K228
Introduction to Knowledge Science I
2015
4th Lecture
Knowing, Science, and Model

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Outline

- Objectives, Contents
- Knowing, Science, and Model
  - Evolution of scientific knowledge, Reasoning
  - Model
  - Science and nature, and humans, Causal relationship
  - Complex systems
  - Emergence and tacit knowing
- Summary
  - World view and methodology of natural science
- Report

Objectives

- To give a motivation and a cue to think about questions such as "what knowing / knowledge / knowledge science are".
- To make a reference point to understand the diversity of knowledge and knowledge science.
- To understand "what model means", and the scope and status of the concept of model.
  - <The methodology of "Science" in a narrow sense> will be explained, not the contents of science but the knowledge creation process of science. (cf. Prof. Nakamori's lecuture)
  - This may not be the same as <a new methodology of "knowledge science">.
  - Namely, you should overcome *the reference point* in order to construct knowledge science.
  - Please consider what you must overcome, and why, how.

Contents

- I will explain the typical way of producing natural scientific knowledge and a kind of ways of thinking about the world and understanding it, which is merely *just one* representative of knowing.
- We will consider the basic features of scientific knowing, such as
  - description and explanation
  - causal relationship
  - the form of reasoning

Let us consider "knowledge" from a case study about "science"

SCIENTIFIC METHODOLOGY

Various kinds of knowledge creation

- Scientific research
  - Discovery of facts, Construction and proof of hypothesizes, laws, and theories.
  - Application of laws and theories, Development of new technology
- Business activity (in all industries)
  - Research and development
  - Innovation (production, algorithm, business model, service, and so on)
- Acquisition of skills and techniques
  - Traditional craft, sports and martial arts
- Arts, Crafts, Design
  - Production, performance
- Politics and administration
  - Institutional design, management of organisms and societies, social innovation
- There must be other activities…
  - They may be treated in this course

Note: these are not exclusive.


Explanation

1. The Japan Sea is the sea between the east edge of the Eurasian continent and Japan islands.
2. The Japan Sea was formed through the rise of sea level due to the global warming in the past.
3. In Wajima, a town along the Japan Sea, dried fish is often made.
4. Dried fish becomes delicious because protein is dissolved into amino acids.

What is the difference?


Explanation

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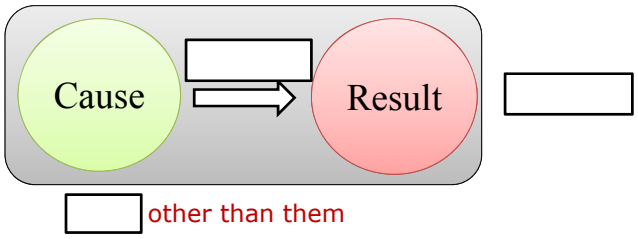
What is the difference?

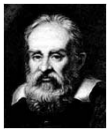
- 1 and 3 are descriptions, 2 and 4 are explanations of causal relations.
- An answer for a question "why is it?"
- The ultimate goal of science is explanations of causal relations of phenomena.
  - But science itself cannot answer the ultimate why-question.
  - "Ask 'why?' three times." = A way to deepen your hypothesis (Itami, 2001, p.160)

What is causality?



Typical example of development of science

- Tycho Brahe
  - Observed the orbits of planets in high precision (accumulation of data).
- Kepler
  - Found the law of planet motion.
    - Find an order in data using hypothesis and math.
- Galileo
  - Found the laws of falling bodies and of inertia.
  - Used experimental method to find laws and to prove hypotheses.
  - Derived the laws deductively (using math) from axioms and principles (basic laws).
    - Proved the axioms by confirming the derived laws in experiments.



See (Tomonaga, 1979, pp.21-97) for details

Typical example of the development of science

- Newton
  - Found the law of universal gravitation and three laws of motion.
    - Derived and proved Kepler's laws (laws in the celestial) and Galileo's laws (laws on the ground)
      = Gave an *integrated* explanation
    - Distant power, a mysterious hypothesis, in a sense (Hypothetico-deductive method)
    - "The world (views)" where the laws are realized

See (Tomonaga, 1979, pp.21-97) for details

What is physics?

