



Monument to Tycho Brahe and Johannes Kepler in Prague, Czech Republic

Visuospatial models of the Sun-Earth-Moon system

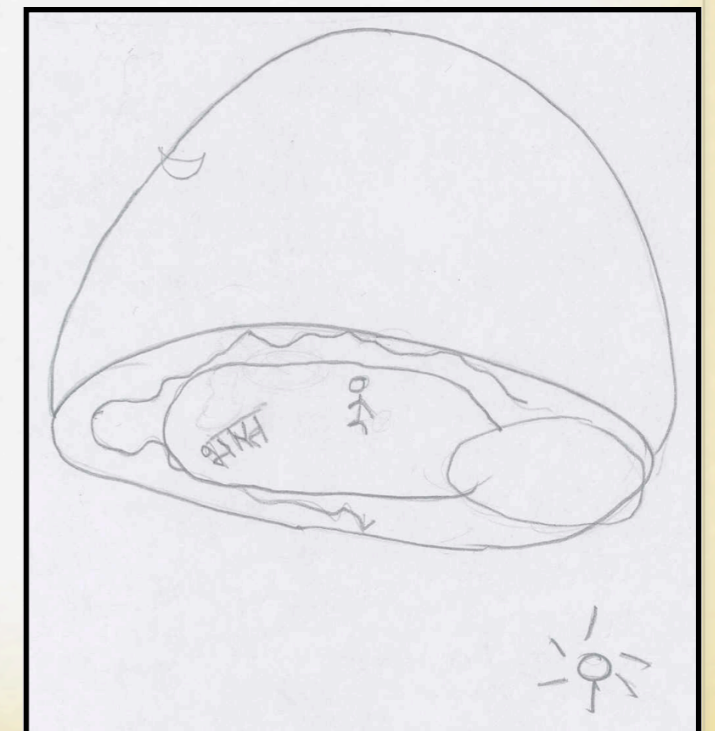
Shamin Padalkar & Jayashree Ramadas

International Conference on Physics Education

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Yet there exist common false notions...

- ❁ Pole Star is the brightest star in the sky.
- ❁ Venus is a star. / Andromeda is a star.
- ❁ Shape of the earth is like a disk.
- ❁ Day-night occur because the earth moves around the sun.



- ✿ Pole Star is the brightest star in the sky.
 - Incorrect individual belief
- ✿ Venus is a star. / Andromeda is a star.
 - Category mistake
- ✿ Shape of the earth is like a disk.
- ✿ Day-night occur because the earth moves around the sun.
 - Flawed mental models (Chi, 2008)

Mental models

- ❖ Internal representation of a concept (e.g. the earth), or an inter-related system of concepts (e.g. the solar system) that corresponds in some way to the external structure that it represents (Chi, 2008)
- ❖ The model can be ‘run’ mentally to depict changes and generate predictions and outcomes (Gentner & Stevens, 1983)
- ❖ Mental models are incomplete, unstable, unscientific and parsimonious (Norman, 1983)
- ❖ People’s ability to run their models is limited

Children's mental models in astronomy

- ✿ Earth (Vosniadou & Brewer, 1992)
 - ✿ Intuitive: Flat earth (square/ disk)
 - ✿ Synthetic: Dual earth, Hollow earth, Flattened earth
 - ✿ Scientific: Spherical earth

- ✿ Day-night cycle (Vosniadou & Brewer, 1994)
 - ✿ Intuitive: Sun is occluded, moves out into space
 - ✿ Synthetic: Sun revolves around the earth, the Earth revolves around the sun
 - ✿ Scientific: The earth rotates around its axis

- ✿ Day-night occur because the earth moves around the sun
- ✿ Seasonal changes are due to variation in the distance between the sun and the earth
- ✿ Phases of the moon are caused due to shadow of the earth

... Can we call these 'mental models'?

