# TEACHING RELATIVITY for PHYSICS TEACHERS

## DEVELOPMENT OF A FRAMEWORK OF RELATIVITY BASED ON INVARIANCE CONCEPT

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# MOTIVATION

- **RESEARCH BACKGROUND**

- Relativity(SR and GR both) is introduced in secondary school textbook in Korea since 2009.
- But many teachers are unprepared.(lack of understanding)
- Absence of the detailed guideline for what has to be taught and what are the central ideas in relativity.
- Most of the evaluation questions are superficial type.

- **RESEARCH PURPOSE**

- To find a way to help teachers in learning/teaching relativity.
- To present a framework of relativity and its development process.
- To present teachers' responses to the framework.

# PREVIOUS STUDIES related with a framework for teaching physics

- **General Science Education**

- Concept map (Novak, 1990)
- Cultural Context Knowledge (Galili, 2012)

- **Relativity Education**

- Schematic diagram for topics and their interrelationship (e.g., D'Inverno, 1992)
- Summary of the book : The scope, core principles and topics (e.g., Taylor, Wheeler and Bertschinger, 2008)
- Chart showing chapters(sections) and their dependence on each other (e.g., Moore, 2012)

# RESEARCH CONTEXT & METHOD (1)

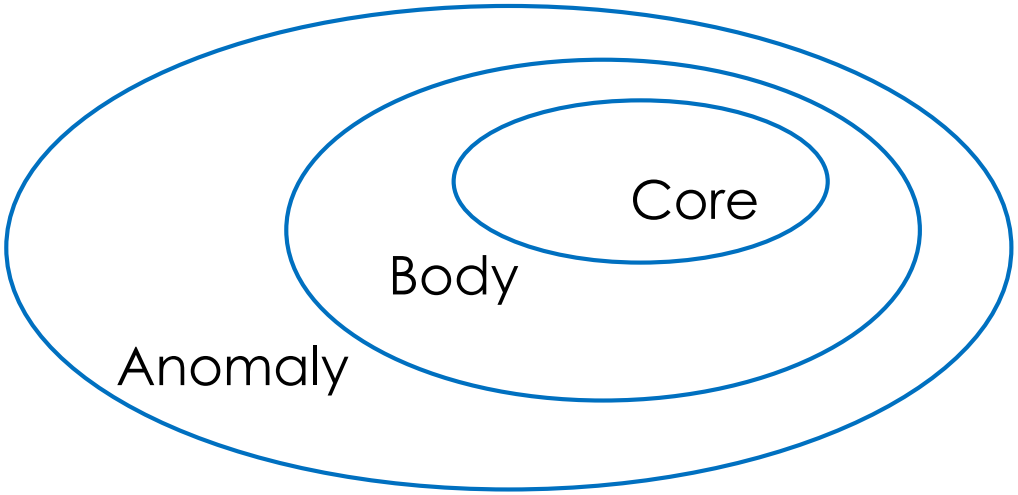
- **UNDERGRADUATE COURSE** (spring, 2016)

- Course title : '*Materials and methods in teaching physics*' at Seoul National University
- Participants : 9 students(pre-service physics teachers)
- Course goal : Analyzing/developing physics textbooks/materials including The evolution of physics written by Einstein and Infeld

| | |
|---|---|
| Step 1 | Presenting the framework as a big picture |
| Step 2 | Class discussion on the framework |
| Step 3 | Individual interview (2 students) |

