# DEVELOPMENT OF VISUAL REPRESENTATION COMPETENCE TAXONOMY FOR SCIENCE TEACHING AND LEARNING

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# Importance of visual representations in science

Evagorou et al. 2015

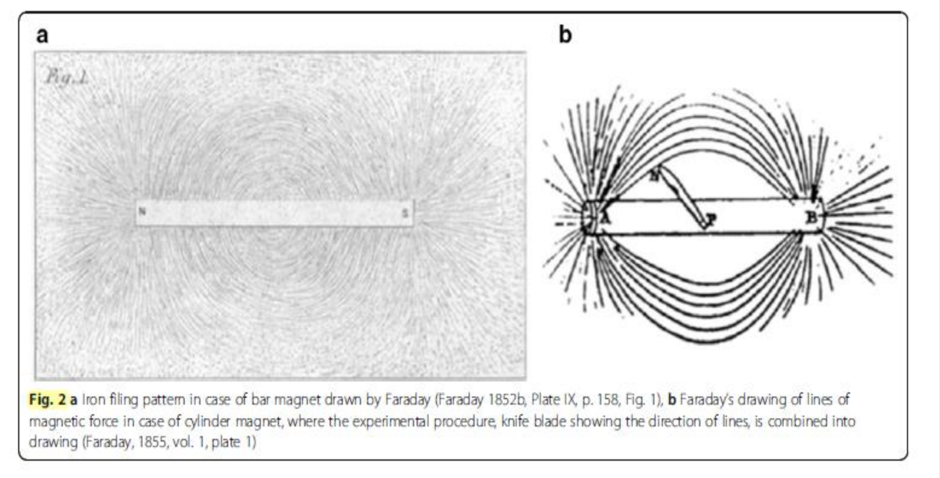
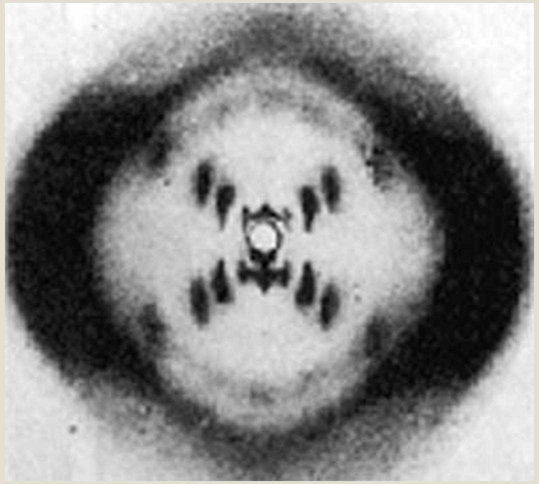
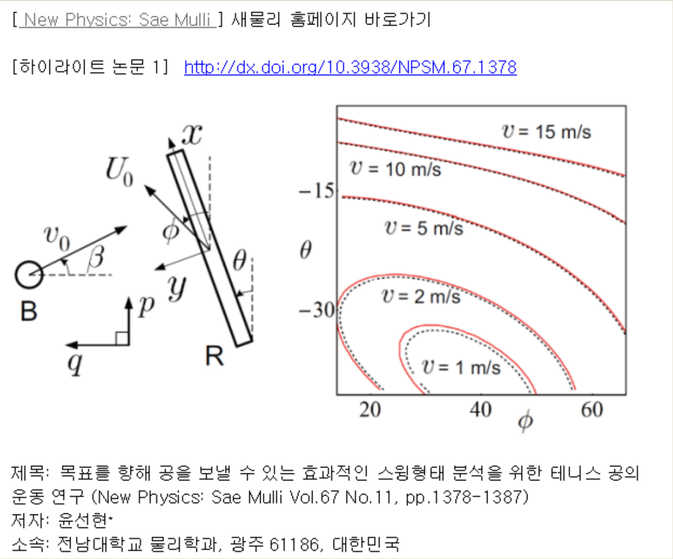