- ❖ Day-night occur because the earth moves around the sun
 - ❖ Phases of the moon are caused due to shadow of the earth
 - ❖ Seasonal changes are due to variation in the distance between the sun and the earth
 - ❖ The earth does revolve around the sun
 - ❖ The earth does cast a shadow on the moon
 - ❖ The sun-earth distance does vary over the year
- ... Correct information but incorrect reasoning

Mental representation (dynamic)

- ✿ Mental model: Spatial and other physical information

Mental process

- ✿ Reasoning: Run the mental model, visualize the effects

Mental model combined with visuospatial thinking is a suitable framework to explain and address alternative conceptions (explanations) in elementary astronomy.

Two basic spatial abilities (Hegarty and Waller, 2005)

- ✿ Mental rotation
- ✿ Perspective taking

are used to mentally simulate or 'run' a mental model.

Spatial tools

Concrete models & diagrams: commonly used to represent, communicate and think about spatial information, useful in pedagogy

Diagrams

2-D

Abstract

Static

Transformable

Spatial tools

Concrete models & diagrams: commonly used to represent, communicate and think about spatial information, useful in pedagogy

Concrete Models

3-D

Realistic

Movable

Rigid

Diagrams

2-D

Abstract

Static

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Spatial tools

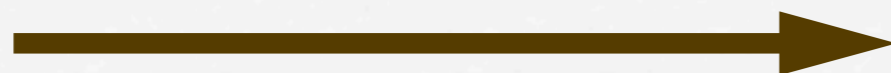
Concrete models & diagrams: commonly used to represent, communicate and think about spatial information, useful in pedagogy

Concrete Models

Gestures

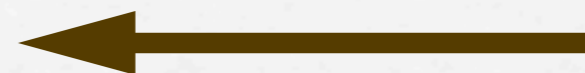
Diagrams

3-D



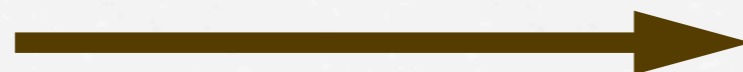
2-D

Realistic



Abstract

Movable



Static

Rigid



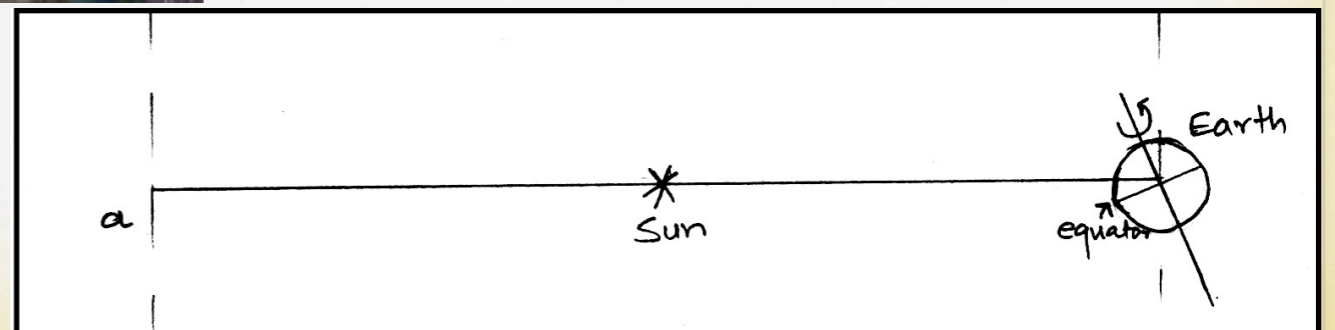
Transformable

Inclined axis



For 1st part of pedagogy see: Padalkar, S. & Ramadas, J. (2008). Modeling the round earth through diagrams. *Astronomy Education Review*, 6 (2), 54-74.

<http://dx.doi.org/10.3847/AER2007018>.



