Best Practice in Science Education

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What is science?

- Explanations of the material world
- Based on observation and testing of theories against nature (facts, hypotheses, laws, theories)

- Importance historically
- Importance in a modern society

Why Science?

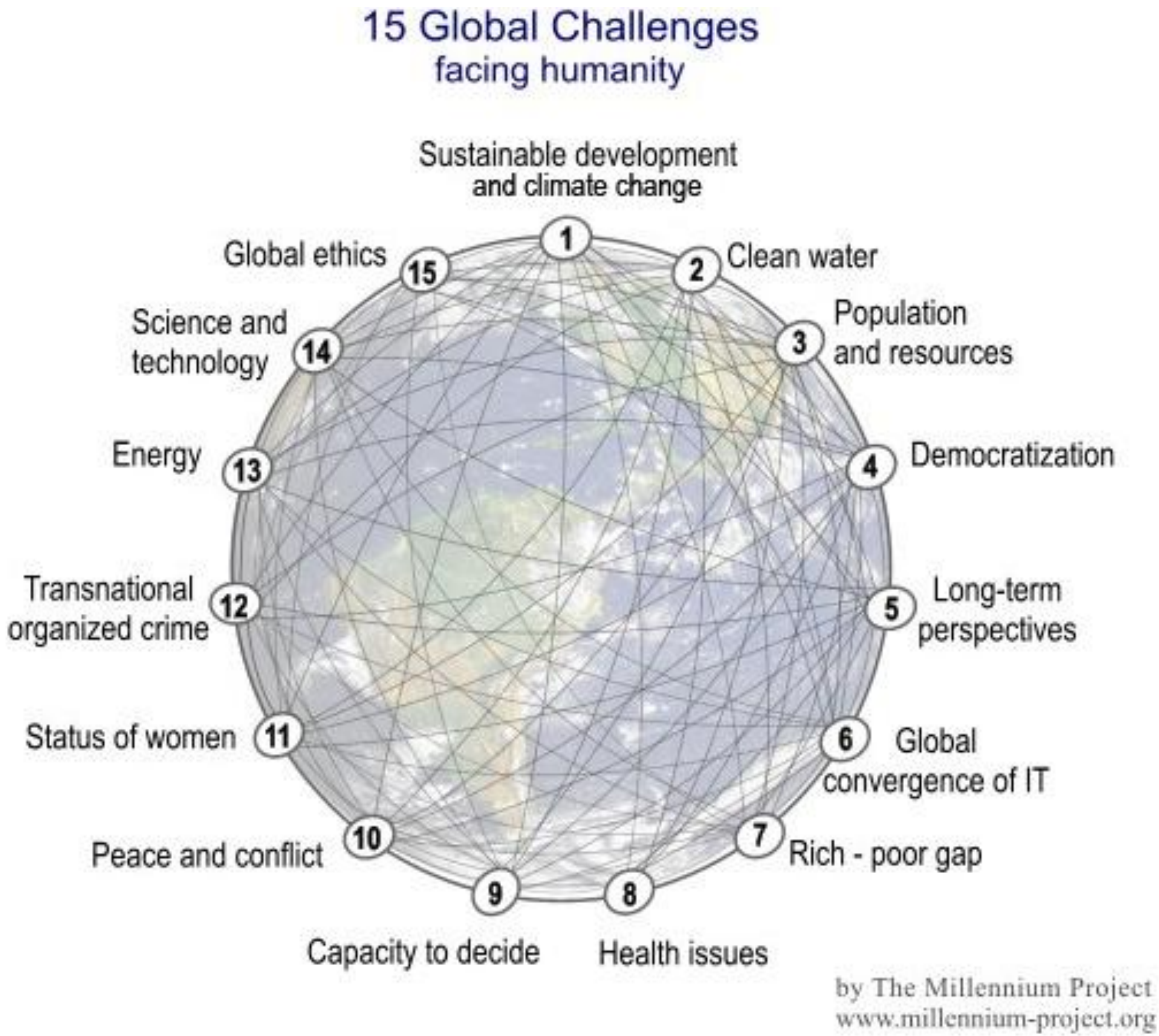
water

climate

food

energy

health


15 Global Challenges
facing humanity
Sustainable development
and climate change
1
2 Clean water
3 Population
and resources
4 Democratization
5 Long-term
perspectives
6 Global
convergence of IT
7 Rich - poor gap
8
Health issues
9
Capacity to decide
10
Peace and conflict
11
Status of women
12
Transnational
organized crime
13
Energy
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Science and
technology
15
Global ethics
by The Millennium Project
www.millennium-project.org

Why does science matter?

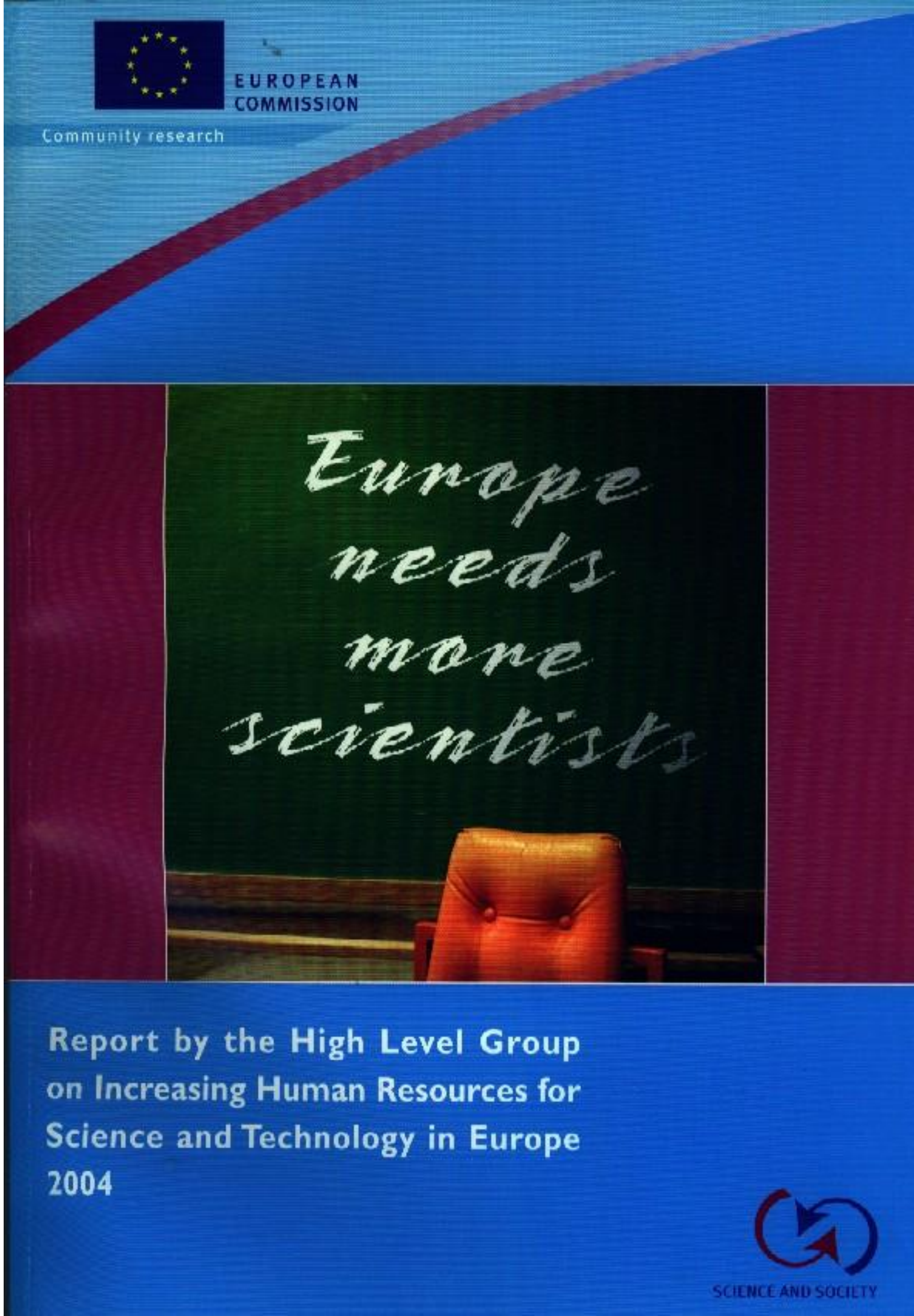
- Science for all
  - Scientific literacy important in a democracy

