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SZEGEDI TUDOMÁNYEGYETEM
UNIVERSITAS SCIENTIARUM SZEGEDIENSIS

Defining and Assessment of Cognitive Outcomes of Inquiry-Based Science Education

SMEC 2014 | SAILS
Thinking Assessment in Science and Mathematics
Dublin City University, Dublin, Ireland, 24-25 June 2014

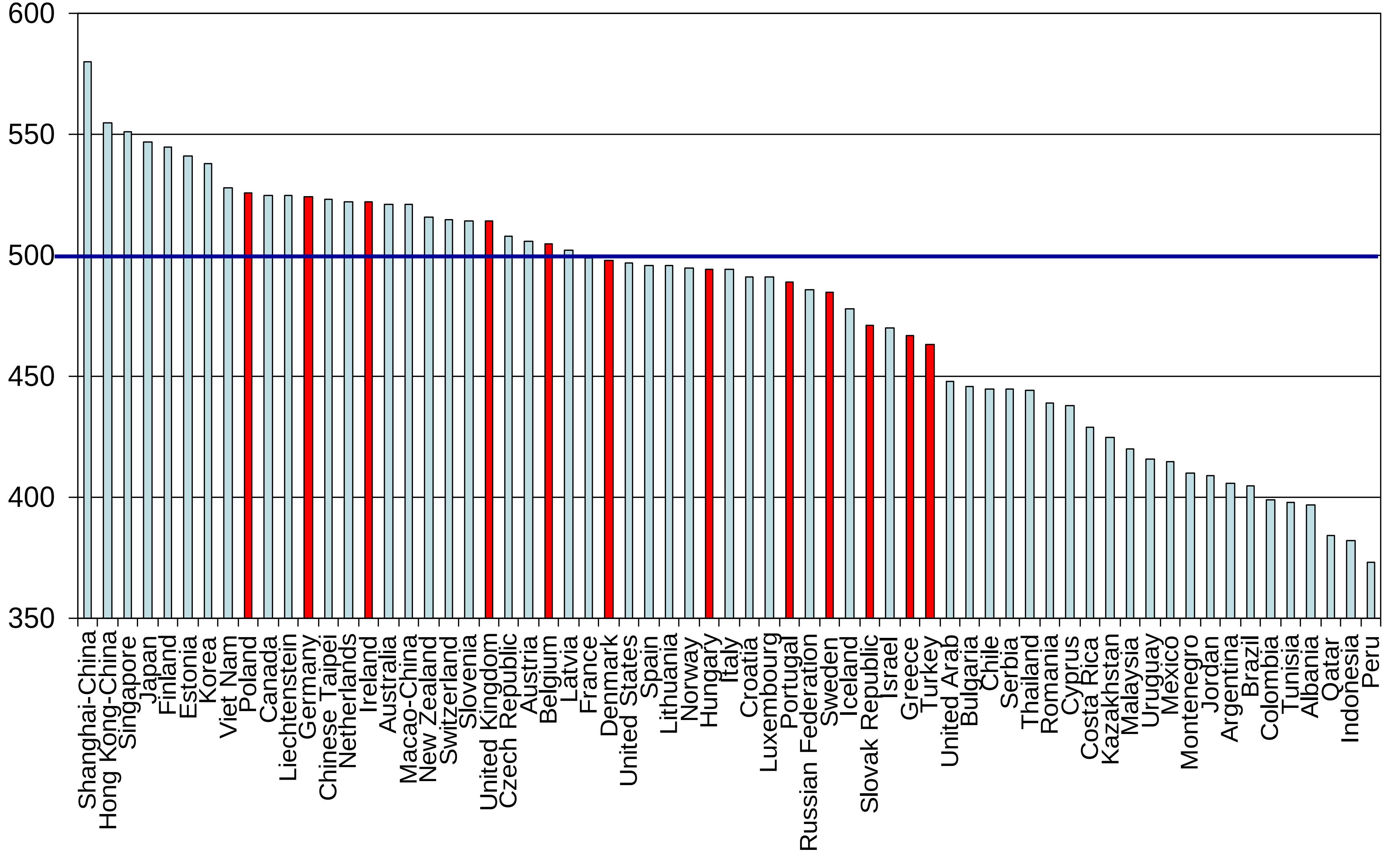
Outline

- Problems of science education and the need for improvement
  - PISA 2012 science results
  - Problem solving in PISA 2012
- Theoretical resources for understanding, representing and solving the problems
- What to assess: Framework development in SAILS
- Challenges, problems and perspectives in implementing assessment

