Design-based research as a framework for promoting adoptions of inquiry-oriented science teaching

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Science is Primary Conference
(Dutch Presidency, 15-16 Oct 2004)

"*Inquiry-based science* is a way to acknowledge that children come to school with considerable common-sense knowledge, theories and ideas. It is a way of maintaining children's enthusiasm, curiosity and eagerness to learn while *we deepen their understanding and skills*."

An acknowledged need to fund projects that support teachers in adopting inquiry-oriented approaches in MST education

Rocard Report, FP7: Science in Society, 2007, DG Research: "A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods *provides the means to increase the interest in science.*"

cf. NRC 2006 and Minner, Levy and Century, JRST 47(4), pp. 474-496.

Rocard Report (pp. 6)
What is meant by science?
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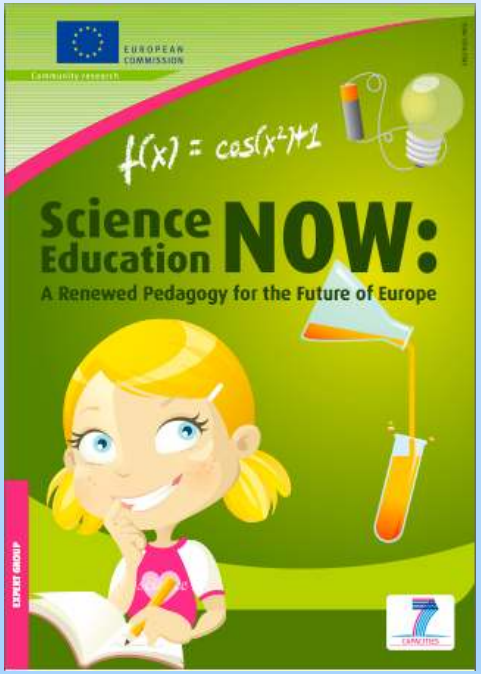

2012 Public Consultation on the future of the Science in Society programme

Open survey,

Expert workshop and Focus group on Young People and Science

To attain sustainable educational change…

- Credible, Reliable Knowledge (science education research)
- Educational Innovations
- Informed Policy Objectives
- Pilot Policy Measures + Monitoring + Evaluation (i.e. scale-up)
- Systemic Reform Initiatives
  - Incentive structures
  - Professional development
  - Curricular realignment
  - Assessment reform

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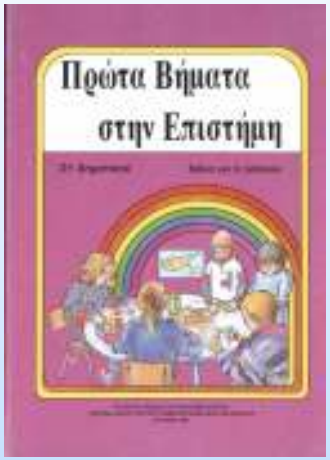
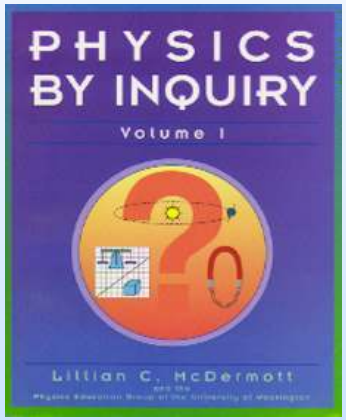
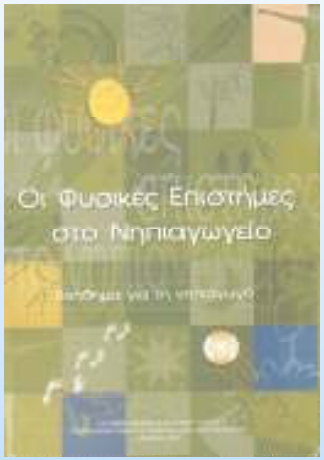
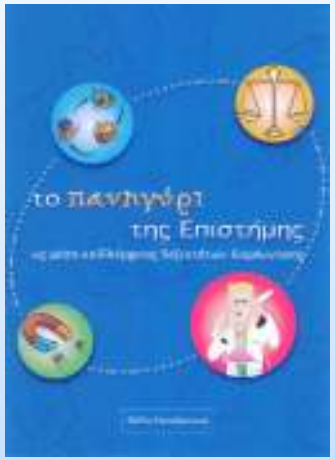
Learning in Science Group, UCY

Network of researcher - teacher collaborators
Research-based curriculum materials...