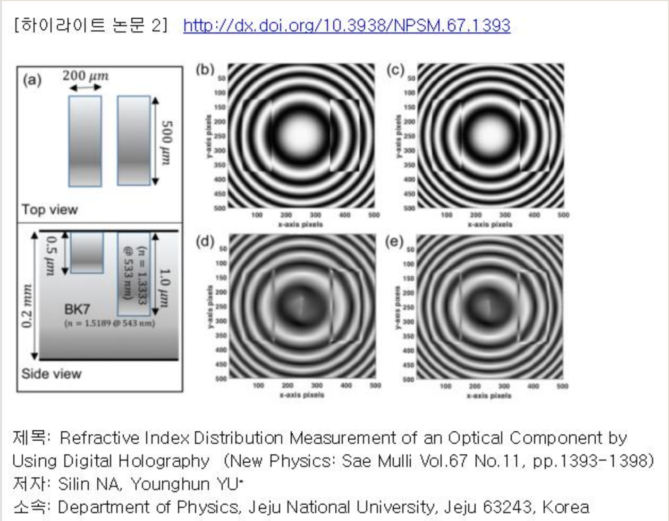

**Fig. 2 a** Iron filing pattern in case of bar magnet drawn by Faraday (Faraday 1852b, Plate IX, p. 158, Fig. 1), **b** Faraday's drawing of lines of magnetic force in case of cylinder magnet, where the experimental procedure, knife blade showing the direction of lines, is combined into drawing (Faraday, 1855, vol. 1, plate 1)

**Visual reasoning** in knowledge production, the example of the lines of magnetic force



X-ray chrystallography of DNA, Use **visual representations as evidence** in the discovery of DNA

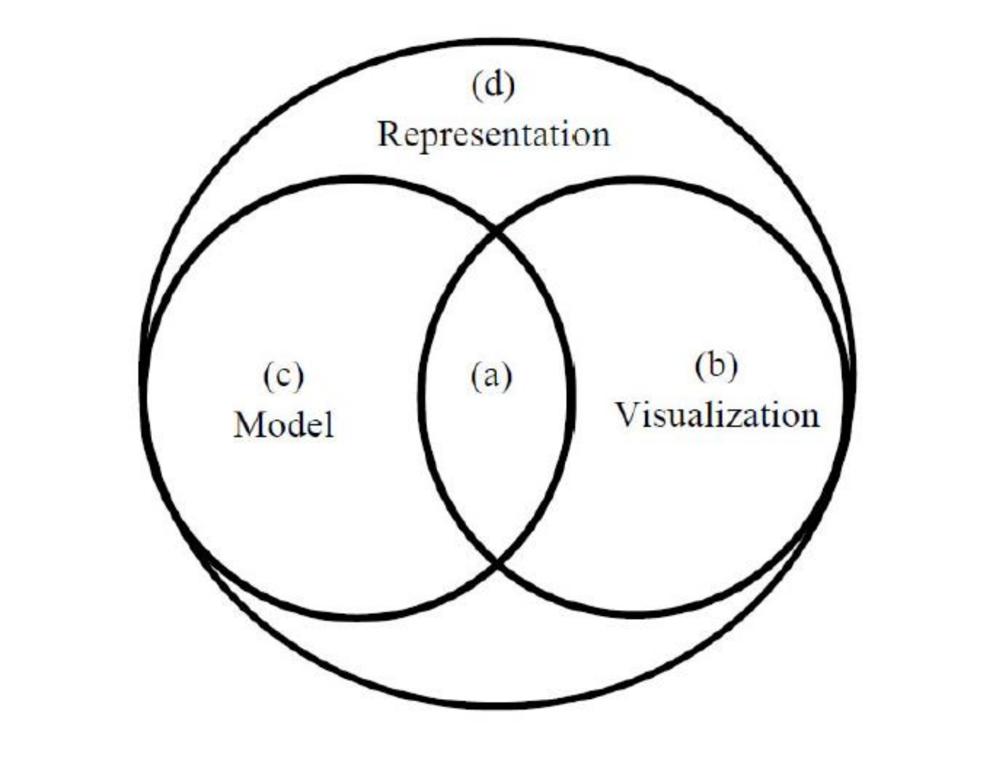



Highlighted articles in physics journal

# Importance of visual representations in science and science education

# Similar terms




- People create **representations** through their intention to have one thing stand for something else, that is, a **representation is seen as a structure that stands for something else**.

- A **model** in science can be developed as a representation to represent a simplification of a phenomenon, and then to be used in the inquiry to develop **explanations of the phenomenon** (Gilbert, Boulter, & Elmer, 2000).