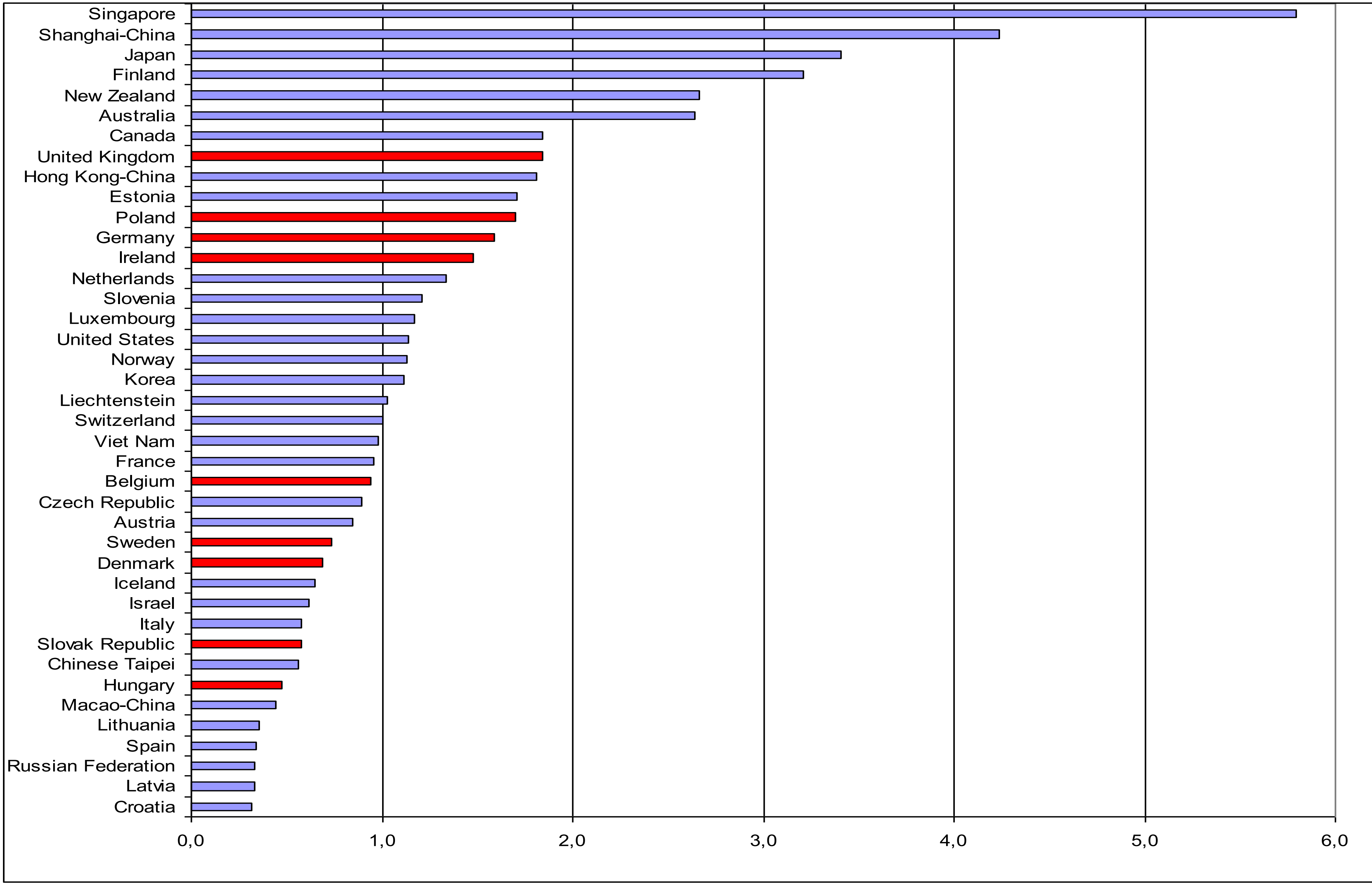
Problems of science education:

Results of PISA 2012

PISA 2012:
Mean achievements in science

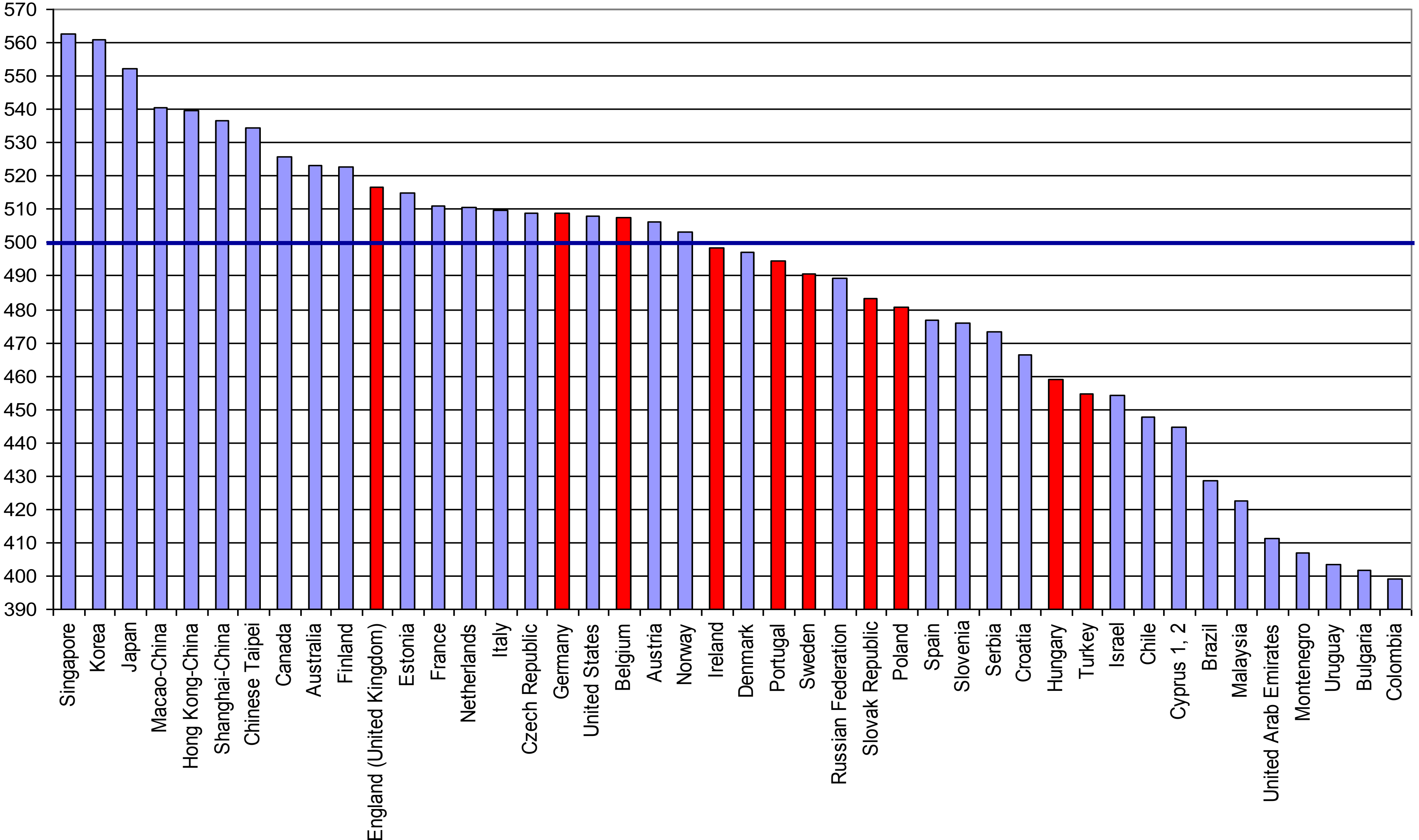


PISA 2012: Proportion of students achieving at level 6 in Science (%)

