Implementation of Inquiry Based Science Education (IBSE): is supporting the teachers sufficient to be successful?

Ton Ellermeijer

Foundation CMA
Netherlands

SMEC-Establish Conference,
Dublin, June 7 - 9, 2012

Overview

- Talents and IBSE
- Policy Science Education Europe
- Establish project
- Teacher training and realizing change
- Some models and thoughts
- Two cases of innovation: Physics Informatics and ICT
- Results and lessons

Talents and how we learn

- Below 6 children already discover relations, like between gravity and movement, illness and growth.
- As well philosophers as developmental psychologists cannot explain us precisely the process of learning.
- 30 years of study of cognitive development of young children changed our views.
- Even very young baby’s can structure experiences, and realize humans are something special.

Talents -2

- From 4 years and on children do the same as adults:
  - They can process large amount of information
  - They can perform systematic experiments
  - They make use of what others do

THE SCIENTIST IN THE CRIB

MINDS, BRAINS, AND HOW CHILDREN LEARN

Alison Gopnik, Ph.D.
Andrew N. Meltzoff, Ph.D.
Patricia K. Kuhl, Ph.D.

From ‘The Scientist in the Crib’

- “Adult scientists take advantage of the natural human capacities that let children learn so much so quickly.”
- “It’s not that children are little scientists but that scientists are big children.”
- Top scientists like to claim they are still 8 years!

Consequences

- Science education should offer more chances for children to adapt their intuitive theories on a natural way by extending their experiences f.i. through the use of instruments and logical methods:

IBSE fits to what we know now on how children learn

Policy Science Education Europe

- Knowledge society
- Role of Science Education
- Rocard report : *Science education now : a renewed pedagogy for the future of Europe* (May 2007) – *Pollen* and *Sinus Transfer* as reference projects.
- calls from the EC, along the line opened by the Rocard report

Knowledge Society and Science?

- Need for new/innovative products and services
- Workforce able to apply knowledge in a creative/innovative way.
- Technical Universities: students are not able to cope with open tasks. Not trained in divergent thinking.
- Science and Technology is not attractive: students don’t see relevance and relation with jobs.

There is a need to change or call it enrich the science curriculum, to attract more students for Science and Technology (Lisbon Agenda!)

But…

- Many students start to dislike science already at age 13/14
- Very low enrollment in Universities
- Lack of Science teachers, especially with University degree

ESTABLISH:

European Science and Technology in Action: Building Links with Industry, Schools and Home

SMEC-Establish Conference,
Dublin, June 7 - 9, 2012

European Science and Technology in Action:
Building Links with Industry, Schools and Home

Objective ESTABLISH

- The objective of ESTABLISH is the dissemination and use of an inquiry-based teaching method for science with second level students (age 12-18 years) on a large scale in Europe **by creating authentic learning environments, involving all stakeholders to drive change in the classroom**

- More, see http://www.establish-fp7.eu/

Types of inquiry-based activities

- ***Interactive demonstration****:* The inquiry part here lies in the responses and explanations from the students.
- ***Guided discovery****:* same as in the above, but in this case the students carry out the experiment introduced to them by the teacher.
- ***Guided inquiry****:* in this case, students work in teams on their own experiment. The teacher has identified the problem and has given a clear-cut objective.
- ***Bounded inquiry****:* same as in the above, but in this case students are expected to design and conduct the experiment themselves with little or no guidance of the teacher and only partial pre-lab orientation. The research problem to be solved is given to them by the teacher,
- ***Open inquiry****:* within a given context, students are expected to propose and pursue their own research question(s) and experimental design. This will usually be a semi-final assignment of senior students. Example: “Setting up an experiment for speech analysis or recognition”.

Inquiry skills (after discussion between project members)

i. Diagnosing problems
Students identify the core of the problems/ questions
Understand and use their prior knowledge to be able to form working hypothesis

ii. Critiquing Experiments
In order to critique experiments intentionally and effectively, students need:
Experience
Analytical skills
Reflective Skills
Formulating arguments
State outcomes in a comparative way
Suggest further developments

iii. Distinguishing Alternatives
Identify key elements of the problem
Identify ranking level for key elements
Express alternatives in suitable form
SWOT analysis

iv. Planning Investigations
Moving from a base of inquiry initiated by student/teacher/other.....
Establishing the hypothesis in a realistic way towards a goal
Consider the hypothesis and methods of answering the hypothesis
Planning involves setting time frame, steps involved, resources required and training in use of any equipment
Monitor and review of approach

***v. Researching conjectures* (hypothesis testing)**
Follows from observations/ facts previously gathered and some preliminary theory / hypothesis that is to be tested
Not just observing but considering why!!
Open ended

Teacher training and realizing change

- So we like to make a change ..
- In a relative sort time (say <10 years)
- Most teachers are already in the job

- Are there effective models for in-service training?
- Does it depend on the kind of change?
- Will it be enough?