Empirical proof

Pursue laws existing behind (at the back/heart of) all sort of phenomena occurring in the natural world surrounding us, but mainly about lifeless things, relying on [ ].
(Tomonaga, 1979, p.6; Emphasis added)

Observed facts include "experimental facts", which we derived from nature by actively acting upon the nature. (Tomonaga, 1979,p.73; Emphasis added)

Reasoning

Express the natural laws mathematically, and not only find the laws separately, but also systematize them by selecting the most basic ones from which the other laws are derivable.
(Tomonaga, 1979, p.73; Emphasis added)

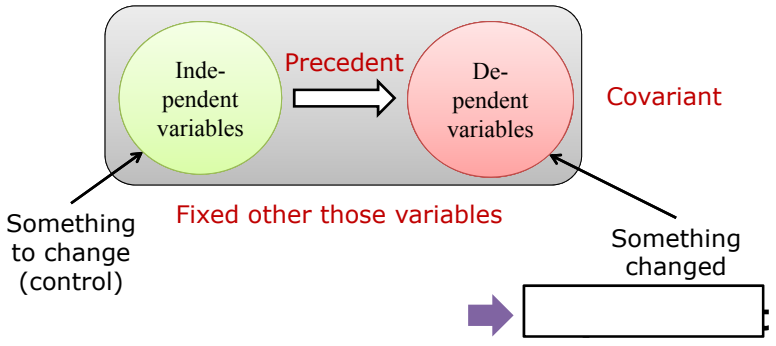
"Exist at the back/heart" ←→"observed facts"

- "Laws existing at the back/heart"
  - Not easy to see.
  - Not always be understandable by intuition from common sense.
  - Hypothesize under an assumption of order and causation that realize the phenomena.
  - Laws are [redacted].
- "Relying on observed facts"
  - Empirically measurable, although we cannot see directly.
  - Verify hypotheses by means of observed facts.

What is causality?

"Causal structure" = causality as *a mode of thinking*

Looking at entity as a series of causes and results

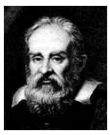


Note: "variable" is not limited to something quantified

Question

How can we view the typical developmental process (stages) of science?






Developmental process

Reasoning

- Enough data observed
- A law/regularity in the data → Descriptive law — Induction
- "*Why?*"
  → [ ] "maybe this is the reason" — Abduction
- Prove by repeating observations and experiments
- "*Why…?*" "Because…" — Deduction
  = Cause and result = [ ]
- → Explanative law — Induction
- Integrate (systematize) laws → theory — Deduction
  - Derive many laws from a few principles

Which are knowledge? Data? Information?
Where and how is knowledge created?

Form of reasoning: [ ]

- The process of reasoning from one or more general or universal proposition(s), law(s), or premise(s) to reach an individual or special conclusion which is logically inevitable.

  - If P, then Q. (premise 1: conditional)
    Now, P is true. (premise 2: hypothesis)
    Therefore, Q is true. (conclusion given)
    - If a planet rotates on its axis towards the east, the sun rises from the east on the planet.
      The earth rotates towards the east.
      Therefore, the sun rises from the [ ] on the earth.
  - If P, then Q. Now, Q is not true. Therefore, P is not true
    - If in an economic boom, stock prices rise.
      Now the stock prices do not rise.
      Therefore, [ ] a boom now.

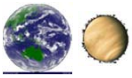
Form of reasoning: Deduction

- If premises are right, the conclusion is necessarily right.
- Reach a [ ] always, but *no new* information
  - Reveal (clarify) something not noticed in a premise

Form of reasoning:
induction

- The process of reasoning from a set of individual instances or special phenomena to reach a common general or universal proposition
  - a_1 is P. a_2 is P. a_3 is P. (All a_i so far were P). Therefore, all a_n are P. (enumerative)

    - The sun rose from the east yesterday, the day before yesterday, one month ago, one year ago, and …. Therefore, the sun rises from the [ ] *always*.
  - A is P. A and B are similar. Therefore, B is P. (analogy)
    - The sun rises from the east on the earth. The earth and Venus are similar. Therefore, the sun rises from the [ ] on Venus.