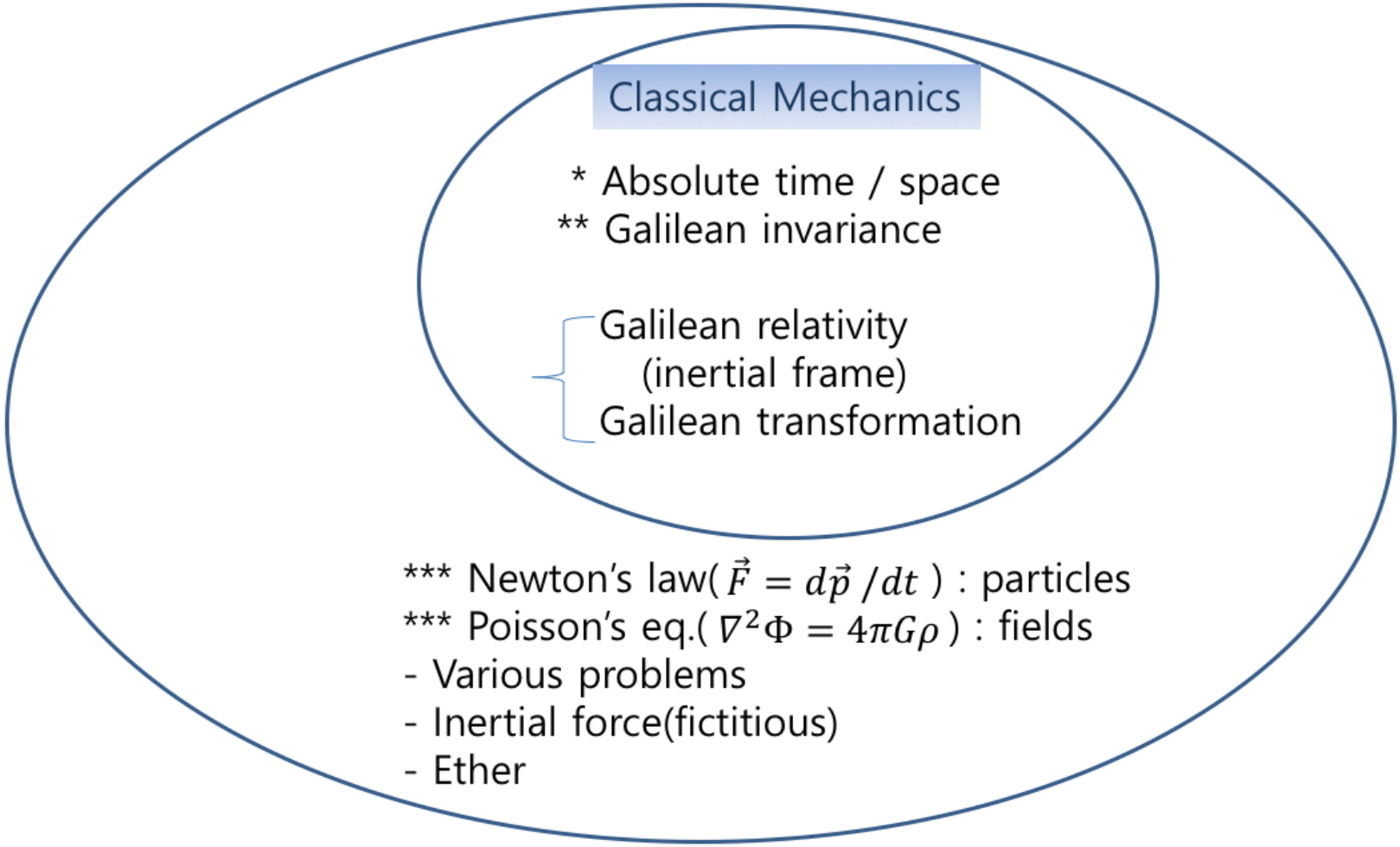
# RESEARCH RESULTS (1) : THE FRAMEWORK OF RELATIVITY

- **Core Knowledge** : fundamental principles, central ideas
- **Body Knowledge** : explained phenomena, laws and experimental results fit in well with the core knowledge
- **Anomaly** : unexplained phenomena, contradictory idea against the core knowledge, alternative ideas, challenging core