- **visualization** as the **cognitive and brain processes** associated with the act of visualizing rather than as a pictorial representation, which is linked to visualizing process (Reiner, 2008).

Rundgren, S. N. C., & Yao, B. J. (2014, December). Visualization in research and science teachers' professional development. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 15, No. 2, pp. 1-21). The Education University of Hong Kong, Department of Science and Environmental Studies.

# Studies on visual representations in science education

**Delivering the information efficiently using visual representations**

- Types and use of VRs in science textbooks (Dimopoulos et al. 2003; Bungum 2008)
- Students' understanding of the given VRs (Chittleborough & Treagust, 2007; Colin, Chauvet, & Viennot, 2002; Topsakal & Oversby, 2013)

**Emphasizing the students' participation in visualizing process**

- Characteristics of students' generated VRs during scientific practices (Gilbert et al. 2008; Dori et al. 2003; Lehrer and Schauble 2012; Schwarz et al. 2009, Waldrip et al., 2010)
- Importance of visual representation competence as the set of scientific skills and practices (Kozma & Russel, 2005, Tippett, 2016)

**How can we use VRs effectively in science classrooms?**

# Educational Taxonomy

- Taxonomy is used to design curriculum, set learning objectives, and conduct an assessment.
- Bloom's taxonomy (1956) → Revised Bloom's taxonomy (Anderson et al., 2001)
- Bloom's Digital Taxonomy for teaching and learning with ICT (Churches, 2009)

| | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating |
|---|---|---|---|---|---|---|
| Factual knowledge | | | | | | |
| Conceptual knowledge | | | | | | |
| Procedural knowledge | | | | | | |
| Metacognitive knowledge | | | | | | |

Lower order→ Higher order thinking skill

Concrete
↓
Abstract knowledge

# Purpose of the study

- Develop two dimensional VRC-T to promote the effective use of visual representations in teaching and learning science and provide a platform for systematic science education research.

**Two Dimensional VRC-T**

| | Cognitive process of visual representation | | | | | |
|---|---|---|---|---|---|---|
| Type of visual representation | | | | | | |
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# Process of the study

**Literature review**
**(The 1st Model)**

- Types of visual representations
- Cognitive theory of visualization process
- Visual representation competence

→

**Teachers' workshop**
**(The 2nd Model)**

- Teachers classify VRs in the science textbooks
- Teachers wrote LOs about VRs based on the 1st model
- Discuss problems and challenges

→

**Survey to experts**
**(The 3rd Model)**

- Classify 16 VRs using 2nd model to analyze agreement rate between the researcher and experts
- Evaluate the appropriateness of learning objectives corresponding to each cognitive process as a four-point scale

# Result1: Type of visual representation

- **According to their characteristic**
  - Simple diagrams, comprehensive diagrams, analytical diagrams, tables, maps, and timelines (Moline, 1995)
  - Maps, Diagrams, Photographs, Equations, Graphs, Pictures, Chart (Ozcelik, & McDonald, 2013)
  - Two-dimensional, three-dimensional / static, dynamic

- **According to the abstractness of object**
  - Macroscopic, sub-microscopic, symbolic (Bucat & Mocerino, 2009; Gilbert & Treagust, 2009; Johnstone, 1993)

- **According to the purpose**
  - Descriptive, explanative, relational (Jo et al., 2015)

# Result1: Type of visual representation

**A. Descriptive R**
- Aa. Realistic description
- Ab. Structure/scale

**B. Procedural R**
- Ba. Method/process
- Bb. Change/comparison

**C. Explanative R**
- Ca. Science concept
- Cb. Scientific theory/law

**D. Relational R**
- Da. Graph
- Db. Organizer
- Dc. Analogy

**A. Descriptive R**
- Aa. Realistic description
- Ab Structure/scale/distribution

**B. Procedural R**
- Ba. Method/process
- Bb. Change/comparison

**C. Explanative R**
- Ca. Science concept/science model
- Cb. Relationship between concepts
- Cc. Analogy

**A. Descriptive R**
- Aa. Realistic description
- Ab. Description using symbol

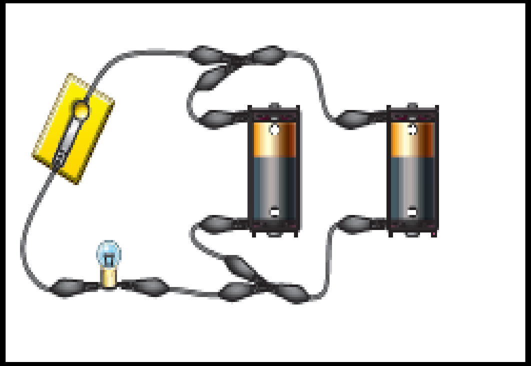
**B. Procedural R**
- Ba. Process of doing things
- Bb. Process of change over time