Form of reasoning: Induction

- Generalize instances
- Reach a new "*descriptive* law (hypothesis)"
- [ ] logically
  - Increase probability
- Used to hypothesize
- Used for a falsification test of hypotheses
  - Interface with experience (observed evidences, experimental evidences)
  - Necessary reasoning for empirical sciences (treating the nature, including humans and societies)
    - Note: mathematics and logic are not empirical sciences

Form of reasoning: Abduction

- The process of reasoning from a set of data or descriptions to reach a hypothesis to explain them, the reasoning to the best explanation
  - A is true. (observed fat)
    If H is hypothesized, then A is well explained.
    Therefore, H may be true. (hypothesis)
  - (There is a basis to set it as a hypothesis.
    or It is (a candidate of) the best explanation.)

- The sun rises from the east on the Earth always.
- If we hypothesize that the Earth [ ], this phenomena can be explained well.
- Therefore, it is appropriate to believe the hypothesis that the Earth [ ].

Form of reasoning: Abduction

- Reach a new "*explanative* law (hypothesis)"
  - Create a candidate of answer for a "why?"-question
- [ ] logically
- Used to hypothesize
  - Hypothetic-deduction
- H cannot be reached directly from observations of A.
  - Possibility to go beyond experience
    = "Laws in the heart (back)"

Proposed by an American pragmatism philosopher Charles Sanders Peirce (1839–1914) (Cf. Douven 2011)
Someone include analogy in abduction
Someone abduction and analogy are induction in a broad sense.

Hypothesis in science

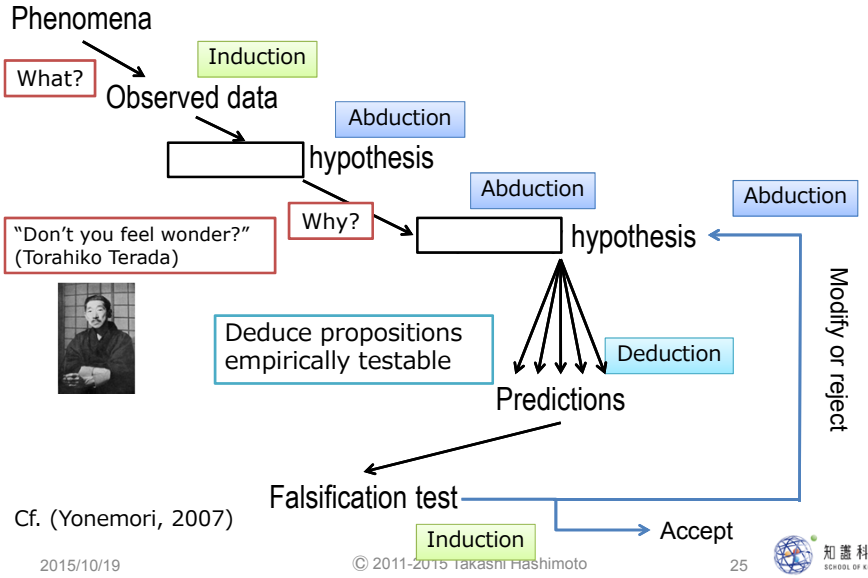
- Hypothesis formation
  - In order to make up a scientific theory from (empirical and descriptive) laws obtained from experiments and observations, we must organize the empirical laws in an integrative manner.
  - Observed facts can be explained by plural hypotheses.
  - We need insight in order to form a hypothesis as a universal explanatory principle from separated observed facts.
  - Hypothesis is created by humans [ ] to some extent, rather than drawn from experiences directly.

  - Tacit knowing (To know tacitly) (Polanyi, 1966)
    - What is relation with "tacit knowledge" (what we know but we cannot say)? (Nonaka and Takeuchi, 1996)

Hypothesis in science

- Hypothesis may not be proven empirically
  - Example: Newtonian dynamics
    - A material particle, as an abstract object
    - Hypothesize absolute time and absolute space
    - Distant action of power (power is transmitted in the empty space)
- For a theory based on hypotheses which are impossible to prove empirically and directly,
  - If we can verify conclusions drawn from the theory,
  - Then we can obtain plausibility of the hypotheses.
  - Finally, introduction of the hypotheses is justified.
    - Hypothetico-deductive reasoning