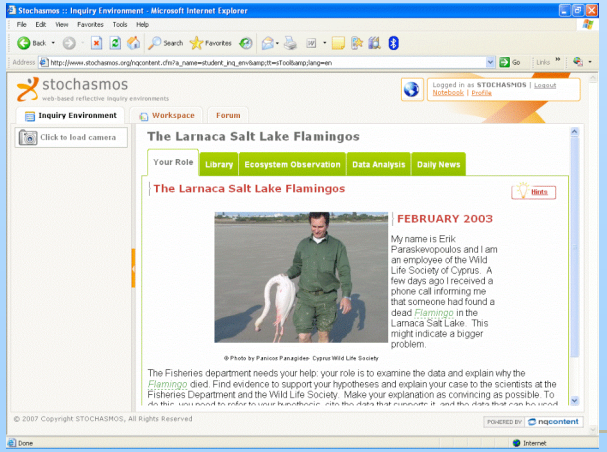








www.stochasmos.org



A problem in science education

The tendency to discredit theoretical ideas through a process of recycled as well as pervasive, non-rigorous use

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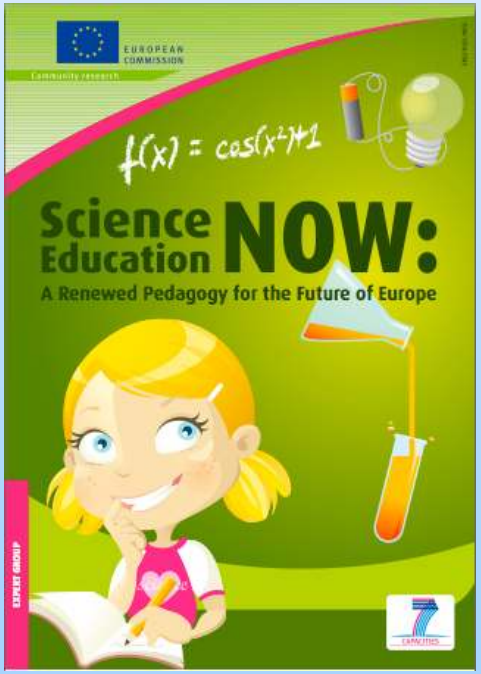

S-TEAM

S-TEAM: FIRING UP SCIENCE EDUCATION

http://www.s-teamproject.eu/

CHANGING THE WAY SCIENCE IS TAUGHT

S-TEAM has been created to change the way science is taught in schools across Europe and beyond. Its task is to make it easier for teachers to use inquiry-based or 'investigative' methods when teaching science. These methods should increase student motivation and engagement with science. In turn, this means more scientifically-literate citizens, and more students taking up careers in science, technology, engineering and mathematics.S-TEAM does not claim to offer an instant cure for the problems of student engagement with science.

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WHAT IS INQUIRY BASED SCIENCE TEACHING?

A project involving countries from all over Europe faces the challenge of developing a common terminology and a common understanding of its basic ideas. Although the roots of IBST (inquiry-based science teaching) as the main approach to improving science teaching and learning in S-TEAM lead back to the early 20th century (Minner. Levy & Century, 2009), the seminars showed that no common definition currently exists at a European level. In many of the participating countries appropriate translations of the term in the national language were not found.

An example of widespread confusion:

Inquiry Vs Investigation

Small comment:

An idea that means everything to anyone, pretty soon will mean nothing to everyone...