- Science for future scientists
  - Important for EU – economic growth, competition, prosperity

Current studies

- Europe need more scientists - EU
- The Global Science Forum – OECD
- Science Education In Europe – Nuffield
- Science Education NOW – EU
- Mind the Gap

Recruitment and interest in S&T: A prime political concern for Europe and (most) OECD Countries…



It can be argued that science education in schools lives in a world of its own. It seems unsophisticated because it is unable to compete with advances within the scientific fields. It is abstract because it is trying to put forward fundamental ideas, most of which were developed in the 19th century, without sufficient experimental, observational and interpretational background….

…without showing sufficient understanding of their implications, and without giving students the opportunity of a cumulative development of understanding and interest. It is heavily in danger of being excessively factual because of the explosion in scientific knowledge and the “adding-on” of topics to an already excessive content base.

Europe needs more scientists, 2004

Bridging the gap between science and society

- What should school science address in a knowledge society?
- What responsibility do schools, public institutions, business and industry share in connections between science and society?
- How do we go about making science careers more attractive?

Recommendations

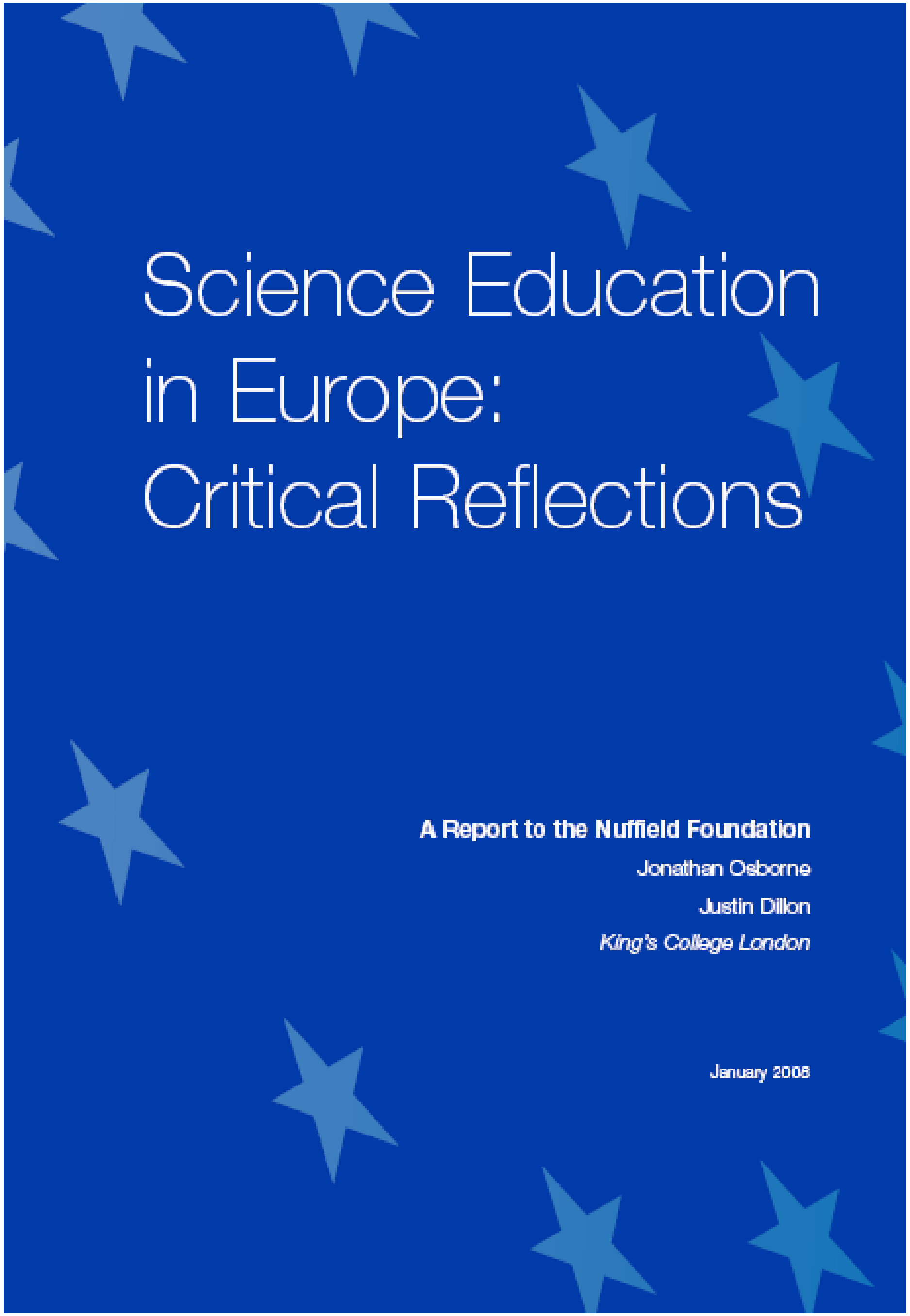
- Continue in-depth studies to show trends
- Long-term studies of student motivation
- Governments should actively promote equal opportunities for all (males and females) and take steps to eliminate negative stereotypes
- Governments should invest in teacher training, curriculum development, exchange of best practice, assessment

Science Education in Europe

A report to the Nuffield Foundation

Jonathan Osborne & Justin Dillon

http://www.nuffieldfoundation.org/fileLibrary/pdf/Sci_Ed_in_Europe_Report_Final.pdf



Questions asked:

- What are the major issues confronting formal secondary science education?
- What evidence is there?
- Is the situation common throughout Europe or is there variation?

