Designing Engaging Learning Practices in STEM

Research collaboration between Finland and Chile 2016 - 2018

This material is based upon work supported by the Finnish Academy (No. 294228). The opinions expressed here are those of the authors and do not represent the views of the funding agency.

Jari Lavonen,
Faculty of Education, University of Helsinki, Finland
Jari.Lavonen@Helsinki.Fi

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

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

How STEM is emphasised in Finnish curriculum and school practices: Project-Based (Science) Learning (PBL)

Case 1: Scientific practices engage students in learning as a part of PBL

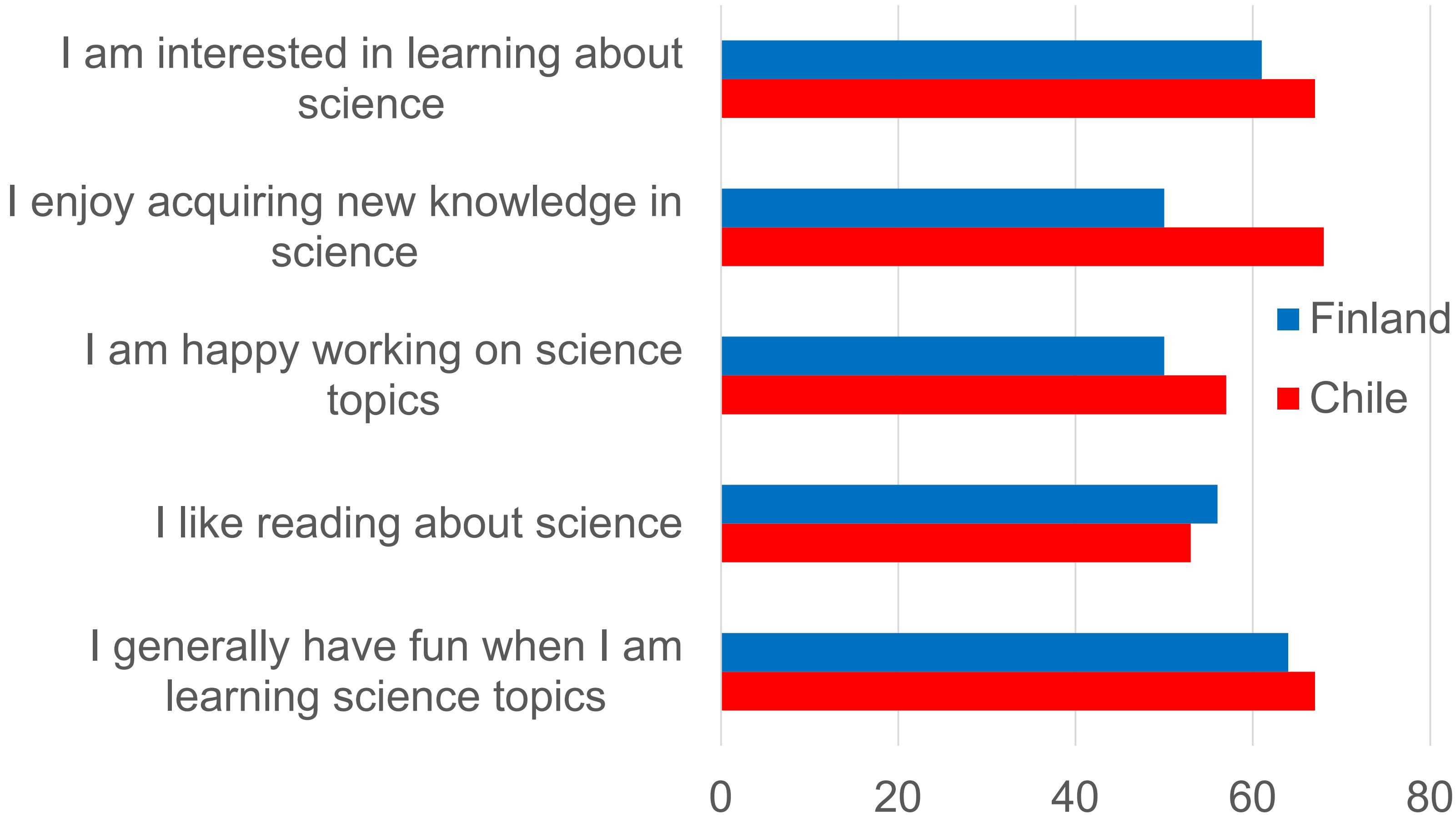
Case 2: Evaluating learning outcomes of a PBL teaching unit

Discussion

Students' declining interest in science learning and STEM careers

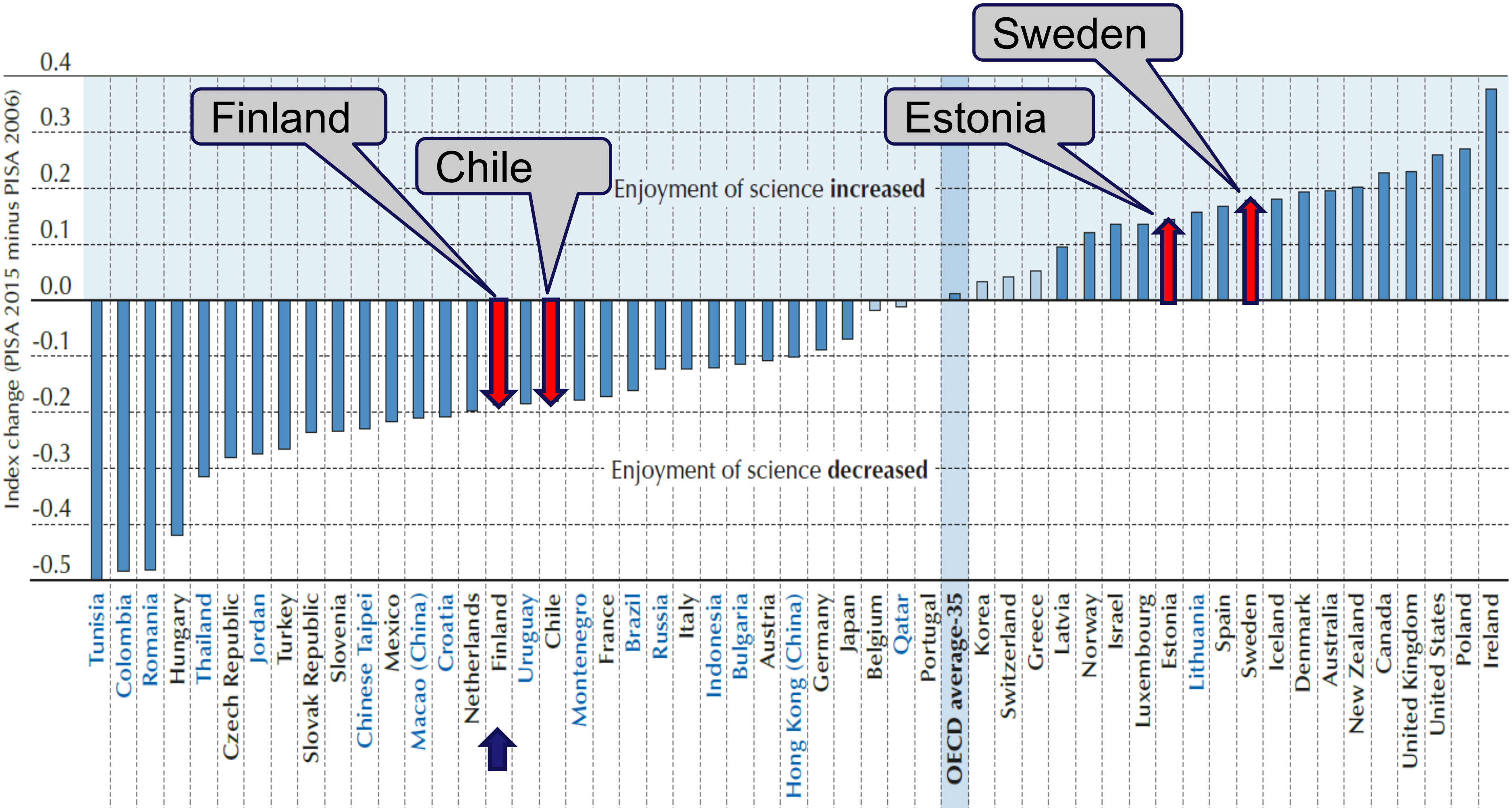
- Students' declining interest in, motivation for, and engagement in science learning (Osborne & Dillon, 2008; Zeyer et al., 2013).
- Lack of interest in STEM careers (discussion in education policy documents).