Relationship among three reasoning; model of evolution of scientific knowledge



Cf. (Yonemori, 2007)

Scientific method

- Effective to acquire new knowledge, to sort out, to [ ], and to apply the knowledge
  - Form of reasoning (deduction, induction, abduction)
  - Proof by rational and logical thoughts and experiments
    - Collective activity
  - Effective means for verification of hypotheses
    - Experiment
  - Effective means for logical thought
    - Logic
    - Mathematical method (Deduction by mathematical models and equations)
  - What needed for both
    - *Model*

Let us consider "knowledge" from a case study about "science"

MODEL

What is model?

- Why a plastic toy-model kit is a "model"?
  - Similar at some aspects interested in

- Why a fashion model is a "model"?
  - [ ]at some aspects interested in
    - Supermodel may not be a good model.
  - Neglect at some aspects not interested in (abstraction)

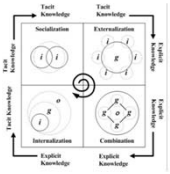
  - The developmental process of science, given above, is also a *model*
    - The real figure of science as a knowledge creation process is very simplified into the process "collect data, discover descriptive laws, create explanatory laws, and integrate them".

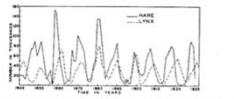
Q: Are there any other kind of "models"?
Q: Why are they "models"?

Model

Indispensable process to modeling

- What is a model?
  - An object which is made [ ] to the reality by extracting the important aspects in explanation for the real object and by excluding the other aspects (abstraction, simplification and idealization)
  - A system to [ ] the causality and mechanism of phenomena, in which multiple hypotheses are combined
    - Not limited to mathematical models
- Example
  - A model of organisms
    $\dot{x} = (a - bx)x$
  - A model of knowledge creation
    - SECI model





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Process essential to modeling

- Abstraction
  - Exclude (neglect) various aspects of real objects and make a theoretical (or mathematical) object
    - Cf: A material particle (an object having only mass and an observable position in space, where some features such as size and material are neglected)
- Idealization
  - Suppose particular conditions not established in reality
    - Cf: No friction, No other object nearby

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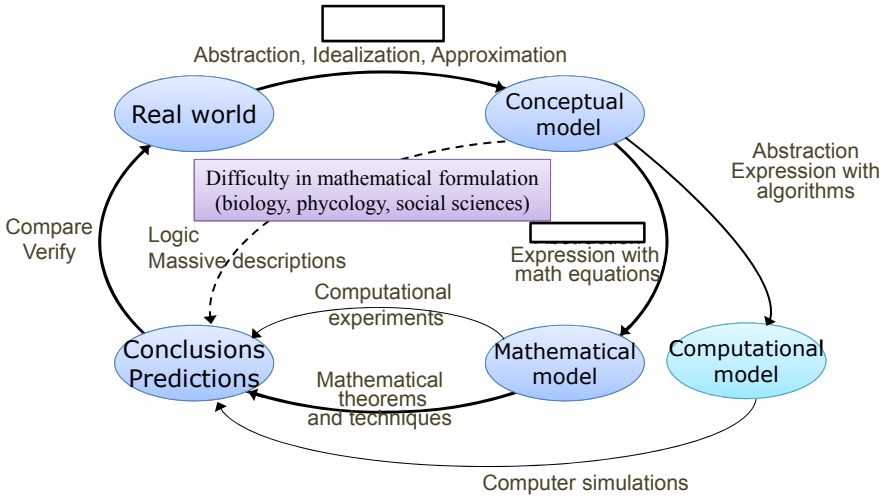
Well observe phenomena

- At first, we need to recognize some problem in the real world.
  - "Don't you feel wonder?" "Why this happens?" "How should we do?"
- Observe phenomena in the real world, and guess cause and mechanism which bring out the phenomena observed
  - This guessing may rely on insight (abduction).
  - The insight is an outcome of detection of similarity with well-known situations from thorough inspections of the phenomena.
- Lucid expression of the guess using technical terms in the specialized field is a "hypothesis".