The State of Science Education in Europe

- Relevance is lacking
- Reforms in Pedagogy needed
- Girls less interested than boys with fewer choosing careers in physical science and engineering
- Reforms in curriculum needed (more human content)

Recommendation 1

- The primary goal of science education across the EU should be to educate students both about the major explanations of the material world that science offers and about the way science works. Science courses whose basic aim is to provide a foundational education for future scientists and engineers should be optional.

Recommendation 2

More attempts at innovative curricula and ways of organizing the teaching of science that address the issue of low student motivation are required. These innovations need to be evaluated. In particular, a physical science curriculum that specifically focuses on developing an understanding of science in contexts that are known to interest girls should be developed and trialled within the EU.

Recommendation 3

- EU countries need to invest in improving the human and physical resources available to schools for informing students, both about careers *in* science – where the emphasis should be on why working in science is an important cultural and humanitarian activity – and careers *from* science where the emphasis should be on the extensive range of potential careers that the study of science affords.

Recommendation 4

EU countries should ensure that:

- Teachers of science of the highest quality are provided for students in primary and lower secondary school;
- Emphasis in science before 14 should be on engaging students with science and scientific phenomena. Evidence suggests that this is best achieved through opportunities for extended investigative work and “hands-on” experimentation and not through a stress on the acquisition of canonical concepts.

Recommendation 5

Developing and extending the ways in which science is taught is essential for improving student engagement. Transforming teacher practice across the EU is a long-term project and will require significant and sustained investment in teacher professional development.

Recommendation 6

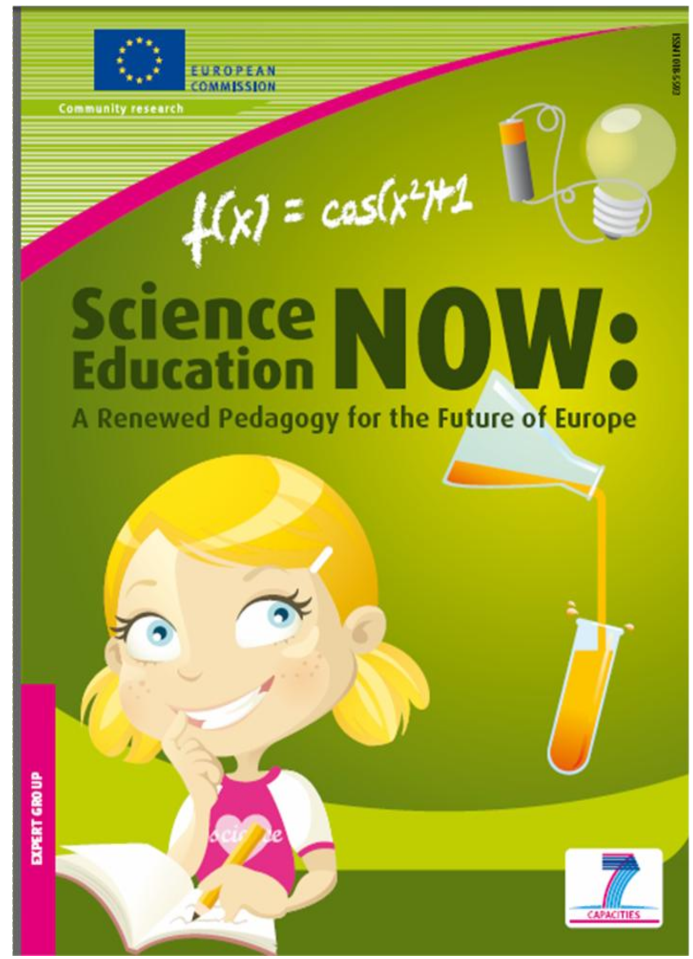
EU governments should invest significantly in research and development work on assessment in science education. The aims should be to develop items and methods should assess skills, knowledge and competencies expected of a scientifically literate citizen.

Recommendation 7

Good quality teachers, with up-to-date knowledge and skills, are the foundation of any system of formal science education. Systems to ensure the recruitment, retention and continuous professional training of such individuals must be a policy in Europe.

Science Education NOW

A Renewed Pedagogy for the Future of Europe

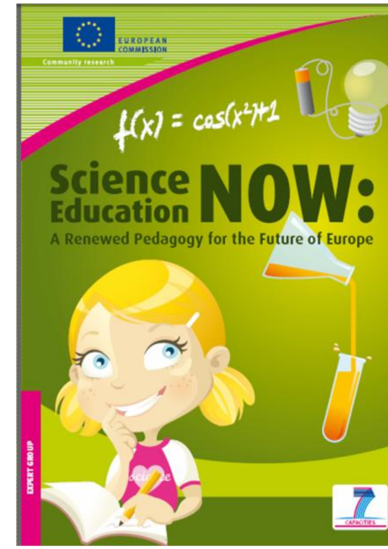


Michel Rochard (Chair)
Peter Csermely
Doris Jorde
Dieter Lenzen
Harriet Walberg-Henriksson
Valerie Hermmo (rapportur)

Background for the report

- Decline in student interest in science, math and technology in Europe
- Modest improvements in Europe despite numerous projects
- Future of SMT important in Europe

Recommendation 1

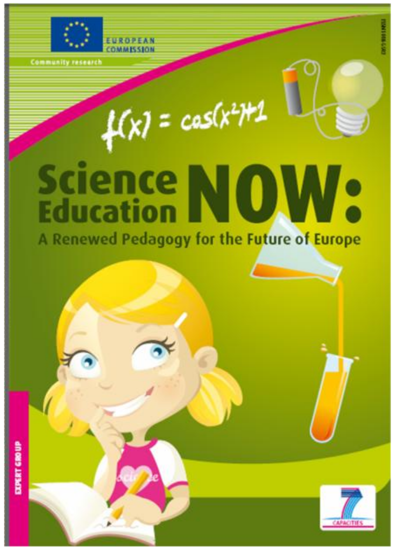


Because Europe's future is at stake decision makers must demand action on improving science education from the bodies responsible for implementing change at local, regional, national and European levels.

What can be done?

- At national levels we can place science on the agenda – everywhere!
- Coordinate the MANY initiatives taking place and evaluate their impact
- National support for large scale curriculum development projects
  - Followed by exchange of ideas
- Allow for re-entry into science domains

Recommendation 2



Improvements in science education should be brought about through new forms of pedagogy.
The introduction of inquiry based approaches in schools and the development of teachers' networks should actively be promoted and supported.

Inquiry Based Science

- Inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debatng with peers and forming coherent arguments.

Linn, Davis and Bell, 2004

Inquiry Based Science is characterized by:

- Authentic and problem based learning activities where there may not be a correct answer
- A certain amount of experimental procedures, “hands-on” activities
- Self regulated learning sequences where student autonomy is emphasized
- Discursive argumentation and communication with peers (talking science)

What can be done?