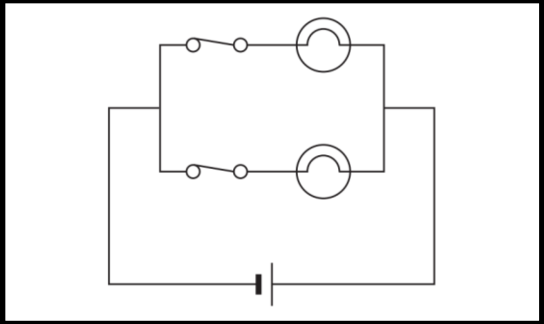
**C. Explanative R**
- Ca. Explanation of scientific model
- Cb. Explanation of relationships between the concepts

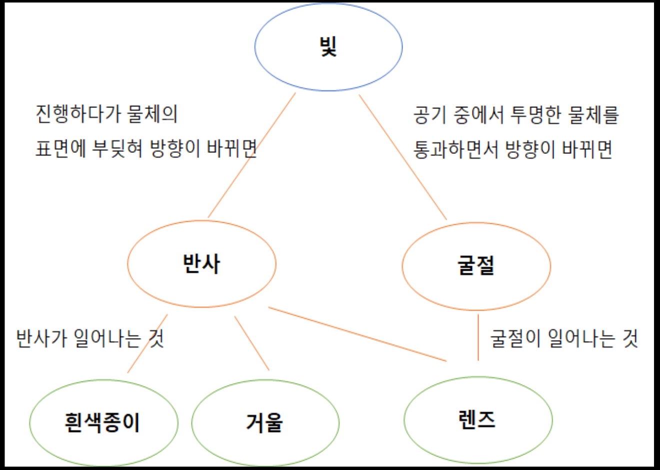
# Result1: Type of visual representation

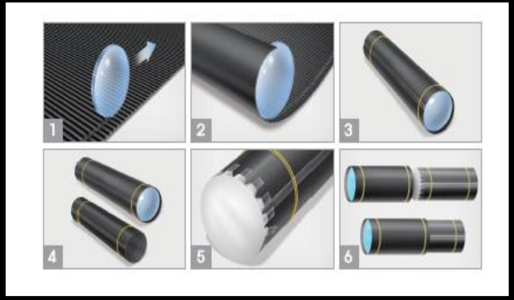
| Category | Sub-category | Definition | Example |
|---|---|---|---|
| **A. Descriptive representation: Delivering the fact by describing the things or phenomena** | Aa. Realistic description | Realistic description of the things or phenomena, external features or internal structures of objects, and behaviour of plants and animals | Appearance of plants and animals, The internal structure of the bulb, cross section of plant stem etc. |
| | Ab. Description using symbols | Using symbols to describe the things or phenomena, external features or internal structures of objects, and behaviour of plants and animals | Electric circuit diagram, Rainfall bar graph, Volcano distribution map using symbols etc. |
| **B. Procedural representation: Showing the process of doing things or the change over time** | Ba. Process of doing things | Describing a set of methods or sequences for performing a task | Procedure of making electromagnet, manual of experimental instruments etc. |
| | Bb. Process of change over time | Describing time and seasonal change or movement of an object | Seasonal constellation, growth of plants and animals, graph of water temperature change over time etc. |
| **C. Explanative representation: explaining the cause and regularity of the phenomena** | Ca. Explanation of the scientific model | Explaining scientific concepts or principles, hypothetical ideas in order to explain the phenomenon | Water cycle diagram, particle representation of gas volume changes etc. |
| | Cb. Explanation of relationships between the concepts | Explaining concepts using metaphors or relationships, hierarchy and inclusion between concepts | Water flow analogy of electric circuit, plant classification diagram, concept map of light properties etc. |