Students’ enjoyment of learning science according to PISA 2015

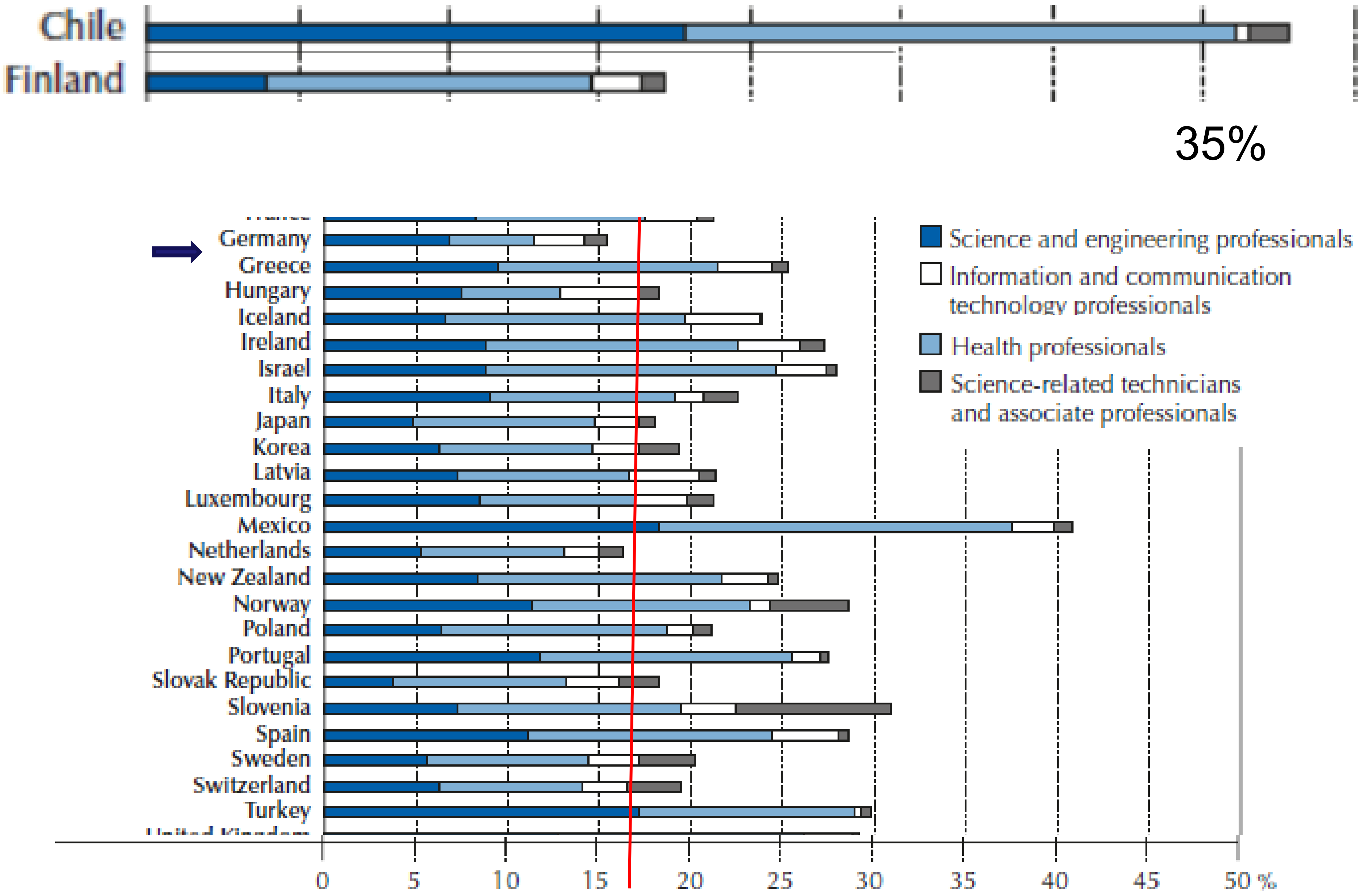


Percentage of students who “agree” or “strongly agree” with the statements

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



Much is already known about …

- emotional, cognitive and behavioral components of engagement (Christenson, Reschly, & Wylie, 2012; Fredricks, Blumenfeld, & Paris, 2004).
- development of task-based 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

  (Eccels et al. 1983; Eccels & 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 …

- …engage in effective learning startegies

  (Krapp, 2000; Schiefile, 1991, 1999)

- …better learn concepts

  (Cordova, Sinatra, jones Taasobshirazi & Lombardi, 2014)

- … 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)

Conceptualisation of situational engagement

- In contrast to those who conceptualize engagement as a monolithic trend …

  … engagement is defined here as varying in intensity across different domains and situations

- Close to definitions of situational interest in science education research (Krapp & Prenzel, 2011).

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 inter...
  - spe... ...gs

... associated with subjective feelings such as happiness, enjoyment, confidence and a lack of boredom or confusion

A student is considered to be engaged in a task when he or she simultaneously experiences feelings of challenge, skill, and interest

= **optimal learning moment**.

“Challenge is t...
that propels...
skill to ne...

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

How STEM is emphasised in Finnish curriculum and school practices: Project-Based (Science) Learning (PBL)

Case 1: Scientific practices engage students in learning as a part of PBL

Case 2: Evaluating learning outcomes of a PBL teaching unit

Discussion

STEM is emphasised in Finnish curriculum and school practices

Student engagement in scientific practices

- It is not common all over the world that 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)

- In the new Finnish science curriculum it is emphasised:
  - the importance of student engagement in science learning
  - engagement in science practices

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

What is STEM in Finnish science curriculum?

- **Body of Knowledge**

  Phenomena ⟷ Core ideas, concepts and models
- **Processes/Methods**

  Knowledge is inquiry- and design-based

- There is no science without inquiry and critical thinking (+creative thinking)

- There is no technology & engineering without design and creative thinking (+critical thinking)

The use of knowledge is important in making sense of phenomena and solve problems

A core ideas (concepts) in K-12 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 from K to 12**: Is teachable and learnable

Disciplinary Core Ideas (Concepts)

Physical Science

- Matter and Its Interactions
- Motion and Interactions, Forces
- Energy
- Waves and

Engineering & Technology

- Engineering Design
- Links Among 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's Place in the Universe
- Earth's Systems
- Earth and Human Activity

What’s new in Finnish STEM learning?

