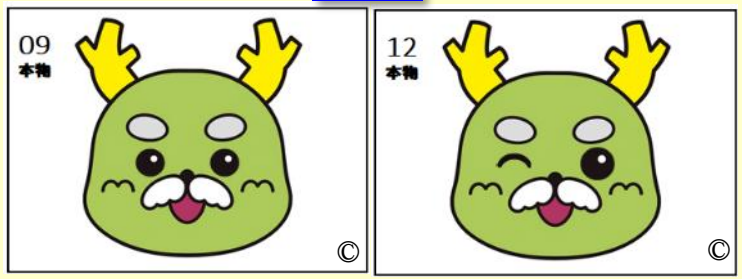
Measuring and generating data

Example of classification model

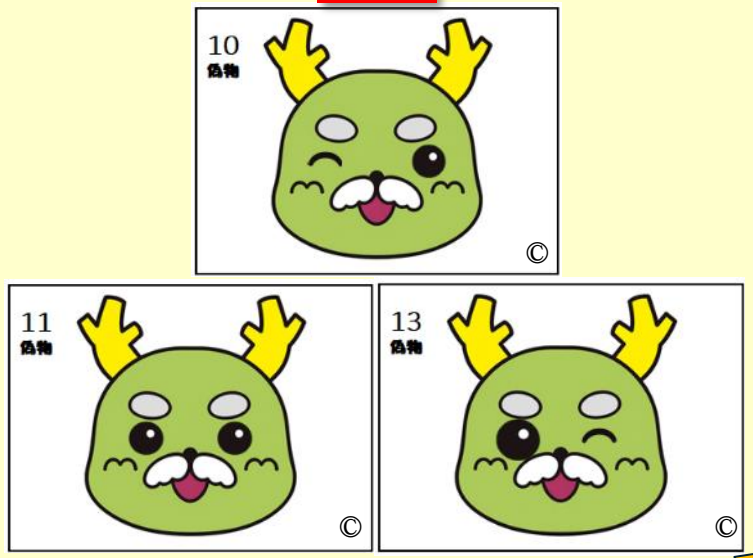


MM activities of students (DaMMS project, Grade 7)

Real



Fake



Variables set by the teacher:
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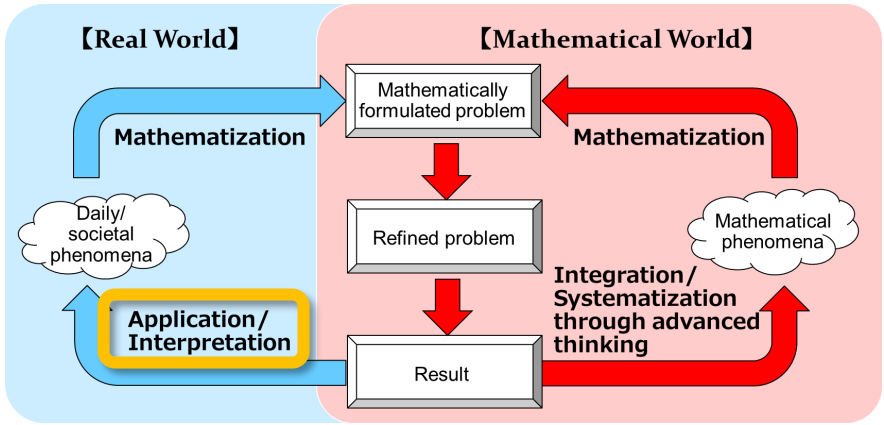
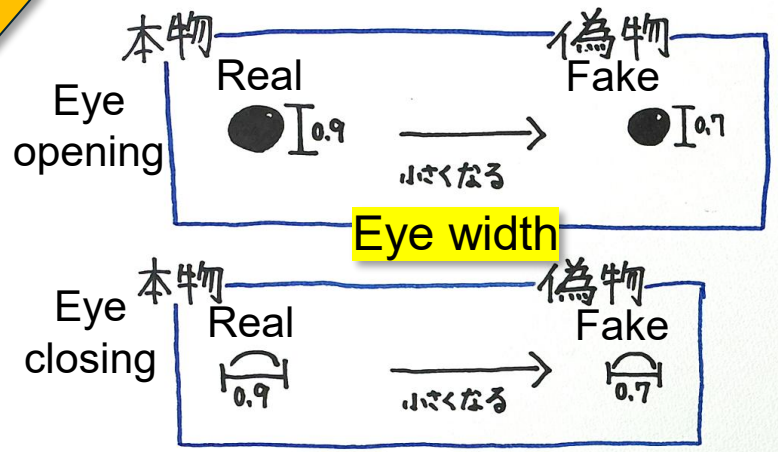
Eye opening/closing (qualitative)
Distance between eyes (quantitative)