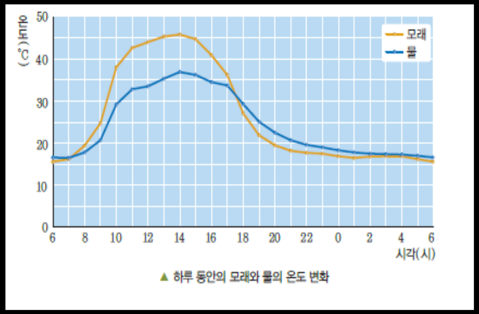
# Examples of VRs in Science Textbooks

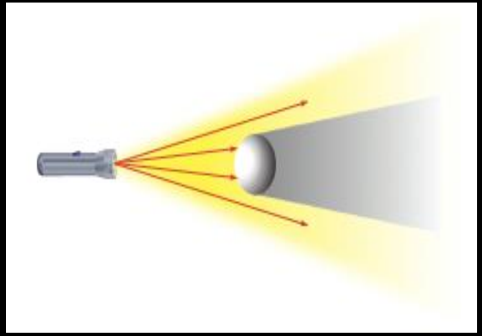


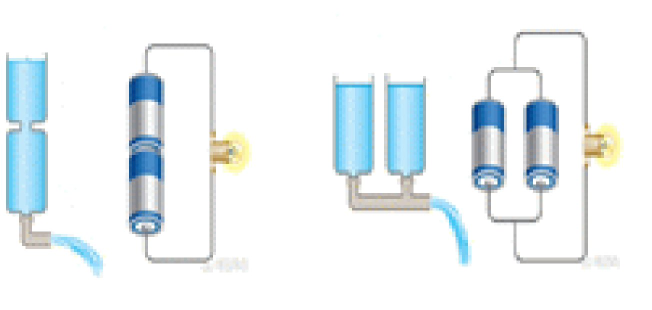




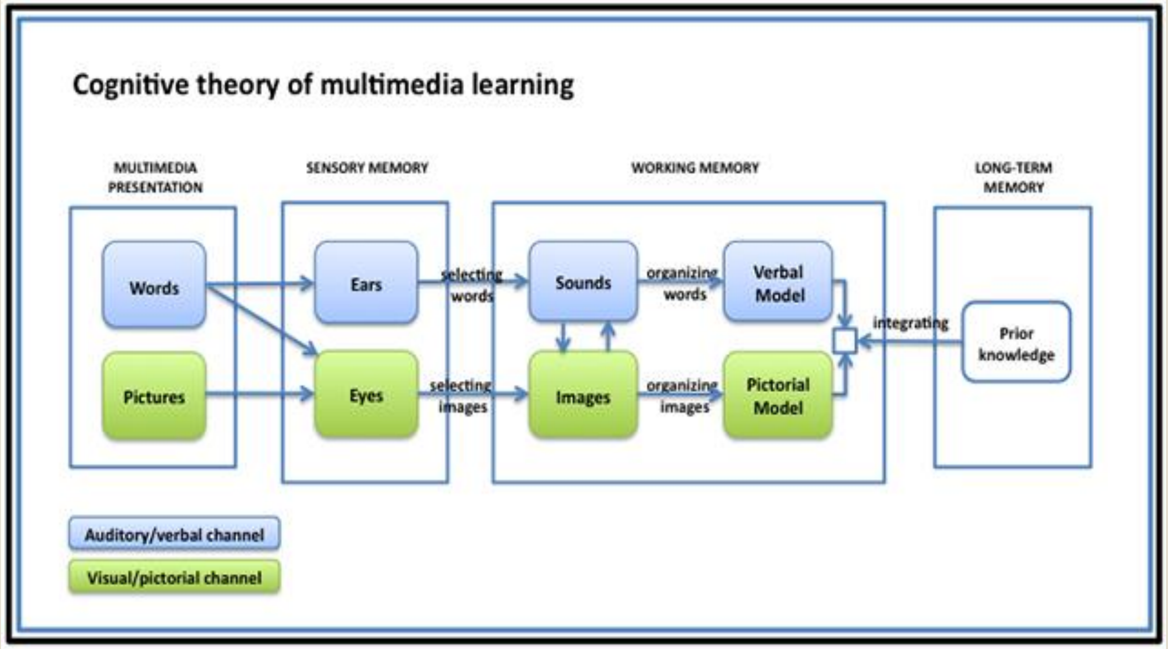





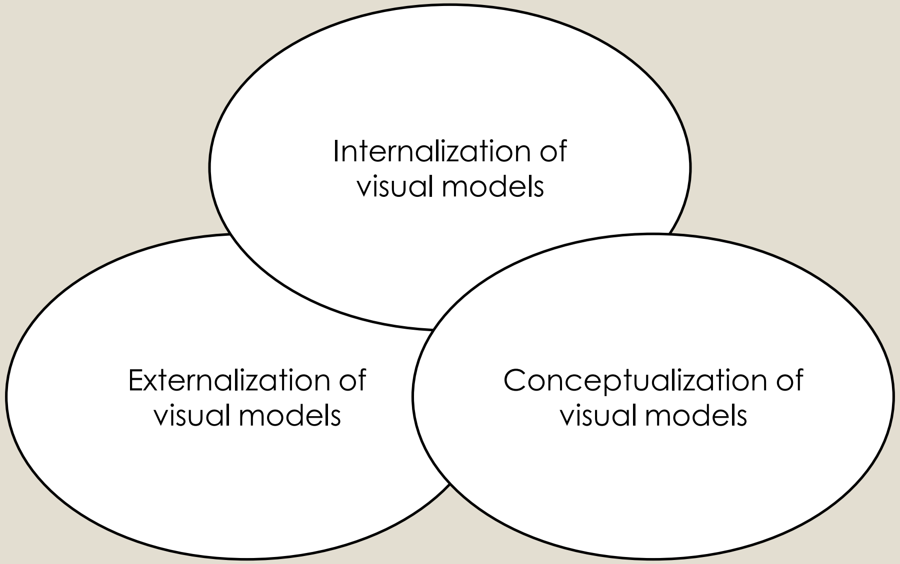





# Result2: Cognitive process of visual representation




Mayer (2000, 2003): cognitive theory of multimedia learning




The overlapping stages of the cognitive process of visualization (Redrawn from Mnuguni (2014))

Interpretation of VR

Integration of VR

Construction of VR

# Key references about representational competence elements

| | | |
|---|---|---|
| Study1 | McKenzie & Padilla (1986) | 'The test of graphing in science (TOGS)' |
| Study2 | Postigo and Pozo (2001, 2004) | 'Graphicacy' |
| Study3 | diSessa & Sherin (2000) | 'Meta-Representational competence' |
| Study4 | Kozma & Russell (2005) | 'Representational competence level' |