- Focus on use of knowledge, like explaining phenomena or designing solutions to problems
- Project based learning:
  - scientific and engineering practices,
  - knowledge building (student in the center)
  - collaboration
  - construction of artefacts
- Organising learning around disciplinary core explanatory ideas;
- Contextualising learning, for example, through a driving question
- Coherence: building and applying ideas across time and themes

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)

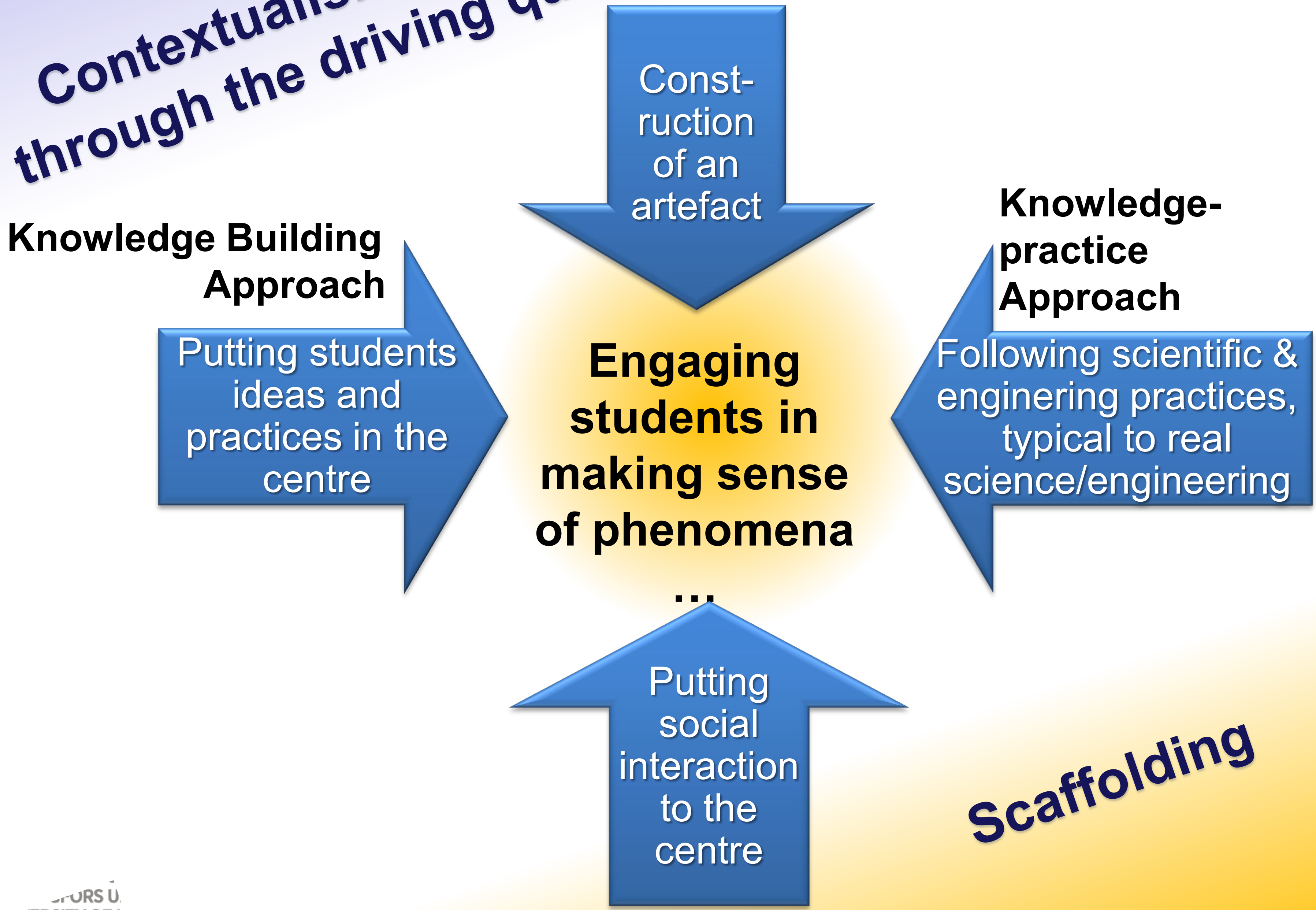
- PLP starts with a *driving question*, a problem to be solved.
- Students
  - are active in **knowledge building**.
  - explore the driving question through participating in scientific and engineering practices (**knowledge practices**) –central to expert performance in the subject.
  - engage in **collaborative 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

Driving Questions

- Driving question contextualize project based learning and drive for inquiry activities
- Key features:
  - **Sense of Wonder**: creates a need to learn and know
  - **Feasible:** students can ask their own questions; design and perform an investigation in order to answer the question.
  - **Worthwhile**: is related to what scientists really do; is rich in science content; is complex enough to be broken down into smaller questions; the question leads to further questions.
  - **Contextualization: i**s anchored in real world issues; has real world consequences; is interesting and important to learners.
  - **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

Contextualising learning through the driving question



Scaffolding

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.

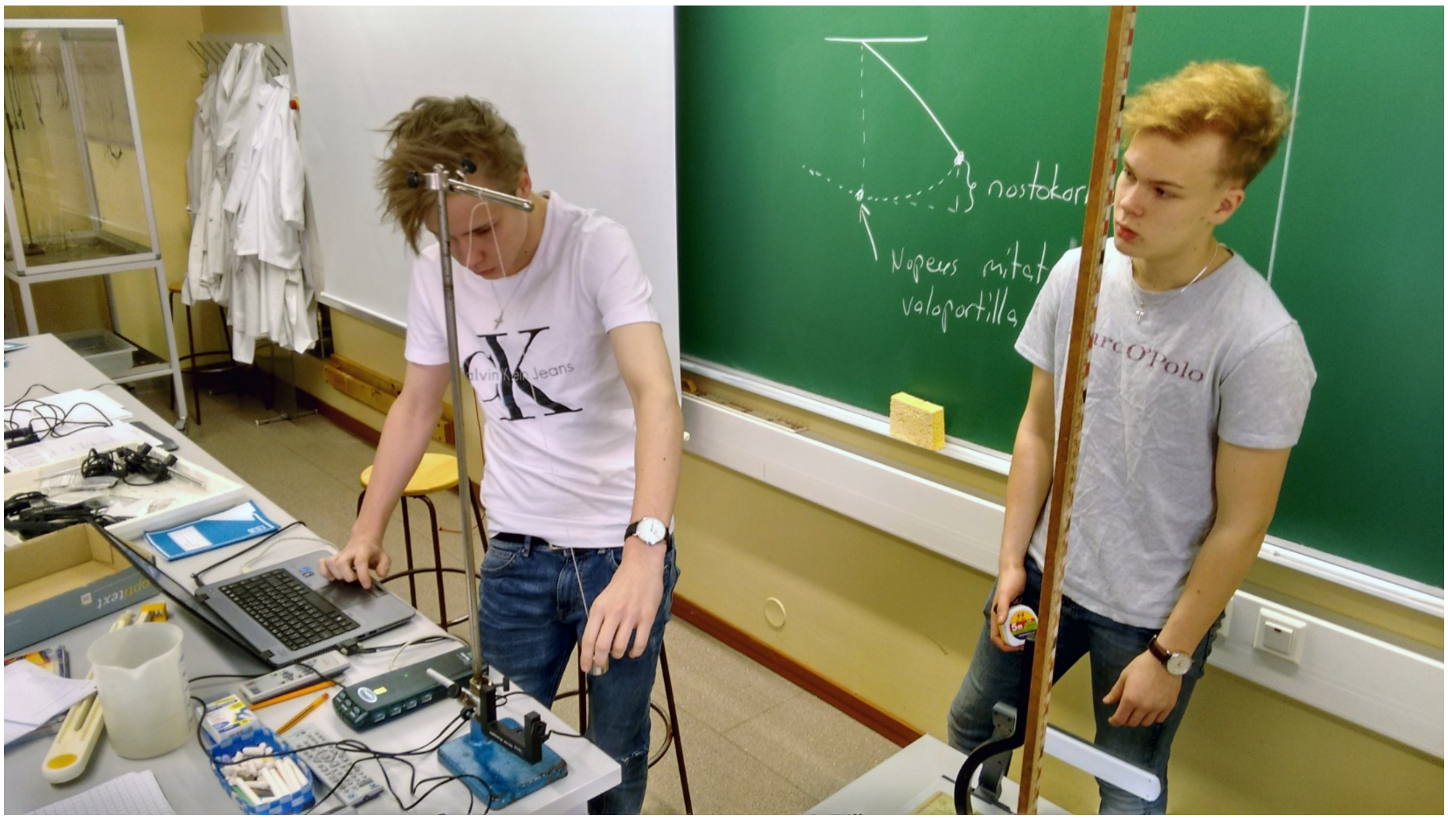
The practices work together – they are not separated!