A History of Science Education Research (George de Boer, 1990)

There is a long history of recycling the same ideas in science education.

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- Pilot Policy Measures + Monitoring + Evaluation (i.e. scale-up)
- Systemic Reform Initiatives
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  - Professional development
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Theoretical credibility undermined…

Cognitive constructivism Vs the Nuffield primary science program

Social Constructivism (Irzik, 2000, 2001)

Conceptual change Vs situated learning
(Nersessian,1991; Posner, 1992; Vosniadou, 2009; Chi, 1994; Dunbar, 1997 Vs Anderson, 1996; Billett, 1996; Cobb, 1999)

Problem Based Learning
(Kirschner, Sweller and Clark, 2006)

Classroom / educational implementation of teaching/learning theory is non-trivial

.. and it cannot be attained without a credible knowledge base

Some effects of discrediting theoretical ideas in science education

The need to bridge the gap between teaching and learning (McDermott, 1994; Devereaux et al., 2009)

The gap between theory and practice in education (Jeronen & Pikkarainen, 1999)

Lethal mutations of educational innovations (Collins, 2004; Pinto, 2005)

The problem reformulated…

Discrediting theory is a symptom of the failure to find rigorous (educational) implementations of coherent (teaching and learning) theory

- The problem emerges in the context of elaborating products and procedures for educational enactment
- It has implications on the utility and impact of educational research findings and more established understandings
- It undermines our ability to design valid assessment frameworks, to document failure or breakthroughs, to demonstrate cumulative progress

What cannot be done about the problem of combining rigour and coherence?

- **Design and development** (Duit, 2000) which involves evaluation, assessment but not research; it is often problem/needs centered rather than theoretically informed)
- **Design research** (A. Collins, 1992, 2004) which does not involve in-situ research
- **Design experimentation** (A.L. Brown, 1992; Brown & Campione, 1998) which is a specific form of controlled experimentation that still retains many latent variables
- **Evidence-based design** (NRC 2002) which does not involve explicit theoretical conjectures nor validation

Intermediate Theoretical Frameworks

Ruthven, Laborde, Leach & Tiberghien,
***Educational Researcher*, 38 (5) pp. 329-342**

- **Grand Theories**
  - e.g. communities of learning, socially mediated knowledge construction
- **Intermediate Theoretical Frameworks**
  - e.g. Theory of didactical situations
- **Design Tools**
  - e.g. didactical variables, learning demand, the communicative approach,

Explicit intent to safeguard rigour in the generative element (i.e. in design) and coherence in the expressed theoretical assumptions

Another example of an intermediate theoretical framework

- Pragmatic Theories for informing teaching designs with motivational theory (Andersen & Krogh, 2011)
- Four grand theories of extrinsic and intrinsic motivation
    - Self determination theory (Deci & Ryan)
    - Goal orientation theory (Pintrich, Boekaerts)
    - Self efficacy (Bandura)
    - Interest (personal, situational) (Krapp & Prenzel)
- CARTAGO framework of motivational constructs with classroom-ecological relevance
    - Competence / self-efficacy
    - Autonomy
    - Relatedness / belonging / meaningful interaction
    - Task value, intrinsic interest in task, attainment value, utility value/relevance, time / effort / load cost
    - Attributions and feedback
    - Goal orientation (mastery / performance)
- CARTAGO 9-dimensional grid with constraints and principles for design

CARTAGO framework for motivational planning and analysis of teaching designs (Andersen & Krogh, 2011)