- Importance of teacher education as a starting point for pedagogical change
- Importance of in-service courses for science teachers that combine network possibilities

Students at all grade levels and in every domain of science should have the opportunity to use scientific inquiry and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and technologies to gather data, thinking critically and logically about relationships between evidence and explanation, constructing and analyzing alternative explanations, and communicating scientific arguments.

NRC 1996

Inquiry based science teaching

- From a goal of providing science education for scientists to providing science education for all
- From an image of science education as what we know to science education as teaching science as a way of knowing
- From an image of science education that emphasizes content and process goals to a science education that stresses goals examining the relation between evidence and explanations

Duschl

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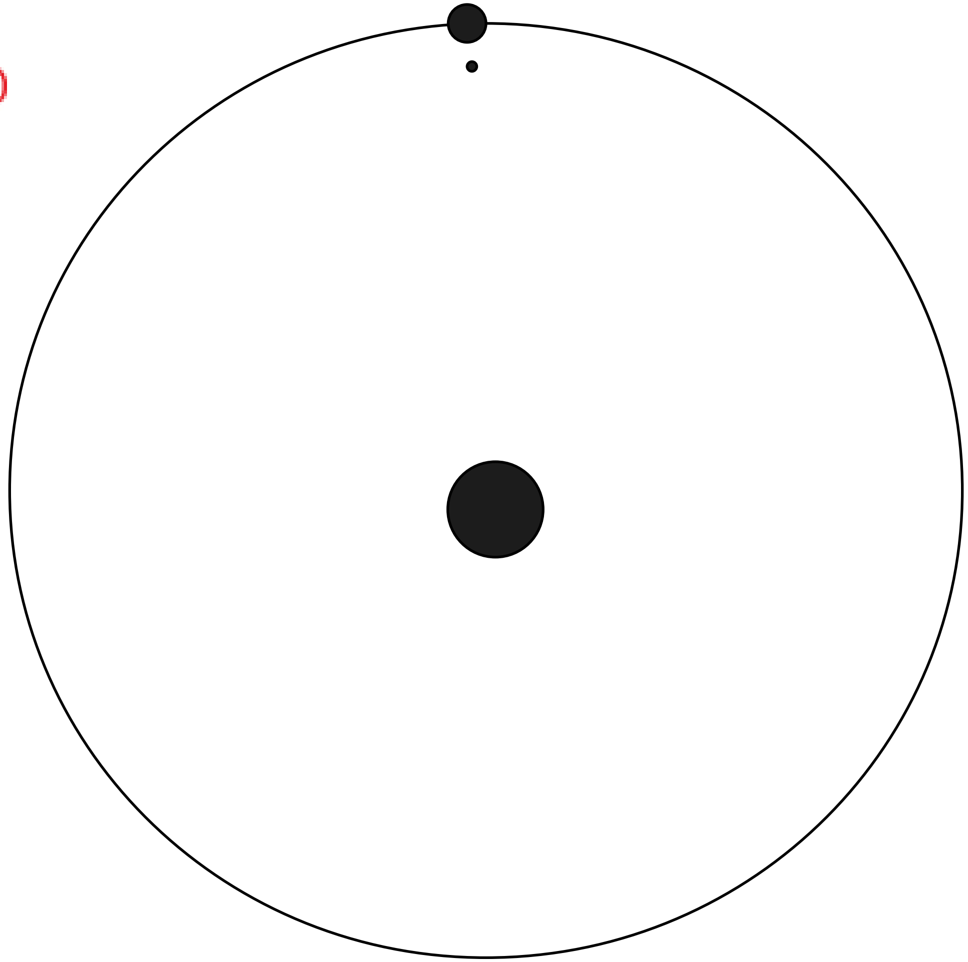
- From and emphasis on individual science lessons that demonstrate concepts to science lesson sequences that promote reasoning with and about concepts
- From the study of science topics that examine current scientific thinking without regard for social context to the study of science topics in social contexts
- From a view of science that emphasizes observation and experimentation to a view that stresses theory and model building and revision

Duschl

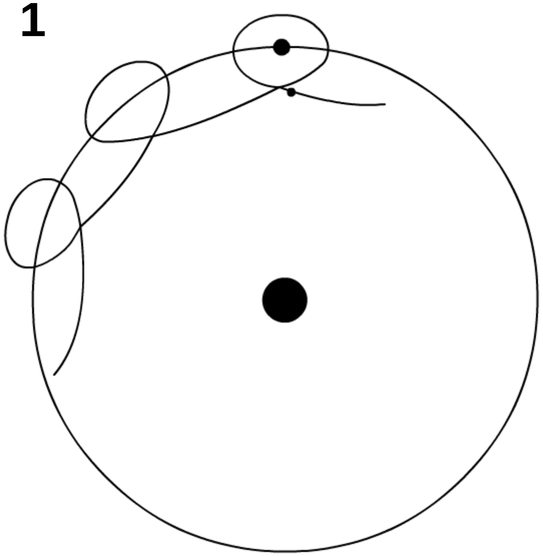


Draw the pathway of the moon during the course of a year

Which model is the best for illustrating how the

moon and the earth rotate around the sun?

1



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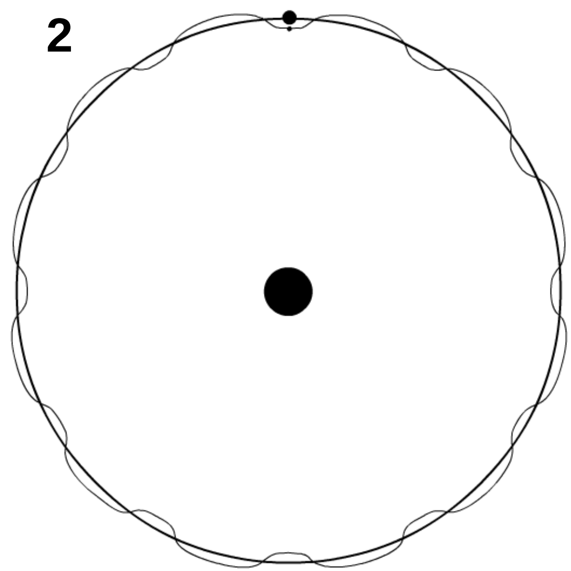