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

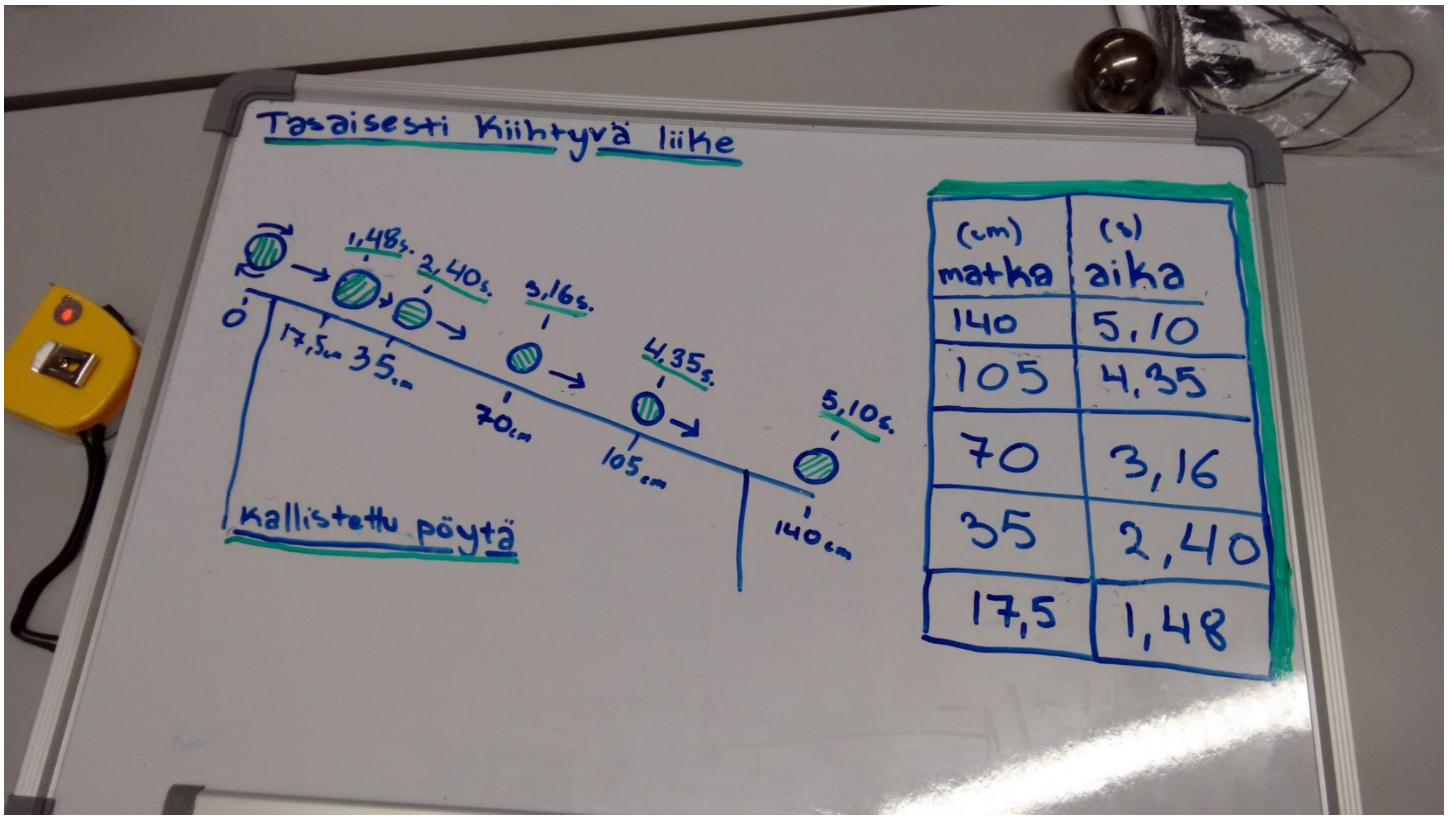
- Students
  - use language to express knowledge
  - express, debate and come to common ideas
  - debate the viability of evidence
  - work together to make meaning
  - build explanations
  - use knowledge for applying, predicting, …
- In a heterogeneous group
  - students learn from knowledgeable others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

Planning and carrying out investigations


valoportilla

Developing a models

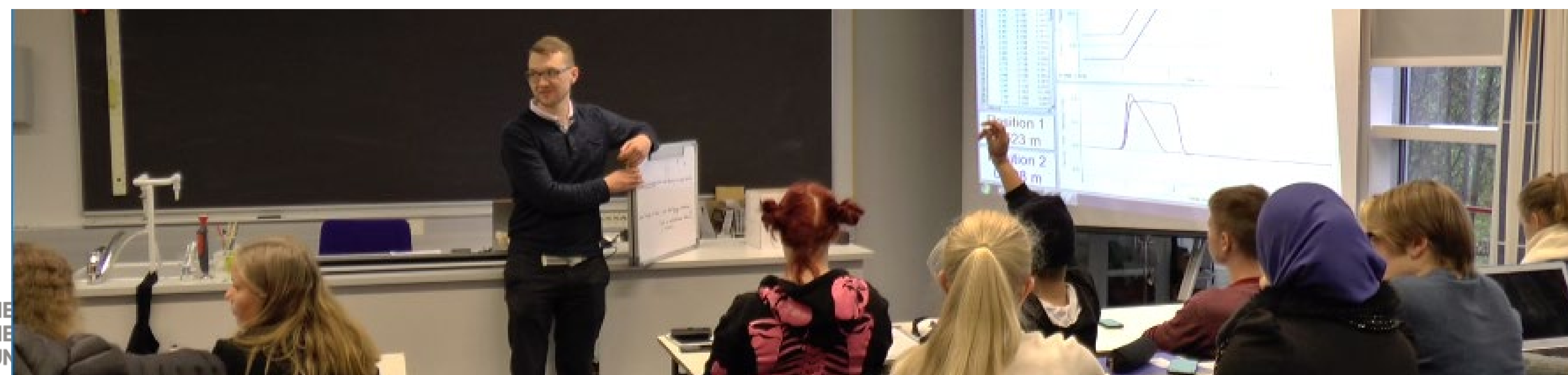
Analyzing and interpreting data



Communicating information

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

- 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?