Phenomenon: Occurrence of seasons

Mental model

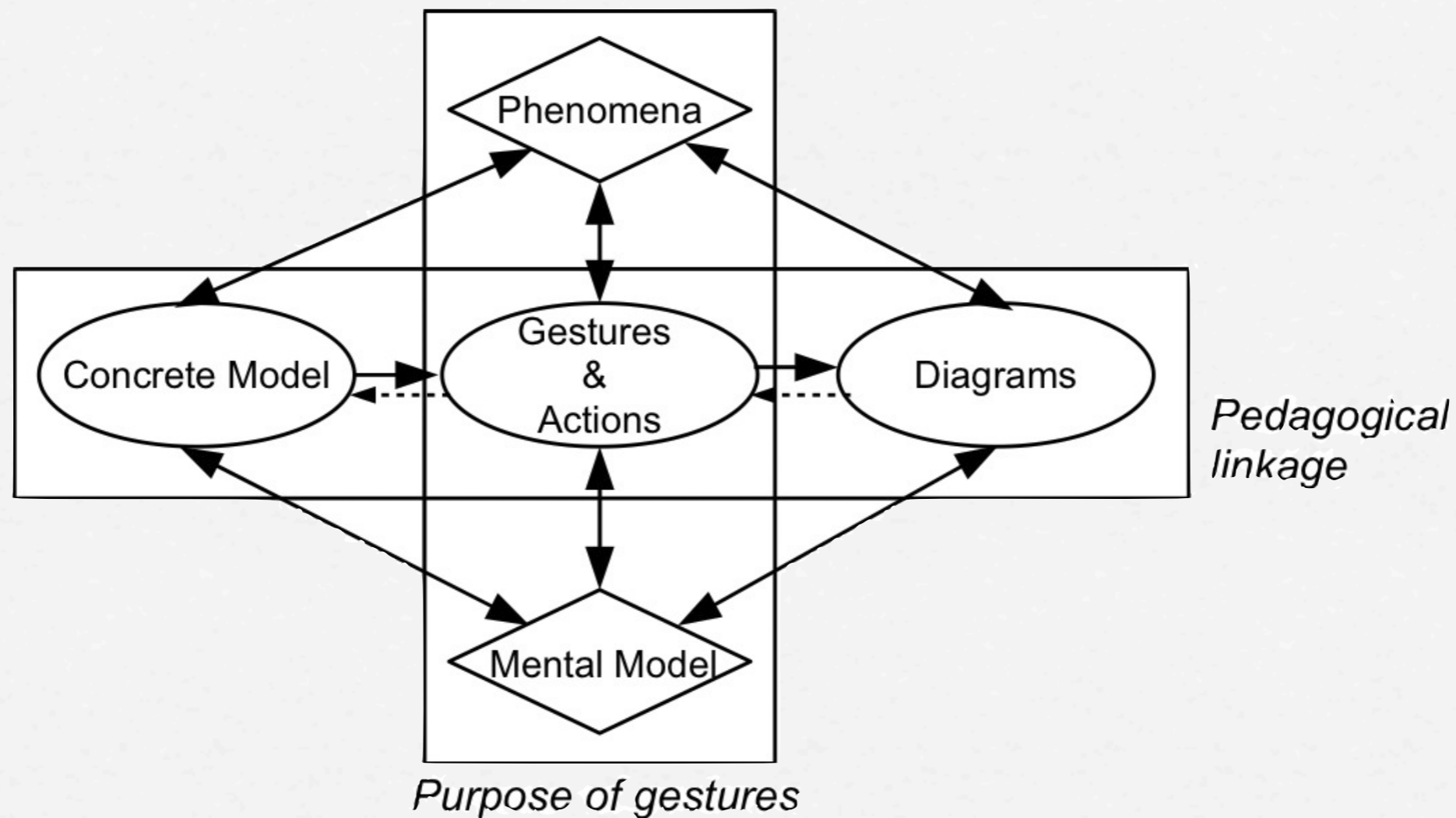
The earth's axis of rotation is tilted by 23.5 degrees

The earth revolves around the sun

Explanation:

- ✿ Allocentric frame: Consider a person at a particular latitude (e.g. on the tropic of cancer) at a given time (e.g. at solstice).
- ✿ Determine the terminator and mentally rotate the earth.
- ✿ Change our frame of reference from allocentric (outside the model) to egocentric (standing on the earth) to visualize path of sun.
- ✿ Change orientation on the earth to imagine path of sun from different latitudes.
- ✿ Change the position of the earth (e.g. at equinox).

