10:30-12:00 諸外国から見た日本の理科授業

Current Status and Research of Science Education in Taiwan

Science Education: Perspectives from a U.S. Researcher

Research interests

Science Modeling	Learning Technologies
Computer Supported Collaborative Learning(CSCL)	Scientific Epistemology

12-Year Basic Education Curricula in Taiwan

Directions Governing for the 12-Year Basic Education Curricula are scheduled to be implemented in August 2018.

Vision

Empowering Each Child: Nurturing individual Potential and Facilitating Lifelong Learning

Future Directions

Guided by the Directions and through joint efforts, curriculum reforms are an ongoing process, and are expected to achieve the following:

Curricular Refinement

Through discussion with stakeholders, schools may develop an appropriate curriculum plan, establish schoolbased courses, and continuously refine curricula.

Instruction Enrichment

Teachers should conduct co-lesson planning and openclassroom teaching,form professional communities, and employ multiple instruction and assessment strategiesnrich instruction.

Engagement in Learning

Learners are willing and able to learn autonomously. The Directions promote learners'engagement and encourage hands-on practice, project-based exploration,and showcase of learning outcomes.

Main Features

Figure: A Wheel-in-Action Diagram of Essential Literacies.

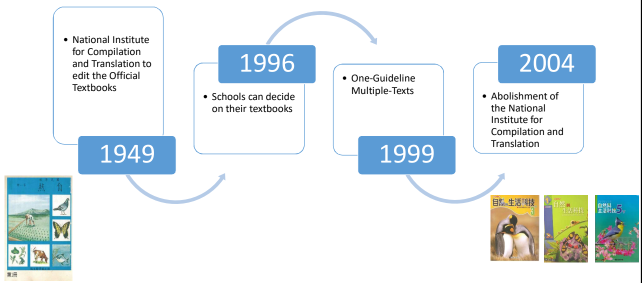
THE DIRECTIONS PROMOTE LEARNING PROGRESSION AS WELL AS CROSS-FIELD INTEGRATION FOR THE FIRST TIME
The Directions apply to elementary schools, junior high schools, and senior high schools. The Directions strengthen a learning transition from elementary schools up to junior high schools and senior high schools. The Directions focus on the cross-field curriculum design, which ensures comprehensive learning among students of all kinds.

THE DIRECTIONS EMPHASIZE THE APPLICATION OF LEARNED KNOWLEDGE TO REAL-LIFE SCENARIOS.
The Directions adopt essential literacies as a pivot for curriculum design and development, and stress that learning should highlight learners' individual development in learning strategies and approaches, and application of learning. This helps to ensure all-around development of learners.

THE DIRECTIONS HIGHLIGHT SCHOOL-BASED CURRICULUM DEVELOPMENT.
The Directions encourage schools at all levels to develop school-based curriculum to bring out their unique features by integrating school visions with community resources.

SCHOOLS AT ALL LEVELS SHOULD PROMOTE AND IMPLEMENT PERSONALIZED LEARNING.
The Directions highlight individuality of learners, development in learners' multiple intelligences and diverse interests. The Directions advocate designing holistic courses tailored for personalized learning.

Evolution of Science Textbooks

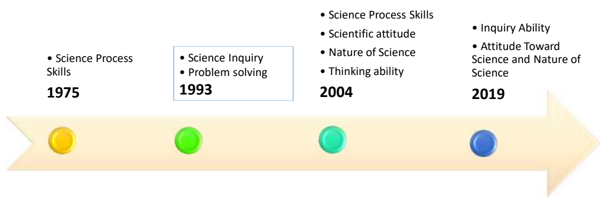


Change in the hours of teaching Science

Grade 1-9 Curriculum Guidelines							
	Science and Technology		Science and Technology		Science and Technology		
	Biology	Technology	Physics and Chemistry	Technology	Physics and Chemistry	Technology	Earth Science
7	3/week	1/week					
8			3/week	1/week			
9					2/week	1/week	1/week

12-Year Basic Education Curricula							
	Science						
	Biology	Physics and Chemistry	Earth Science	Physics	Chemistry	Science Inquiry and Practices (1)	Science Inquiry and Practices (2)
7	3/week						
8		3/week					
9		2/week	1/week				
10-12	2 credit* 8 credit**		2 credit* 4 credit**	2 credit* 10 credit**	2 credit* 10 credit**	2 credit*	2 credit*

