Designing Engaging Learning Practices in STEM

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1. **Students' declining interest in science learning and STEM careers (Science, Technology, Engineering, Mathematics)**

2. ***Finnish New Curriculum*: Engaging students in learning through collaboration and scientific practices: Project-Based Learning (PBL)**

3. **Case 1: PBL engages students in science learning**

4. **Case 2: PBL supports science learning outcomes**

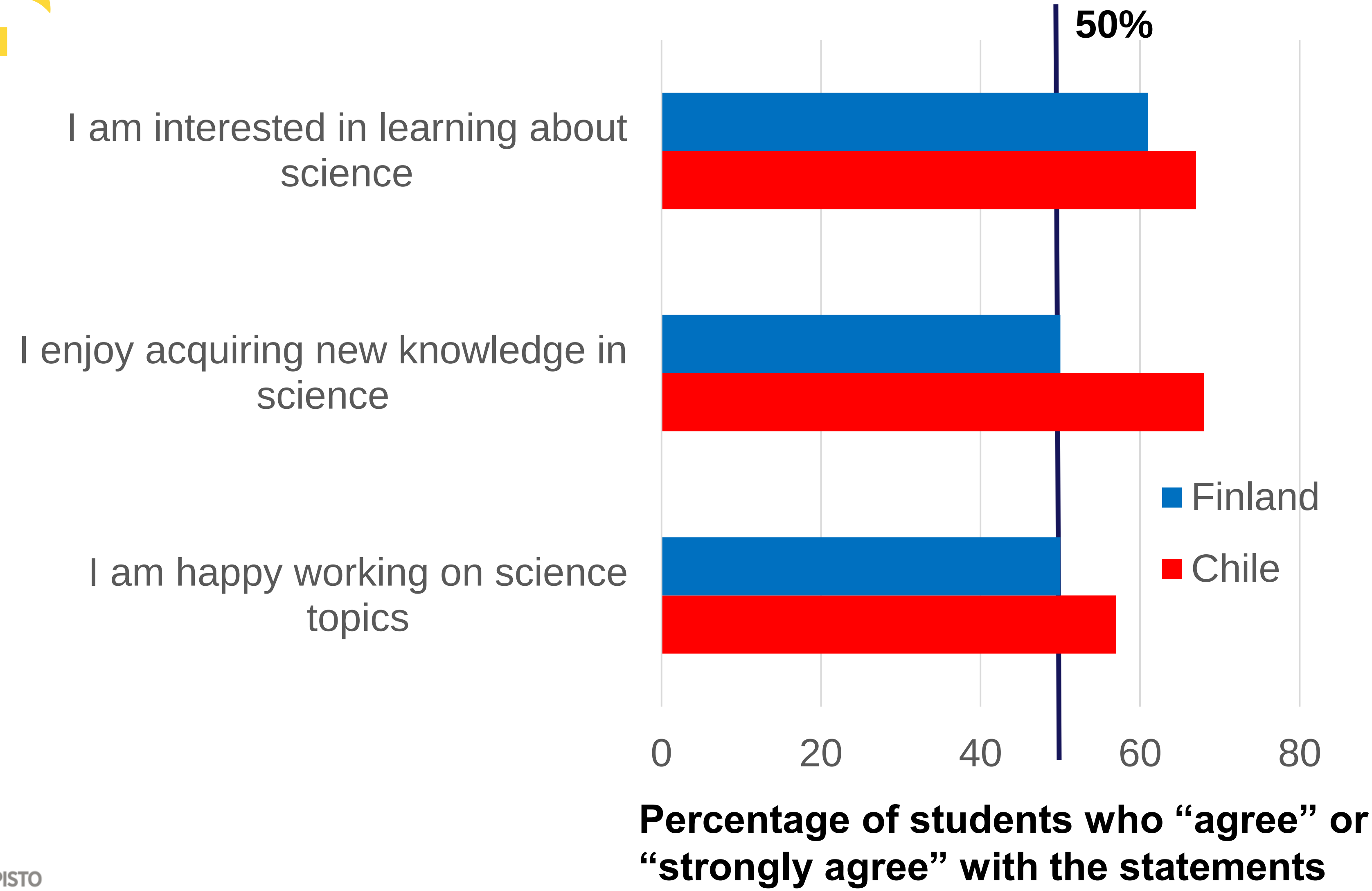
5. **Final remarks**

Students’ declining interest in science learning and STEM careers

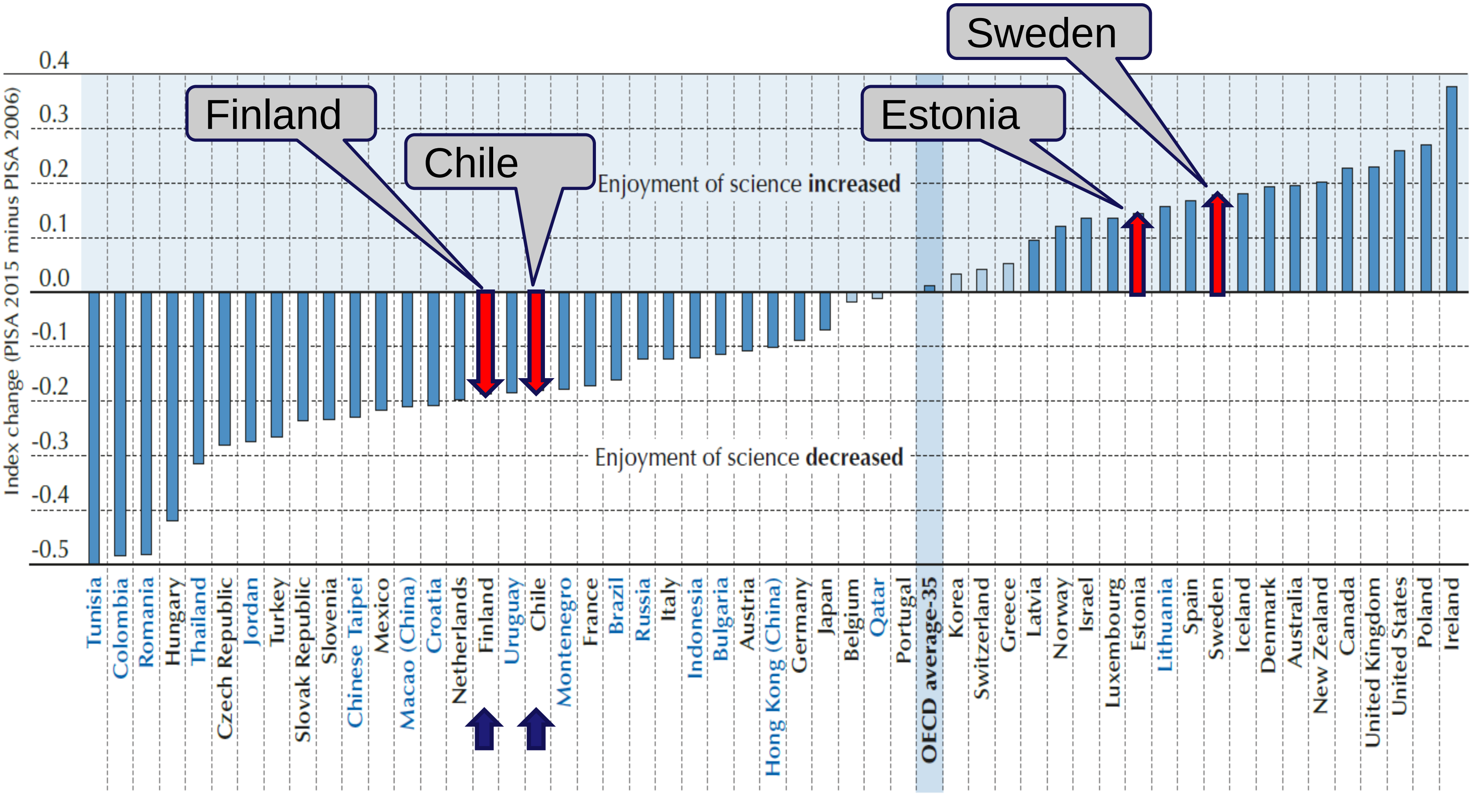
- Students’ <u>declining interest</u> / engagement in science learning (Osborne & Dillon, 2008; Zeyer et al., 2013).