Data, Evidence and Scientific Explanation

- **Question:** A question to be answered through the investigation/observation
- **Data**: Gathered information through an investigation/observation
- **Evidence**: Interpreted data (after analysing data in some way) being supportive or contrary to a prediction or conclusion
- **Claim**: A statement that responds to the original question.
- **Reasoning**: In a reasoning statement, **a claim and evidence is connected** to show how data links to the claim. A **core explanatory idea is used for explaining** why data counts as evidence to support the claim by using scientific principles.
  Reasoning is the process where science knowledge is applied for answering the question.
- **Scientific Explanation**: Scientific explanation explains the phenomena or a behaviour of an object.
- **Argument**: Evidence → Claim → Conclusion

  reasoning *probably*

  Backing knowledge

  Rebuttal

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

How STEM is emphasised in Finnish curriculum and school practices: Project-Based (Science) Learning (PBL)

Case 1: Scientific practices engage students in learning as a part of PBL

Case 2: Evaluating learning outcomes of a PBL teaching unit

Discussion

Scientific practices engage students in learning as a part of PBL

Jari Lavonen[1], Janna Linnansaari[1], Kalle Juuti[1], Katariina Salmela-Aro[1],

[1]Department of Teacher Education, University of Helsinki, Finland

This material is based upon work supported by by the Finnish Academy (No. 294228). The opinions expressed here are those of the authors and do not represent the views of the funding agencies.

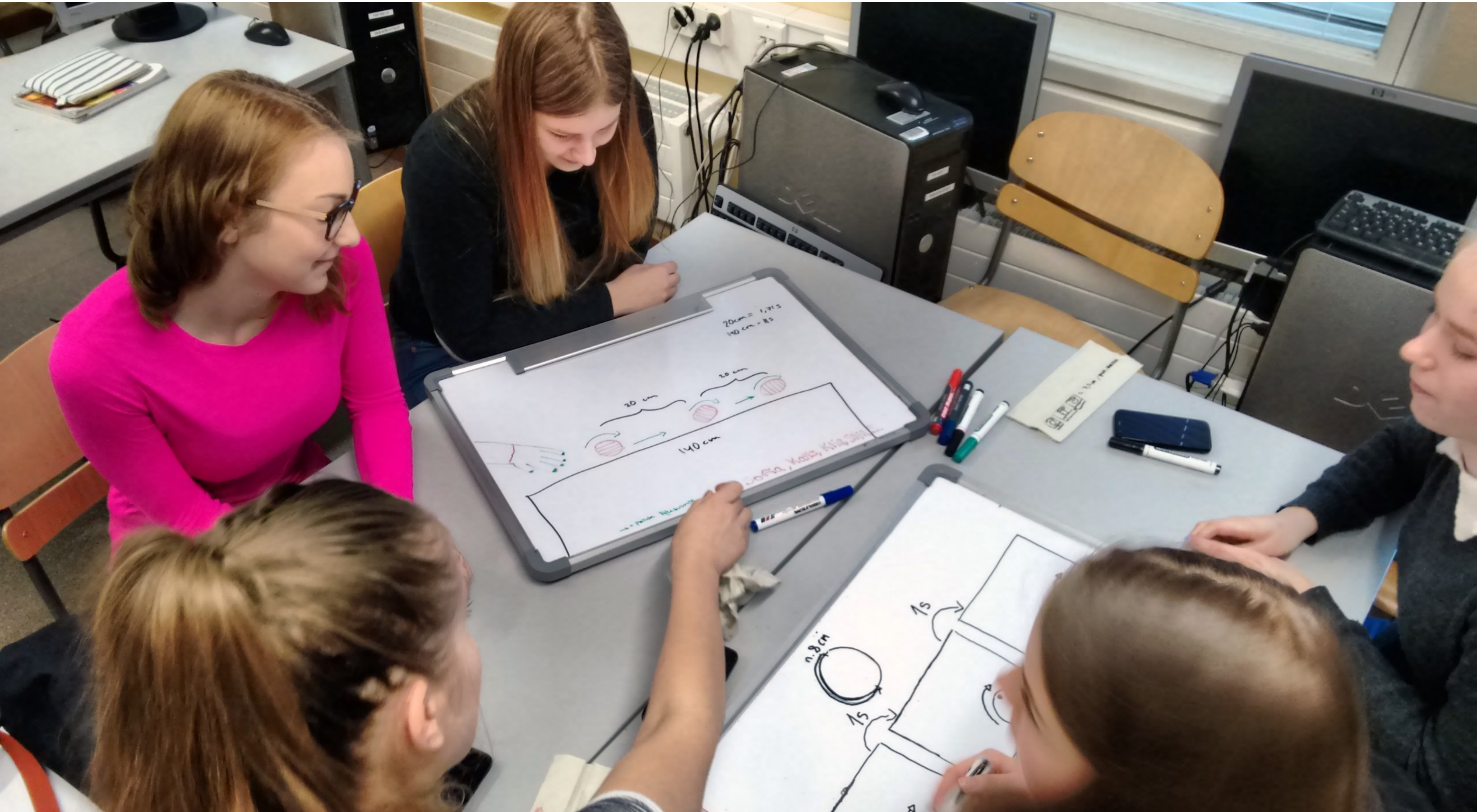
Aim of the study …

… has been support teachers through a professional development (PD) project to design teaching modules which engage secondary students in science learning in Finland and research:

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

(2. What characteristics of the PDP supported Finnish teachers to plan engaging teaching modules?)

Introduction



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 2015 and 2016

2015	2016
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.

Limitations of surveys and interviews

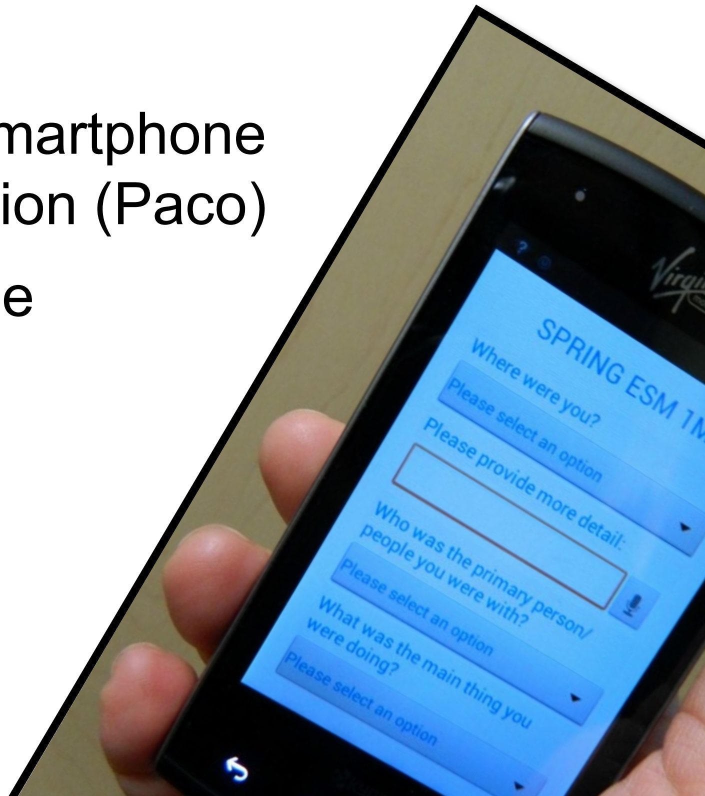
- Surveys and interviews have limitations because they obtain retrospective measures of students' reports on engagement experiences and their subjective feelings about them (Tuominen-Soini & Salmela-Aro, 2014).
  - Researchers agree that engagement is a changeable, malleable experience that occurs over time, existing studies pay limited attention to how students experience science-learning situations (Fredricks & McColskey, 2012).
  - Basic assumption is females are less engaged in science learning are based on surveys but not on measurements in real situations.