	Dimension	
Cognitive/theoretical	***Competence Emphasis*** ⟷	**Procedural/Skills oriented**
Weak teacher scaffolding	***Scaffolding*** ⟷	**Strong process scaffolding** (modeling, feedback…)
Students decide all (problems, procedures, interpretation, organization, ..)	***Degrees of freedom/student ownership*** ⟷	**Teacher decide all** (problems, procedures, interpretation, organization, ..)
Individualized organization	***Social Organization*** ⟷	**Social organization** (e.g. Planned Interdependence and sharing…)
Student personal (life-world) authenticity	***Task authenticity*** ⟷	**Science authenticity**
Standard/Routine	***Task demand*** ⟷	**Novel/Challenge**
play, excitement, activeness & dynamics, novelty, "coolness" cf. e.g. (Swarat, 2008; Perry, 1992; Mitchell, 1993).	***Situational Catch*** ⟷	**Lack of left side elements**
Within personal control (e.g. effort, use of strategies/tools..)	***Attributional signals*** (task, report, feedback) ⟷	**Beyond personal control (takes ability, coincidence influenced…)**
Improving - is important (incremental, ipsative goals)	***Goal structure*** (task, report, feedback) ⟷	**Outperforming -** is important (norm referenced goals)

Scientific Inquiry

(as an intermediate *teaching and learning framework* that mediates between theory and practice)

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work.

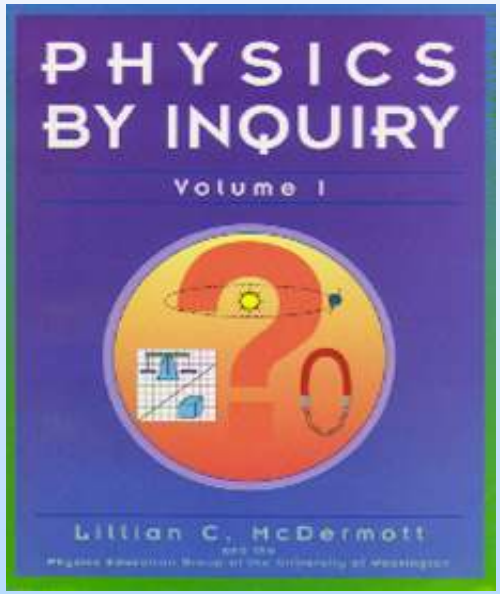
Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

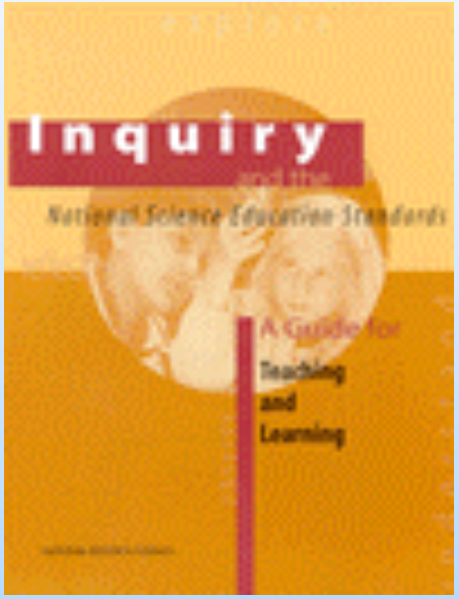
(NRC, 2000)

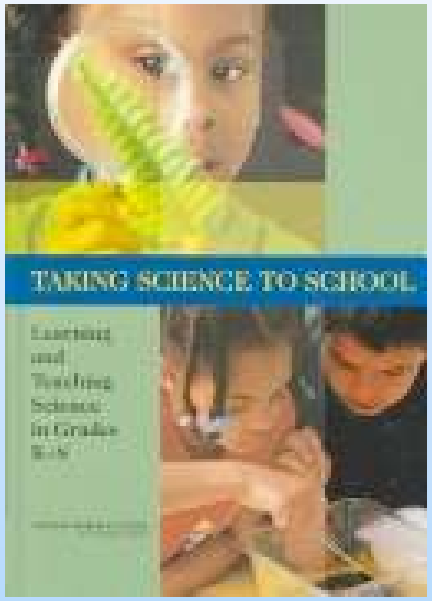
Progression of paradigms in science teaching and learning

- Knowledge Transmission - Content delivery model
- Discovery Learning (Activity based science)
- Knowledge Construction (Minds on) with social interaction
- Inquiry oriented teaching and learning (Authenticity)

For reliable information on the intermediate theoretical framework:







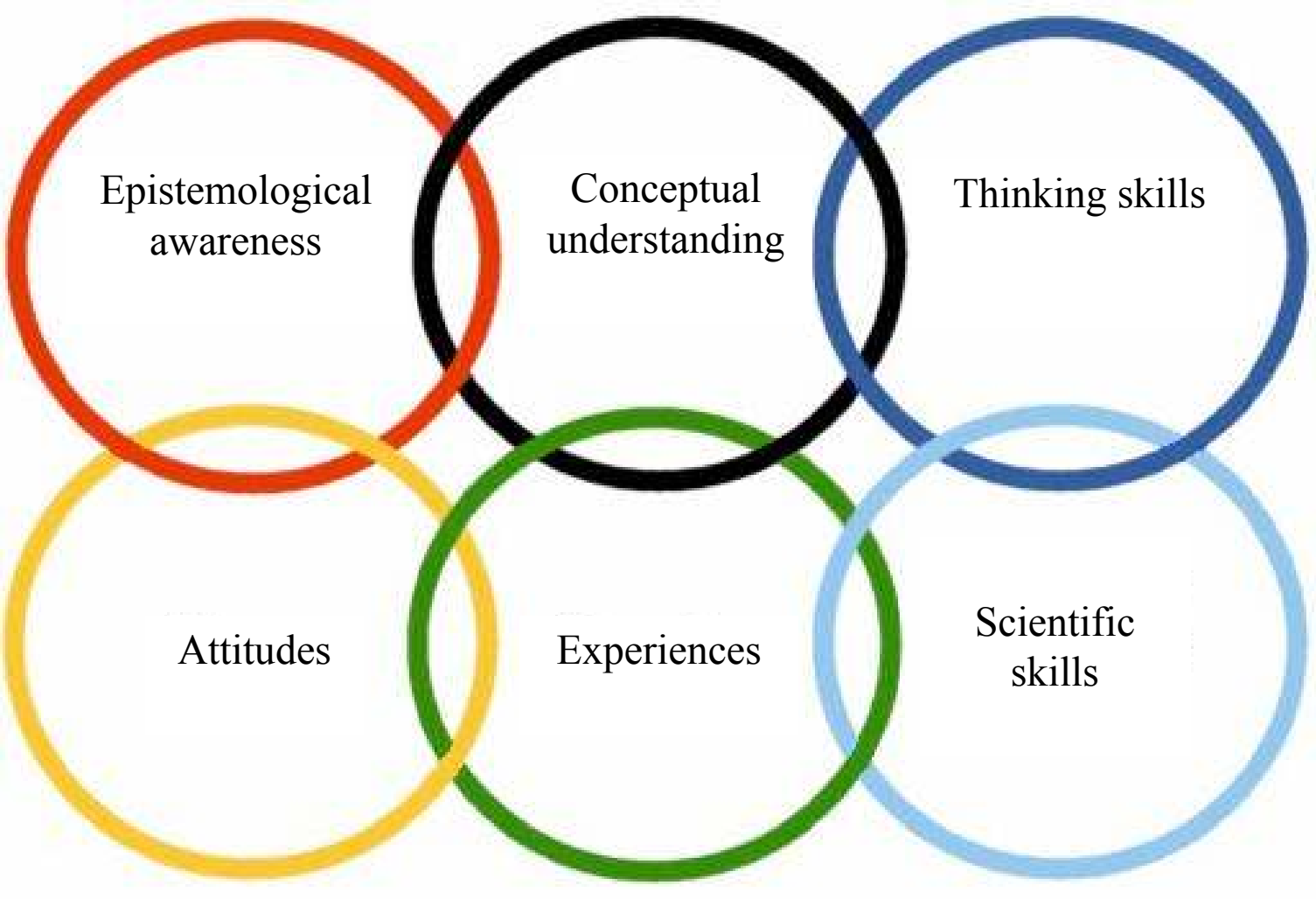
- L. C. McDermott, Physics by Inquiry, Wiley, 1992
- Inquiry and the National Science Education Standards, NAP, 2000
- Duschl et al., Taking Science to School, NRC, 2007