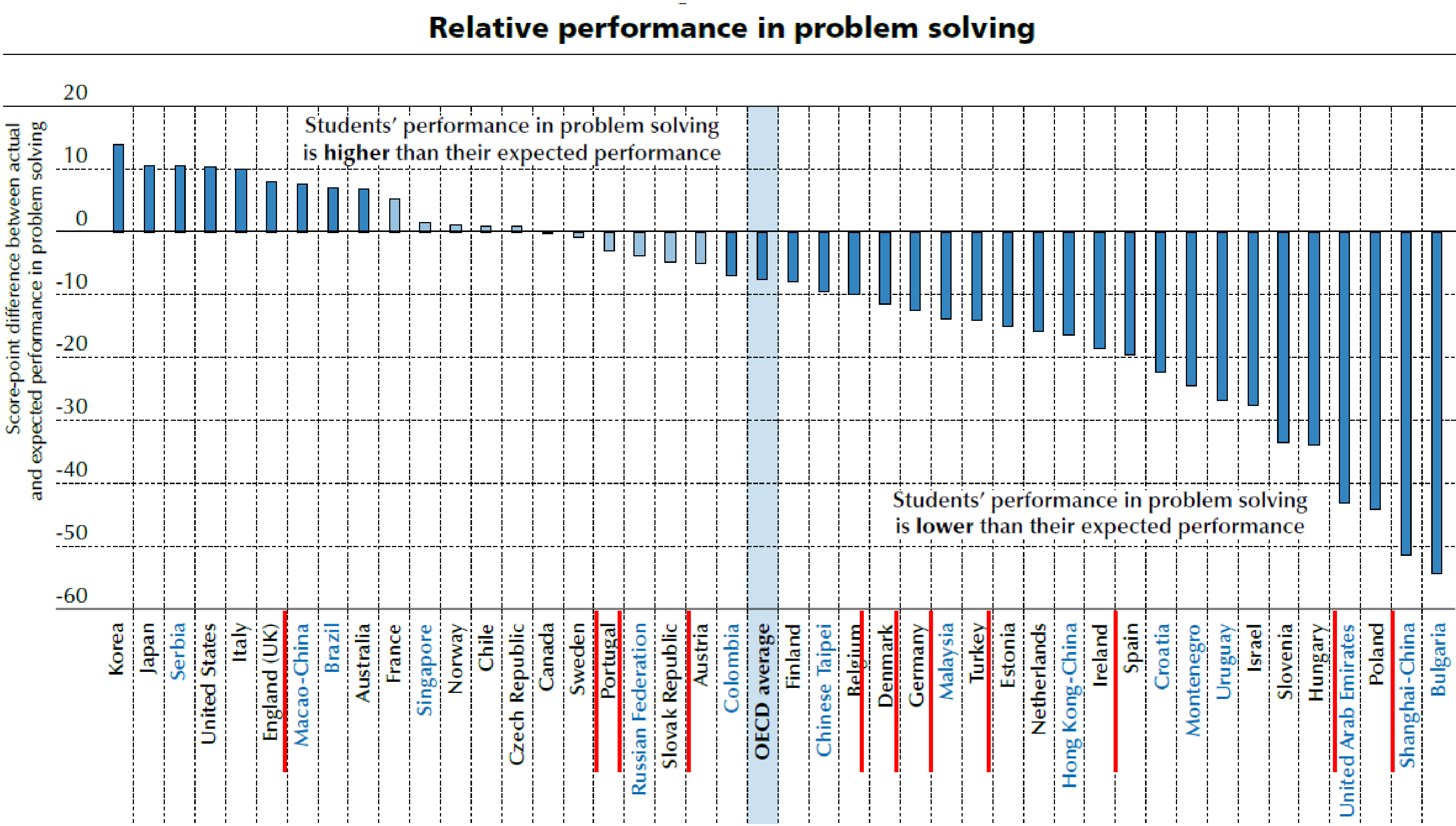


Although in many countries the traditional goals of science education are not met yet, new goals appeared: to develop the 21st century skills, e.g. creativity, critical thinking and problem solving.