# An example : CLASSICAL MECHANICS

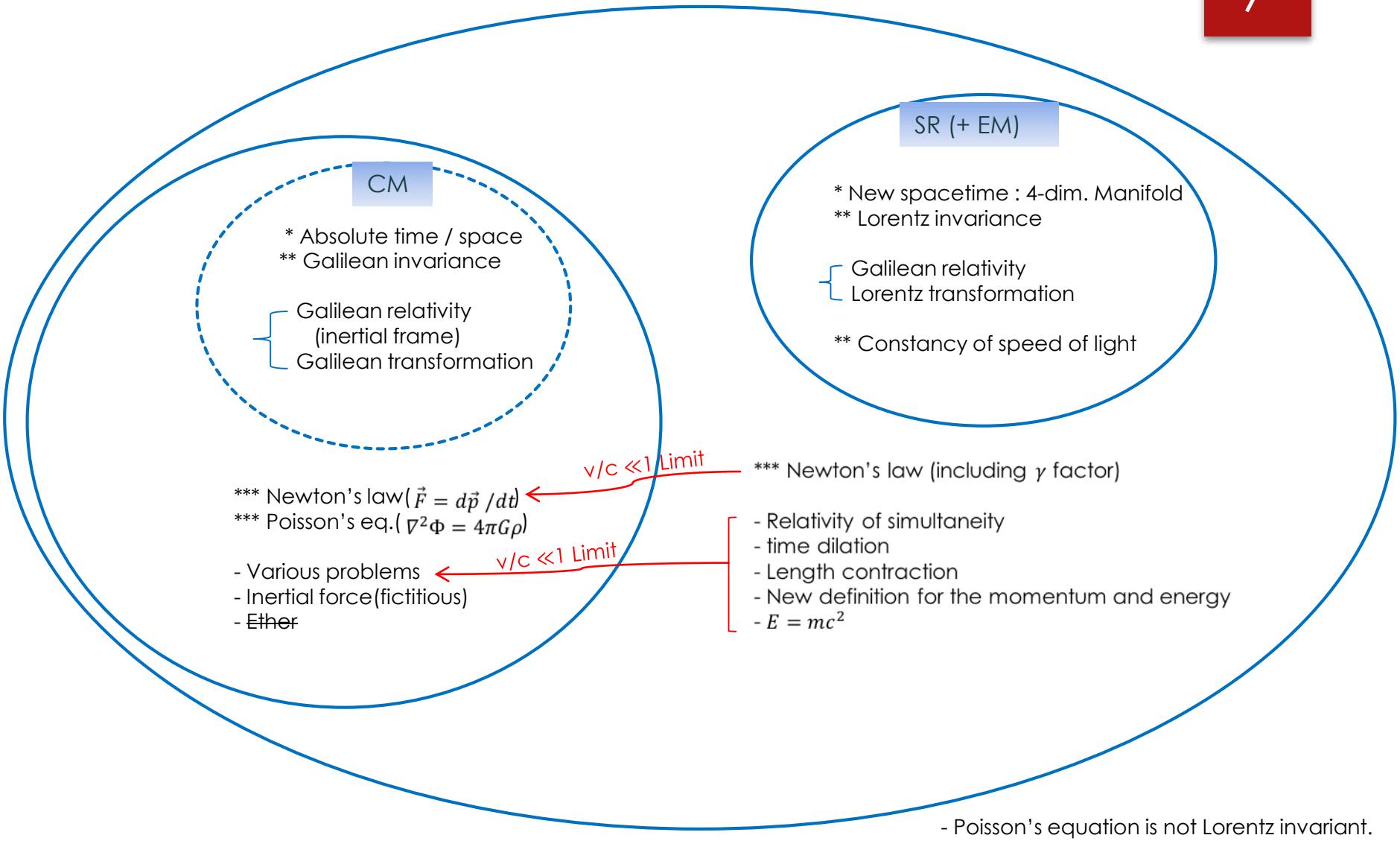





-Electromagnetism
(constancy of speed of light)
-Precession of Mercury(43"/100 years)