Inquiry-based learning

A framework for science teaching and learning

- Learning
  - active engagement of students in the learning process
  - epistemologically *authentic* procedures
  - social interaction and collaboration
  - holistic learning **objectives**
- Learning environments
  - designed to promote construction of meaning and gradual development of skills and awareness
  - assessment has a formative role in providing feedback to the teaching and learning process

Integrated Learning Goals



Inquiry-based learning

A framework for science teaching and learning

- Teaching
  - the teacher adopts the role of facilitator and aims to provide an example of an inquiring person
  - the teacher does not function as the bearer of expert knowledge but rather facilitates the establishment of a community of inquiry based on honesty, trust (Ann Brown) and multiple roles (differentiation)
  - motivation: there are structured procedures for the emotional engagement of students in the learning process
- Teaching and Learning Materials
  - taught curriculum that frames the learning process
  - designed and validated through a process of research

Inquiry-based learning: degrees of freedom

- Degree of structure
  Open inquiry - guided inquiry
- Degree of emphasis on reflection and interpretation of reflective strategies
  Planning, monitoring and evaluation
  Metacognitive strategies: abstraction, generalization
- Degree of ICT involvement
  Simulations, modeling tools, sensors, data analysis tools
  Communication tools
- Investigation spaces

Teaching/Learning Materials for Inquiry-Oriented Learning

- Teaching/Learning materials are a teaching resource that can be used effectively only after systematic preparation of teachers.
- Teaching evolves through a sequence of activities, without extensive lecture or «theory exposition»; negotiation of meaning and active participation in community are valued features encouraged by the teacher
- Learning is achieved at least partly through investigation
- Active student engagement in the learning process, collaborative interaction, continuous re-negotiation of ideas on the base of evidence, observation and theoretical understandings are critical attributes of inquiry-oriented teaching and learning.
- Teaching is restricted to guidance and facilitation of learning. It takes the form of questioning and semi-socratic dialogue more commonly than of explaining.
- Reasoning and argumentation are more commonly inductive and less frequently (and usually only at the latter stages) deductive.

Teaching/Learning sequences are developed, evaluated and refined through iterative processes of research in authentic classroom environments.

Inquiry Based Science Education

What are the defining features?

Criteria for a scientific discipline

Criteria that emerge from work by Hirst, Popper, Kuhn, Medawar in relation to the nature of science

- **Involves unique concepts** which are defined operationally
- Hypothetico-deductive structure that links theory with phenomena and evidence
- Established paradigm with widely acceptable knowledge
- Conclusions and theories that are subject to falsification
- **Characteristic methodology**
- Formulates interpretations and predictions

Inquiry Based Science Education

What are the defining features?

IBSE is a teaching and learning framework. As such, it builds in socio-constructivits perspectives on learning by introducing the dimensions of

a. **authenticity** in teaching-learning activities as a frame for bridging the gap between science doing and science learning

b. **epistemic anchoring** as a frame for enhancing student awareness of the nature of science and technology and their distinct roles in society

c. **emergent autonomy** as a frame for moulding initial motivational bases into self-directed goal orientation and sustained self-regulation strategies

Inquiry Based Science Education

What are the defining features?

IBSE is a teaching and learning framework

*… that also seeks to provide a **process** frame for enacting designed and validated teaching-learning sequences as a mechanism for reforming teaching practices in MST education with emphasis on **collaborative learning processes** and **meaningful outcomes such as key competencies and coherent conceptual frameworks**.*

Design Based Research provides a methodological frame for <u>how</u> to achieve this

SER perspectives on the design of teaching interventions

- Developmental Research (Lijnse)
- Educational Reconstruction (Kattman & Duit)
- Teaching-Learning Sequences (Meheut & Psillos)
- Activity Sequences (McDermott)
- Learning/Knowledge Hypotheses in promoting classroom knowledge (Tiberghien)

Some open issues

- What is the difference between *research-informed*, *research-based* and *research-validated* teaching/learning programs?
- When and how can we use various evaluation methods in order to safeguard validity?
    - Pre-post test approaches
    - Artifact analysis
    - Classroom discourse analysis
    - Video studies
- The tension between the complexity of characterizing / monitoring learning in progress, demonstrating sufficient learning gains and achieving credibility

What is Design Based Research (DBR)?