- <u>Lack of interest in STEM careers</u>

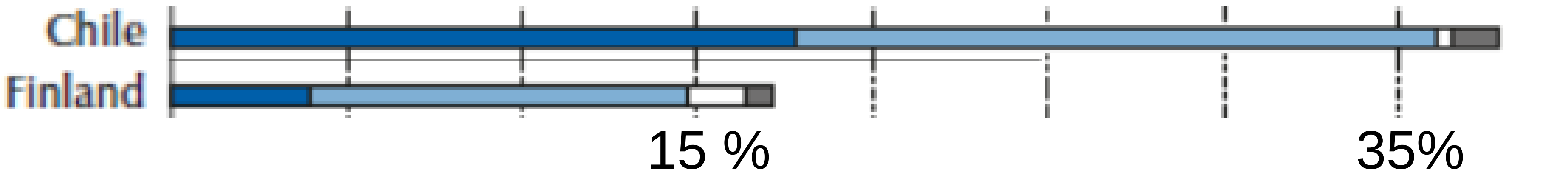
Students' enjoyment of learning science according to PISA 2015

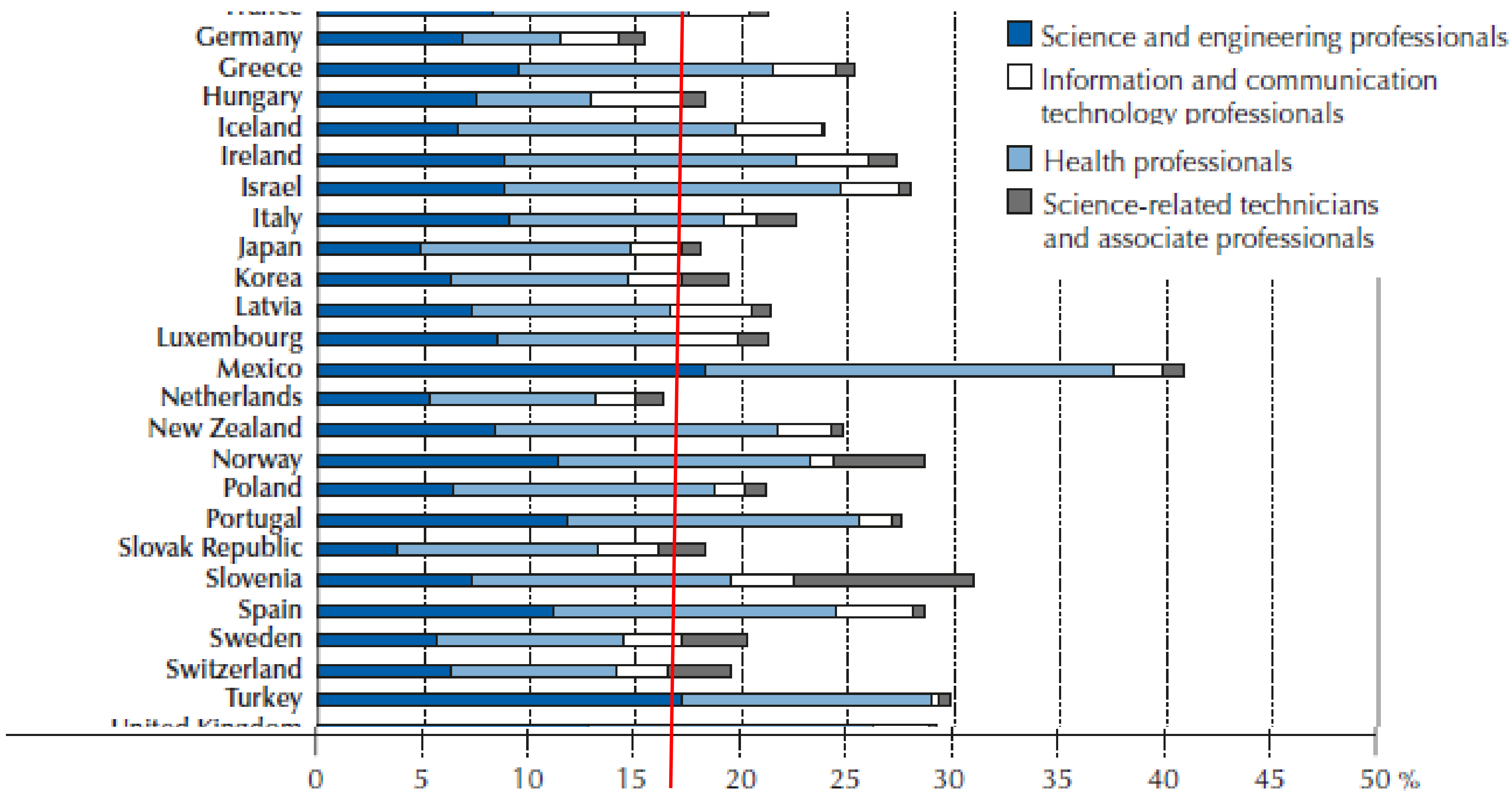


Change between PISA 2006 and 2015 in students' enjoyment of learning science

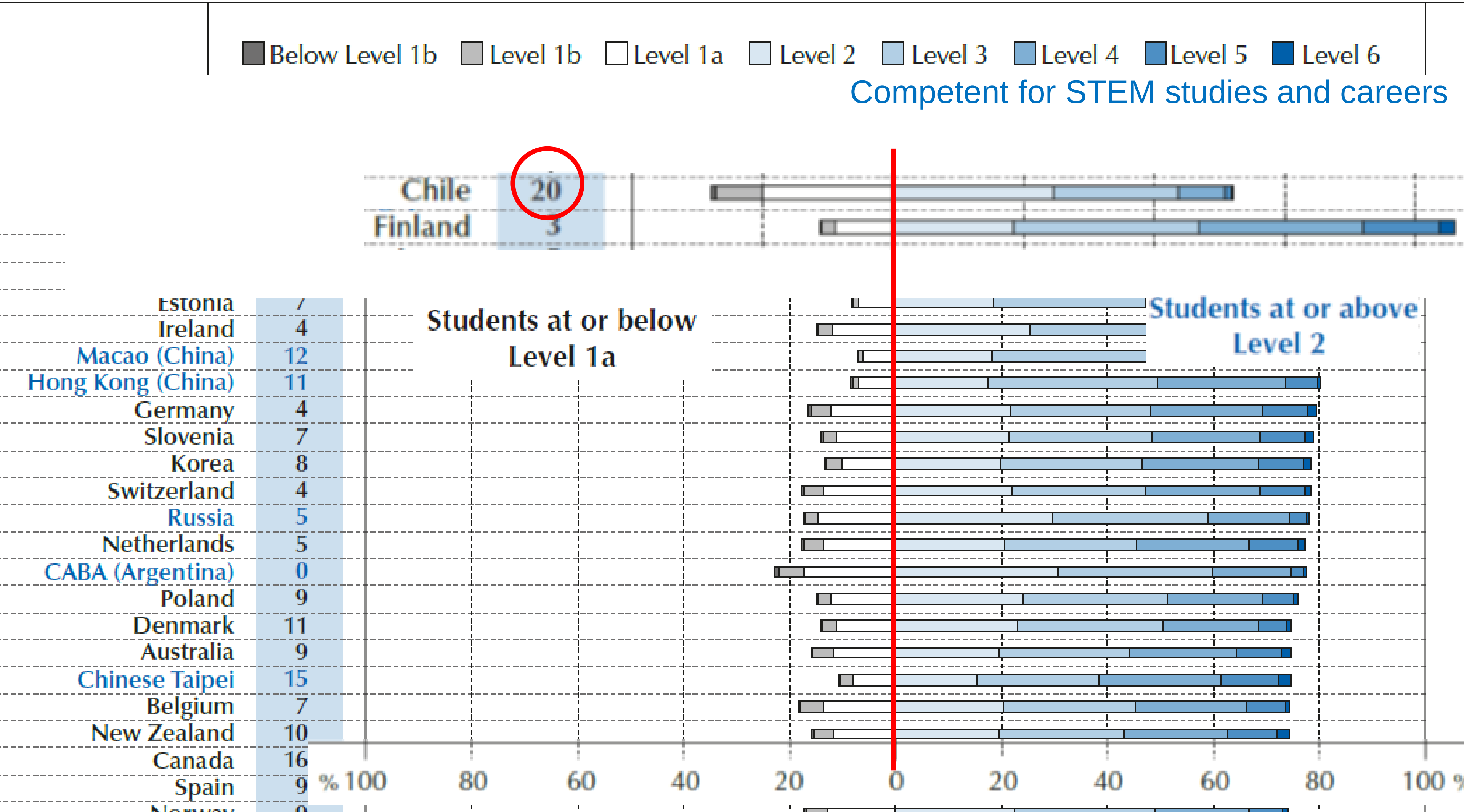


Percentage of students who expect to work in science-related professional and technical occupations when they are 30





Students at the different levels of PISA proficiency in science, as a percentage of all 15-year-olds



Much is already known about …

- emotional, cognitive and behavioural components of engagement (Christenson, Reschly, & Wylie, 2012; Fredricks, Blumenfeld, & Paris, 2004).
- development of interest in the context of POI through choosing an appropriate activity (Krapp & Prenzel, 2011).
- a task is valued because of its characteristics and how it fulfils the individual needs, values and goals

  (Eccles et al. 1983; Eccles & Wigfield, 2002)
- differences in male and female students' engagement in science learning (Tytler, Osborne, Williams, Tytler, & Cripps, 2008).
- …

Why it is important that students are interested in science learning?

Students who are more interested are more likely to …

- … show higher level of self-regulation and effort
  (W. Lee, M-J Lee & Bong, 2014; Trautwein et al., 2015)
- … spend more time on learning tasks
  (Ainley, Hidi, & Berndorf, 2002)
- …engage in effective learning startegies
  (Krapp, 2000; Schiefile, 1991, 1999)
- …better learn concepts
  (Cordova, Sinatra, jones Taasobshirazi & Lombardi, 2014)

Engagement in the context of flow theory (Csikszentmihalyi, 1990)

- Situational momentary experience which vary in intensity across different domains and situations

- Preconditions for engagement are
  - the situational interest of the task *(content and context specific)*, and depends on knowledge, value and feelings
  - student's skills related to the activity or the task *(situational resources)*,
  - challenge of the activity or the task *(situational task demands)*.