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)

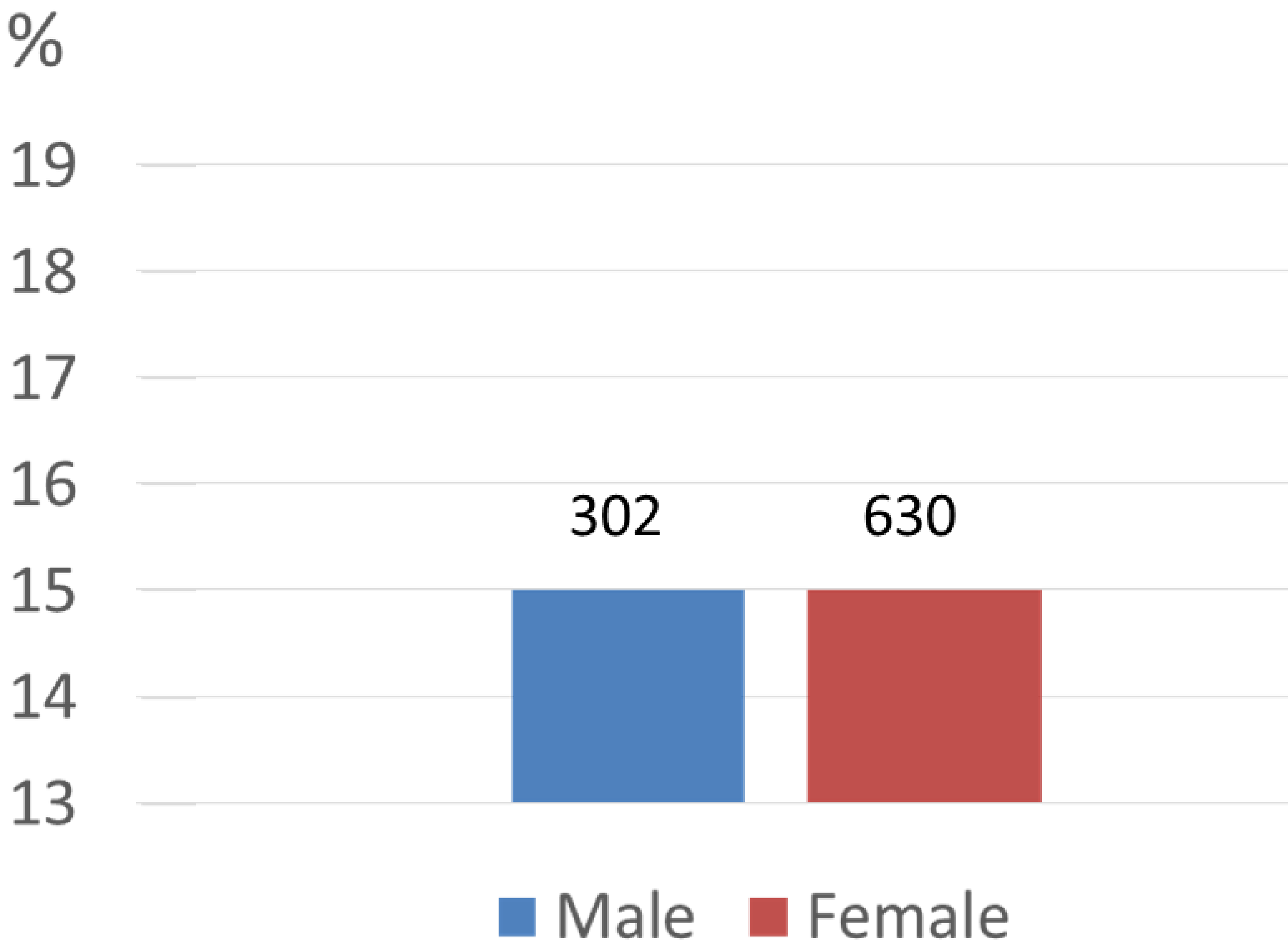
Are you feeling…Happy
Are you feeling…Energetic
Are you feeling…Anxious

Data and data analysis

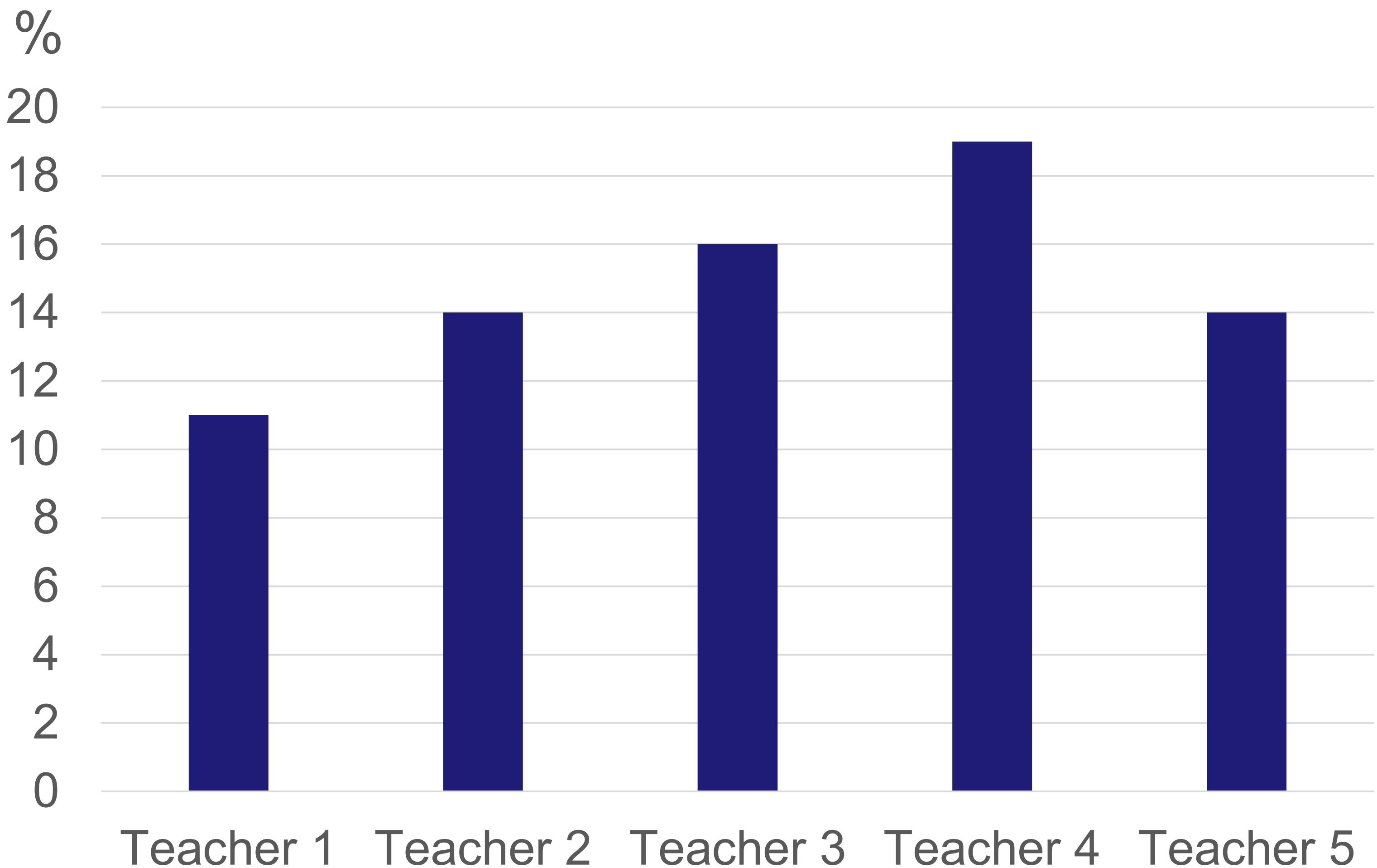
- The structure of data allows many different types of analyses
  - Percentages of times students report being engaged for a given situation (in science, in school)
  - Multi-level, hiearchical linear models where students are nested within responses
  - Cluster analyses where the engagement profiles of different students can be compared