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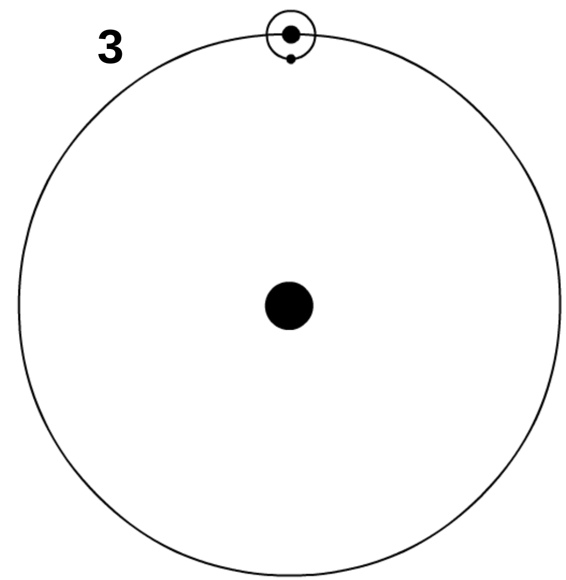
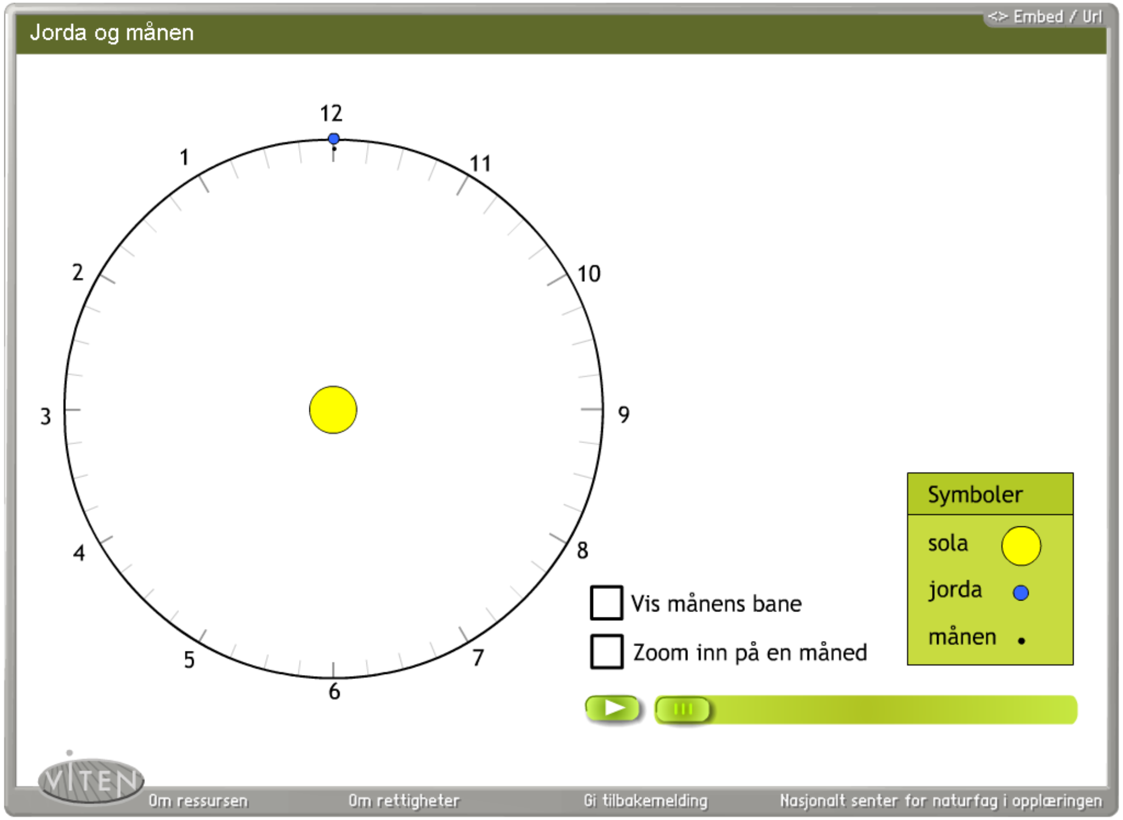


http://filarkiv.viten.no/?content=moon_rotate



Critical response strategies for developing inquiry

- **Call for clarification – students revisit or rehearse their answers**
  - How else might you say that? Is there anything you could add to make that more understandable? Could you rephrase that?
- **Calling for evidence**
  - How do you know that? What is your proof? What data did you find that would help you explain your decisions? What do you think your data show? Can you use your data to make up a rule to describe your results?

Critical response strategies for developing inquiry

- **Calling for Evaluation**
  - What else do you think could have caused that? If you did this investigation again, what would you do differently? Why would you do that? Why do you consider your answers reasonable? How could you change this investigation? How do you think you could make the investigation better? Why would it be better?

Critical response strategies for developing inquiry

- **Wait times I and II**
  - Teacher questions and student answers; student answers and teacher asks a new question
- **Playing the devil's advocate**
  - Considering other ideas from teacher or peers. Important for controversial issues
- **Not looking for the "right" answer**

Science Scope. September 2008. Vol 32; Nr.1 (pages 12-14)

The Inquiry Continuum

- Confirmation Inquiry
  - The question and procedure are provided, results are known in advance.
- Structured Inquiry
  - The question and procedure are provided, students generate an explanation supported by the evidence they collect

The Inquiry Continuum 2

- Guided Inquiry
  - The teacher provides the research question, students design the procedure

- Open Inquiry
  - Students ask questions, design procedures, carry out investigations and communicate results

5E model

- Engaging
- Exploring
- Explaining
- Elaborating
- Evaluating

Engaging (Teacher)

- Creates interest
- Generates curiosity
- Raises questions
- Elicits responses uncovering what students are thinking

- Explains concepts
- Provides definitions and answers
- States conclusions
- Provides closure
- lectures

Engaging (Student)

- Asks questions such as, Why did this happen? What can I find out about this? What do I already know about this?

- Asks for the correct answer
- Seeks one solution

Explore (teacher)

- Students working together without direct instruction
- Observes and listens to student interaction
- Asks probing questions to help students
- Allows students time to think through problems
- Acts as a consultant

- Provides answers
- Tells or explains how to work on problems
- Provides closure
- Tells students they are wrong
- Provides facts to solve problems
- Leads step by step to solutions

Explore (student)

- Thinks freely but within limits of the activity
- Forms new predictions and hypotheses
- Tries alternatives and discusses them with others
- Records observations and ideas
- Lets others do the thinking (passive)
- Works quietly with no involvement
- Plays around with no goal in mind

Explain (teacher)

- Encourages students to explain in own words
- Asks for justification (evidence) and clarification
- Uses students' previous experiences as basis for explaining concepts

- Accepts explanations that have no justification
- Neglects to solicit students' explanations

Explain (student)

- Explains possible solutions or answers to others
- Listens critically to other explanations
- Refers to previous activities
- Uses recorded observations in explanations
- Proposes explanations from thin air with no relationship to previous experiences
- Beings up irrelevant experiences and examples
- Accepts explanations without justification