| Study5 | Yoon et al. (2016), Jo et al. (2017), Cho et al. (2017) | 'Visual representation competence' |

# Result2: Cognitive process of visual representation

1. Interpretation of VR
- 1.1 Interpreting surface information
- 1.2 Interpreting in-depth information
- 1.3 Interpreting conceptual information

2. Integration of VR
- 2.1 Transforming
- 2.2 Evaluating

3. Construction of VR
- 3.1 Constructing surface information
- 3.2 Constructing in-depth information
- 3.3 Constructing conceptual information

1. Interpretation of VR
- 1.1 Interpreting Explicit Information
- 1.2 Interpreting conceptual information

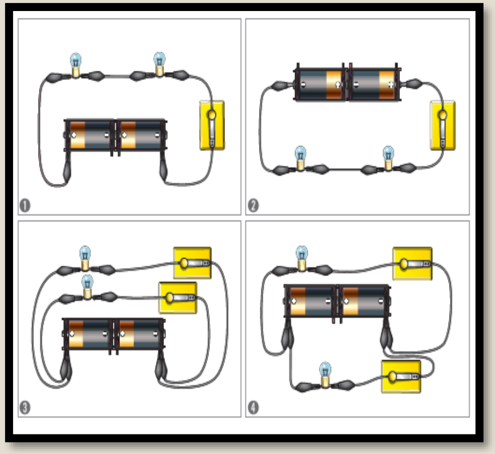
2. Integration of VR
- 2.1 Transforming (across various forms a nd situations)
- 2.2 Evaluating the appropriateness

3. Construction of VR
- 3.1 Constructing representations based o n senses, rules, and information
- 3.2 Constructing representations based o n reasoning