Models for in-service?

Internationally, teachers report that the amount of professional development available is extremely varied, and that much of it comes in the form of one-off conferences and other short-term forms of support that have not been shown to be effective either in the development of teaching practices or the improvement of schools. Nor are professional development opportunities clearly linked to opportunities to progress in a career and to play a greater role in a school—important factors in developing and retaining teachers.

-The International Summit on the Teaching Profession, 2011

Lynn A. Bryan, GIREP-EPEC, 2011

Models for in-service?

- **Traditional**: short courses delivered by a University or Teacher College, format like during pre-service. May be distance technology applied.

  Content might be just additional or new physics, teaching methods, new technology.
- Most of time very little direct link to classroom.
- **School-based**: all science teachers involved.

- Lack of follow-up, effect most of time small

What is needed? (Lynn A. Bryan)

- High quality PD takes into account that teachers must be given **time** to learn new content and pedagogy, adapt their instruction to reflect what they have learned, and analyze the outcomes of their new/refined knowledge and practice.
- High quality PD fosters **professional communication and colleagueship**, which have been shown to sustain motivation for enacting reform.
- High quality PD is **"information rich"**: multiple sources of information on teaching and learning processes.

Who owns the problem?

- The government, the school, the teacher..
- Who is paying, who is deciding? What are the incentives?

- What is influence of autonomy of teachers/schools on impact of in-service?

- Finland? They have teacher in driving chair!!

Two examples

- The introduction of a new chapter in the Physics curriculum: Physics Informatics
- Implementation of the use of ICT, since 1984

Physics Informatics

- Reflect relation between Physics and Computer Science.
- Module for 15/16 year old students to introduce automatic systems with their building elements.
- first design activities in Physics classroom!
- Also: backgrounds of measurement with computer: sensor, analog to digital conversion, sample rate, etc
- And in module for 17/18 years introduction of numerical modeling for analyzing phenomena/measurements.

Process of Implementation

- Study of most important concepts – 1986
- Accepted by national curriculum committee - 1989
- Nation-wide in-service training, each school at least one physics teacher – 1989/1990 (15 half days over a semester)
- Support by government for new equipment.

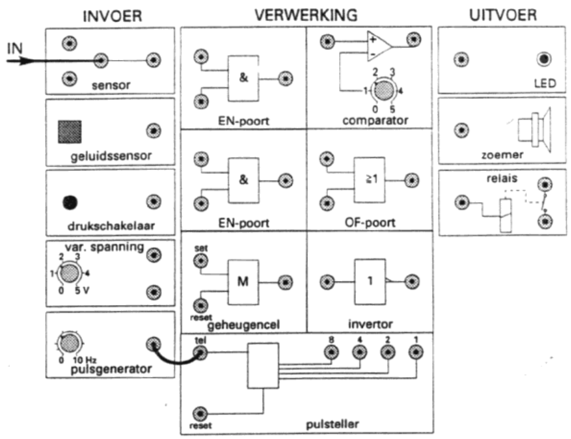
Position in the curriculum

- Reflected in the examination program (since 1991)
- in all textbooks
- reflected in final examinations (since 1994)
- But also: students and even teachers like the topic a lot!
- Many student activities and design projects with the System Board

Question from national exams

Punt Q wordt geaard. De spanning van P gebruiken we als ingangssignaal op een systeembord. Zie figuur 15.

figuur 15



Deze spanning wordt groter naarmate er meer rook in de luchtkamer komt. De zoemer op het systeembord moet geluid gaan geven als de spanning tussen P en Q boven een bepaalde waarde komt. Het geluid mag daarna niet meer ophouden, óók niet als de rook verdwenen is. Figuur 15 staat ook op de bijlage.
De functies van de geheugencel en van de teller worden geactiveerd door een hoog ingangssignaal.

3p **22** ☐ Teken in de figuur op de bijlage de verbindingslijnen zó, dat er een systeem ontstaat dat aan de gestelde eisen voldoet.