Results

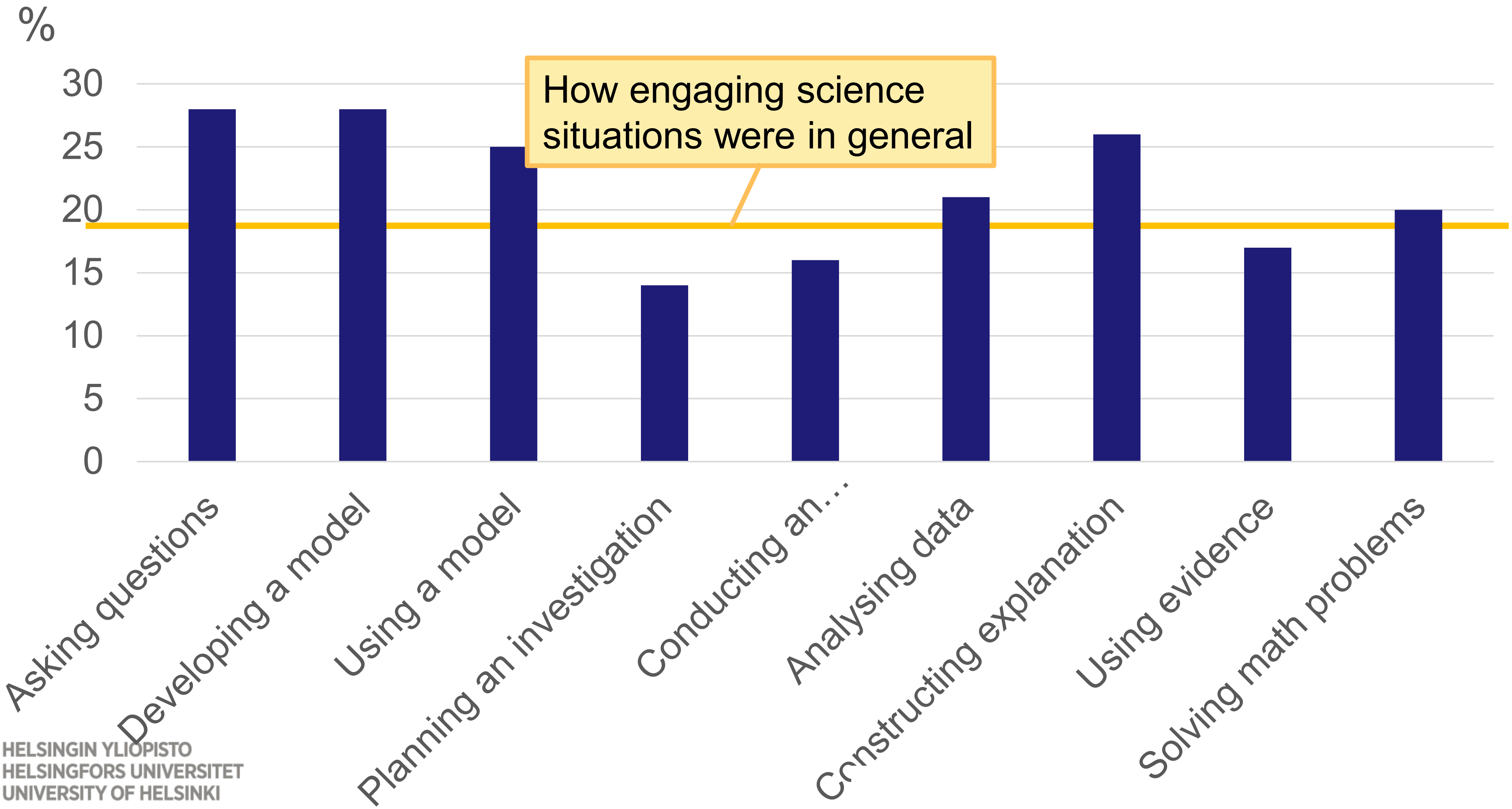
Engaged Responses in Science Class by Gender in 2015