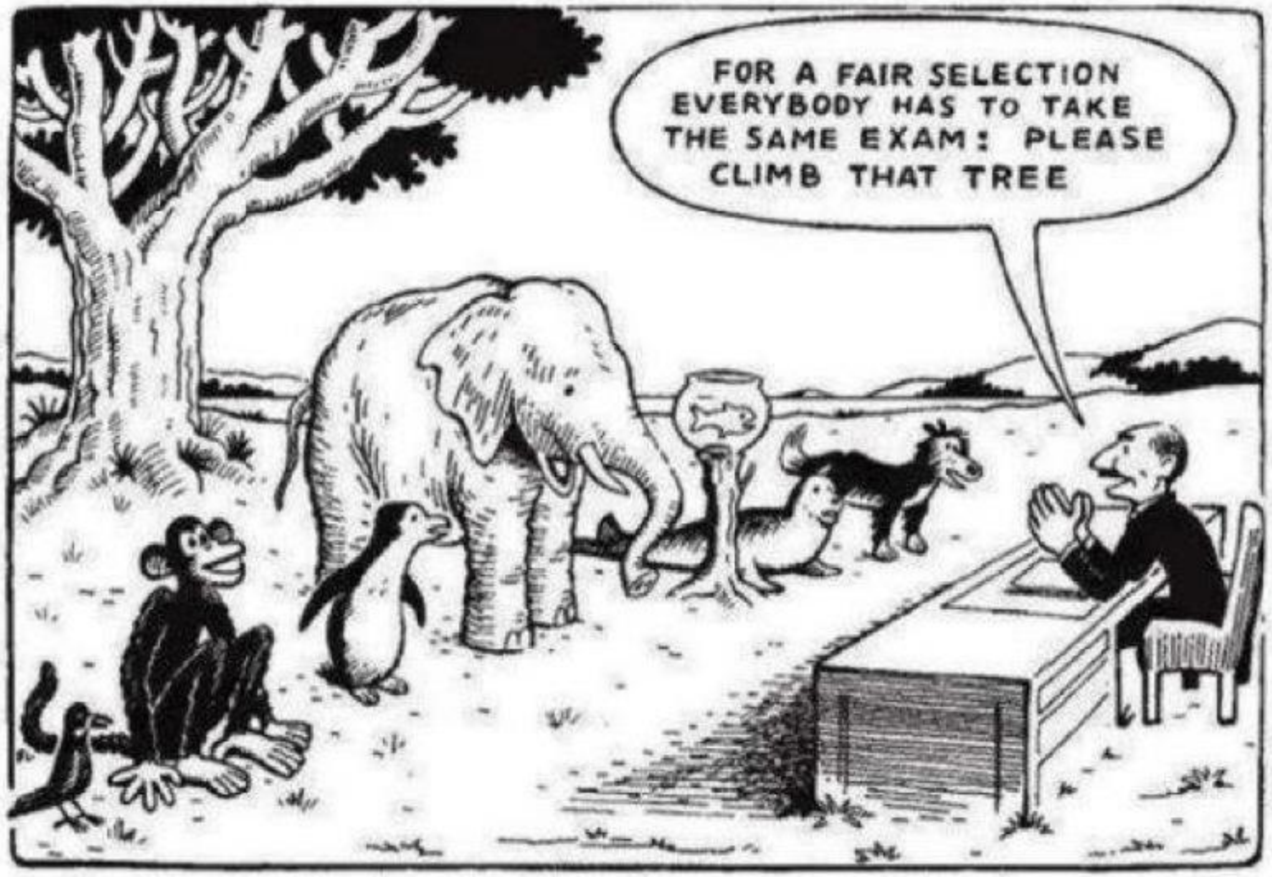
PISA 2012: Achievements in Problem Solving



Relative performance in Problem Solving



Does the same solution work for each country?



Our Education System

Some conclusions of the PISA results

- There are large differences between the SAILS partner countries
  - in the mean achievements
  - in the quality of students’ knowledge
- High achievements in the main domains do not guarantee good problem solving
- A deeper understanding of the organization of students’ knowledge is needed
- A more sophisticated assessment framework is required

How can Inquiry-Based Science Education contribute to the improvement of science achievements?

Can IBSE improve Problem Solving skills?

In the first phase, EU projects focused on developing IBSE methods and training of teachers to use them.

"Experience alone does not create knowledge."

Kurt Lewin

EU FP7 projects on science education

CarboSchools+	European network of regional projects for school partnerships on climate change research
CoReflect	Digital support for Inquiry, Collaboration, and Reflection on Socio-Scientific Debates
Mind the Gap	Learning, Teaching, Research and Policy in Inquiry-Based Science Education
HIPST	History and Philosophy in Science Teaching
EUCUNET	European Children´s Universities Network
YOSCIWEB	Young people and the images of science on websites
MOTIVATION	Promoting positive images of SET in young people
S-TEAM	Science-Teacher Education Advanced Methods
ESTABLISH	European Science and Technology in Action Building Links with Industry, Schools and Home
FIBONACCI	Large scale dissemination of inquiry based science and mathematics education
PRIMAS	Promoting Inquiry in Mathematics and Science Education
KIDSINNSCIENCE	Innovation in Science Education - Turning Kids on to Science
SED	Science Education for Diversity
TRACES	Transformative Research Activities. Cultural diversities and Education in Science
PROFILES	Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science
Pathway	The Pathway to Inquiry Based Science Teaching
INQUIRE	Inquiry-based teacher training for a sustainable future
Pri-Sci-Net	Networking Primary Science Educators as a means to provide training and professional development in Inquiry Based Teaching
SECURE	Science Education Curriculum Research
ECB European	Coordinating Body in Maths, Science and Technology Education

“If you can not measure it,
you can not improve it.”

Kelvin

Recent projects deal with assessment as well.

For this new approach, we need new knowledge.

"There is nothing so practical as a good theory."

Kurt Lewin

Maybe a set of good theories is even more practical…

Theories on what to assess and how to assess

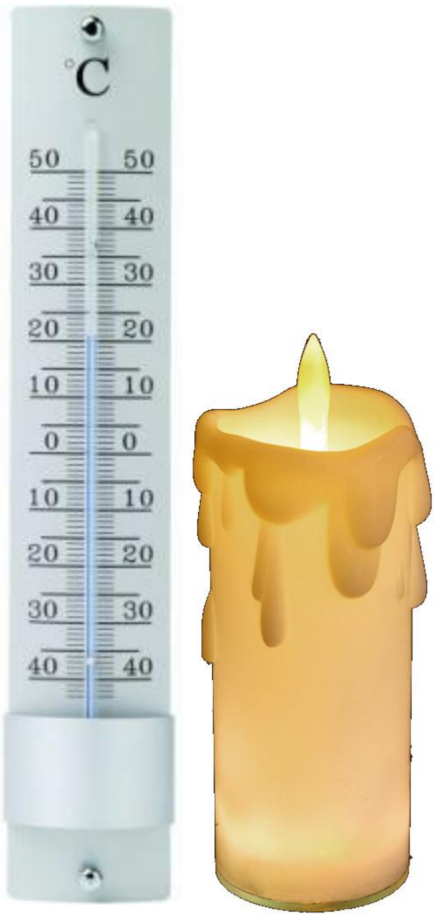
- What to assess?
  - theories of cognition
  - cognitive development
  - learning and instruction
  - curriculum development
  - standards and standard setting
- How to assess?
  - theories of educational and psychological assessment
  - classical test theory
  - modern (probabilistic) test theories

A typical misunderstanding of the role of the indicators

An analogy

Measuring and increasing room temperature

A low-cost solution



"Teaching to a test is easy.
Teaching for life is hard."