"Challenge is the engine that propels interest and skill to new levels"

Students’ declining interest in science learning and STEM (Science, Technology, Engineering, Mathematics) careers

***Finnish New Curriculum*: Engaging students in learning through collaboration and scientific practices: Project-Based Learning (PBL)**

Case 1: PBL engages students in science learning

Case 2: PBL supports science learning outcomes

Final remarks

Student engagement in science learning through scientific practices

- In many countries teachers do not guide students to ask relevant questions, build models, solve problems, make decisions, and create new ideas.

  (Krajcik, Codere, Dahsah, Bayer, & Mun, 2014; Krajcik & Czerniak, 2013)

- The new *Finnish science curriculum* emphasises:
  - the importance of student engagement in science learning
  - make sense of phenomena through engaging in scientific practices and in collaboration with other students
  - learn core ideas or concepts and models

- The *European Commission's Horizon 2020 Work Programme* (EU, 2016) emphasises that STEM learning at school should better represent real STEM practices.

A core ideas (concepts) in school science…

- **Disciplinary significance**: Broad importance across science (engineering)
- **Explanatory Power**: Used for explaining phenomena
- **Generative**: A key tool for understanding or investigating more complex ideas and solving problems
- **Relevant to peoples' lives**: Personal, local (society) and global context
- **Usable for school science**: Is teachable and learnable

Disciplinary Core Ideas (Concepts)

Physical Sciences

- Matter and its interactions, chemical reaction
- Motion and forces, interactions
- Energy
- Waves and fields

Engineering & Technology

- Engineering design
- Links between engineering, technology, science, and society
- Technologies for information transfer

Life Science

- From molecules to organisms: structures and processes
- Ecosystems: interactions, energy, and dynamics
- Heredity: Inheritance and variation of traits
- Biological evolution: Unity and diversity

Earth & Space Science

- Earth and the Universe
- Earth's Systems
- Earth and Human Activity

What are Scientific and Engineering (STEM) Practices?

The multiple ways of knowing and doing that scientists and engineers use to study the natural world and design world.

The practices work together – they are not separated!

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Developing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Collaboration

- Students
  - use language to express knowledge
  - express, debate and come to common ideas
  - debate the viability of evidence
  - work together for supporting meaning making
  - build explanations and models
  - use knowledge for applying, predicting, …
- In a heterogeneous group
  - students learn from each other
  - high achieving students work as role models for low achieving students
  - all students are members of the community

Project-Based (Science) Learning (PBL)

Planning of science education in the context of *Project Based Learning (PBL)*

(Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; Krajcik & Czerniak, 2013)

- PLP starts with a *driving question*, a problem to be solved.
- Students **make sense of phenomena**:
  - are active in **knowledge building;**
  - explore the driving question through participating in scientific and engineering practices (**knowledge practices**) –central to expert performance in the subject;
  - engage in **collaborative activities**;
  - create a set of products (**shared artefacts**) (external representations of the class's learning).
- *Students are scaffolded* in order to help them participate in activities normally beyond their ability.

Formative assessment

Learning science research emphasizes following characters of (science) learning (Krajcik & Shin, 2015):

- *Knowledge building* refers to the process of creating cognitive artefacts, like concepts and models.
- *Knowledge practices* in the context of (science) teaching and learning, like reasoning, critical thinking, and scientific practices, such as questioning, observing, modelling.
- In *social interaction* learners develop understandings of principles and ideas through sharing and debating ideas back and forth with others.
- *Cognitive tools or artifacts*, such as graphs, robots …., help learners see patterns in data.

Driving Questions

- Driving question contextualize project based learning and drive for inquiry activities
- Key features:
  - **Trigger interest**: creates a need to learn and know
  - **Contextualise:** anchor the topic in real world issues; has real world consequences; is interesting and important to learners.
  - **Feasible:** students can ask their own questions; design and perform an investigation in order to answer the question.
  - **Worthwhile**: is rich in science content and practices; is complex enough to be broken down into smaller questions; the question leads to further questions.
  - **Ethical**: do not harm living organisms or the environment
  - **Sustainable**: allows students to pursue solutions over time; encourages students to explore ideas in great detail

Examples of Driving Questions

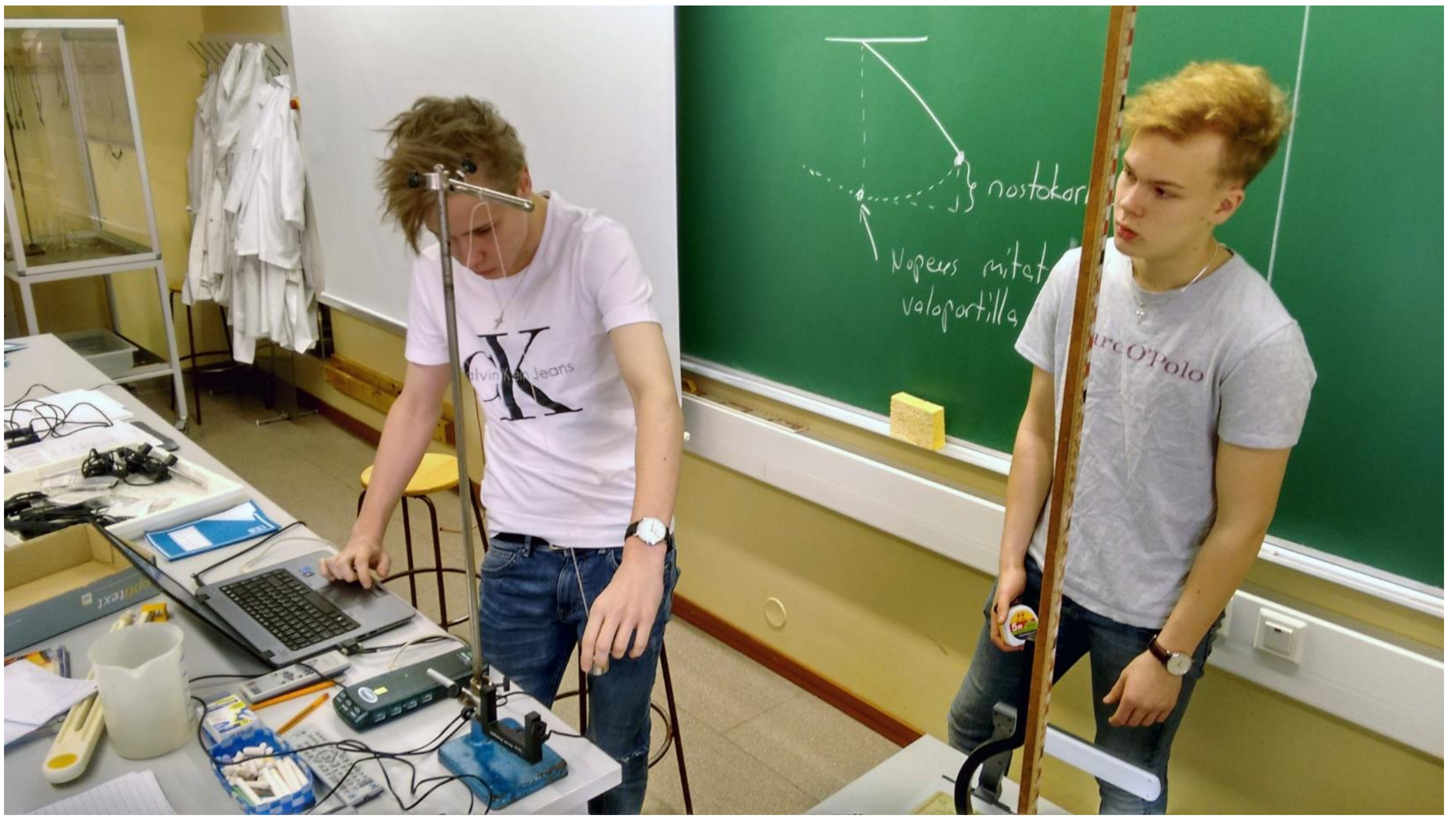
- **Why some objects fall quick and some slowly?**

- Why different materials behave in a different way?
- **What material (plastic, paper, metal) I choose for a bag?**

- What foods are good for me to eat?
- How good is the soil in my playground for growing plants?