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



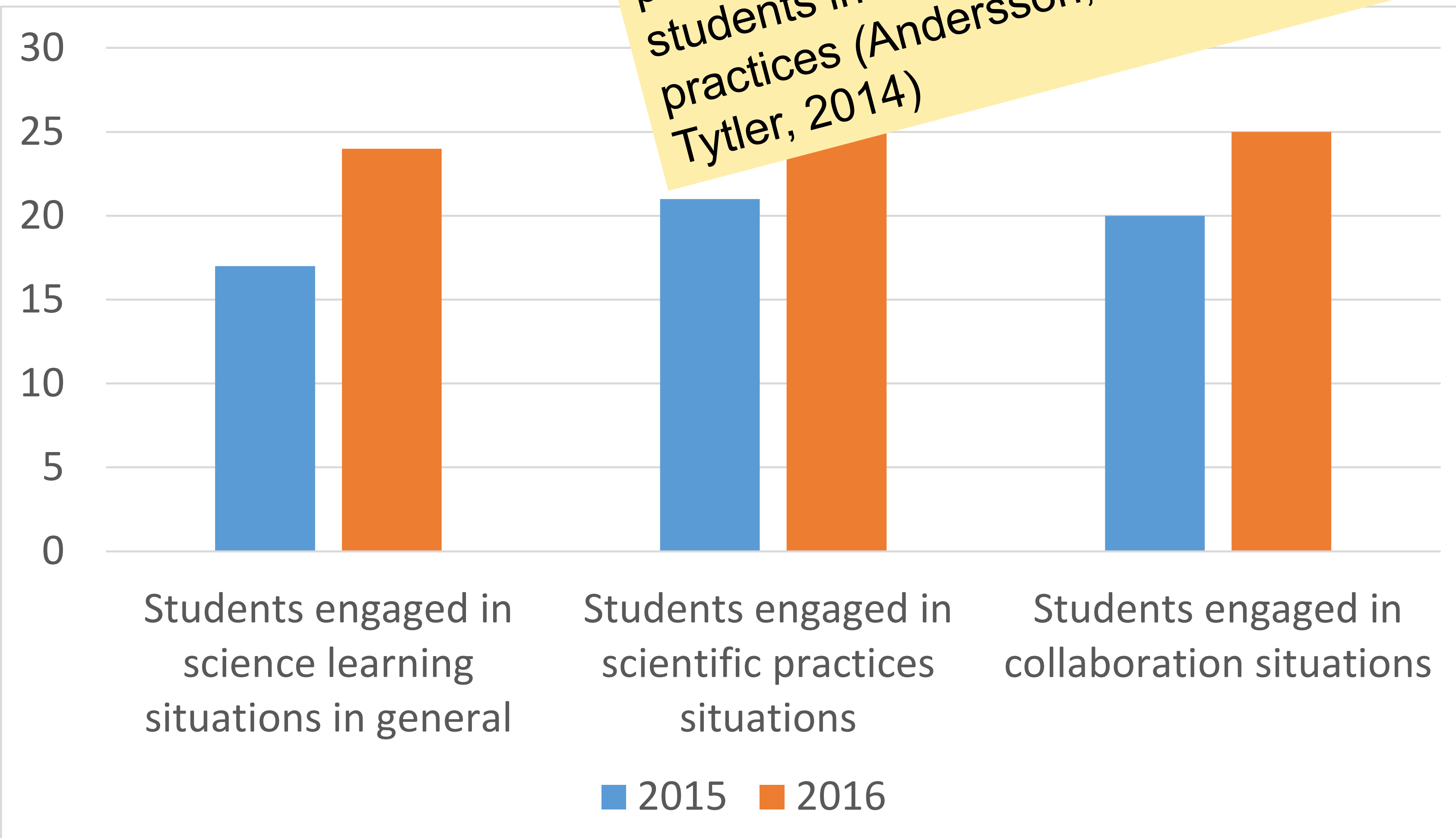
Percentage of students reported engaged in learning



Students’ Engagement M 15 and 2016

Collaboration as such is less engaging than scientific practices. Our research proved that teachers could guide students in engaging scientific practices (Andersson, 2007; EU, 2004; Tytler, 2014)

% of studnets



Discussion

In general

- Science 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.

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

How STEM is emphasised in Finnish curriculum and school practices: Project-Based (Science) Learning (PBL)

Case 1: Scientific practices engage students in learning as a part of PBL

Case 2: Evaluating learning outcomes of a PBL teaching unit

Discussion

Evaluating learning outcomes of a project based learning teaching unit

Jari Lavonen[1], Janna Linnansaari[1], Kalle Juuti[1], Katariina Salmela-Aro[1],

[1]*Department of Teacher Education, University of Helsinki, Finland*

This material is based upon work supported by the Finnish Academy (No. 294228). The opinions expressed here are those of the authors and do not represent the views of the funding agencies.

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

$F = 0.27^{ns}$

$F = 13.1^{***}$

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

How STEM is emphasised in Finnish curriculum and school practices: Project-Based (Science) Learning (PBL)

Case 1: Scientific practices engage students in learning as a part of PBL

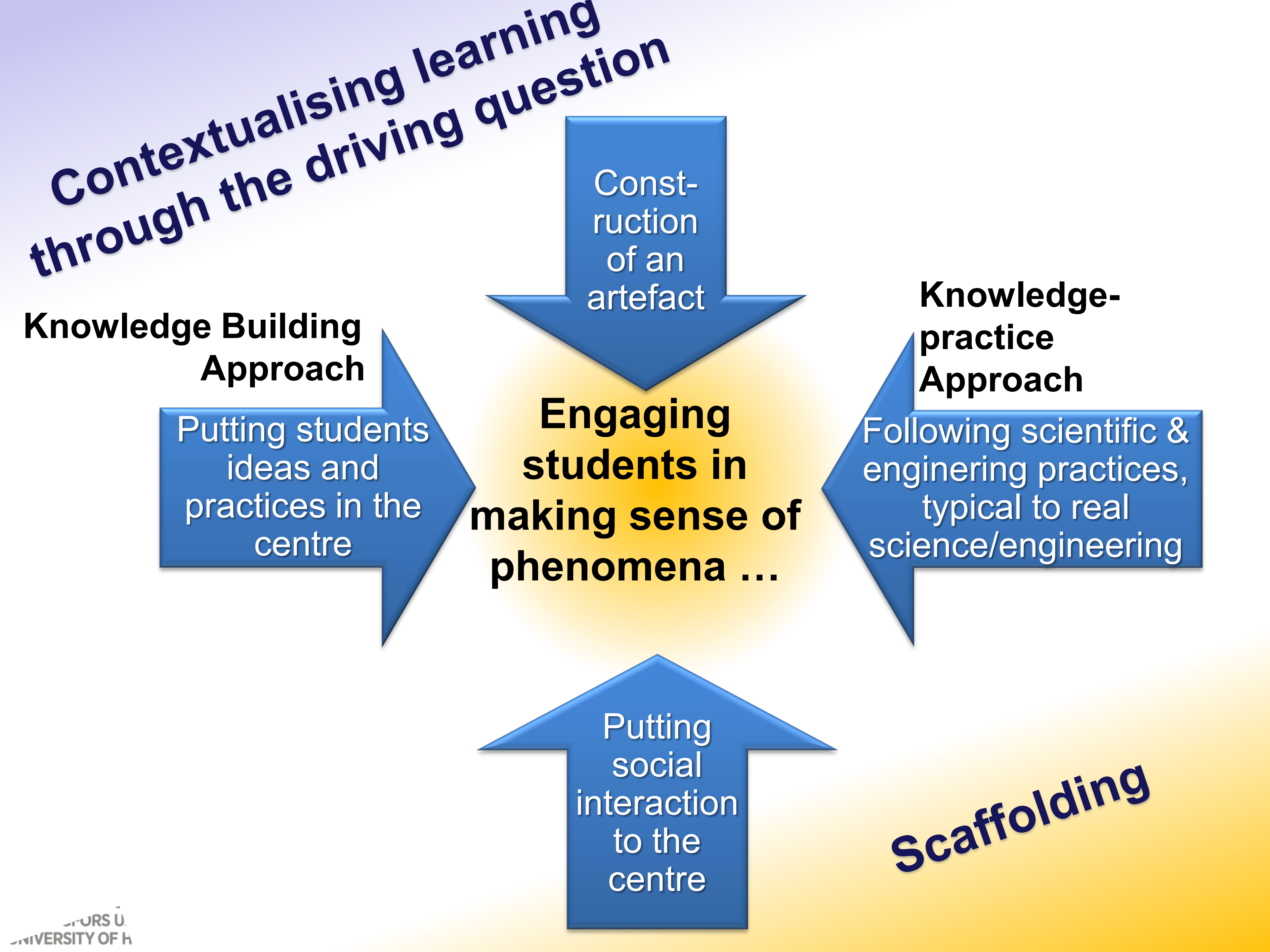
Case 2: Evaluating learning outcomes of a PBL teaching unit

Discussion

The findings indicate that …

Traditional science practices do not
(i) engage students in learning,
(ii) support students to learn science.

➔ Science teachers should **engage studnets in learning through changed practices which** engage students in science learning and support students to learn science!


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


Thank you!