What do we really mean by increasing students’ achievements?

… increasing
the quantity of students' knowledge

or

… improving
the quality of students' knowledge

For measuring students' knowledge we need a more sophisticated instrument than this one.

A framework for representing problems of the quality of students’ knowledge

Dimensions of Knowledge

INTERNAL REFERENCE
Basic skills – general abilities continuum
Cognitive skills, competencies etc.

EXTERNAL (SOCIAL) REFERENCE
General literacy: social, cultural, ”lay”, “civic” dimension.
PISA reading literacy, mathematical literacy, scientific literacy.
Technical literacy, musical literacy, ICT literacy etc.

EXTERNAL (PROFESSIONAL) REFERENCE
Expertise (disciplinary/professional dimension)
Expert knowledge, professional knowledge

…nce education and … on of knowledge

PISA 2012 Problem Solving

BASIC SKILLS – GENERAL ABILITIES

Psychological determination

GENERAL LITERACY

Cultural determination

PISA mathematical and scientific literacy

Disciplinary determination

CONTENT KNOWLEDGE – EXPERTISE

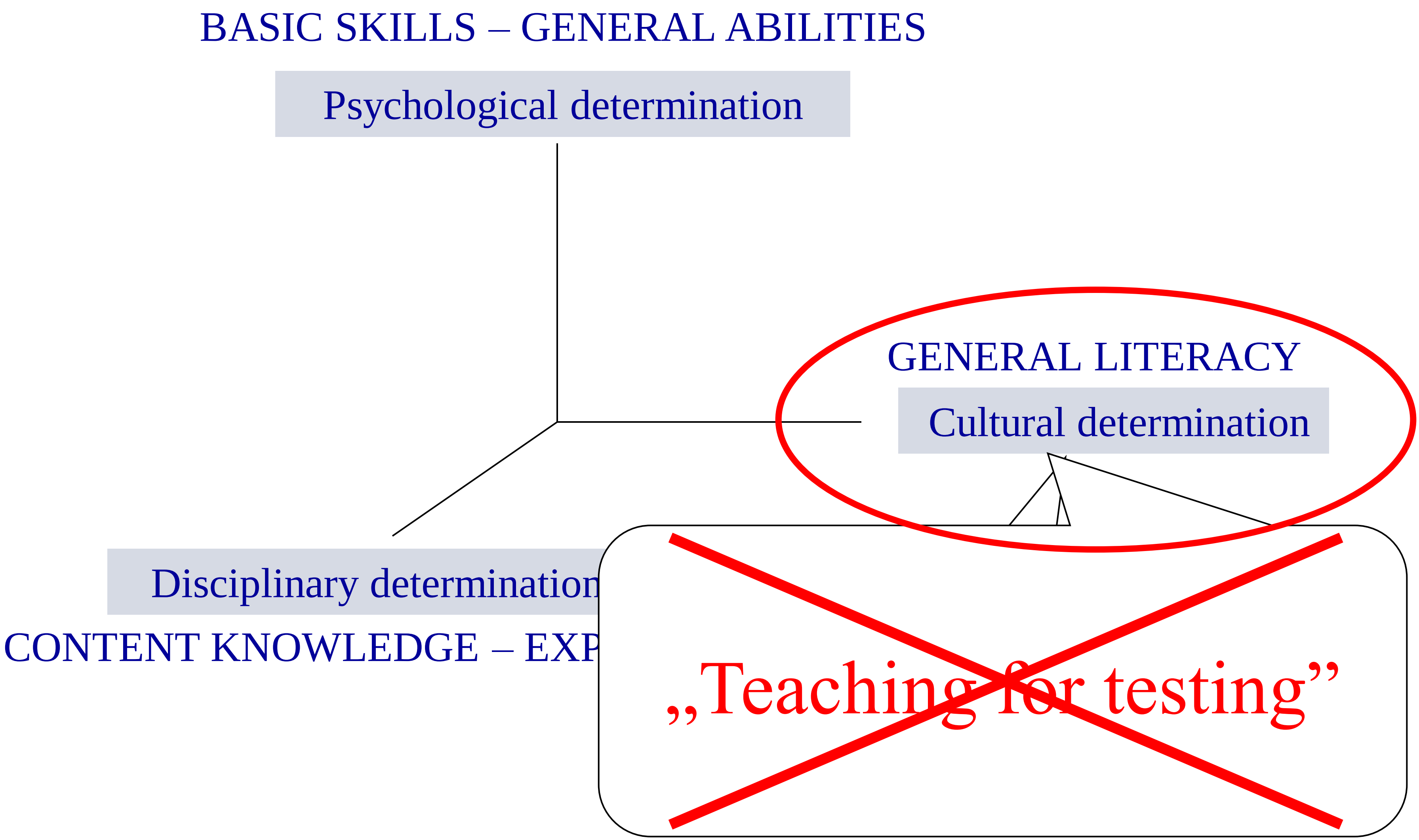
1st and 2nd IEA Science and Mathematics Study

How PISA results can be improved?