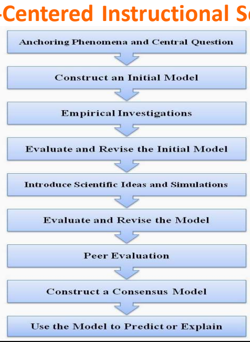
*Compulsory **Elective Subject



Learning Performance in Science

Area		Sub-area	
Inquiry Ability	thinking ability (t)	imagination and creativity (i)	ti
		reasoning and argumentation (r)	tr
		critical thinking (c)	tc
		modeling (m)	tm
	problem solving (p)	observing and identifying (o)	po
		planning and executing (e)	pe
		analyzing and finding (a)	pa
		discussing and communicating (c)	pc
Attitude Toward Science and Nature of Science (a)	interest in science (i)		ai
	habit of scientific thinking and inquiry (h)		ah
	nature of science (n)		an

Model-Centered Instructional Sequence



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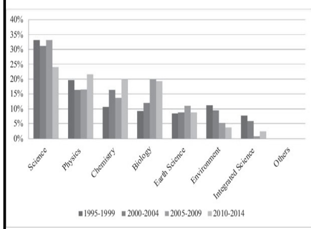
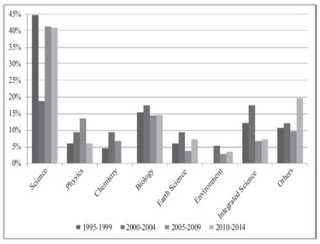
Major Academic Associations and Research Journals of Science Education in Taiwan

Association/Publisher	*Starting Year*	*Research Journal*	*Publishing Year*
Association of Science Education in Taiwan	1988	Chinese Journal of Science Education	1993-
National Science Council	1957	Proceedings of the National Science Council, R.O.C., Part D: Mathematics, Science and Technology Education	1991-2002
Ministry of Science and Technology (Formerly National Science Council)	2014	International Journal of Science and Mathematics Education	2003-
National Taiwan Normal University	1967	*Journal of National Taiwan Normal University (Mathematics & Science Education)*, combined with Education and renamed as *Journal f Research in Education Science* in 2009	1997-2008
The Physics Education Society of the R.O.C.	1975	Chinese Physics Education	1997
Chemical Society Located in Taipei	1950	Chemistry Education in Taiwan	2014
The Biological Society of China	1959	Chinese Bioscience	2003-2012
Chinese Society for Environmental Education	1992	Journal of Environmental Education Research	2003

Longitudinal Changes in "Research Subject Areas"

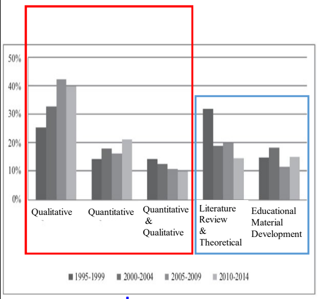


Japan

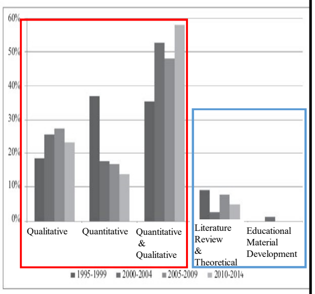


Taiwan

Longitudinal Changes in "Research Methods"

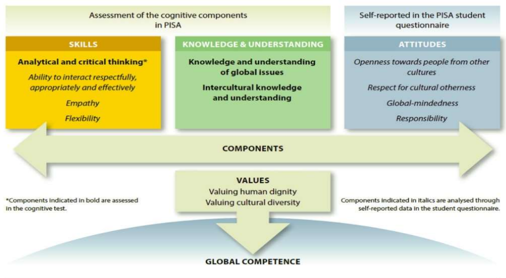


Japan



Taiwan

The dimensions of the proposed assessment of Global Competence



https://www.oecd.org/pisa/aboutpisa/Global-competency-for-an-inclusive-world.pdf

Snapshot of performance in science, reading and mathematics

	Science		Reading		Mathematics		Science, reading and mathematics	
	Mean score in PISA 2015	Average three-year trend	Mean score in PISA 2015	Average three year trend	Mean score in PISA 2015	Average three-year trend	Share of top performers in at least one subject (Level 5 or 6)	Share of low achievers in all three subjects (below Level 2)
	Mean	Score dif.	Mean	Score dif.	Mean	Score dif.	%	%
OECD average	493	-1	493	-1	490	-1	15.3	13.0
Singapore	556	7	535	5	564	1	39.1	4.8
Japan	538	3	516	-2	532	1	25.8	5.6
Estonia	534	2	519	9	520	2	20.4	4.7
Chinese Taipei	532	0	497	1	542	0	29.9	8.3
Finland	531	**-11**	526	**-5**	511	**-10**	21.4	6.3