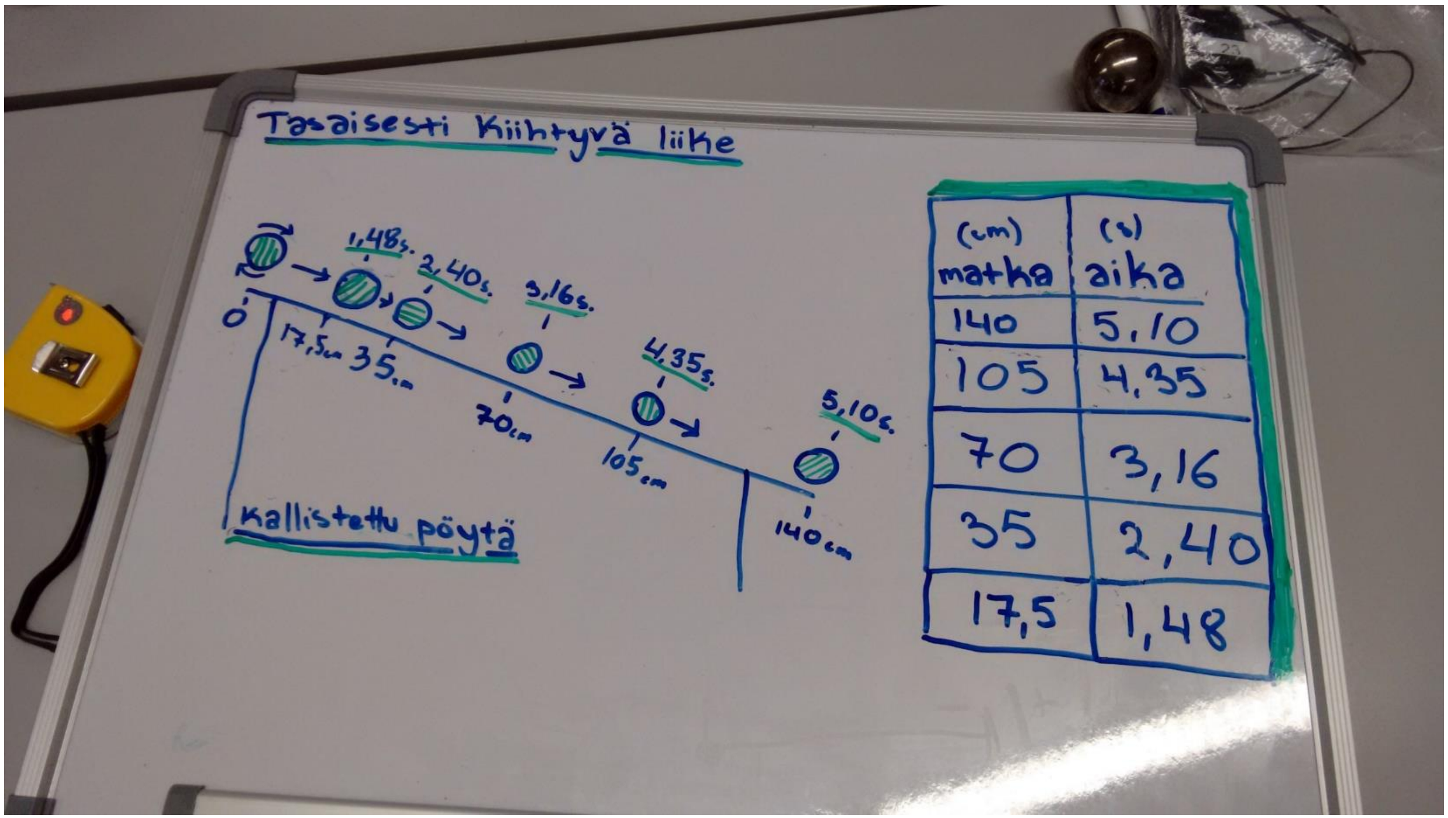
Asking questions and Planning investigations

Carrying out investigations



Analyzing and interpreting data

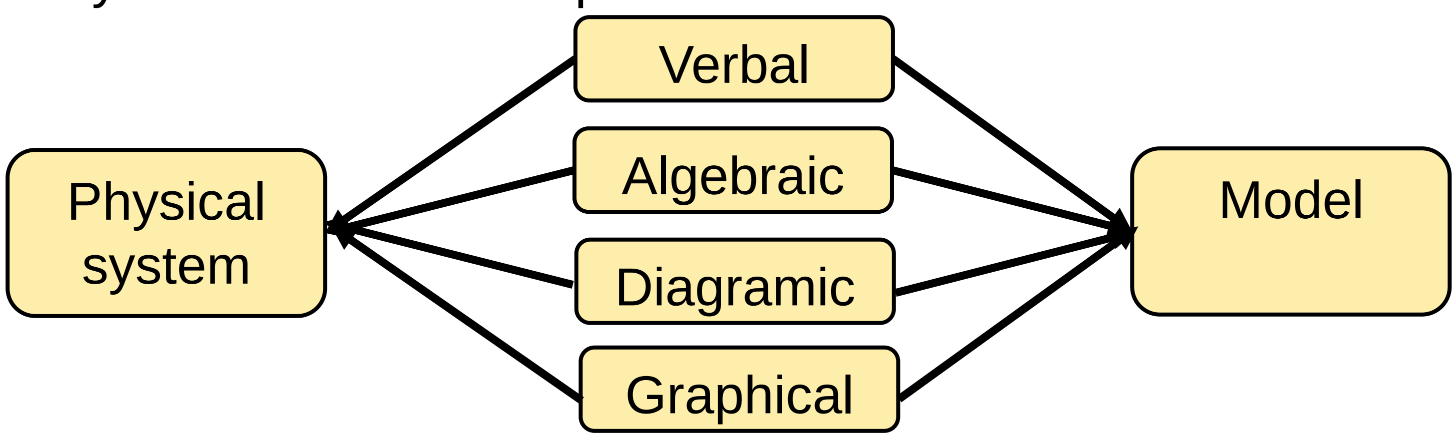
Developing a model (table and motion map)



Communicating information

What is a scientific model?

- A model represents
  - objects (physical systems) and
  - the relationships between objects to explain and predict phenomena (provides a causal mechanism)
  - in a consistent and logical way emphasising properties.
- The model has multiple representations, which taken together define the structure of the physical system.
- Symbolic and other representations:

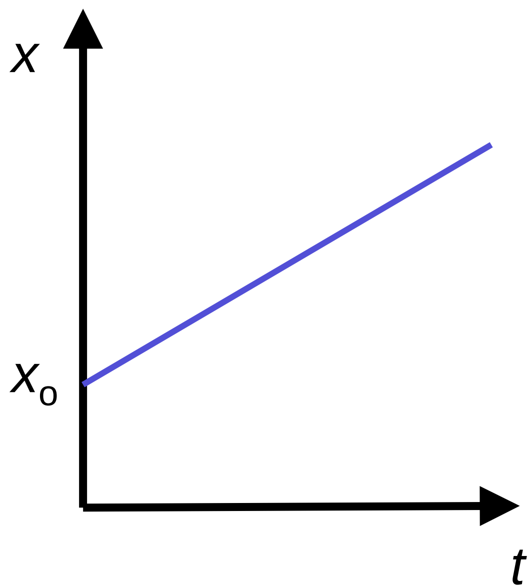


Multiple representations

- a particle moving at constant velocity

time (s)	*distance* (m)
15	100
30	200
45	300
60	400
75	500

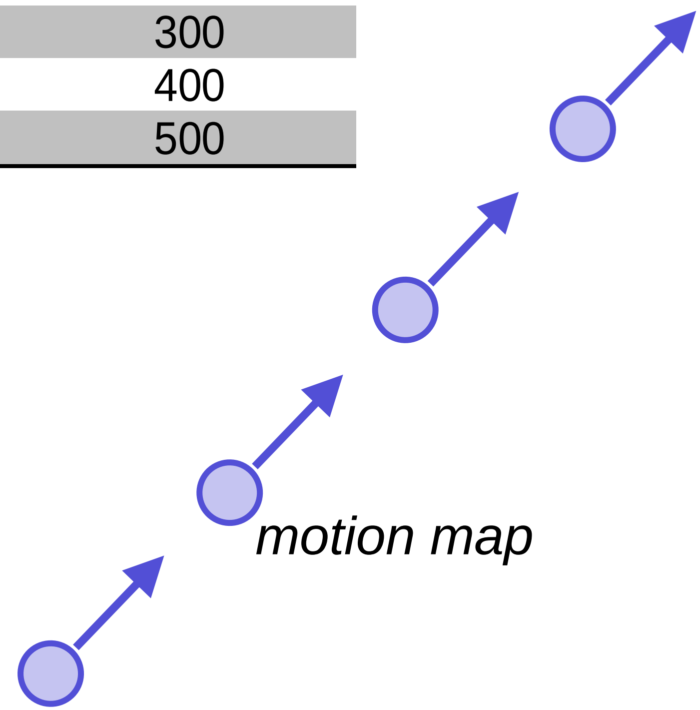
table



graphical

$$x = x_o + vt$$

algebraic



motion map

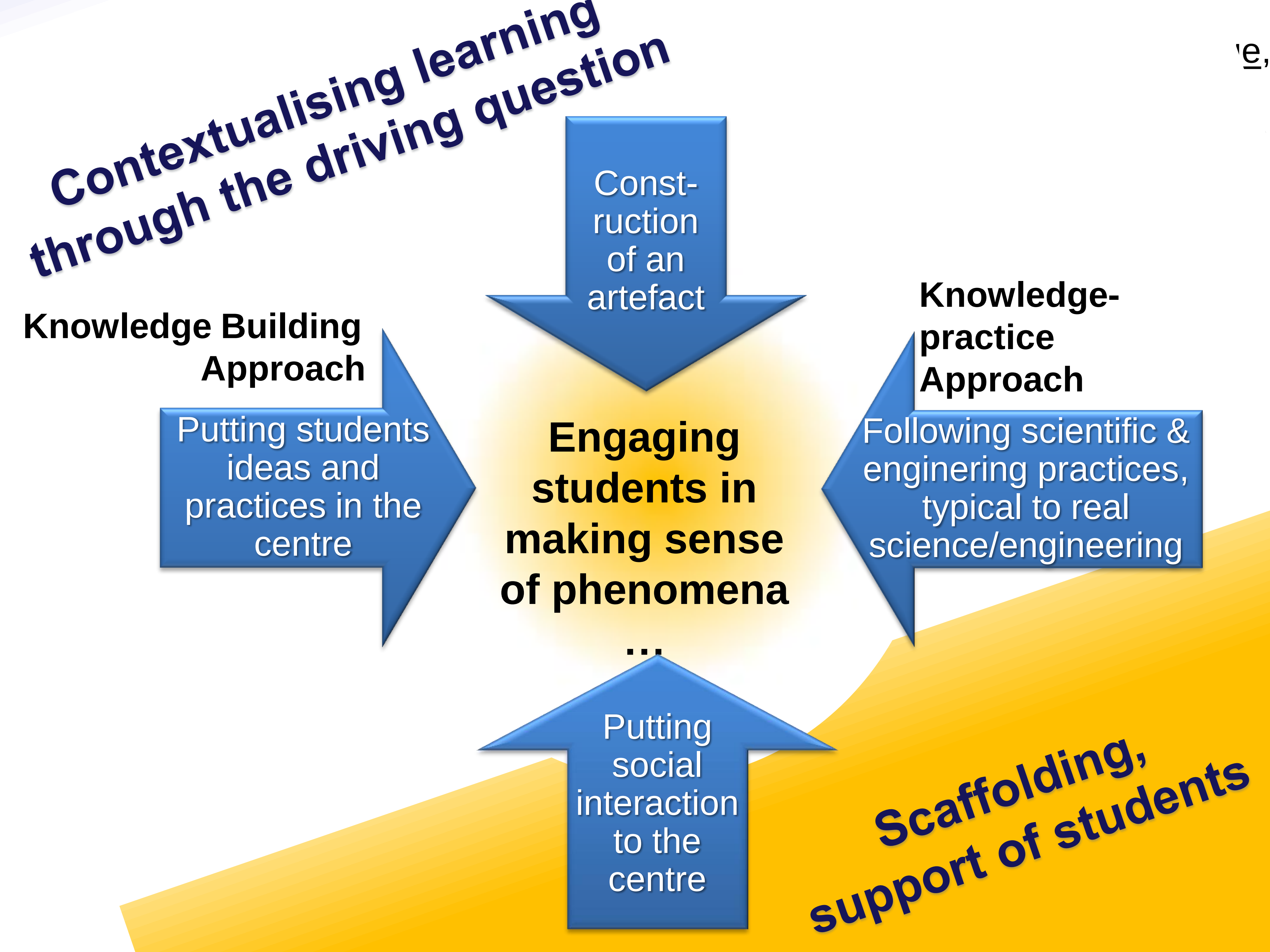
- with explicit statements describing relationships

Developing a model

- **Question**: What question is being explored?
  What kind of relationship/correlation is investigated?
- **Plan**: What objects/entities/variables are needed in the model?
  What properties are associated with each of the objects/entities/variables?
- **Build**: What relationships exists between the objects/entities/variables?
- **Test**: Do the set of relationships provide a causal account?
  i.e., Does it explain the phenomena?
  Does it account for all the evidence?
- **Revise**: Does your model still provide a causal account for any new evidence or other phenomena?
  How should it be changed?

The teacher supports students while they work on the modelling activities by asking questions:

- What is your model?
- What is the representation you use for the model? Could you use another type of representation?
- What is your research question?
- What is your experimental design in order to find answers to the questions?
- What is your data? What is your evidence?
- What do you claim? Is your evidence supportive for the claim?
- How is the model based on your data?


Contextualising learning through the driving question
Const-ruction of an artefact
Knowledge Building Approach
Putting students ideas and practices in the centre
Engaging students in making sense of phenomena …
Knowledge-practice Approach
Following scientific & enginering practices, typical to real science/engineering
Putting social interaction to the centre
Scaffolding, support of students

Students’ declining interest in science learning and STEM (Science, Technology, Engineering, Mathematics) careers

Finnish New Curriculum: Engaging students in learning through collaboration and scientific practices: Project-Based (Science) Learning (PBL)

Case 1: PBL engages students in science learning

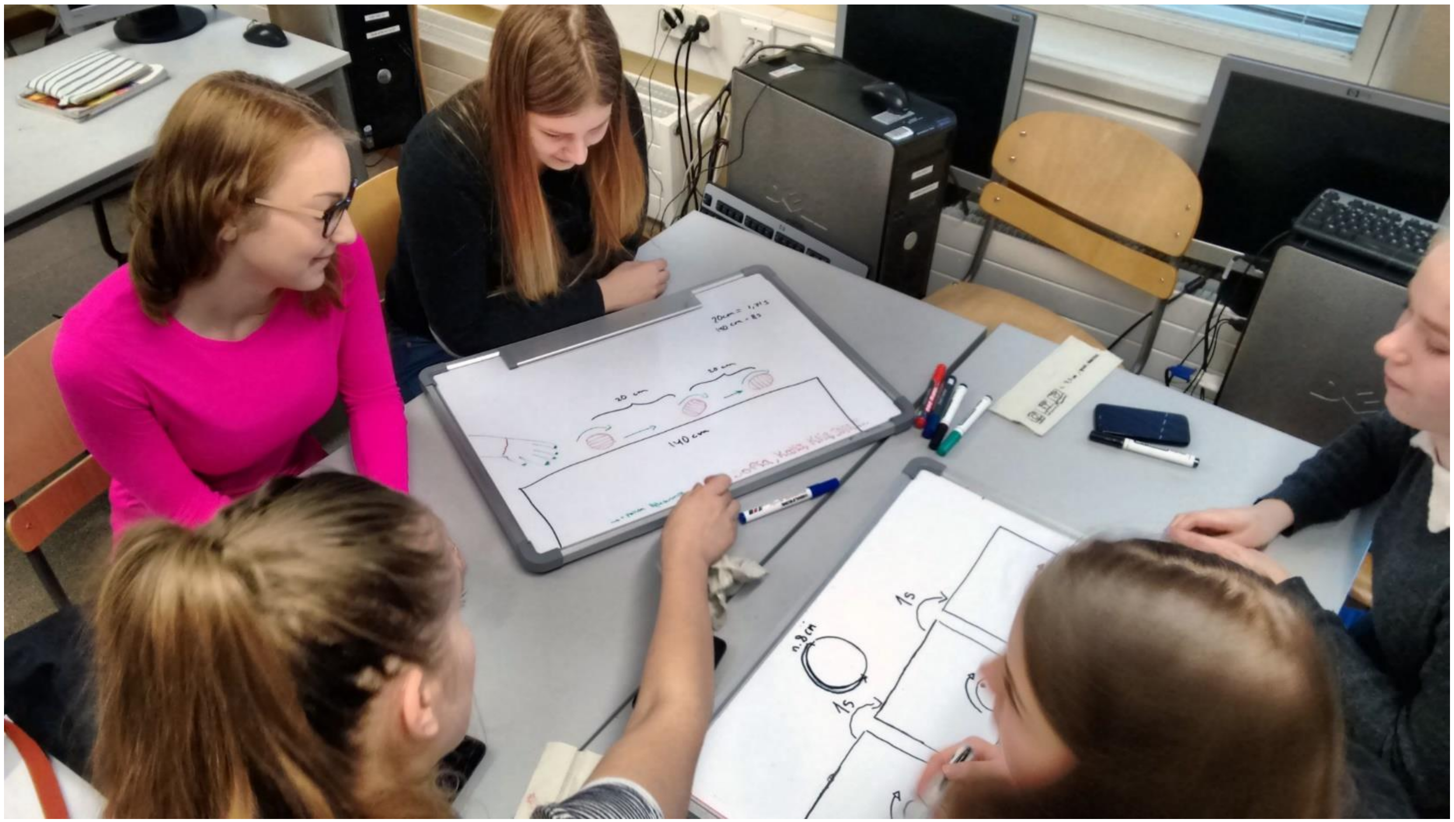
Case 2: PBL supports science learning outcomes

Final remarks

Research question

How did the designed PBL teaching modules support students' engagement in learning?

Engagement



Pre-conditions: interest, skill, and challenge

- **Skill** is defined as a mastery related to specific tasks.
- **Challenge** is defined as a desire to persist in a science-learning situation (Eccles & Wigfield, 2002).
- **Situational interest** is defined as a psychological predisposition for a specific object (topic, task, knowledge) (Hidi & Renninger, 2006; Krapp &Prenzel, 2011).

- A student is considered to be engaged in a task when he or she simultaneously experiences elevated feelings of challenge, skill, and interest = **optimal learning moment**.

Methodology

Sample and data

- Student engagement data was collected 2016 and 2017

2016	2017
seven classrooms (grades 9 to 12)	seven classrooms (grades 9 to 12)
167 students	193 students
1760 engagement measurements	2686 engagement measurements

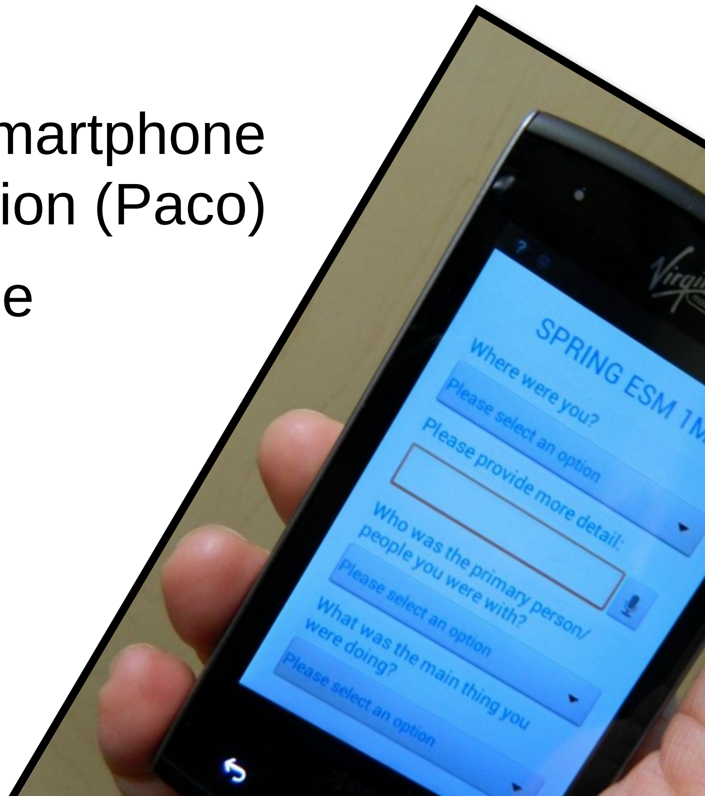
- Within both countries, the samples were selected from convenience and cannot be generalized to the larger population.