The gesture link



Padalkar, S. and Ramadas, J. (2010). Designed and spontaneous gestures in elementary astronomy education. *International Journal of Science Education*. 33(12), 1703-1739.
DOI:10.1080/09500693.2010.520348

Examples of gestures

Path of the Sun (Phenomenon)...

<http://web.gnowledge.org/pedagogic-gestures/>



Apparent flatness of earth

Direction of rotation (Model)...

Orientation change...



Design

- ✿ Pretest in the beginning of the first part (Grades 4, 7)
Observations, Textbook information, Cultural information,
Models and Explanations
- ✿ Three parts of teaching (Grade 7 → 8)
 - ✿ Part I: Earth (roundness and rotation)
 - ✿ Part II: Sun-Earth system (revolution, parallel sun-rays)
 - ✿ Part III: Sun-Earth-Moon system
- ✿ Post test at the end of the last part (Grade 8 experimental and control)
- ✿ Interviews of selected students

Evaluation

- ❖ One of the tests was designed to probe students' mental models and explanations based on them
- ❖ Sample questions:
 - ❖ Draw diagram of the earth and show the direction of rain falling on every place on the circumference of the diagram.
 - ❖ What changes will take place in the motion of the sun, the moon, stars if the earth stops rotating around its axis?
 - ❖ Draw a diagram of the earth if it is seen from exactly in the plane of the equator. Draw the axis of rotation of the earth and the equator. Draw a person on equator. Draw a line of horizon for that person. Show 'Up', 'Down', 'North' and 'South' directions for that person. At what angle would a person standing on the equator see the Pole Star?

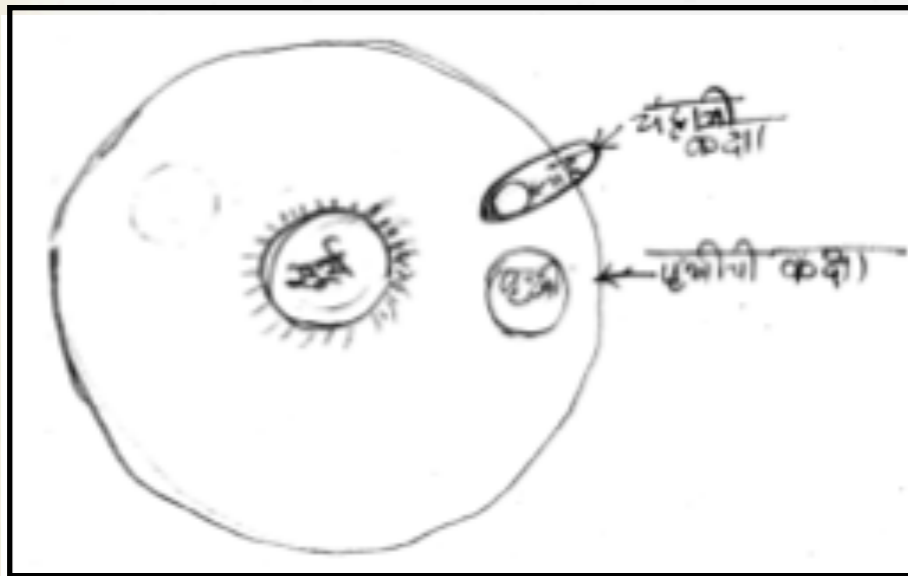
Sample

- ✿ Grade 7 - 8 students from three schools in the State of Maharashtra; Medium of instruction: Marathi
- ✿ Urban: Students from a school in slum area of Mumbai volunteered
- ✿ Rural: Class from a school in a single building of a temple in a farming village
- ✿ Tribal: Class in a residential school for nomadic tribal children