Dit systeem blijkt vaak vals alarm te geven. Daarom stellen we als extra eis, dat de zoemer pas geluid gaat geven als er gedurende vier seconden zonder onderbreking rook geconstateerd is.
De pulsgenerator is verbonden met de ingang 'tel' van de pulsteller die de afgegeven pulsen telt. De pulsgenerator staat ingesteld op 2 Hz. Figuur 15 is nogmaals op de bijlage afgedrukt.

4p **23** ☐ Teken in deze nieuwe figuur op de bijlage de verbindingslijnen zó, dat ook aan deze eis voldaan wordt.

- Designing an automatic smoke - detector system
  - First: detect and give a signal
  - Second: give a signal after 4 seconds of non - interrupted smoke

To conclude

- Within 10 years from idea to normal classroom practice!

Slinky

- Introducing nonrigid bodies in Galilean and Newtonian framework
- Counterintuitive
- Different parts fall at different rates, but
- Center of mass falls same as ball!
- Helps students to appreciate beauty and validity of Newton’s Second Law, and
- Is playfullness

Implementation of the use of ICT

- Since 1985 policy to implement the use of computers
- Since appr 1990 in national curricula for physics, chemistry and biology, and in examinations

What did we do? How far are we?

- Agreement on main uses of ICT: to enrich student and teachers with tools to improve their possibilities to do science/work as a scientist:
  - Measurements
  - Analyzing data
  - Modeling
- Training of teacher trainers (40), delivering of courses nationwide (1987 – 1991)
- At least 2 teachers/school

In parallel: development of an integrated, open tool

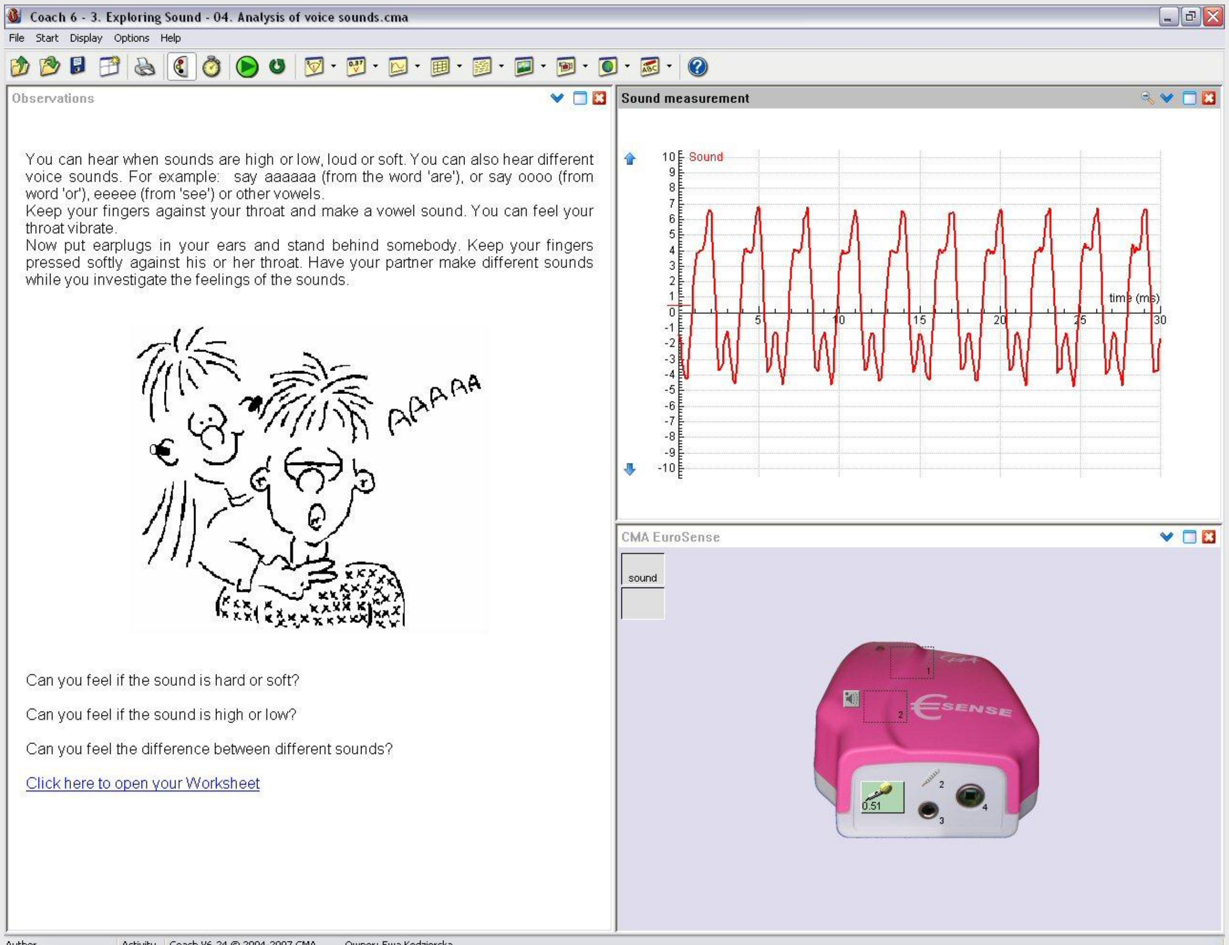
“Open” learning environment that offers the tools integrated, which can be used to solve many different problems.