Inquiry

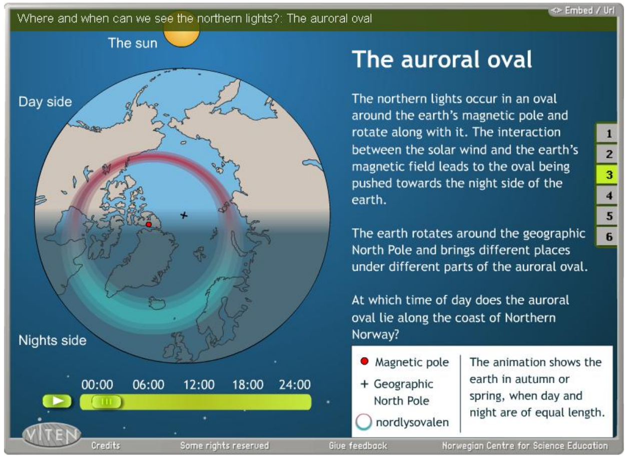
- http://www.thirteen.org/edonline/concept2class/index.html

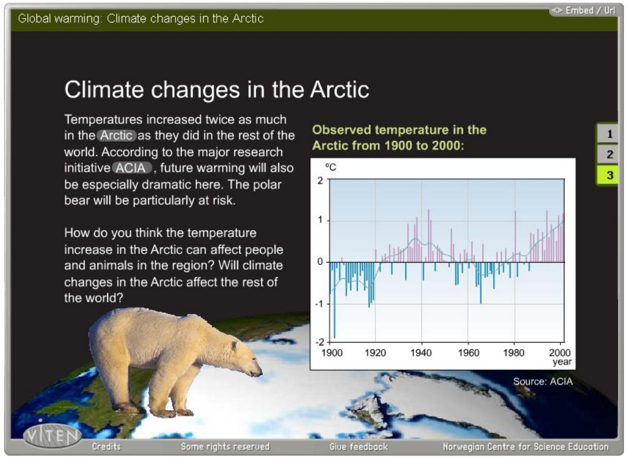
Northern lights
http://northernlights.viten.no

Global warming
http://globalwarming.viten.no

Gene technology
http://genetechnology.viten.no

Naturfag.no
Web site for science teacher resources (teaching programs, experiments, videos, animations)





SINUS

A Teacher Professional Development Model in Science and Mathematics Education

Problem areas of mathematics and science education in Germany

- Complex tasks requiring conceptual understanding
- Scientific thinking and reasoning
- Huge amounts of students with fundamental deficits
- Little gains in competence over the school years

The SINUS programme

Based on the assumption that it is the professional responsibility of teachers to improve the quality of instruction and school: Four principles

- Identification of problem-areas and creation of work packages (“modules“)
- Introduction of quality development at participating schools
- Cooperation between schools/teachers & researchers on learning/instruction
- Providing ideas, material, support, advice

From problem areas to modules

1. Further development of the task culture
2. Scientific work and experiments
3. Learning from mistakes
4. Securing basic knowledge
5. Cumulative learning: Experiencing increase in competencies
6. Integrative features of instruction
7. Promoting girls and boys
8. Developing tasks for cooperative learning
9. Strengthening students' responsibility for their learning
10. Assessment: Measuring & feedback of students' competencies
11. Quality development within and across schools

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Module 1: Further development of the task culture

Away from mono-cultures ('routine tasks') - towards

- ... variety!
- ... tasks that allow for creative application of knowledge in authentic situations and meaningful contexts
- ... tasks that allow for different ways to solve them
- ... a larger variety of teaching methods and strategies whenever

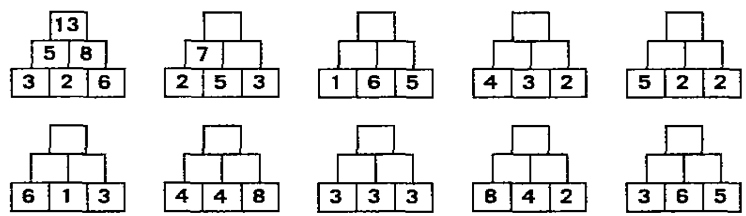
  ... a new concept, principle, phenomenon, etc. is introduced and elaborated,

  ... the new knowledge is practised by applying it to new cases or situations,

  ... content taught already is repeated

Practicing addition of numbers

1.



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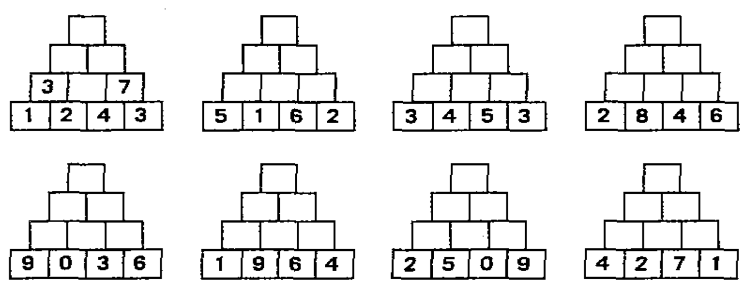

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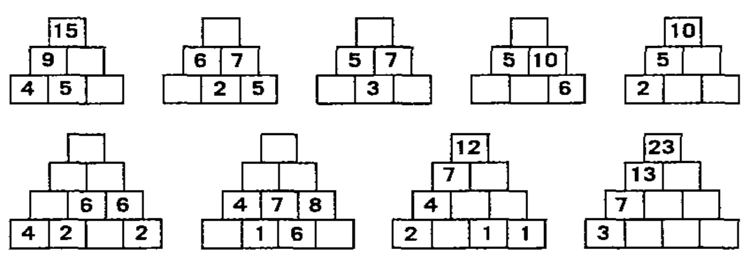
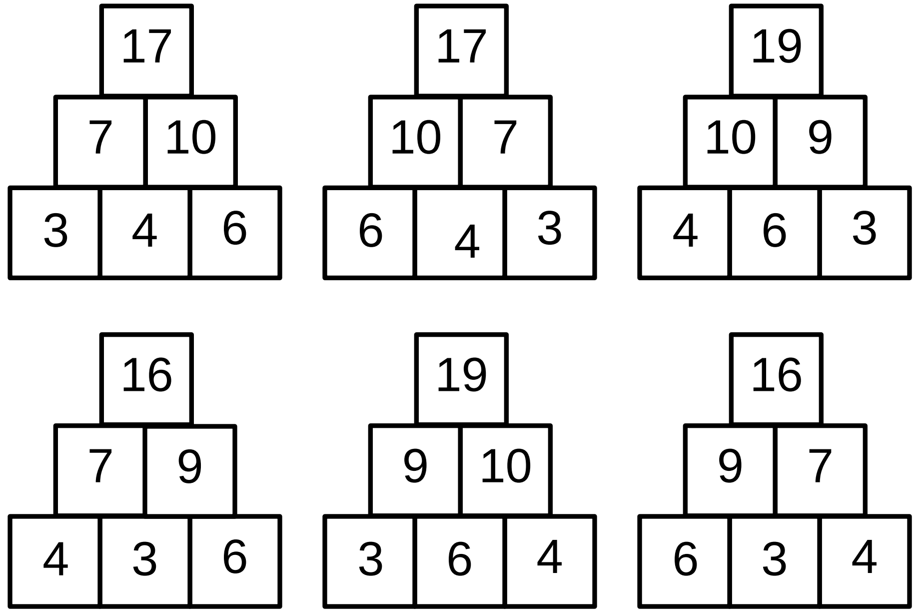