# THE FRAMEWORK OF SR



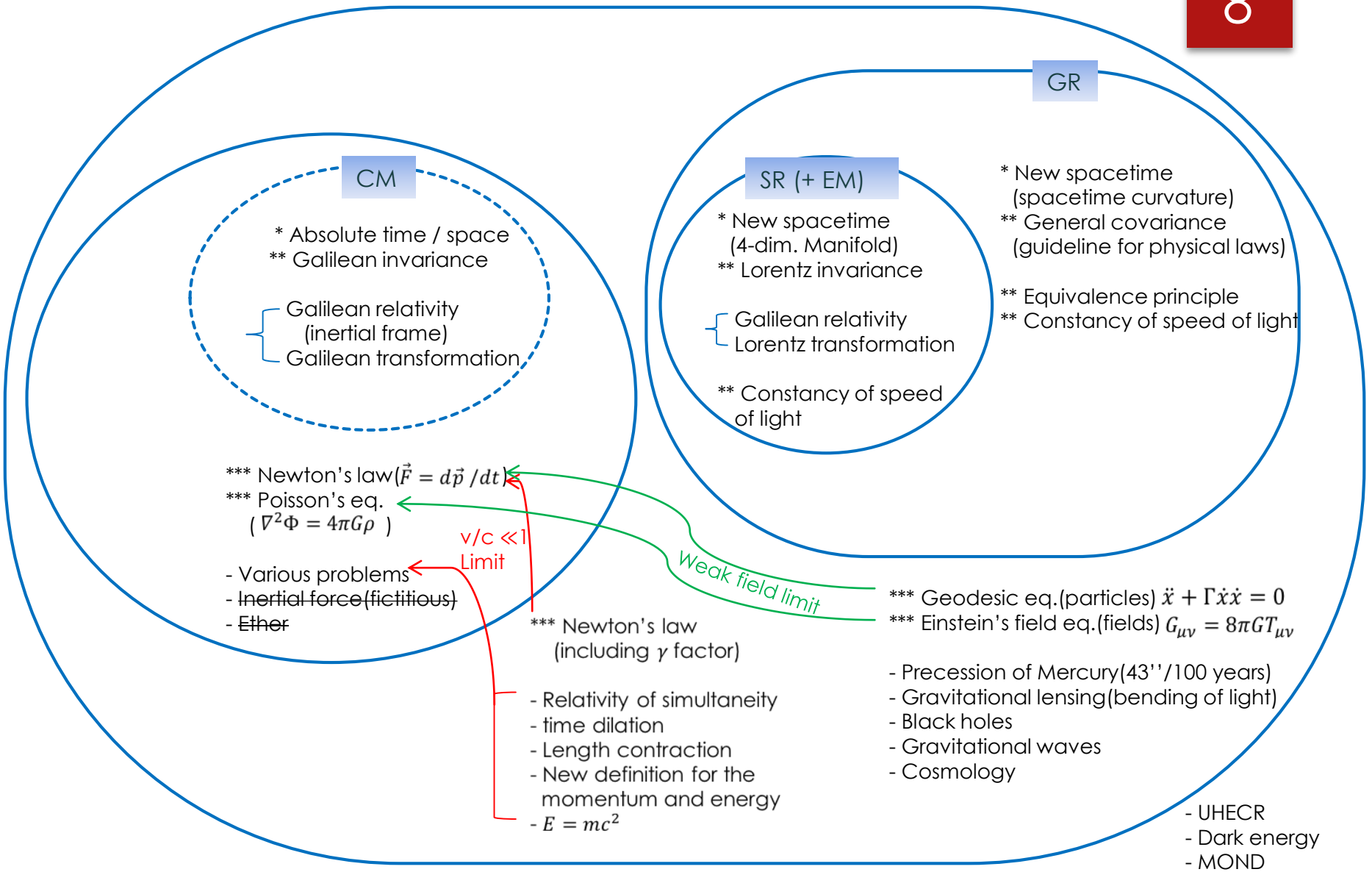



- Poisson's equation is not Lorentz invariant.
- Precession of Mercury(43''/100 years)
- Application to non-inertial frame

, ~~ABC~~ : abolished concepts after introducing new core

# THE FRAMEWORK OF RELATIVITY






, ~~ABC~~ : abolished concepts after introducing new core

# PROPERTIES OF THE FRAMEWORK

- Visually clear distinction between the *core* knowledge and the *peripheral* knowledge.
- Similar to CCK(Galili, 2012), but different in the following points :
  - More intuitive terms : *Core, Body* and *Anomaly*