Three different approaches may be considered

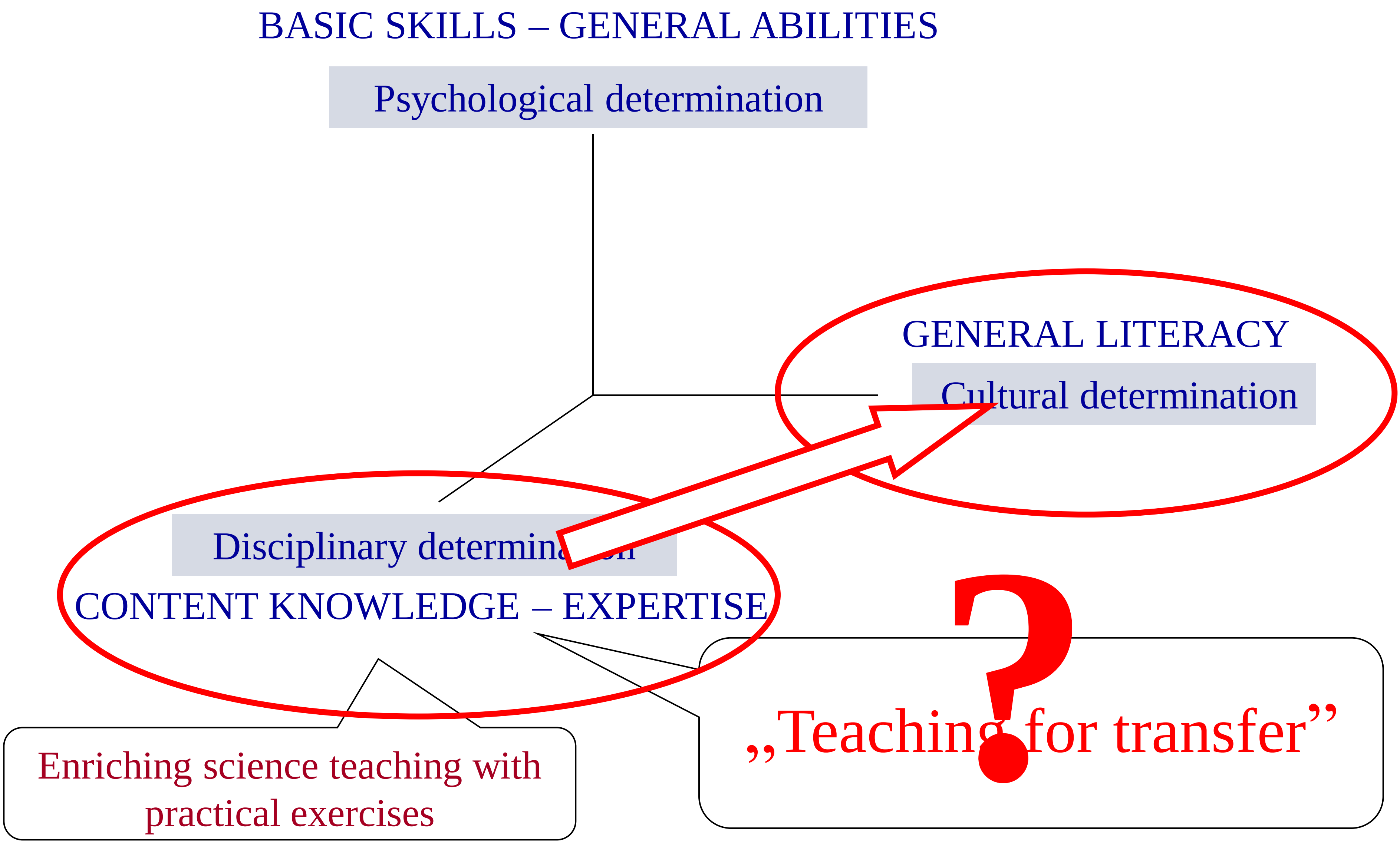
The worst option:
direct teaching

The most trivial but worst option



Better option:
low-road transfer

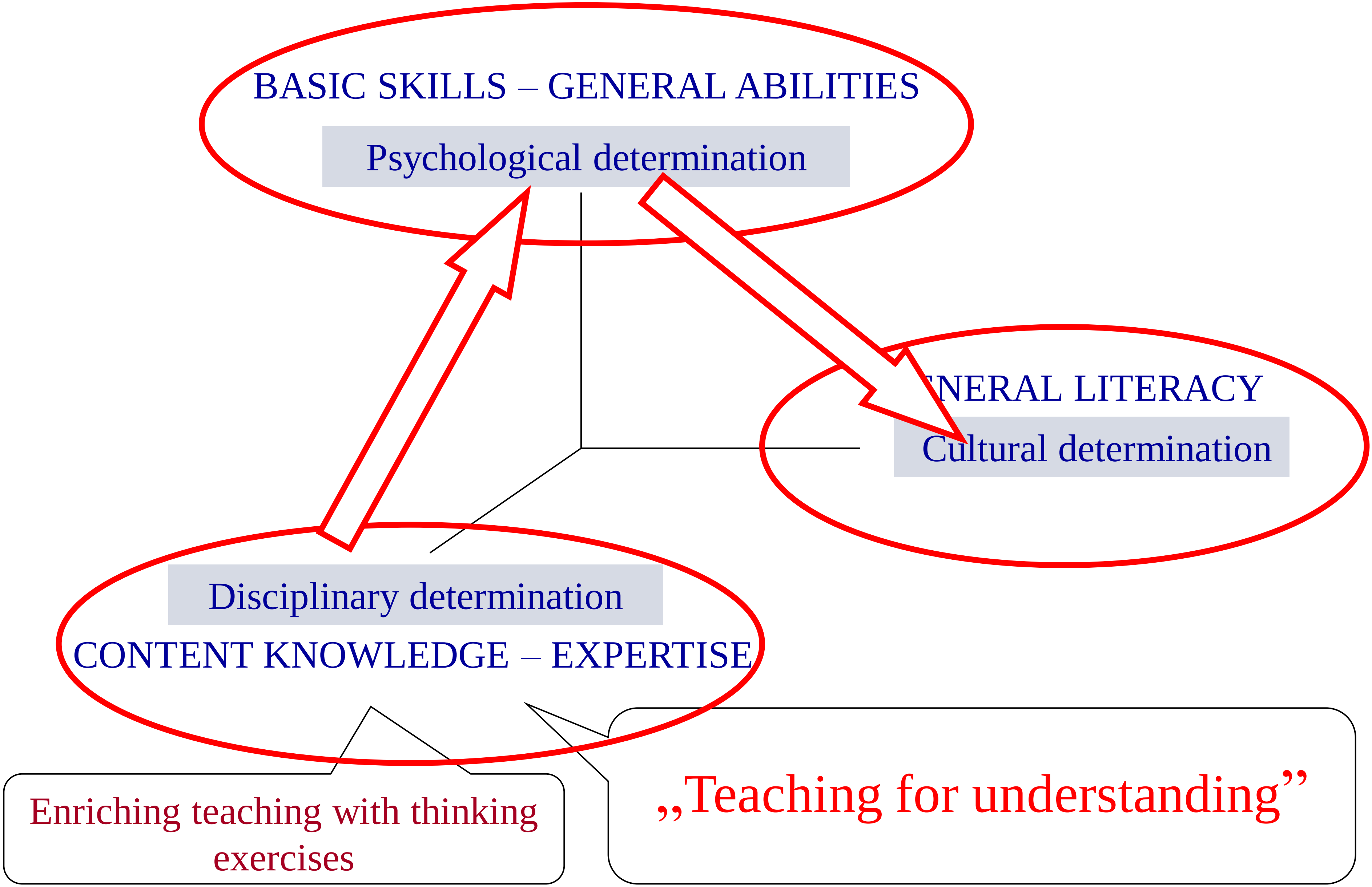
Better option: low-road transfer



The best option:
high-road transfer

- improving thinking
- improving understanding

The best option



SAILS

Strategies for Assessment of Inquiry Learning in Science

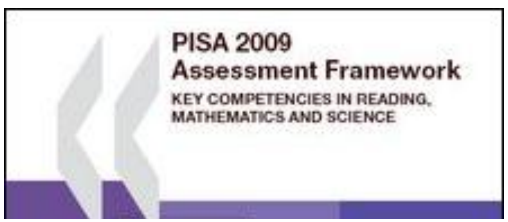
The SAILS project has received funding from the European Union's Seventh Framework Programme [2012-2015]

CAPACITIES

Framework development in SAILS

How an assessment framework looks like?

PISA | TIMSS | Diagnostic



PISA
- application (literacy)

TIMSS
- content
- reasoning
- application

Diagnostic
- content
- reasoning
- application

Framework development for SAILS

- Inquiries (content, process, skills)
- Disciplinary content knowledge
  - Big ideas
  - Conceptual development (conceptual change, misconceptions)
  - Learning progression
- Application of scientific knowledge (scientific literacy)
  - Applied areas
  - Application through transfer
- Reasoning
  - Operational reasoning
  - Higher order thinking skills
  - Scientific reasoning

Inquiry skills

- Wenning:
  - Identify a problem to be investigated
  - Formulate a hypothesis
  - Design experimental procedures to test the prediction
  - Conduct a scientific experiment; collect meaningful data, organize, and analyze data accurately and precisely