Measurements in real situations through experience sampling method (ESM)
(Csikszentmihalyi & Schneider, 2000)

Offer an insights on students’ engagement in science learning situation.

Use of smart phones:

- Students signaled on smartphone using a special application (Paco)
- ESM Survey is the same each time
- A hybrid of random and scheduled signaling



Students answering the ESM questionnaire

ESM Survey

Where are you?
Who are you with?
What are you doing?
…

II. How do you feel about the main activity (4-point scale):

<u>Challenge</u> of the activity: [Low/High]
Your <u>skills</u> in the activity: [Low/High]
Is this <u>activity interesting</u> [Not at all/Very much]
…..

III. How do you feel about the main activity? (4-point scale: Not at all/Very much)

Is this activity <u>important</u> for you?
Do you feel <u>competent</u> in this activity?
….

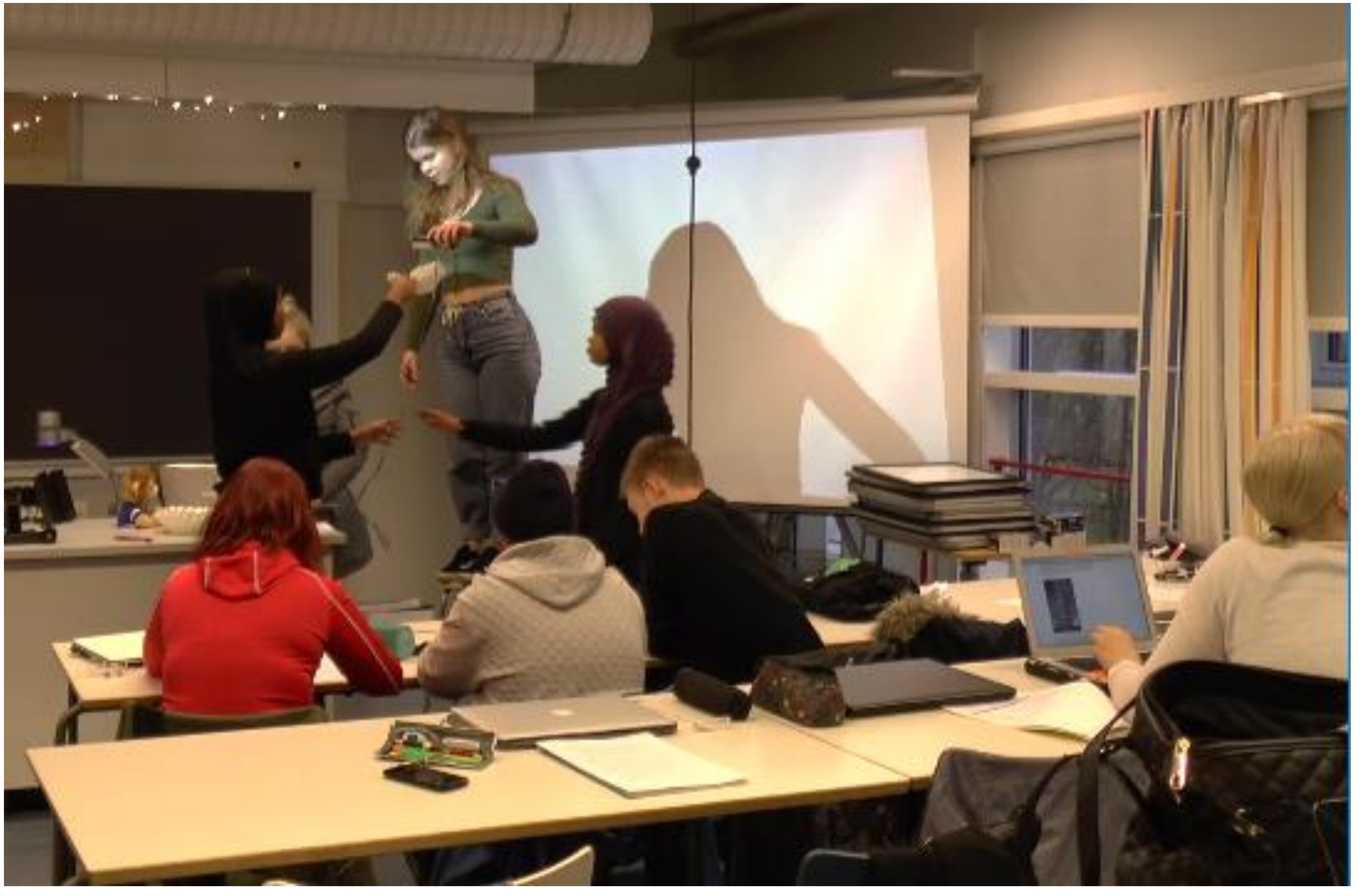
IV. Indicate science activity

Asking questions
Building a model
….

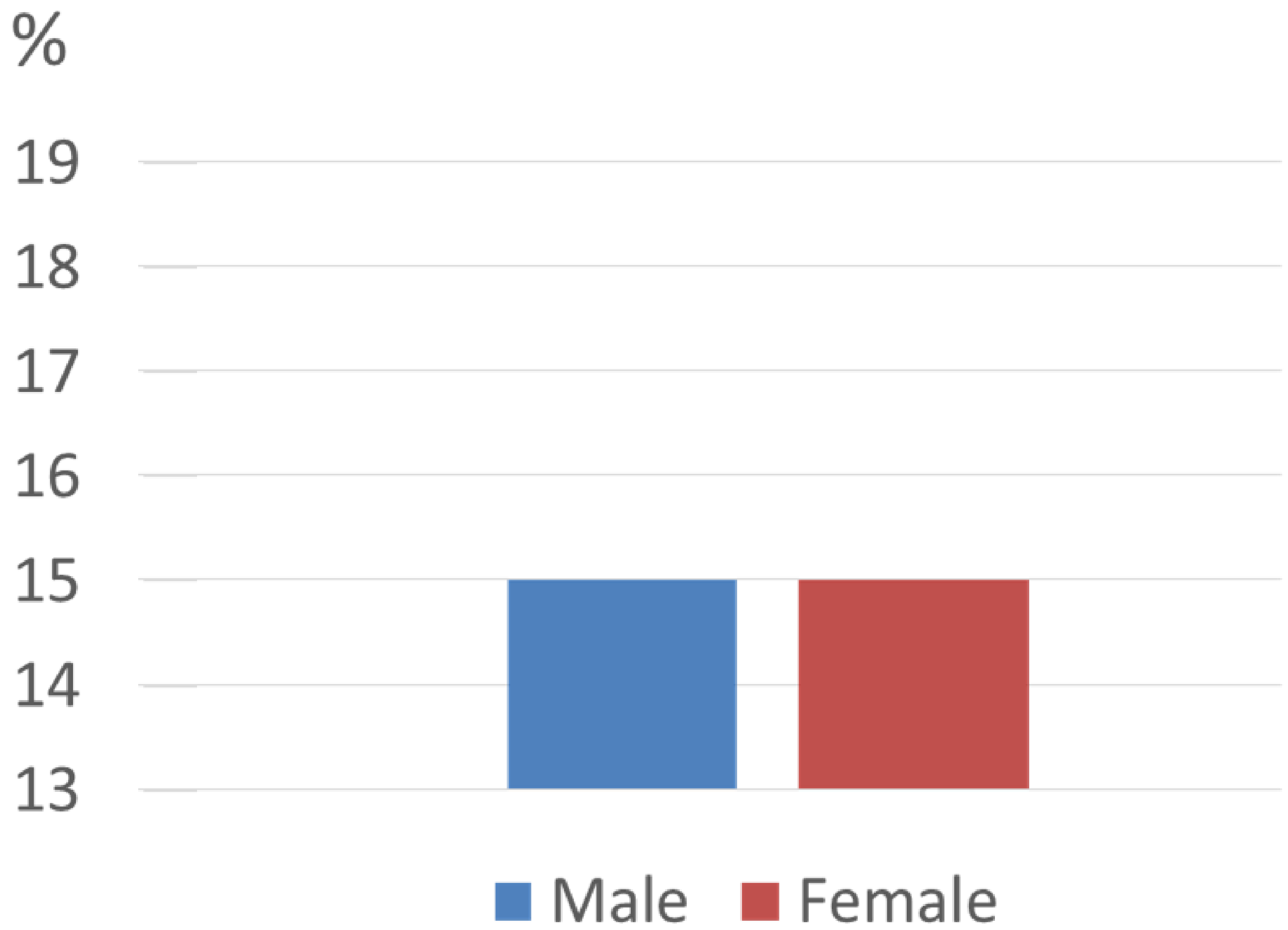
V. How are you feeling? (4-point scale: Not at all/Very much)