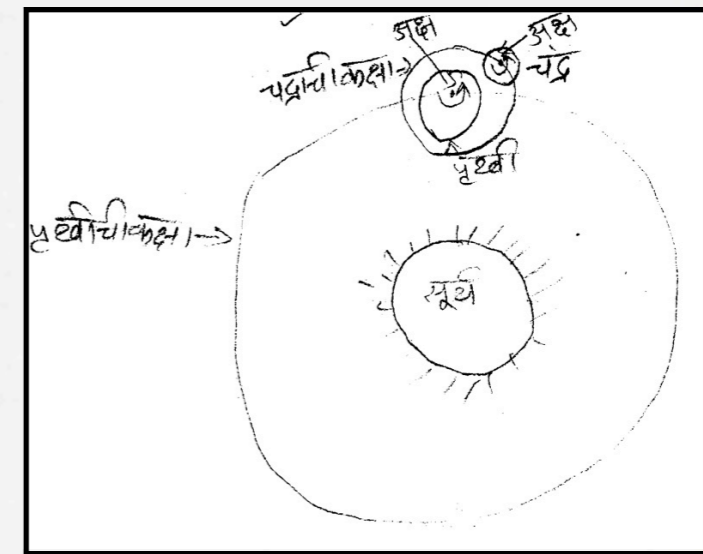
	Urban	Tribal	Rural	Total
Girls	4	4	12	20 (29%)
Boys	14	13	21	48 (71%)
Total	18	17	33	68

Results

The sun-earth-moon model



Incoherent diagram



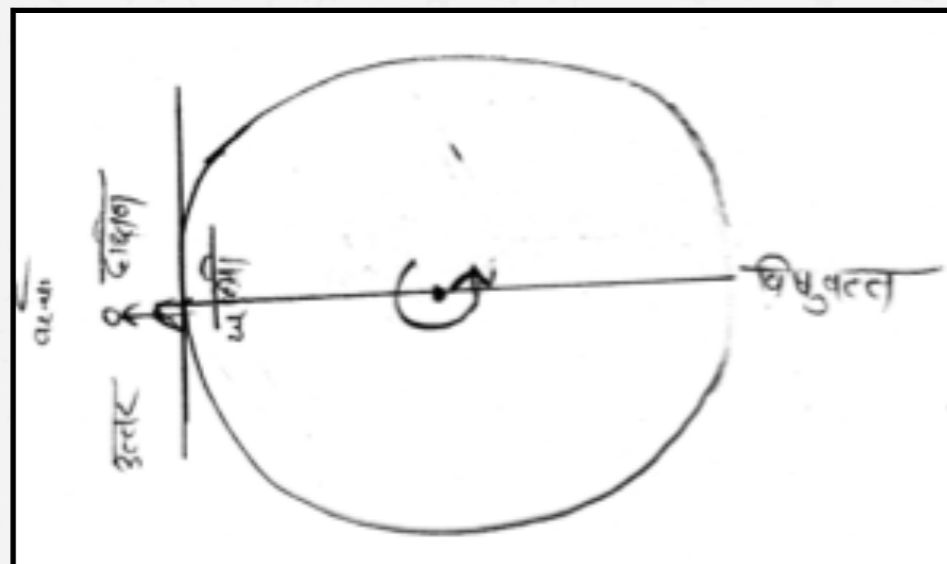
Coherent diagram

	Expt (Pre)	Expt (Post)	Control
Grade	7	8	8
% Coherent diagrams	5.08*	15.97*	2.44

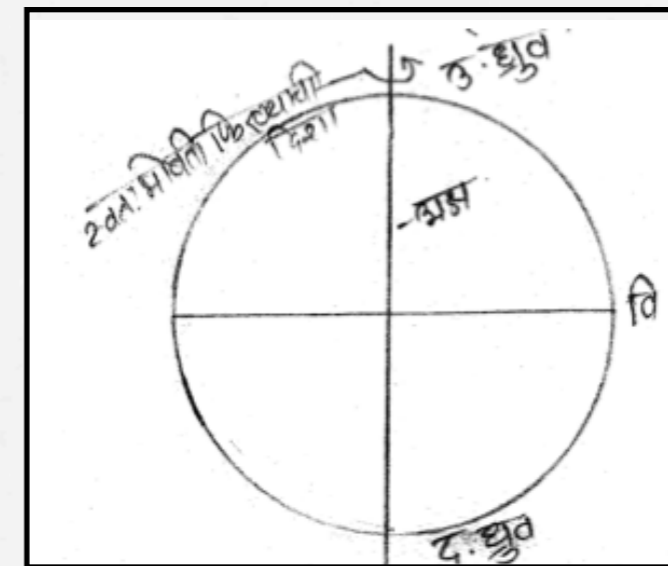
* significant difference - z test, $p < .05$