Modeling

- Describe the observed phenomena as in detail as possible
  - Here we perform idealization and approximation.
  - It is important to identify the basic and essential concept.
  - Aiming at excluding unnecessary information, and simplifying situation.
- The process of identification, approximation, and idealization
  ➔ The formation of a model
- Identify variables concerning an object in the real world, and the relationships among the variables
  - Mathematical model: the relationships is expressed in terms of mathematical symbols and formula.

Steps of model construction



Notes

- The steps are very complex and related with each other. The division is just for convenience
- The real model and mathematical model are not divided entirely.
  - Conclusions and predictions are often obtained from the combination of both models.
- Social science, biology, psychology (behavioral sciences)
  - May include concepts, issues, conditions which are difficult for quantification.
  - The essence might be lost in transformation from real model to mathematical model.
  - In such case, outcomes from mathematical model may not be conclusions about the real world.

Let us consider "knowledge" from a case study about "science"

SCIENCE, NATURE, EXPERIENCE

中谷宇吉郎 雪の科学館
NAKAYA UKICHIRO MUSEUM OF SNOW AND ICE

"Snowflakes are letters sent from heaven."

Ukichiro Nakaya,
physicist from Ishikawa,
studied snow crystal,
http://en.wikipedia.org/wiki/Ukichiro_Nakaya

Object of science

In the world of science, such terms as "natural phenomena", "real figures of the nature", or "laws among them" are often used. It is important that all of them are found by humans. Although we would find the real state of the nature, it is just found by [ ].

(Nakaya, 1958, p.19; emphasis added)

Object of (natural) science

- Those which we can find "[laws]" among abstract attributes of natural phenomena that are spatiotemporally related, and can verify the laws.
  - Observable
  - Reproducible
  - Objectifiable (inter-subjectively)

  - Anything having those characteristics can be an object of natural science.
    - The kind of objects such as living things, humans, or society does not matter. The "natures" of objects and our "attitude" toward them are important.
    - We may be able to find such nature in human and society.

    Q: How about knowledge? Knowledge creation?

    Q: Impossible? Why? May we say "impossible" so easy?

Science and nature

If we consider [the relationship between nature and science] in such a way, we can recognize that it is not the case that there is a fixed and hidden reality somewhere, and that we may find it through scientific explorations when we are successful.
The reality and the laws of nature, which science finds, are [ ] between humans and nature in this sense.
(Nakaya, 1958, p.22; emphasis added)

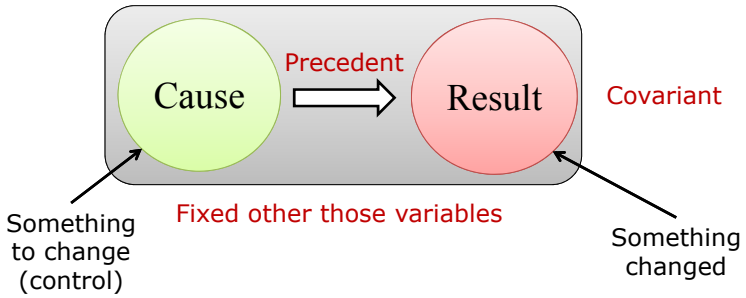
Let us consider "knowledge" from a case study about "science"

COMPLEX SYSTEMS

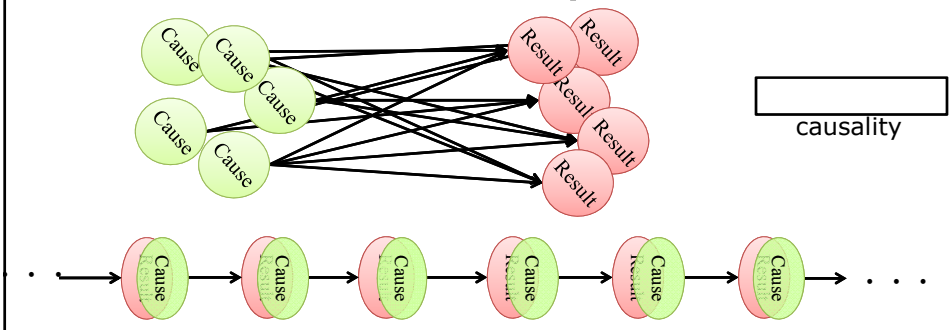
Causality structure

"Causal structure" = causality as *a mode of thinking*

Looking at entity as a series of [ ] and [ ]



In reality…



"For want of a nail, the kingdom was lost."
"A butterfly flapping its wings in Beijing might change the weather in New York.