MEXT (2018)

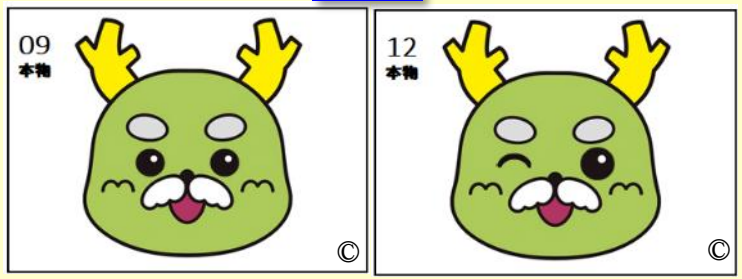
Application

Example of classification model

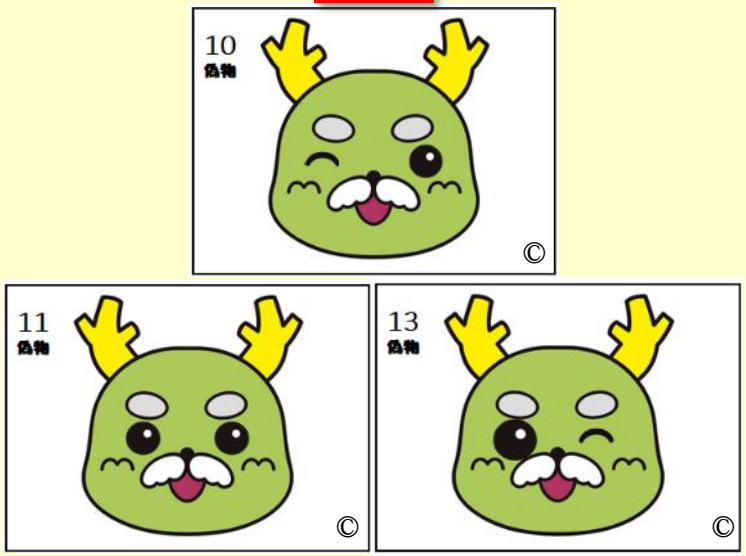


MM activities of students (DaMMS project, Grade 7)

Real



Fake



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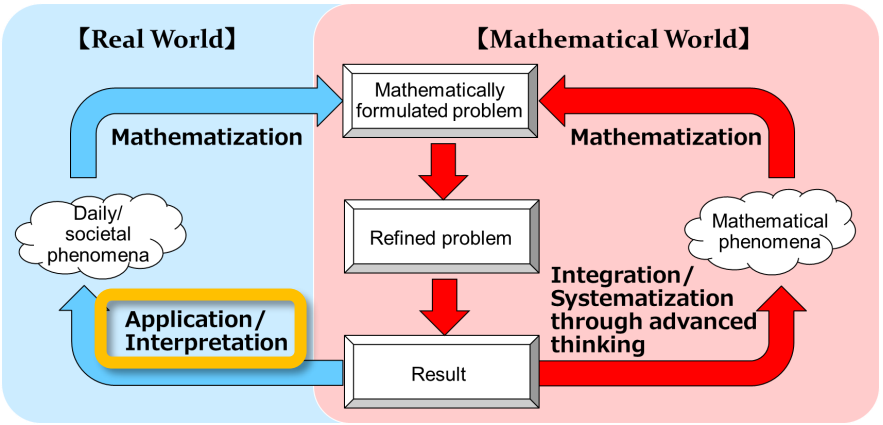
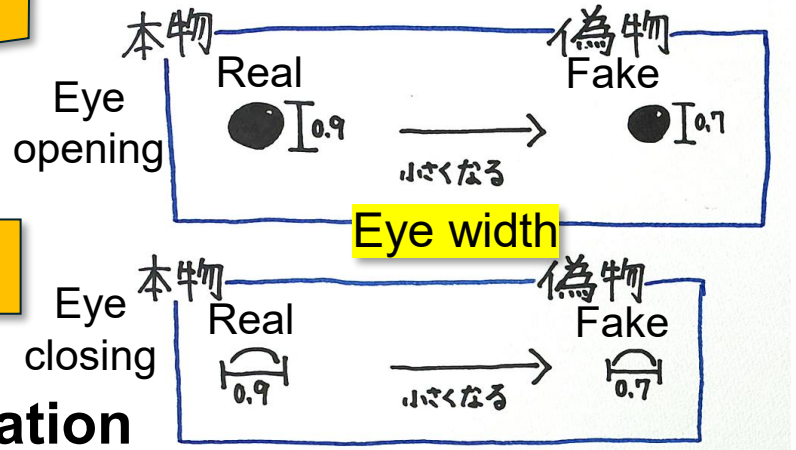
Eye opening/closing (qualitative)
Distance between eyes (quantitative)