Are you feeling…Happy
Are you feeling…Energetic
Are you feeling…Anxious

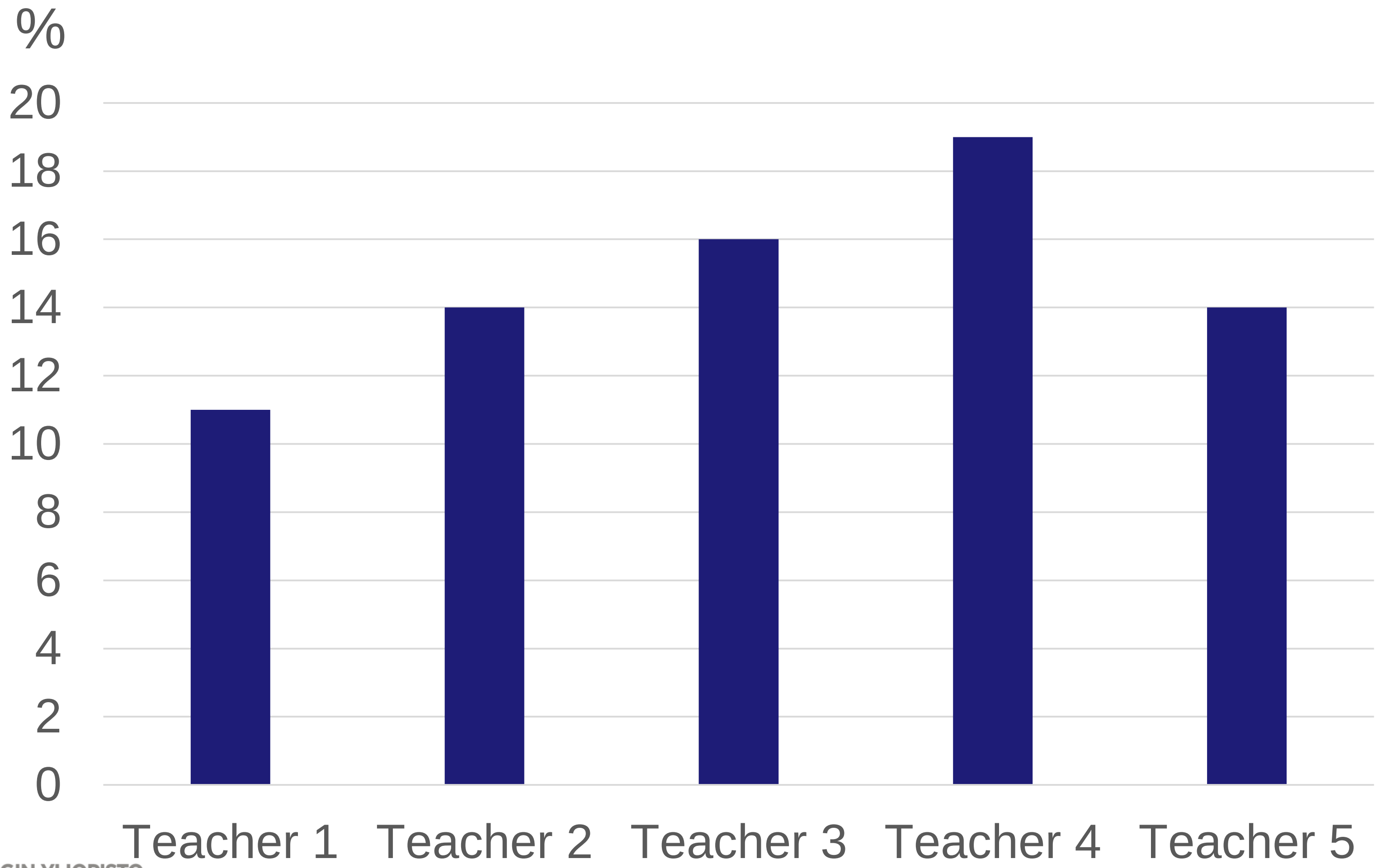
Results



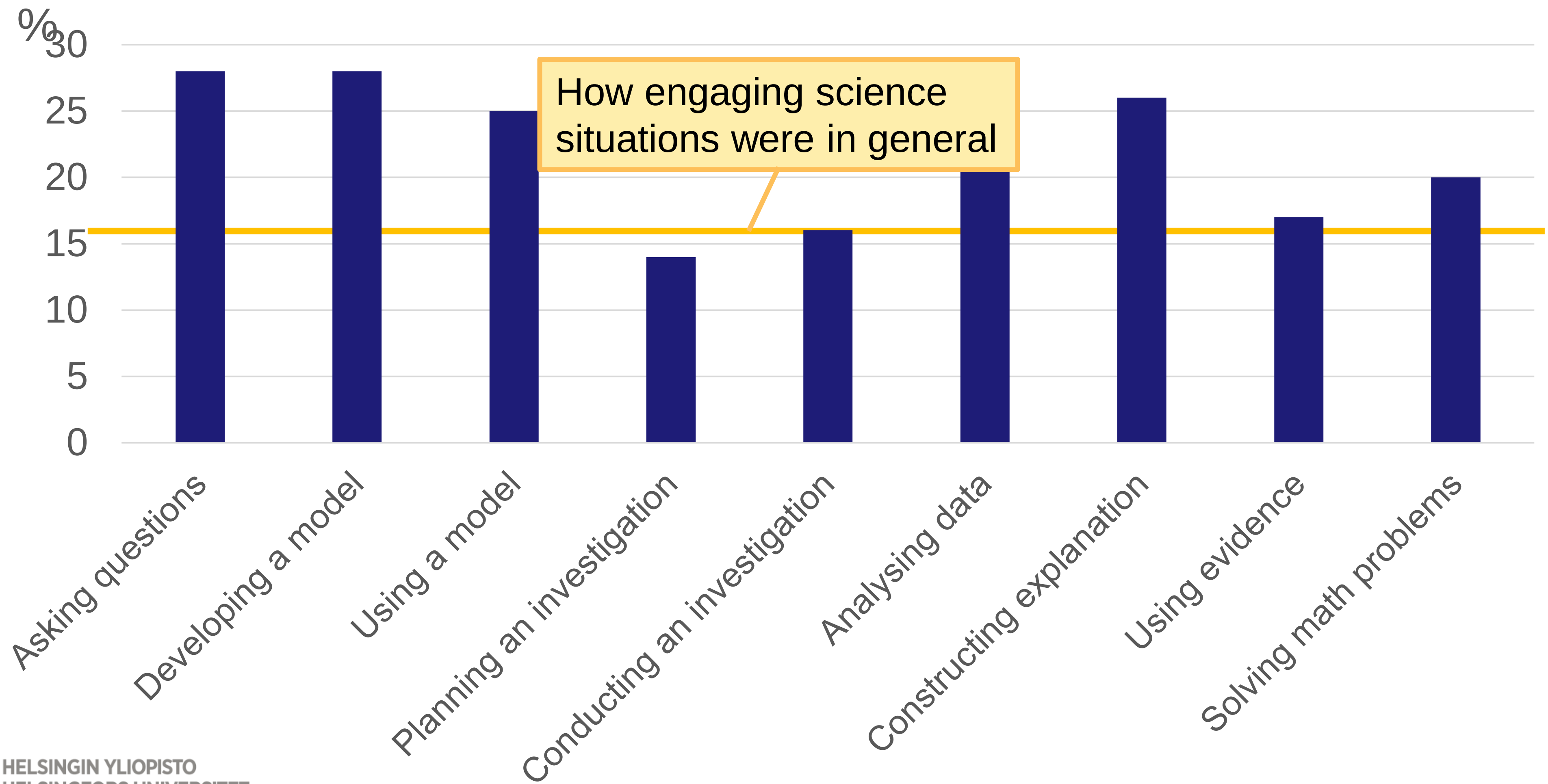
Engaged Responses in Science Class by Gender in 2016