    ⇨ Easy for students to express their thought
  - Intimately related through the invariance concept
- In accordance with Einstein's thought : e.g. *Evolution of Physics*(1938)
- Not presented unilaterally, but can be made by students and instructor together during the class time

# RESEARCH CONTEXT & METHOD (2)

- **GRADUATE COURSE** (spring, 2016)

- Course title : '*Modern Physics* & *Education*' at Seoul National University
- We spent the first 5 weeks for introducing relativity (2.5 for SR and 2.5 for GR)
- Participants: 14 students (diverse composition)

  middle school(5), high school(2), science high school(1), undergraduate(2), physics-biased(1), PER-biased(3) - among them 58% are in-service secondary school physics teachers

| | | |
|---|---|---|
| Step 1 | Lecture | Teaching SR/GR for 5 weeks (3 hours per week) |
| Step 2 | Exposure to the framework | Introducing & explanation (about 20 min.) |
| Step 3 | Post-questionnaire | "Was the framework helpful for you to understand the relativity?" and "In what sense?" |
| Step 4 | Class discussion | Just after completing the questionnaire |
| Step 5 | Individual Interview | 5 teachers are interviewed with a semi-structured protocol |

# RESEARCH RESULTS (2)
# : TEACHERS' RESPONSES TO THE FRAMEWORK

**1) Realization of the unity and interconnected relationship**

"(After I learned with using the framework) looking back, there was lack of unity(full explanation using *invariance*) in my lectures[at the high school]. And I introduced GR suddenly without any reason for the transition from SR to GR." - *Teacher A*

**2) Fundamental principle, invariance and universality of Nature**

"Such a classification of concepts may put the knowledge into shape. [...] I want my pupils know the most fundamental and underlying principles which interprete natural phenomena, although not every students will become scientists." - *Teacher B*

"I had no idea about *invariance* before. But I realized its importance through the class. Now I think that meaningful thing is to teach something unchanged , something absolute. The important thing is to let my students know something universal and the essence of science." - *Teacher A*

# RESEARCH RESULTS (2)
# : TEACHERS' RESPONSES TO THE FRAMEWORK

**3) Role as a guide or a map**

"Sometimes I got lost in learning relativity because I had no idea about which is central and which is peripheral. [...] It is possible to distinguish core idea from body knowledge via the framework of relativity, so that I would not get lost." – *Teacher C*

"This[the framework] would play a role of compass." - *Teacher B*

**4) Understanding of the unification**

"Before the class, I regarded relativity as extremely special case and restricted field of physics. But now I take an opposite view : relativity is the universality-ori ented theory. ... If a teacher who realized this feature is questioned like 'What is the relativity for anyway?', (s)he would say that relativity pursue the essence of Nature." - *Teacher A*

**5) Importance of the inertial frame**

"I had no chance to study and think deeply about inertial frame of reference." - *Teacher B*

# SUMMARY

- We have developed the framework of relativity and there were positive changes in the teachers' understanding of relativity.
- The framework shows clear distinction between *Core*, *Body* and *Anomaly* of relativity.
- The framework is expected to play a role of a map or a guide
- The importance of Invariance, universality and unification is well understood with the help of using the framework : from CM to SR / from SR to GR
- One more remarkable response : "*Changing a view of Nature*"

A pre-service teacher wrote :

"I realized that Nature is quite different from what I thought about it. There is more to Nature than meets my eyes. What I observe is not everything. Nature would behave contrary to what I think."

# DISCUSSION and FURTHER STUDY

- We need to further develop the framework for meeting the diverse needs of learners who want to understand relativity.

For instance,

- Making connections between the framework and other resources(e.g., related books, reading materials, multimedia)

⇨ Learners would find more detailed explanations when needed.

- Developing *Worksheets* :

⇨ Activity(drawing/explaining a framework) would lead students to understand the main contents and overall relationship between them.

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**Thank you**