- An umbrella of methodologies that encompass theoretically framed, empirical research of learning and teaching based on particular designs for instruction aiming to achieve the status of sustainable innovation.
- Serves the dual goal of developing effective learning environments and using such environments as natural laboratories for studying learning and teaching.
- Facilitates the binary interaction of research and innovation and the study of theoretical claims in situ.

What is DBR?

- DBR as engineering (Brown, 1992; Collins, 1992; Brown & Campione, 1998)
  - iteration
  - emergent phenomena
  - variation in developmental trajectories of intellectual growth
  - customization of teaching
  - outcome, climate and system variables (Collins, 1999)
- Generalized design knowledge
  - design principles (Linn)
  - case studies (Vanderbilt)
  - scaffolding tools and approaches (ThinkerTools project)

Some critical attributes of DBR

It provides a methodical framework for modifying the intervention as it unfolds (in order to respond to the dynamic, contingent nature of decision making during teaching, and thus make the intervention “work” in a complex setting) without placing at risk the need for empirical control that leads to theoretical connections and provides answers to the question “what makes a specific intervention successful in a specific setting?”

Some critical attributes of DBR

The extent to which interventions can be refined to meet the theoretical expectations reveals valuable insight on the validity of theoretical claims. Hence, DBR can inform theoretical understandings of teaching and learning without having to exclude or ignore the complexity of learning environments (a common problem with controlled experiments).