  - Apply numerical and statistical methods to numerical data to reach and support conclusions
  - Using available technology, report, display, and defend the results of an investigation to audiences that might include professionals and technical experts
- Fradd:
  - Questioning
  - Planning
  - Implementing
  - Concluding
  - Reporting
  - Applying

Developing learning units

- A structure in which different examples can be documented
  - Understanding of Inquiry
  - Unit Structure
    - Section 1: Topic
    - Section 2: Content
    - Section 3: Inquiry skills
    - Section 4: Suggested Learning Sequence
    - Section 5: Assessment opportunities

A hard issue:

Improving cognitive abilities

Cognitive abilities often mentioned in the context of IBSE

- intelligence
- creativity
- critical thinking
- scientific reasoning
- problem solving

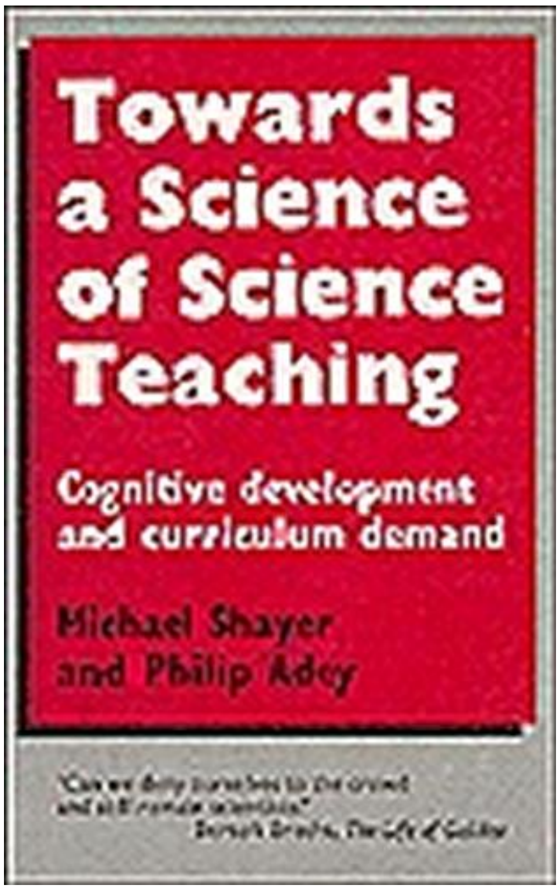
  PISA 2012: dynamic problem solving

  PISA 2015: collaborative problem solving

Reasoning skills relevant for mastering, organization and application of scientific knowledge

- control of variables
- organization, seriation, class inclusion, classification, multiple classification, set operations
- combinatorial reasoning, operation of binary logic
- probabilistic reasoning, risk estimation, correlational reasoning
- relations, relational reasoning
- ratio, proportional reasoning
- measurement, product of measures
- analogical reasoning, inductive reasoning
- causality
- hypothesis generation and hypothesis testing