https://www.oecd.org/pisa/aboutpisa/Global-competency-for-an-inclusive-world.pdf

Snapshot of students' science beliefs, engagement and motivation

	Mean science score	Beliefs about the nature and origin of scientific knowledge		Share of students with science-related career expectations			Motivation for learning science			
		Index of epistemic beliefs (support for scientific methods of enquiry)	Score-point difference per unit on the index of epistemic beliefs	All students	Boys	Girls	Increased likelihood of boys expecting a career in science	Index of enjoyment of learning science	Score-point difference per unit on the index of enjoyment of learning science	Gender gap in enjoyment of learning science (Boys - Girls)
	Mean	Mean index	Score dif.	%	%	%	Relative risk	Mean index	Score dif.	Dif.
OECD average	493	0.00	33	24.5	25.0	23.9	1.1	0.02	25	0.13
Singapore	556	0.22	34	28.0	31.8	23.9	1.3	0.59	35	0.17
Japan	**538**	**-0.06**	**34**	**18.0**	**18.5**	**17.5**	**1.1**	**-0.33**	**27**	**0.52**
Estonia	534	0.01	36	24.7	28.9	20.3	1.4	0.16	24	0.05
Chinese Taipei	**532**	**0.31**	**38**	**20.9**	**25.6**	**16.0**	**1.6**	**-0.06**	**28**	**0.39**
Finland	531	-0.07	38	17.0	15.4	18.7	0.8	-0.07	30	0.04

https://www.oecd.org/pisa/aboutpisa/Global-competency-for-an-inclusive-world.pdf

Science Education: Perspectives from a U.S. Researcher

Jeanna R. Wieselmann

My Research in Japan

- National Science Foundation (NSF) Fellowship
- Research in Japan for 3 months through partnership with Japan Society for the Promotion of Science (JSPS)
  - Shizuoka University
  - Professor Yoshisuke Kumano

U.S. Education Background

- Public education controlled by individual states
  - Standards
  - Curriculum
  - Courses
  - Teaching methods
  - Textbooks
- Some states give power to local school districts
  - Over 25,000 school districts in the U.S.

Current Challenges

- Low science scores
  - 50% proficiency in science
- Disparities between groups of students
  - Gender
  - Race/ethnicity
  - Socioeconomic status
  - Language

Science Reform

- 1950s-1970s: Space Race
  - National security and international competition
- 1983: A Nation at Risk
- 1989: Science for all Americans
- 1993: Benchmarks for Scientific Literacy
- 1996: National Science Education Standards

NGSS Background

- 2011: A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas
  - National Research Council
  - Built on 1996 National Science Education Standards
  - Includes ideas and practices of engineering
- 2013: Next Generation Science Standards (NGSS)
- December, 2016: 18 states and the District of Columbia had adopted the NGSS

Practices

PRACTICES FOR K-12 SCIENCE CLASSROOMS
1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

Disciplinary Core Ideas

- Key ideas in science with broad importance
- Key tool for understanding more complex ideas
- Increasing depth across grade levels
- Example: Matter and Its Interactions

How NGSS is Different

- Standards expressed as **performance expectations**
  - Combine practices, core ideas, and crosscutting concepts
  - Identify what should be assessed
  - Describe end goals of instruction

Performance Expectations

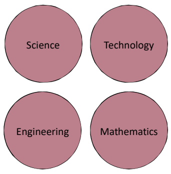
MS-PS1-2 Matter and its Interactions		
Students who demonstrate understanding can: MS-PS1-2. **Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.** [Clarification Statement: Examples of reactions could include burning sugar or steel wool, fat reacting with sodium hydroxide, and mixing zinc with hydrogen chloride.] [*Assessment boundary: Assessment is limited to analysis of the following properties: density, melting point, boiling point, solubility, flammability, and odor.*]		
The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:		
Analyzing and Interpreting Data Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings. ***Connections to Nature of Science*** **Scientific Knowledge is Based on Empirical Evidence** • Science knowledge is based upon logical and conceptual connections between evidence and explanations.	**PS1.A: Structure and Properties of Matter** • Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. **PS1.B: Chemical Reactions** • Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.	**Patterns** • Macroscopic patterns are related to the nature of microscopic and atomic-level structure.