[ ] of causality

Something of great importance may depend on an apparently trivial detail. The saying comes from a longer proverb about a battle during which the loss of a nail in a horseshoe leads to the loss of a horse, which leads to the loss of the rider, which leads to the loss of the battle, which in turn leads to the loss of a whole kingdom.

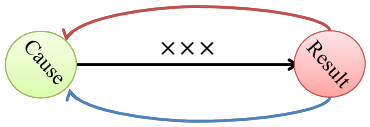
Complex causation

Moreover…

Result [ ] its cause (destabilize)
Ex: Self-reproduction, Deflation spiral

Positive feedback

Fluctuation

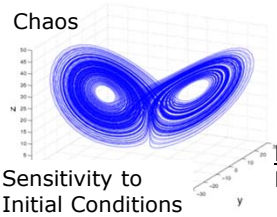


Feedback
Nonlinearity

Negative feedback

Result [ ] cause (stabilize)
Ex: Thermostat, Homeostasis

Chaos



Sensitivity to
Initial Conditions

Ever changing,
Not fixed and periodic

Emergence, maintain, and collapse of (dynamic) structure

Complex systems

Chain of many-to-many causality

Mixture of negative and positive feedbacks

Nonlinearity

Fluctuations

Openness
Many-to-many relationships
Diversity
Autonomy
Multi-scale
Fractal structures
…
…

Complex systems

Emergence
Self-organization
Evolution

"predicative integration"

Tacit knowing and emergence

Emergence Ordered structures or patterns are brought about autonomously, i.e., without external commands and controls, through interactions among elements
→ An upper level structure (hierarchy) is made Irreducible to the lower levels.
Ex: Cells→Organ, Sound→word→grammar→literature

Polanyi considered how scientists conceive a theory, a law, a hypothesis → A kind of [ ] (Polanyi, 1966)

Tacit [ ] to know tacitly

From cases, existing knowledge, observed facts, we actively comprehend a kind of whole structure, as a hypothesis that explains them = **Emergence** → Abduction

"We can know more than we can tell."

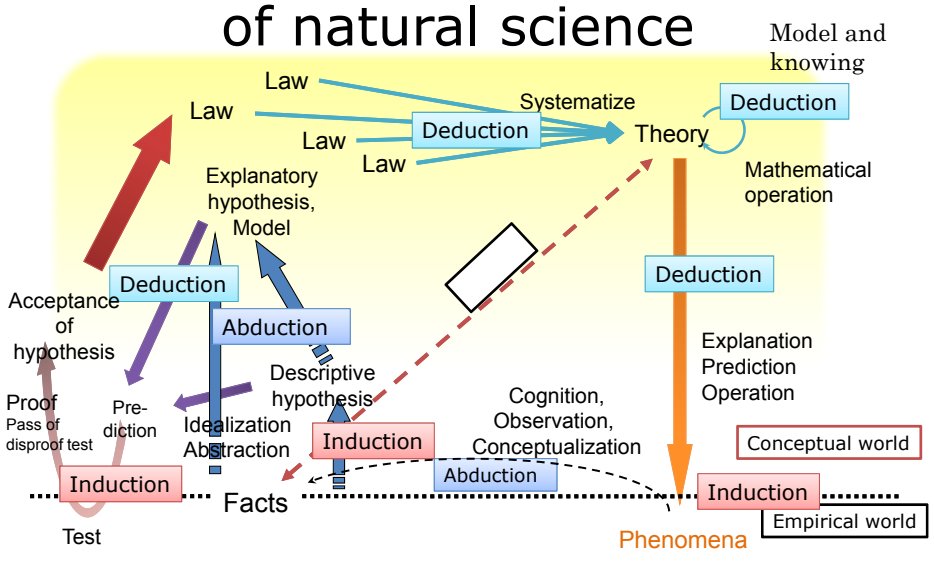
Let us consider "knowledge" from a case study about "science"