Cognitive development and science education

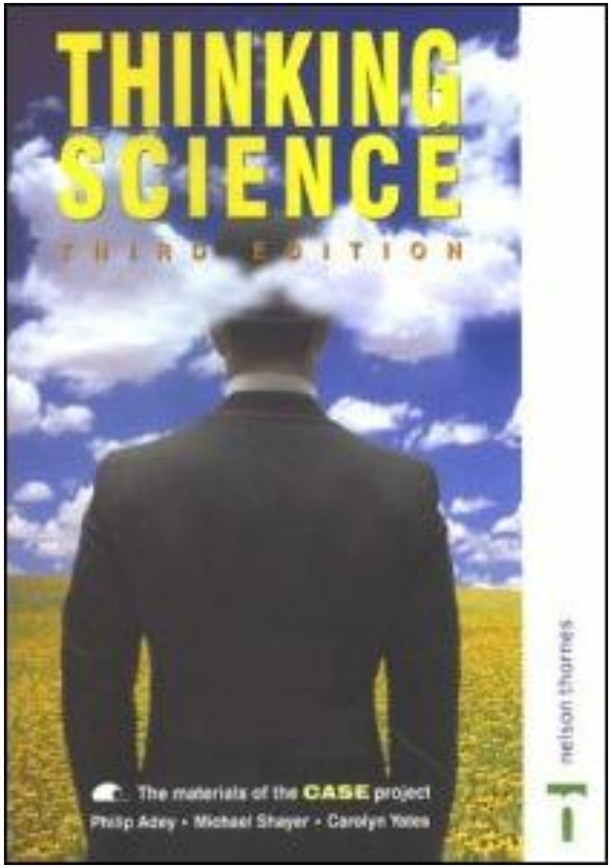


Michael Shayer and Philip Adey:

Towards a Science of Science Teaching

(1981)

Cognitive Acceleration through Science Education (CASE)

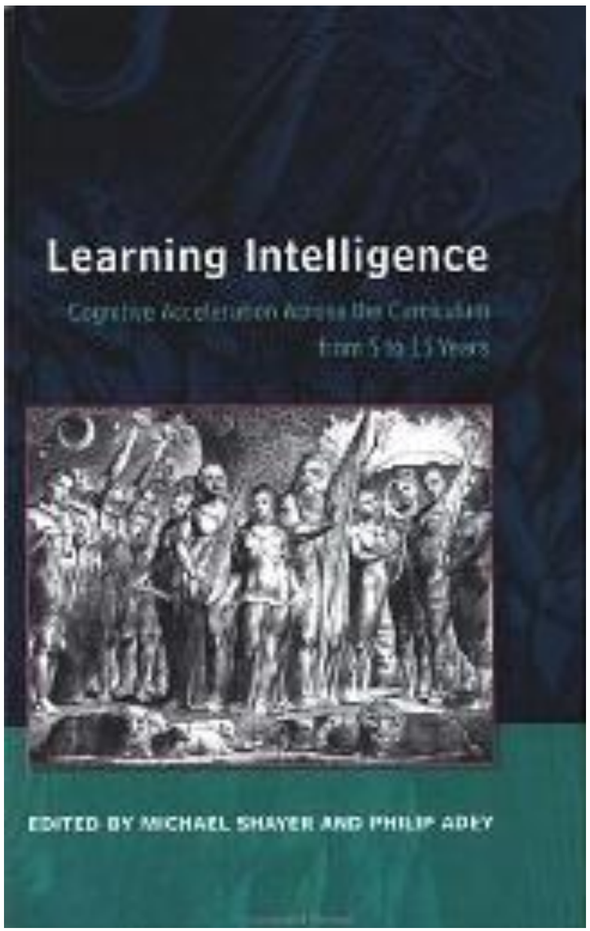


Philip Adey, Michael Shayer and Carolyn Yates:

Thinking Science

(1989)

Broader effects of CASE

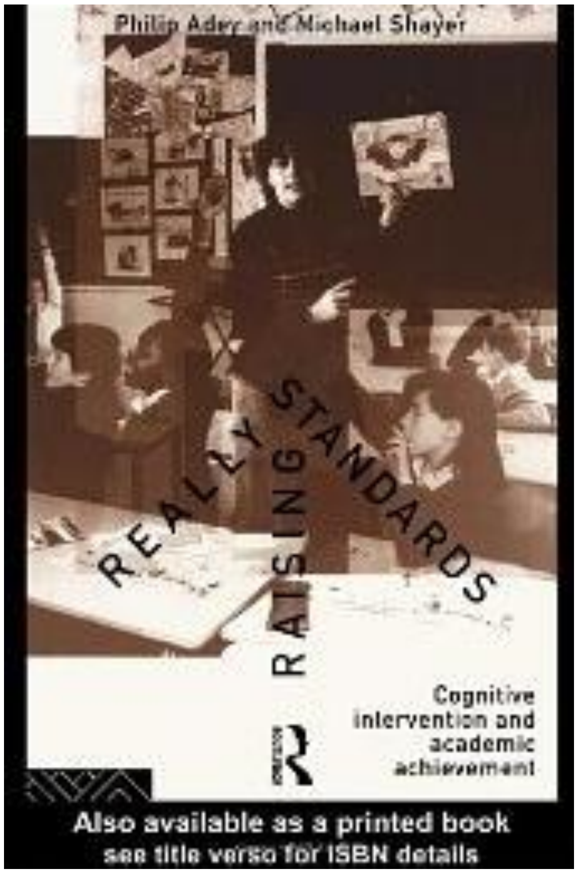


Michael Shayer and Philip Adey:

Learning Intelligence
Cognitive Acceleration across the Curriculum from 5 to 15 Years

(2002)

Lasting effects of CASE



Philip Adey and Michael Shayer:

Really Rising Standards
Cognitive Intervention and Academic Achievement

(1994)

Challenges in implementing assessment in SAILS

Bridging the gap between “21st century skills” and IBSE

- Strengths of “traditional” science education
  - expertise, expert knowledge (immediately applicable in the given contexts)
  - content related skills (mechanical routines)
  - domain specific problem solving
- Challenges in implementing IBSE
  - it cannot be reduced for teaching a few inquiry skills
  - it cannot be done by using old teaching routines

Bridging the gap between formative classroom assessment and assessing more general, lasting outcomes of inquiry learning

- Formative assessment deals with small pieces of knowledge and skills, but understanding and transfer can be assessed only in a broader context
- Formative classroom assessment provides immediate feedback, but general skills develop over a long period

Thanks for your attention!

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11:30-12:30

- 60 min