Exploring number pyramids



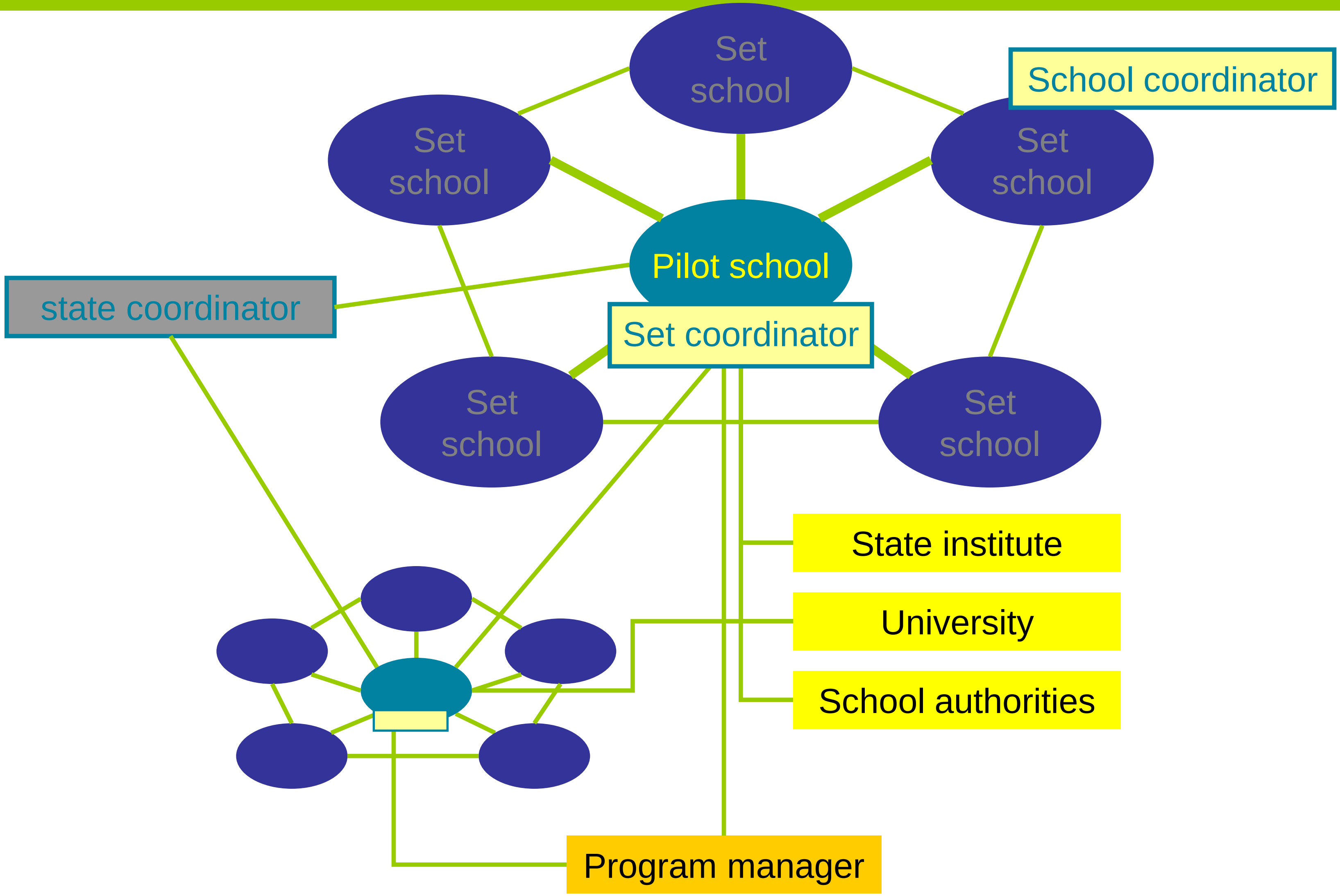
What do you notice looking at the pyramids?

Please talk to your neighbour for two minutes.

Module 2 - Experiments

- Traditional teaching method: Experiments are a tool to reach a particular aim (e.g. a formula)
  - errors have to be avoided, hence "everything" is planned: how to set up the experiment, how to measure (without errors)
  - there is usually no or only very little room for students' active engagement
- Experiments as a challenge for thinking ('Minds On' - not only 'Hands On‘)
  - Supporting students to generate "research" questions and hypotheses by themselves
  - Supporting discourse among students about planning and interpretation of an experiment
  - Supporting students to reflect on their work and their conclusions