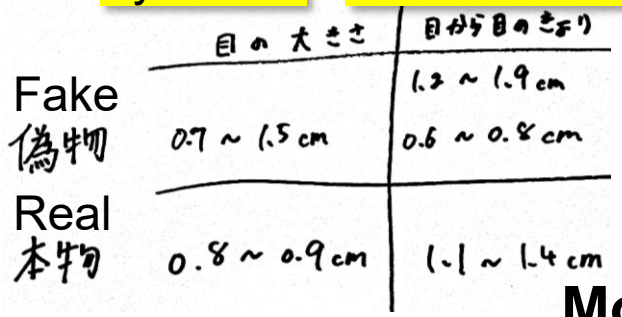
MEXT (2018)

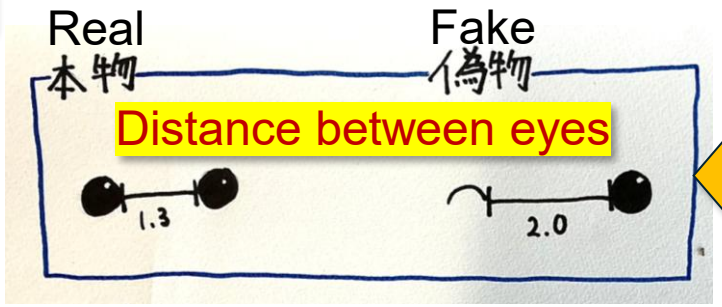
Interpretation/Validation

Example of classification model



Eye width | Distance between eyes





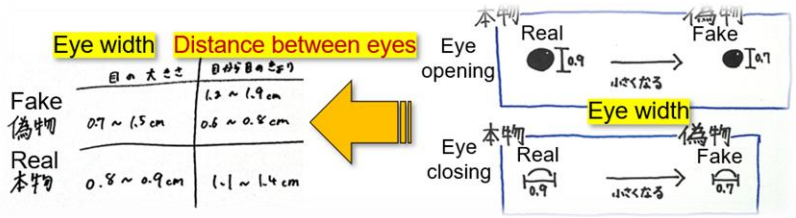
Modification

Modification

Potential of MM as an instructional approach integrating core topics in DS, CT, and AI into K-12 mathematics learning

(see also Kawakami & Saeki, 2024a, 2024b; Kawakami & Spooner, 2025)

Reinterpreting and leveraging MM included in existing math curriculum



Validation pursuing shareability and generalizability of models

DS

Highlighting data generation and data-driven activities

Mathematization (i.e. variable generating and selecting)

Mathematical Modeling (MM)