Differences in Engagement by Science Teacher in the United States and Finland

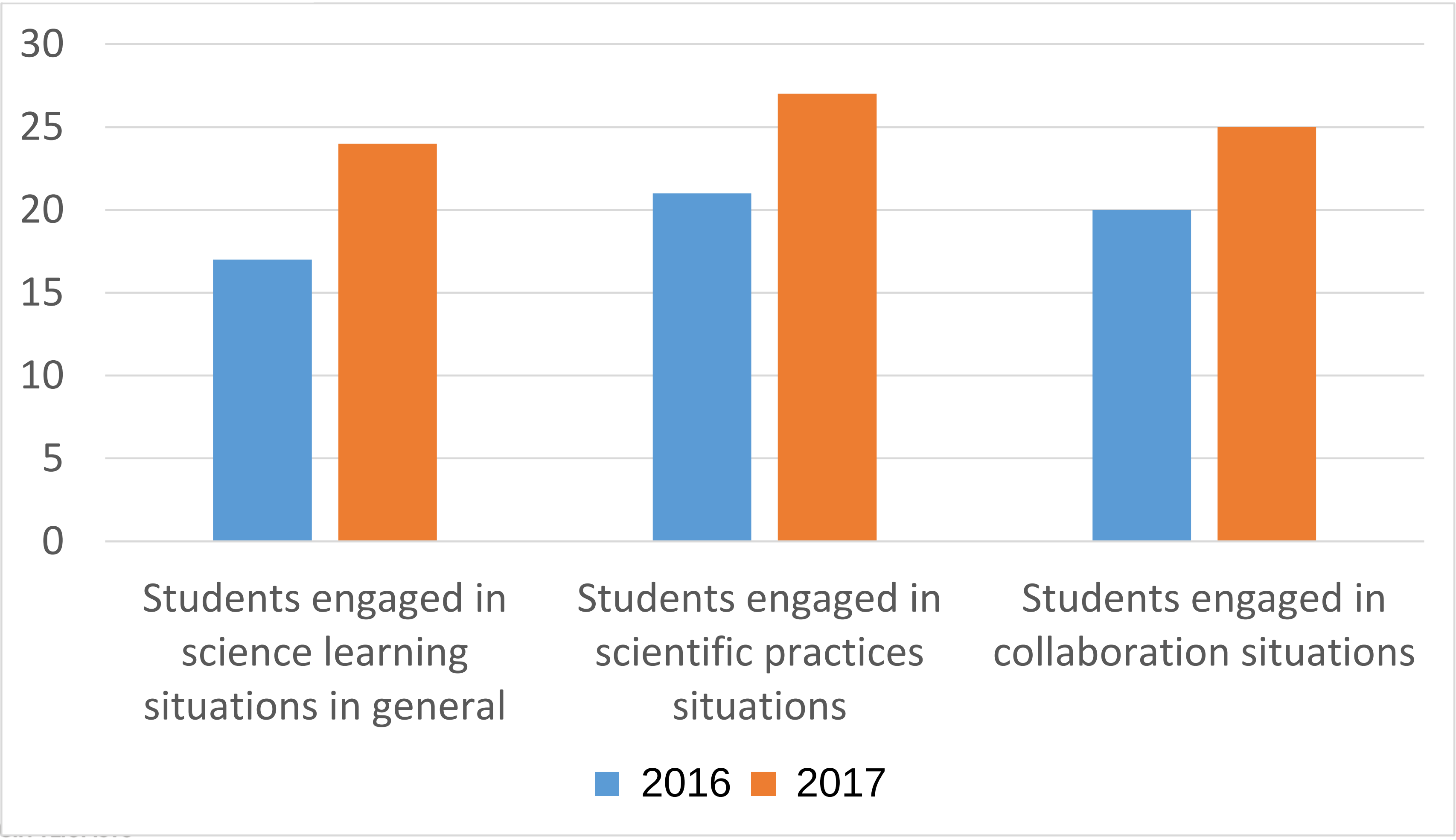


Percentage of students reported engaged in learning



Students' Engagement Measurements in 2016 and 2017

% of students



Final remarks

In general

- scientific practices were, in general, more engaging than other situations in science class.
- Engagement did not vary by gender.
- There is a large amount of variation in student engagement between teachers.
- “Asking questions” and “Developing model” are engaging in both countries! (also “Using a model” and “Analyzing data”)

Need for more research

- More research is needed to better understand the pedagogy used with scientific practices:
  Why are some teachers more successful?

- Myth of gender differences?
  It seems that gender differences are smaller when the measurements are done in situations.

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Research question

How did the designed PBL teaching modules support students' science learning?

A teaching module for first grade high school mechanics

- **Unit Driving Question:**
  Why do some objects take different amounts of time to fall from the same height?
- **Students who demonstrate understanding can:**
  - analyze data on the motion and recognize when the object moves with constant or changing velocity:
    Models for motion.
  - analyze relationship among the net force on a macroscopic object, its mass, and its acceleration:
    Newton's Second Law.
  - Apply scientific and engineering practices for design, evaluate, and refine an experimental design which could be used for modelling previous topics.

Measuring STEM Learning Outcomes

- Design of a questionnaire:
  - Type of knowledge
  - Cognitive processes
  - Science and engineering practices dimension (use of knowledge in practices dimension)
  - Curriculum competence descriptions

- Quasi experimental design:

Research group:	O_1	X	O_2
Control group:	O_1		O_2

12. Relevant research question

Take a look to the video related to the moving of a sledge.

http://youtube.com/watch?v=3pk8gOFgmnw

Pose two questions on the basis of which it is possible to examine the links/correltaion between the measurable issues relating to the phenomena in the video.

***Conceptual knowledge**:* velocity, acceleration, force, distance
***Cognitive processes dimension** Apply and create*
***Science practice**: formulation of questions and recognising of problems*
***Competence**: design and evaluate scientific enquiry*
***Correct answer**: What is the correlation between the mass of the sledge (how many people in the sledge) and the time it takes to go down?*
What is the correlation between the base of the sledge and the time it takes to go down?
No scores (0) is given of a question with a simple answer (How long time the way downhill takes? or Is the velocity constant?)
1 score is given of a questions with an answer very much or very little or yes/no (How much the surface area influences acceleration?)
Obvious question without question term. 1 score (mass influence acceleration)
***Scores**:4 (2 + 2)*

4. Forces acting on a ball

Watch a slow-motion video about football kicking.

Http://youtube.com/watch?v=v0zowDrCbEs

Which forces are acting on a ball after a few seconds from the kick? Draw a picture.

Pre-test – post-test design

	pre-test		post-test	
	Mean	Std. Deviation	Mean	Std. Deviation
Experiment group **N = 28**	10.7	3.6	15.3	2.7
Control group **N = 25**	10.2	4.0	12.0	3.9

$F = 0.27^{ns}$

$F = 13.1^{***}$

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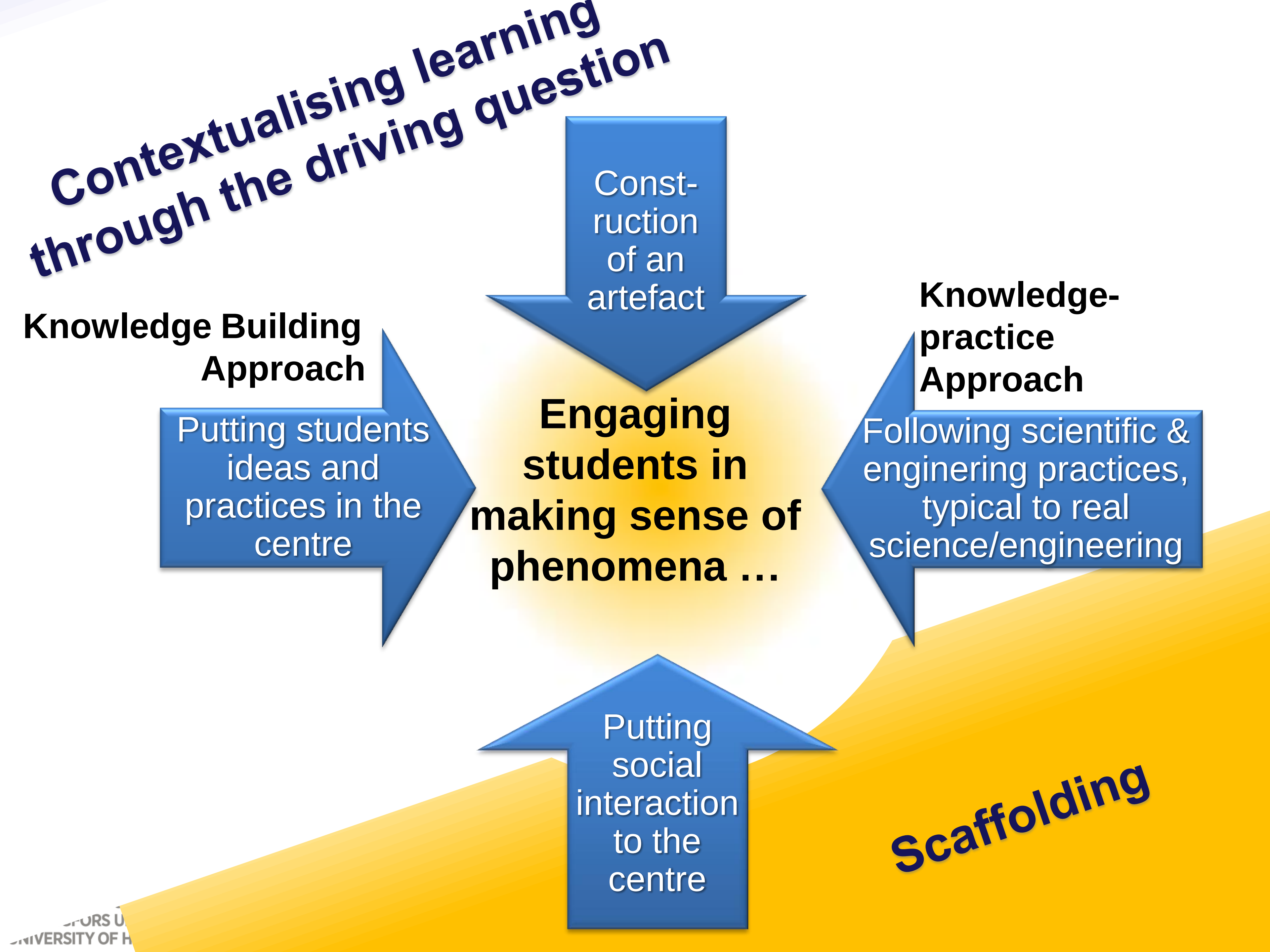
The findings indicate that …

Project Based Learning could …

1. engage students in learning,
2. support students to learn science (learning outcomes).

➔ Science teachers should **engage students in making sense of phenomena through changing practices** ….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Thank you!