# Result2: Cognitive process of visual representation

| Category | Sub-category | Key predicates |
|---|---|---|
| **1. Interpretation of VR: Interpreting the information and meaning presented in the given visual representation.** | 1.1 Interpreting Explicit Information | • Identifying symbol or value<br>• Reading symbol or value |
| | 1.2 Interpreting conceptual information | • Interpolating/Extrapolating (from a graph)<br>• Interpreting the meaning by making inference such as predicting, generalizing, and concluding<br>• Interpreting through scientific concepts and terms |
| **2. Integration of VR: Evaluating or transforming the given visual representations by linking them with prior knowledge, concepts, and experiences** | 2.1. Transforming (across various forms and situations) | • Transforming the given representation into a different form<br>• Applying the given representation to similar situation<br>• Matching between different forms of representations showing the same information |
| | 2.2. Evaluating the appropriateness | • Selecting the proper one<br>• Justifying the use of the specific representation<br>• Criticizing the inadequate expression or use of the representation<br>• Understanding that scientific representation is not always the mirror of reality. (nature of representation) |
| **3. Construction of VR: Constructing visual representations to show the observed features and scientific ideas** | 3.1 Constructing representations based on senses, rules, and information | • Drawing the features of observed phenomena or objects<br>• Making a map of location or distribution based on the given information<br>• Using the scientific symbols according to the rules (e.g. arrow indicating force) |
| | 3.2 Constructing representations based on reasoning | • Illustrating scientific concept or principle<br>• Drawing a concept map or hierarchical chart to present the relations between concepts<br>• Drawing/Making a visual model to present one's scientific idea (hypothesis) and use it to explain and to predict the phenomenon |

# Examples of learning objectives



**1.1 Interpreting Explicit Information**

- Students can identify the light bulb, the battery, and the switch In the given figure.

**1.2 Interpreting conceptual information**

- Students can group the given figures according to the connection method

**2.1. Transforming (across various forms and situations)**

- Students can connect the light bulb, the battery, and the switch according to the given figure.

**2.2. Evaluating the appropriateness**

- Students can tell what is convenient when batteries, switches, and bulbs are expressed with simple symbols.

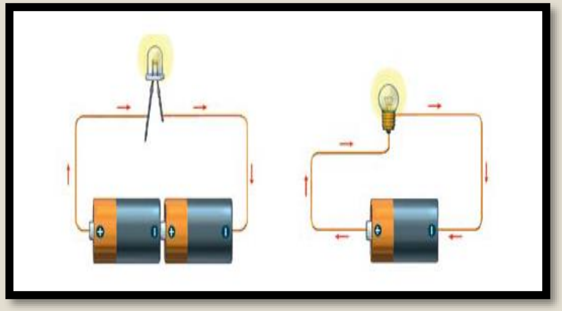
**3.1 Constructing representations based on senses, rules, and information**

- Students can draw circuit when they observe an electric circuit with a light bulb, battery, and switch connected.
- Students can draw serial and parallel connection of bulbs when they listen to / read scientific explanation.

**3.2 Constructing representations based on reasoning**

- Students can illustrate all the possible ways of connection how to light up two bulbs.

# Examples of learning objectives



| | |
|---|---|
| 1.1 Interpreting Explicit Information | • Students can tell that the arrow indicates the direction of the current. |
| 1.2 Interpreting conceptual information | • Students can tell that the current commonly flows from positive to negative pole of battery in the given figures. |
| 2.1. Transforming (across various forms and situations) | • Students can draw arrows indicating current when the batteries are reoriented or additional bulbs are connected. |
| 2.2. Evaluating the appropriateness | • Students can point out the wrong direction of the current when they look at various diagrams showing current direction. |
| 3.1 Constructing representations based on senses, rules, and information | • Students can illustrate current flows from positive to negative pole of battery when they listen to / read scientific explanation. |
| 3.2 Constructing representations based on reasoning | • Students can illustrate how current should flow for home appliances (such as an electric rice cooker) to work. |

# Expected use of VRC-T

- **Practical use**
  - helpful to utilize the visual representations more actively/effectively in teaching and learning science
  - assess students' visual representation competence and devise appropriate educational activities for it

- **Further studies**
  - hierarchy in cognitive processes
  - the validity for secondary science education needs to be explored and confirmed

# Thank you!

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