Results

Model of the earth



Inconsistent perspective

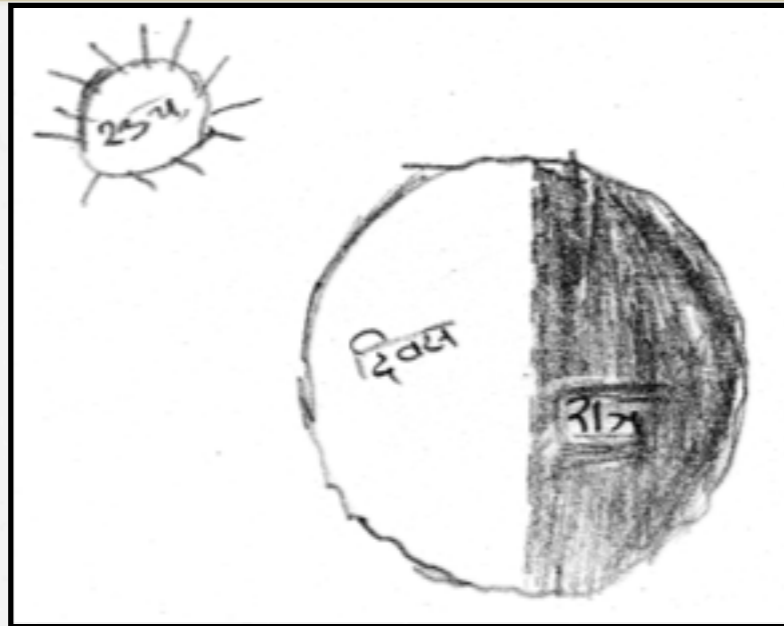


Consistent perspective

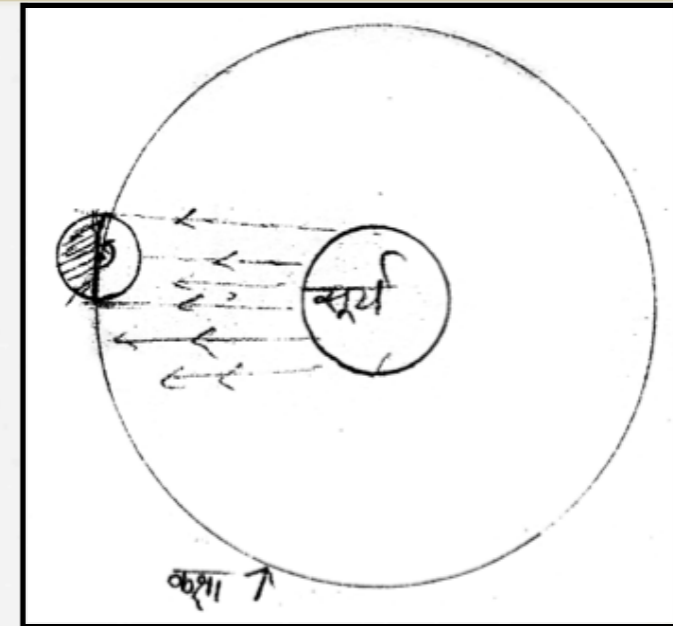
	Expt (Pre)	Expt (Post)	Control
Grade	7	8	8
% Consistent perspective	4.24*	23.12*	2.63

* significant difference - z test, $p < .05$

Results



Motion not shown



Axial and orbital motion

	Expt (Pre)	Expt (Post)	Control
Grade	7	8	8
% Showing axial motion	0.73*	34.29*	3.2
% showing orbital motion	0*	15.45*	0.66