Authoring facilities to adapt to the level of the student

Important Aspects...

- Give opportunities to work like a professional scientist with possibilities to:
  - collect high-quality, real-time data,
  - to construct and use computer models,
  - to compare results from experiments, models and theory.
- Should be universal for using with many different curricula.

Measurement with sensors

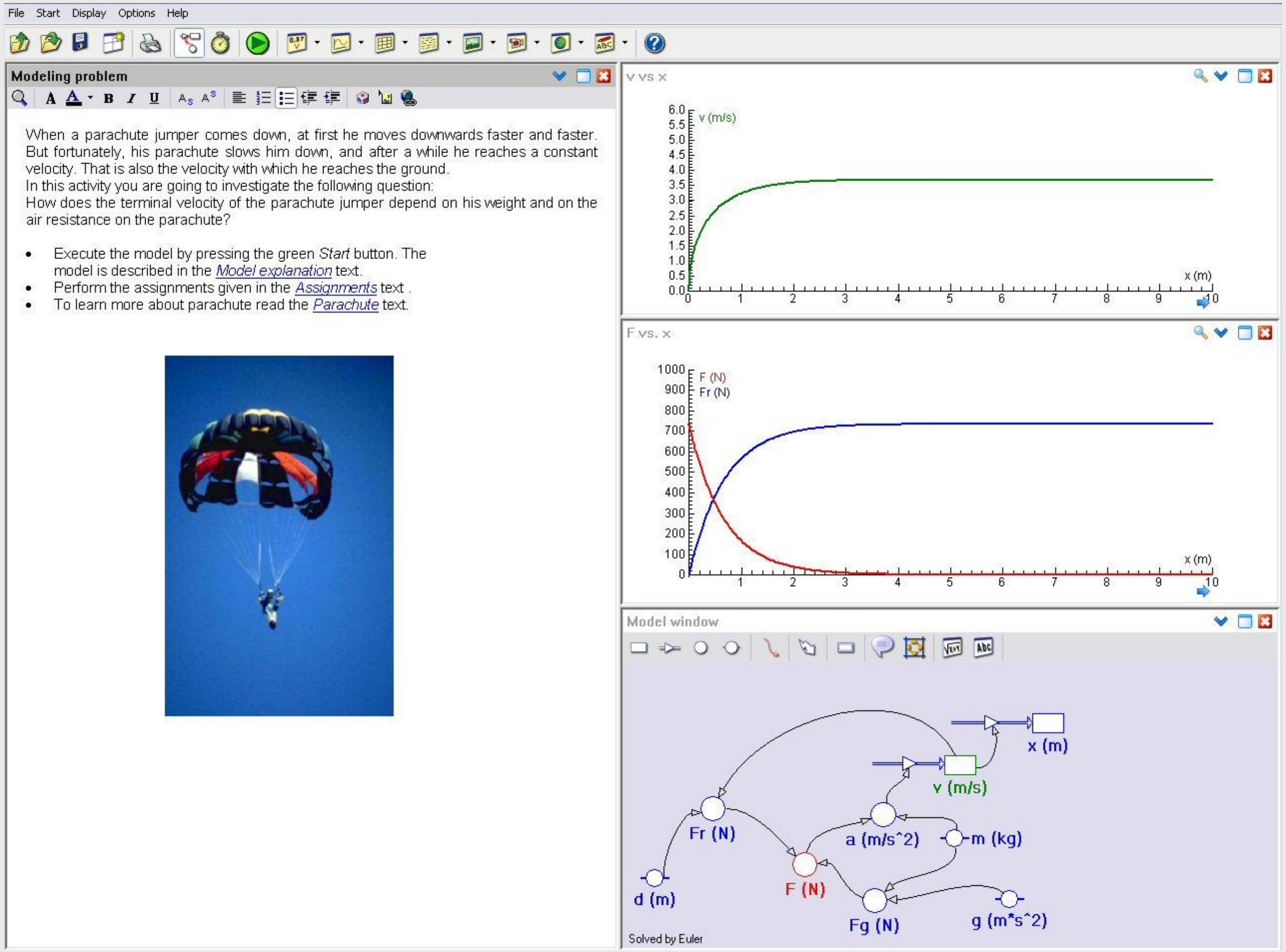


Examples

- Video-analysis: high jumper, beer
- Picture-analysis: Golden Gate
- Modeling: Parachute Jumper

- Project involving measurement and modeling: Bouncing balls

Modeling (System Dynamics)

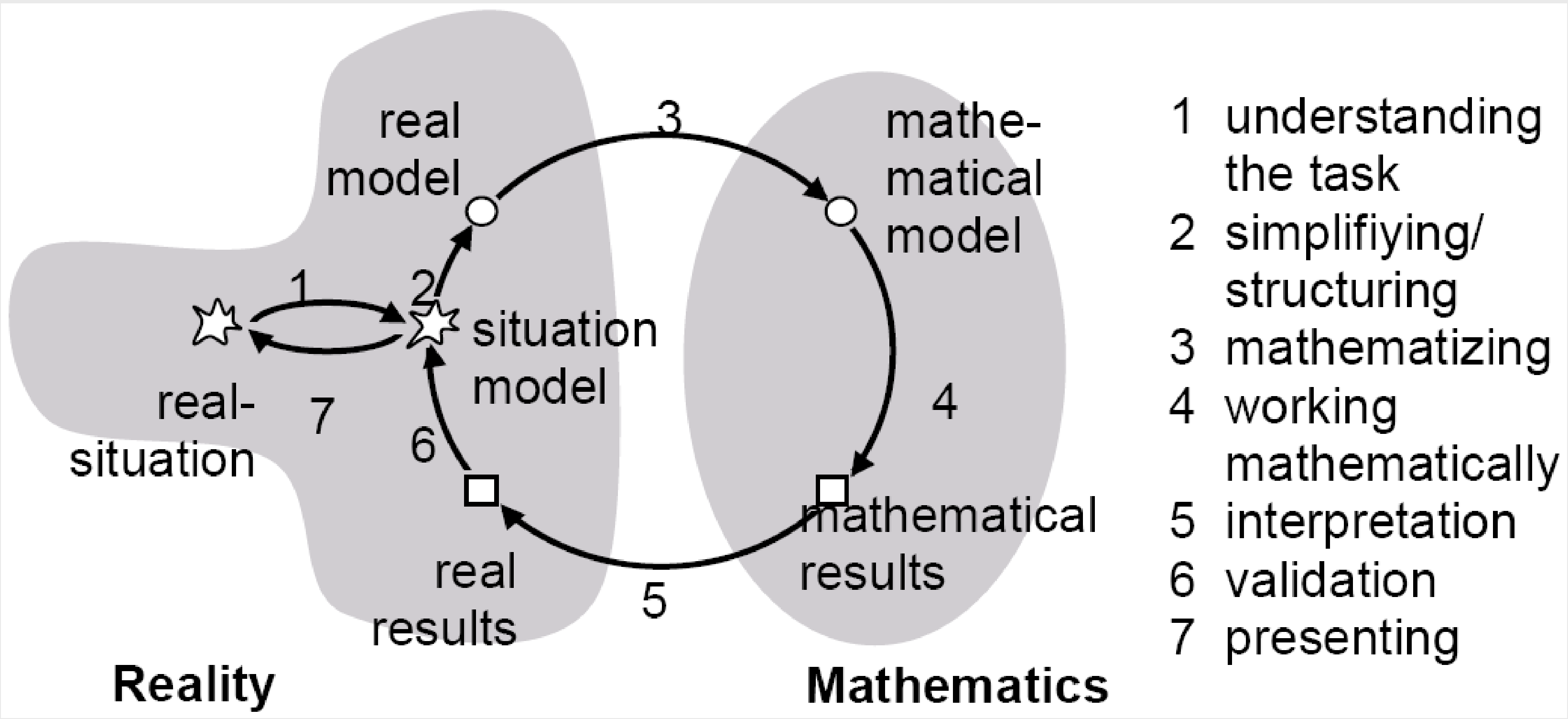


Bouncing balls – upper level

Goals of activities:

- engage students investigations that include modelling and measurements on high-speed video
- emphasize modeling cycle and develop a critical attitude by working with several models for one and the same phenomenon

Modelling cycle (Blum&Leiß (2005)



Going several times through a modelling cycle

Bouncing Balls

- Experiment - Video measurement (manual)
- Simple model of bouncing rubber jazz ball
- Video measurement table tennis ball (point-tracking)
- Model without air resistance
- Model without air resistance using flight times
- Model with air resistance
- Model with air resistance and with non-constant coefficient of restitution
- Animation

Power of predictions

- We (Heck and Ellermeijer) used measurements (video) and models of runners to predict possible time for 100 m of Usain Bolt, based on his Olympic run in Beijing.
- We predicted 9.55 and 9.61 s could have been realized (article submitted Nov 2008).
- Bolt did 9.58 summer 2009
- See issue of American Journal of Physics, Nov 2009

Models of sprinting

1. **Models based on Newton's 2nd law of motion:**

$a(t) = F_{propulsion}(t) - F_{resistance}(t)$

<u>Keller model</u>: $v' = F - v/t$, $v(0) = 0$ (pupil's data)

Exact solution: $v(t) = F\,t\,(1 - e^{-t/t})$

2. Models based on an energy balance

Power balance: $P_0 = P_f + \mathrm{d}E/\mathrm{d}t + \mathrm{d}H/\mathrm{d}t$ with

P_0 power needed for motion

P_f power loss due to resistance

$\mathrm{d}E/\mathrm{d}t$ change of external mechanical energy

$\mathrm{d}H/\mathrm{d}t$ power loss due to heat production

$P_0 = P_{aer} + P_{an}$, aerobic + anaerobic power

Ward-Smith model (100m sprint, Carl Lewis)

$$\mathrm{d}H/\mathrm{d}t = \alpha\, v(t)$$

$$\mathrm{d}E/\mathrm{d}t = \mathrm{d}(\tfrac{1}{2}mv^2)/\mathrm{d}t = m\, v\, \mathrm{d}v/\mathrm{d}t$$

$$P_\mathrm{f}(t) = \mathrm{F}_\mathrm{drag} \times v = \tfrac{1}{2}\, C_\mathrm{d}\, A\, v\, (v - w)^2$$

$$P_\mathrm{an}(t) = P_\mathrm{max} \exp(-\lambda\, t)$$

$$P_\mathrm{aer}(t) = R\,(1 - \exp(-\lambda\, t))$$

Some research findings -1

NSF funded project : Technology Enhanced Elementary and Middle School Science (TEEMSSII)

"Educational technologies — computers, probeware, and networking — can significantly enhance science learning at elementary grades. ICT is particularly valuable at helping students to: understand cause-and-effect relationships, visualize change, gain insights into the ways systems act, relate math, science, and technology, and support explorations of emergent behaviour" (Concord Consortium 2003).

Some research findings -2

- “Various learning technologies [ICT] … allow students to engage in aspects of inquiry that they would not otherwise be able to do. Learning technologies allow students to explore their ‘What if..?’ questions. They allow students to use similar tools and engage in similar activities of scientists. Because less time is needed for gathering and recording data, more time is available for interpreting and evaluating data” (Novak & Krajcik 2004).

Some research findings -3

- “This research indicates that MBL activities have pedagogical promise for learning science concepts and graphing skills… Real-time graphing of data appears to be a key feature for both cognition and motivation” (Brasell 1987)

Conclusions

- Students can work directly with high-quality, real-time data in much the same way professionals do
- Math & Science learning resembles practice - be in contact with current research work
- Investigations are characterized as being challenging, complex & open-ended, cross-disciplinary, and requiring strong commitment and broad range of skills.

Why full use of possibilities is so limited?

- Level of implementation is rather good (in Netherlands and few other countries), but still (lots of) room for improvement
- Teachers?
- (National) curricula?
- Textbooks?
- (National) examinations?

- Needed is systemic change / concerted-simultaneous actions!

To conclude

- We have experienced a great conference
- Thanks to the CasteL team
- Thanks to active participating teachers
- And, next time we will analyze Irish Dancing

Thank you!

Ton Ellermeijer
contact:
ton@cma-science.nl

www.cma-science.nl