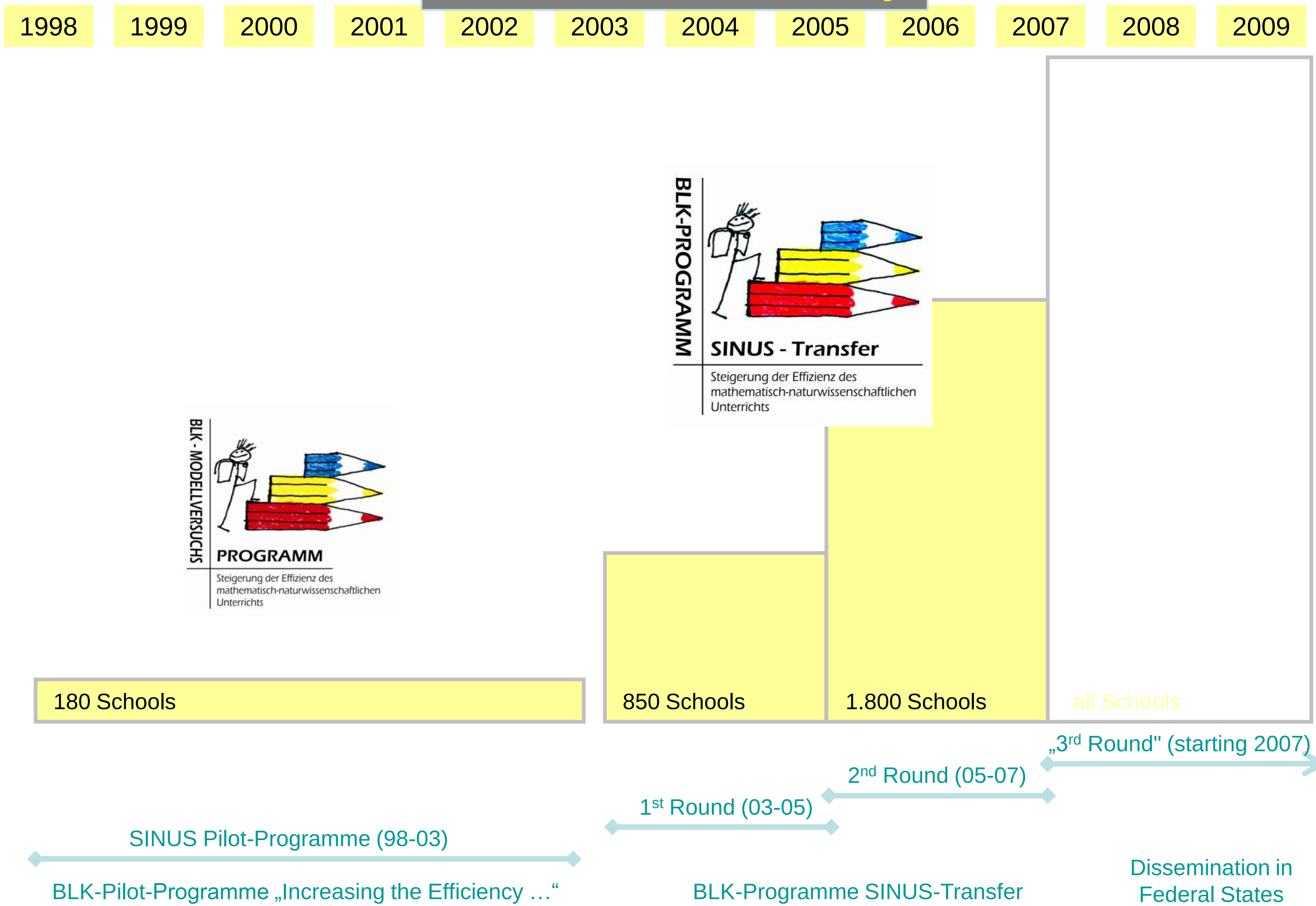
Organisation



Working with schools

- First steps:
  - Selection of modules and setting
  - Collaborative reflection, development, and evaluation of instruction
  - Exchanging ideas, materials and experiences on the level of schools and networks of schools
- Necessary: Support from the principle
- Beneficial: Integration of the work in the school program
- Conferences with training sessions and workshops
- Internet server (information management)

Programme History



Key factors of effective professional development

- School based
- Collaborative
- Long-term
- Linked to the curriculum
- Focused on student learning

Key results

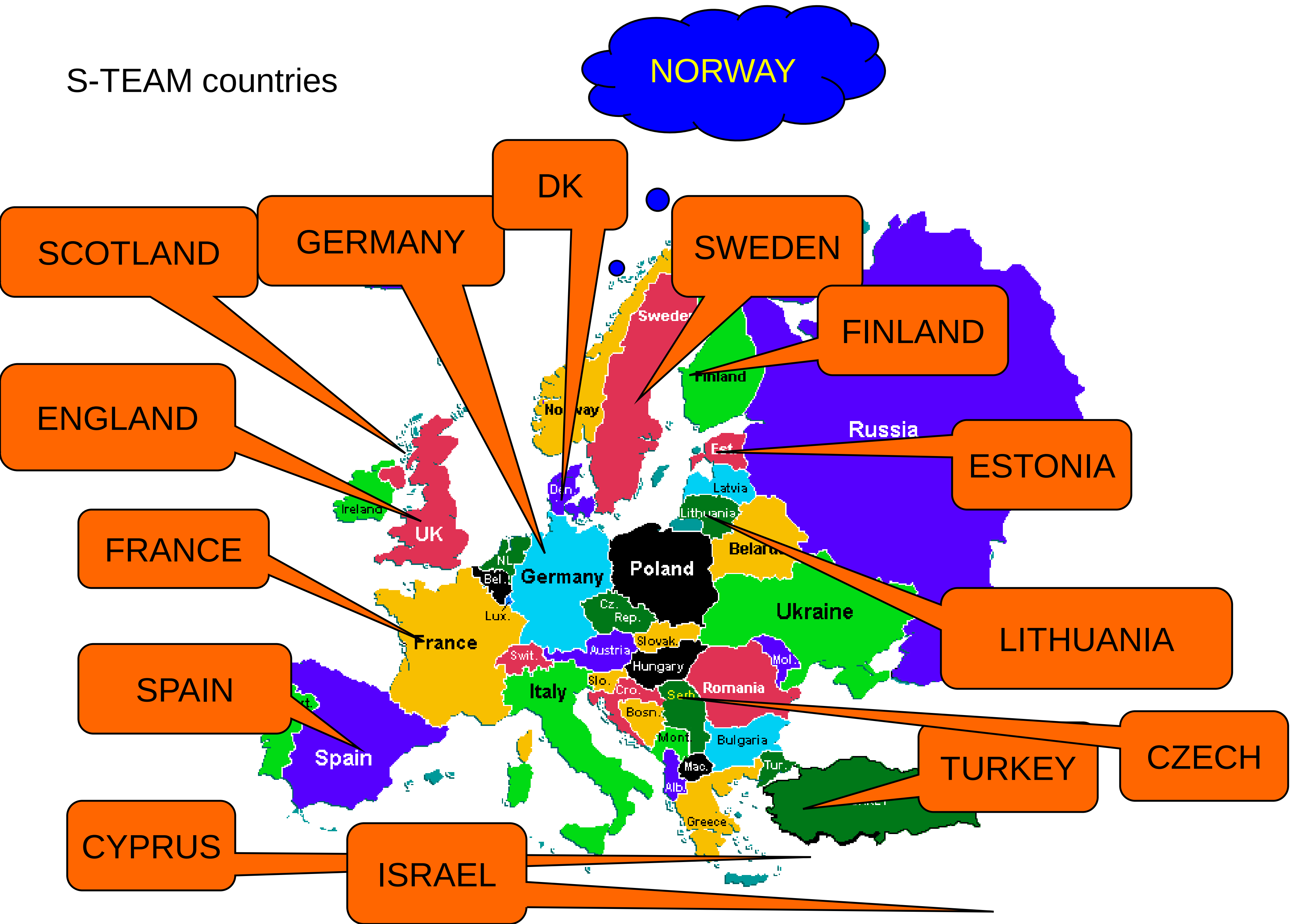
- At teacher level:
  - Program well accepted by teachers
  - Teachers collaborate and perceive progress
- At student level:
  - Evidence for effects of the SINUS-Program on student motivation, self concept, cognitive activation, and performance
  - Strongest effects for schools with low performing students
- In general: coordination plays a crucial role

S-TEAM
Science-Teacher Education Advanced Methods

- 100 people/25 institutions/15 countries
- Involved in science teacher education
- Providing a tool kit for science teacher education, using inquiry based methods

S-TEAM
FIRING UP SCIENCE EDUCATION

S-TEAM countries



S-TEAM Aims

- Improve scientific literacy and..
- Increase popularity of MST careers
- Through....
- Better student engagement
- Through...
- Better teaching

S-TEAM
FIRING UP SCIENCE EDUCATION

The Pedagogy of Science Education in a national context

- Curriculum design
- Assessment frameworks
- Teacher knowledge base
- Teacher education
- Research influence and dissemination
- Resources
- Prevailing social policies and attitudes

S-TEAM
FIRING UP SCIENCE EDUCATION