SUMMARY

From phenomena to theory

- Phenomenon
  - Raw entity (object/event) occurring in the real world
- Fact
  - Entity that is a part of phenomena illuminated from a viewpoint
    - Accepted data about the world, which are correctable
- Hypothesis
  - Assumptions about facts, explaining the relationships between causes and results [ ]
- Law
  - Consistent hypothesis which was repeatedly verified (passed falsification tests many times).
- Theory
  - Knowledge that [ ] laws and principles

World view and methodology of natural science



World view and methodology of natural science

- Observe phenomena under a certain concept, knowledge and theory; and Obtain facts.
  - Tension between facts and theories (Theory is inevitable to recognize facts, Theory is constructed to explain facts.)
- Abstract side issues, and find essential quantities
  - Identify independent variables, dependent variables and other variables.
  - Perform abstractions and idealizations
  - Bring out essential issues by making situations as simple as possible
  - Approximate, as needed
    - Thanks to these operations, a general law, free from concrete objects, may be clarified.

World view and methodology of natural science

- Integrate a bunch of facts with a concept, and make a descriptive hypothesis which can be falsified in principle
  = Induction
  - Clarify prerequisites and be aware of implicit assumptions
  - Quantify phenomena by defining appropriate coordinates (scale), and derive a quantitative relation among phenomena.
- Make a falsifiable explanatory hypothesis about the causality behind (at the back of) the bunch of facts and about the mechanism behind (at the back of) the descriptive law.
  = Abduction
  - Make a model in which causal relations are arranged.
  - Use knowledge such as existing theories and laws.

World view and methodology of natural science

- Derive empirically testable predictions as many as possible from the hypothesis using supplemental knowledge (laws) = Deduction
  - Express the law mathematically
  - Perform logical reasoning (deductive operations)
  - Utilize simulation, as well
- Prove the predictions through experiments and observations
  - Verify them in the relation with other laws
  - Process statistically

World view and methodology of natural science

- Modify the hypothesis, if obtained results are inconsistent with the predictions = Abduction
  - Refuse the hypothesis, if modification is not possible totally.
- Accept the hypothesis, if the results are consistent with the predictions (if the hypothesis passed a falsification test)
  - When many people, in a scientific society, accept the hypothesis through repeated tests, the hypothesis is regarded as a law.
  - Explain many phenomena viewing them through the law.

World view and methodology of natural science

- Recognize organized relationships with other laws, and make a "theory" by systematizing the laws
  - Make a theory (systematized laws) as simple as possible, which can organize hypotheses, predictions and experimental results.
  - Actually, this process includes proposing an "explanatory hypothesis" which explains several laws, doing test repeatedly with the same processes, and putting the laws together.
  - Abstract concepts and expand applicable domains of the laws
  - Deduce the theory and find laws
- Apply the theory and laws to operate real entities
  - Recognize new phenomena

As a reference point

- The knowledge and knowledge creation told in this lecture are normative and idealized "images" based on the model of natural science.
- Knowledge is not limited to this.
- What are the relations of knowing and knowledge that will (or will not) be told in this course with the scientific knowledge?
- Can academic knowledge in knowledge science be captured by this "image"?
- Can this "image" be applied to knowledge science as practices?

Report

- Question
  - Suppose you would claim the following assertion by Galileo, and make an explanation that convince others of the assertion.

    Galileo did not hesitate to say, "Look, if the data refute the theory, the data are probably wrong". (Chomsky, 2002, p.98)

  - This assertion appears in an interview of Chomsky, a theoretical linguist, where he explains a fact that Chomsky's language theory is called "the Galilean style". Here "the Galilean style" is thought of as the common way of thinking in the methodologies of natural sciences.

Report

- Volume
  - The body must be 2-3 pages in A4 paper. This pages does not include a cover sheet and references.
- Format
  - Put a cover page including the appropriate title, name, affiliation, student ID.
    - The appropriate title should be a concise phrase (sentence) representing the content and the claim of your report. It must not be a formal title like “Report No.1 of K228”.
- Deadline
  - 11/2 (Monday) 23:59
- Way to submit
  - Upload a PDF file of your report at Report Upload Site.
  - Select the proper lecturer who assigned the report.

References

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