NGSS Adoption

- December, 2016: 18 states and the District of Columbia had adopted the NGSS
- Barriers
  - Teacher Training
  - Need for curricular resources
  - Time to revise standardized tests
  - No financial incentives to adopt

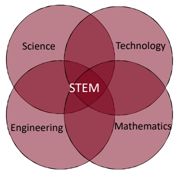
Science, Technology, Engineering, and Mathematics (STEM)

- Science, technology, engineering, and mathematics as separate subjects



Science, Technology, Engineering, and Mathematics (STEM)

- STEM subjects are integrated



14:30-16:30 諸外国の理科教育研究/共同研究の可能性

Experiences of designing and implementing model-based instruction in Taiwan

Gender and STEM: Research Overview

Models and Modeling in Science Education

- Promoting students' understanding of models and modeling is one of the major goals of science teaching (National Research Council, 1996, 2007, 2012).

Modeling in NGSS

- The Next Generation Science Standards (NGSS) suggests during middle school
  - Develop a model to describe unobservable mechanisms
  - Develop and use a model to describe phenomena.
  - Models can be used to represent systems and their interactions

Theoretical perspective

- Understanding of models and modeling is part of the nature of science
- Understanding of models and modeling is a major subscale within modeling competence (Nicolaou and Constantinou, 2014)
  - Modeling practices
  - Meta-knowledge

Model competence framework

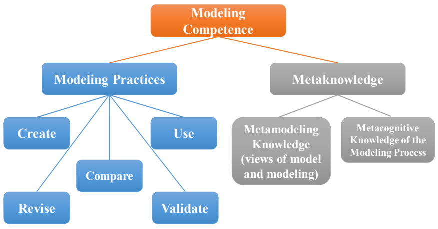


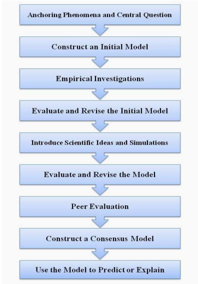
Fig. 1. The modeling competence framework.

Nicolaou, C.T., & Constantinou, C.P. (2014). Assessment of the modeling competence: A systematic review and synthesis of empirical research. *Educational Research Review, 13*, 52-73.

Sequence of teaching and modeling procedure

- Based on inquiry: questioning, hypothesizing, investigating, analyzing, modeling, and evaluating (Schwarz & White, 2005)
- EIMA: engaging, investigating, modeling, and applying (Schwarz & Gwekwerere, 2007)
- Based on scientific reasoning: analysis, reasoning, explanation, and evaluation (Sins, Savelsbergh and van Joolingen, 2005)

Model-Centered Instructional Sequence



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Study 1: The impact of models-based teaching on the different science competence

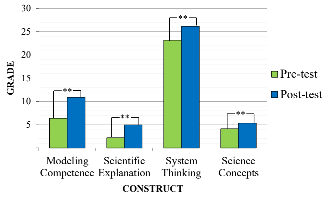
Goals of the curriculum design

- Modeling practice
- System thinking
- Understanding of models and modeling
- Understanding of science concepts

Model-based Teaching in Earth Science

- Two classes of ninth grade students
- 10-hours of model-based curriculum based on the MIS model
- Students were engaged in experiments, reading, and discussion
- Students construct drawings of a model the “El Nino”

Students' growth



Study 2: The effects of model-based curriculum design on the students' understanding of models and modeling

Research Inquiry

- Teachers have difficulty to understand and design model-based curriculum.
- Researchers have not linked the design aspects of the curriculum and instruction to the effects students' understanding of models and modeling.

Importance of students' understanding of models and modeling

- Engaging students in model-based activities can improve their understanding of models and modeling (Schwarz et al., 2009).
- Students' advanced understanding of models and modeling support their use and creation of models for learning science (Gobert et al., 2011; Sins, Savelsbergh, van Joolingen, & van Hout-Wolters, 2009).

Teachers

- Two middle school teachers participated
  - Teacher A: earth science and biology teacher (5 years of teaching experience)
  - Teacher B: biology teacher (8 years of teaching experience)
- The two teachers involved in curriculum design, teaching, and reflecting upon teaching

Curriculum design

- The modeling activities were based on the Model-Centered Instructional Sequence (Baek et al., 2011).
- The students were engaged in a series of activities consisting of investigation, reading, discussion, model building and model revision.
- The content area
  - Earth science curriculum: model of El Nino
  - The first and second Fishery: marine ecology and fishery sustainability.