CT

Highlighting algorithmic representations and reasoning

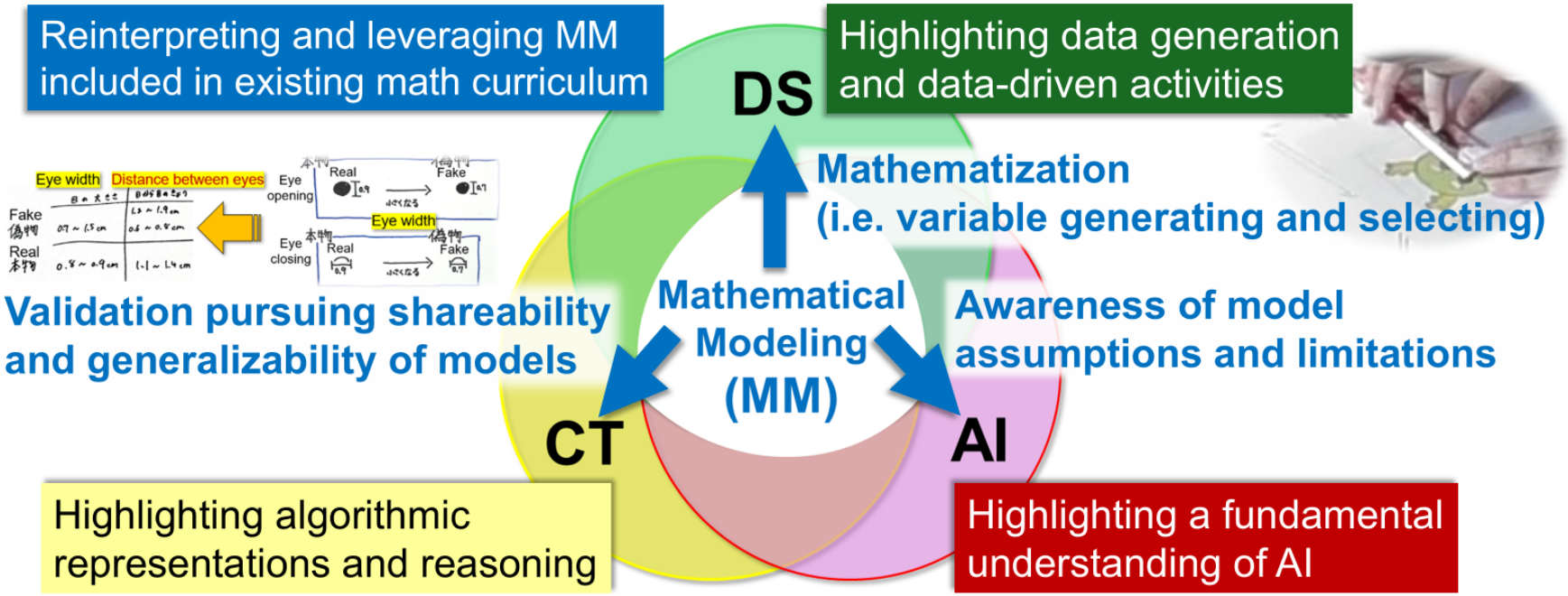
AI

Awareness of model assumptions and limitations

Highlighting a fundamental understanding of AI

A challenge for Japan…

- **Aligning the core topics of DS, CT, and AI with the future math curriculum**, which is crucial for enabling **many teachers** to incorporate **such teaching practices into their regular math lessons**.



Appendix: Japanese examples of professional learning related to MM, statistics, and DS in K-12 mathematics

- **Providing educational resources** (e.g., tasks, lesson plans, principles, instructional videos)

(e.g.)

- ***"Handbook of lesson study for mathematical modeling"*** from research project (JSPS KAKENHI No. JP25350204): For teaching **MM** (see also Saeki et al., 2023)
- ***"A collection of high school lesson examples for cultivating mathematical literacy"***, published by Ministry of Education, Culture, Sports, Science and Technology (MEXT): For teaching **MM** & **statistics** **(not limited them)**
- ***"DS toolkit" in Inquiry Project for High Schools*** led by Tokyo Gakugei University: For teaching **statistics** & **DS**
- ***"Classroom practices for decision-making and consensus-building using mathematical sciences"*** from research project (JSPS KAKENHI No. JP20H01739): For teaching **MM**, **statistics**, & **DS** **(not limited to them)**

- **Holding seminars and workshops on teaching statistics and DS (containing AI & CT in part)**

(e.g.)

- ***Japan Conference on Teaching Statistics (JCOTS)*** led by Stat Edu Committee of the Japan Statistical Society
- ***Japan Data Science in Schools Project (JDSSP)*** led by high school teachers and advised by researchers

- **Implementing certification exam on knowledge and application skills in statistics and DS**

(e.g.)

- ***Japan Statistical Society Certificate (JSSC)***

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