* significant difference - z test, $p < .05$

Results

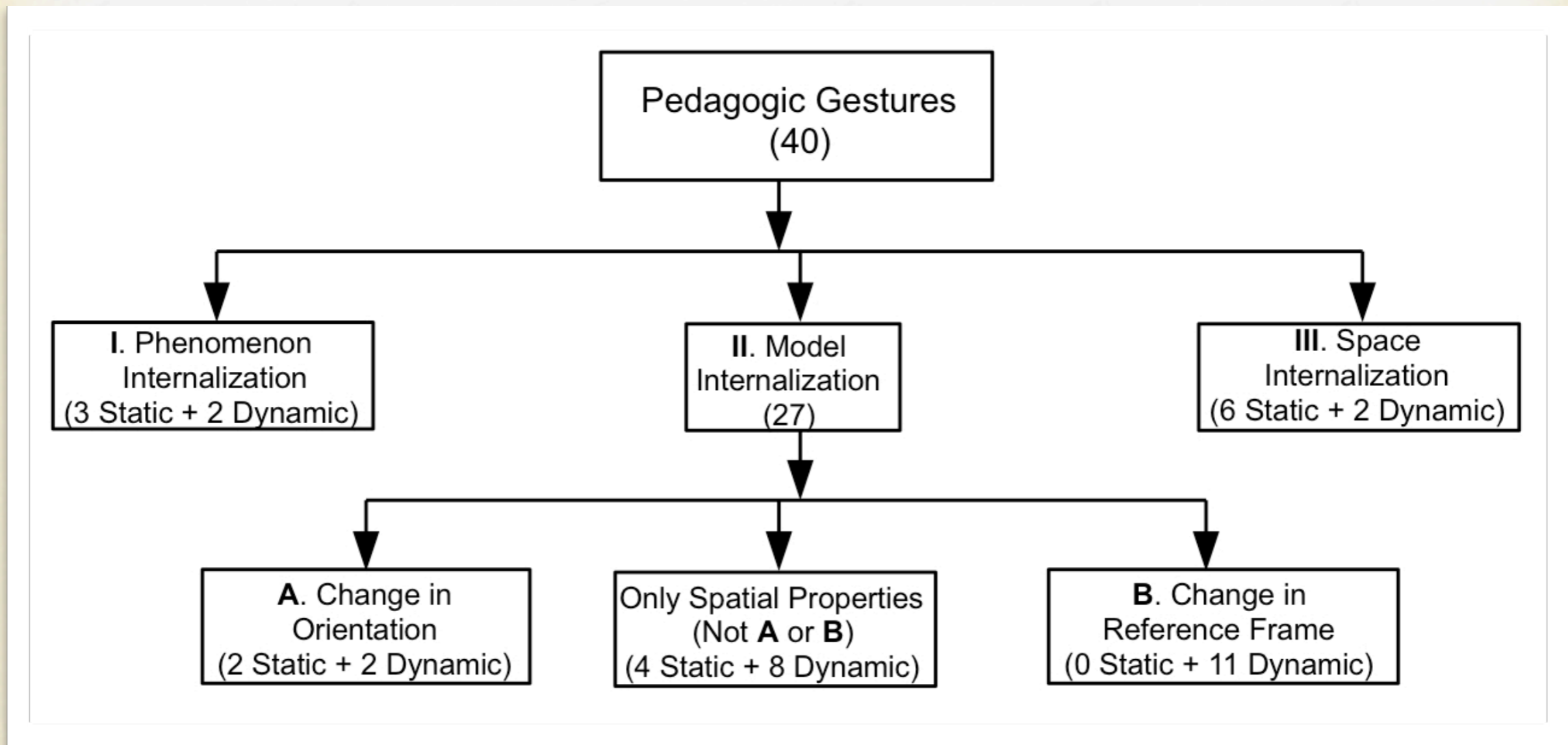
- ✱ Grade 7 students' score on the test improved in Grade 8 after the intervention [$t(35) = 11.01, p < 0.001$]
- ✱ For Grade 8, the treatment group performed better than the comparison group [$t(128) = 11.42, p < 0.001$]

	Grade	Mean	S.D.
Expt (Pre)	7	17.18	4.03
Expt (Post)	8	31.7	9.41
Control	8	16.57	5.66

References

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Gestures and diagrams to teach astronomy



<http://web.gnowledge.org/pedagogic-gestures/>