Goals of the curriculum design

- Modeling practice
- Understanding of models and modeling
- Understanding of science concepts

Instrument

- Students' Understanding of Models in Science (SUMS) Survey (Treagust, Chittleborough, & Mamiala (2002).
  - 27 items
  - five constructs
  - five-point Likert scale

Constructs in SUMS

- models as explanatory tools (ET)
- models as exact replicas (ER)
- multiple representations (MR)
- the changing nature of scientific models (CNM)
- how scientific models are used (USM)

Sample questions

- Models are used to show an idea. (ET)
- A model needs to be close to the real thing. (ER) (reversed)
- Many models show different parts of an object or show the objects differently. (MR)
- A model can change if new theories or evidence prove otherwise. (CNM)
- Models are used to make and test predictions about a scientific event. (USM)

Data analyses

- Confirmatory factor analysis (CFA) was performed to confirm the reliability and validity of the questionnaire.
- T-tests were performed to understand the differences between the posttest and pretests results.
- ANCOVA tests were performed to investigate the extent to which the results in the three curricula differ.

Evolution of the curriculum design

	Duration of the curriculum	Nature of Model	Constructed Model	Modeling Cycle
Earth Science	12 hrs	implicit	drawings	one model (three times)
1st Fishery	9 hrs	explicit	concept map	one model (three times)
2nd Fishery	14 hrs	explicit	concept map; food web	two models (three times each)

Changes in teaching practices

- During the earth science curriculum
  - Teacher A thought it was not necessary to use the reading material for the Nature of Models and Modeling even though the material was available at that time
  - Teacher A explained briefly and verbally “what is a model” and the process of modeling
  - Teacher A was not fully comfortable with using the wording of models and modelling and discussions about models were limited

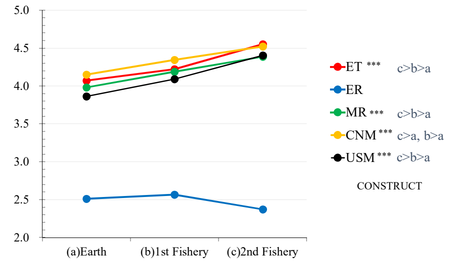
Changes in teaching practices

- During the1st Fishery curriculum
  - Enhanced the teacher professional development
  - Both Teacher A and Teacher B used the reading material for the Nature of Model and Modeling
  - Instruction regarding the nature of model and modeling followed by a whole class dicussion
  - But both teachers rarely mentioned models or modeling during the rest of the curriculum.

Changes in teaching practices

- During the 2nd Fishery curriculum
  - Teacher B used the reading material for the Nature of Model and Modeling
  - Whole class discussion regarding the nature of model and modeling
  - Teacher B emphasized the epistemic goals of building models when the students were revising the models

Comparison between the three curricula



Conclusions

- ET and USM improved in all three curricula.
- The students showed no improvements in the understanding of ER construct.
- As the instruction and curriculum design improved, students’ understanding of models and modeling seemed to progress further.

Gender and STEM: Research Overview

Jeanna R. Wieselmann

Statement of the Problem

Increase in STEM jobs (Vilorio, 2014)

- Underrepresentation of females in STEM fields (NSF, 2015)
- Decreasing STEM interest after elementary school (Turner et al., 2008)
- Reduced time for science in formal school settings (CEP, 2007)

Theoretical Framework

- Social Cognitive Career Theory (Lent et al., 1994)
  - Career interests influenced by individuals' self-efficacy and perceived likelihood of positive outcomes
  - Gender differences in self-efficacy as early as first grade (Eccles, Wigfield, Harold, & Blumenfeld, 1993)
- Mindset (Dweck, 2000)
  - Growth mindset: belief that effort can make people smarter
  - Fixed mindset: belief that intelligence is innate

Research Questions

- How do elementary girls perceive STEM following their experience at STARBASE Minnesota?
- How do elementary girls perceive themselves and other females in STEM?
- What do elementary girls view as indicators of success in STEM?

Participants

- 30 participants (girls in grades 4-5)
- Eight schools from six school districts
- Stratified sampling

STEM Interest
- Low: 8 students
- Medium: 10 students
- High: 12 students

Research Design

- Single embedded case study (Yin, 2014)
  - Contextualized in STARBASE experience
  - Multiple units of analysis
- Pre- and post-STARBASE interviews
- Interviews conducted with pairs of students
- Semi-structured interview protocol
- Data collected in February-June 2016

Data Analysis

- Multiple coding cycles
- Constant comparative analysis

1. Inductive (open) coding → 2. Pattern coding → 3. Pattern codes consolidated to themes

(Miles, Huberman, & Saldaña, 2014)

Discussion and Implications

- Consider rigor and pedagogy in STEM teaching

- Growth mindset – value effort
- Focus on critical thinking
- Need for future research on informal STEM and gender equitable practices