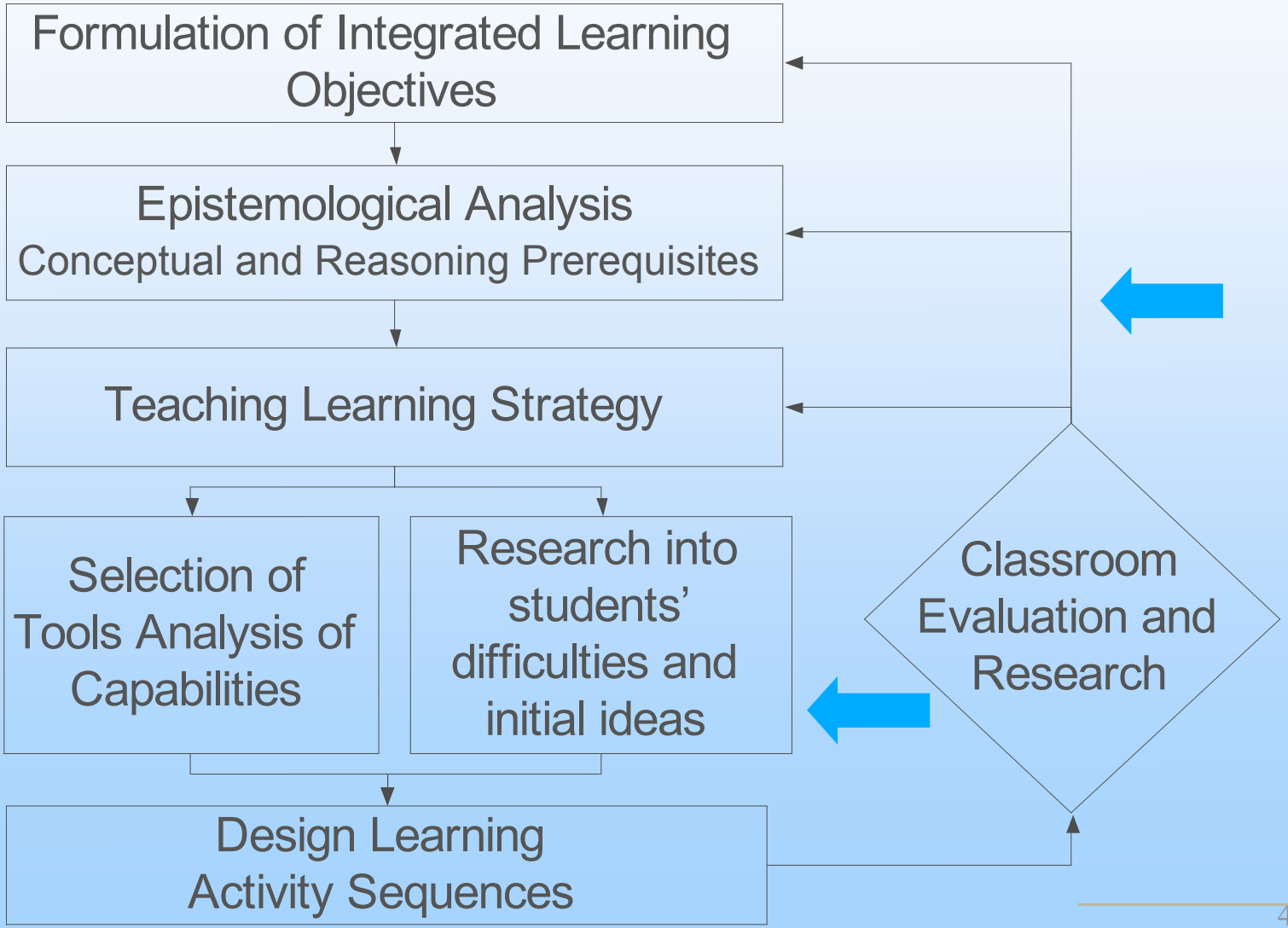
Some advantages of DBR

- It contains explicit mappings of theoretical conjectures and assumptions; as a result the constraints of ecological validity are made transparent (generalizability)
- It provides rich descriptions of “the context” in a way that intangible aspects of teaching interventions become problematized and thus accessible (eg how to organize a classroom discussion, how to lead a group dialogue…)
- It bridges laboratory studies of learning/teaching with studies of complex instructional interventions
- It allows for the isolation of variables at one level without ignoring the complexities introduced by the remaining levels of a complex system such as schooling (eg individual, group interactions, classroom environments, school settings, learning communities, systemic constraints, social priorities and specifications…)

(Kelly: special issue of Educational Researcher, 32(1) 2003;
Sandoval & Bell: special issue of Educational Psychologist, 39(4) 2004;
Barab & Squire, JLS 13(1) 2004; Dede, JLS 13(1) 2004)

A Methodology for designing teaching and learning materials

(Papadouris & Constantinou, J. Curric. Studies, 2009)



An illustration of two aspects of DBR

- **Emergent activity structures**
  (Sandoval, 2004; Krajcik, 2007)
  From one iteration to the next, the activity structure is modified to reflect renewed understandings of the complexity of the learning challenges

- Methodological alignment

University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties (2006-2009)
http://lsg.ucy.ac.cy/materialsscience/

MATERIALS SCIENCE

Materials Science:

Module Topics

- Modern Materials and their Applications
- Materials for Acoustic Insulation
- Optical Properties of Materials
- Thermal Properties of Materials
- Material Density and its Implications for Sinking and Floating
- **Electromagnetic Properties of Materials**

Design Rationale

- Aimed to explore combining two approaches
  - –Inquiry based learning
  - –Learning by design
- Inquiry is a teaching and learning framework that seeks to enhance the authenticity of school science
- Design facilitates active learning and engages students in the basic human approach to meeting life's challenges (Haury, 2002)
- *Design* as a process of technological evolution.
- Inquiry as the process of science
  - –The combination is a rich context for exploring epistemological issues about connections and differences between science and technology, as well as their core processes (Constantinou et al. IJSE, 2010, 32(2) pp. 143-172)

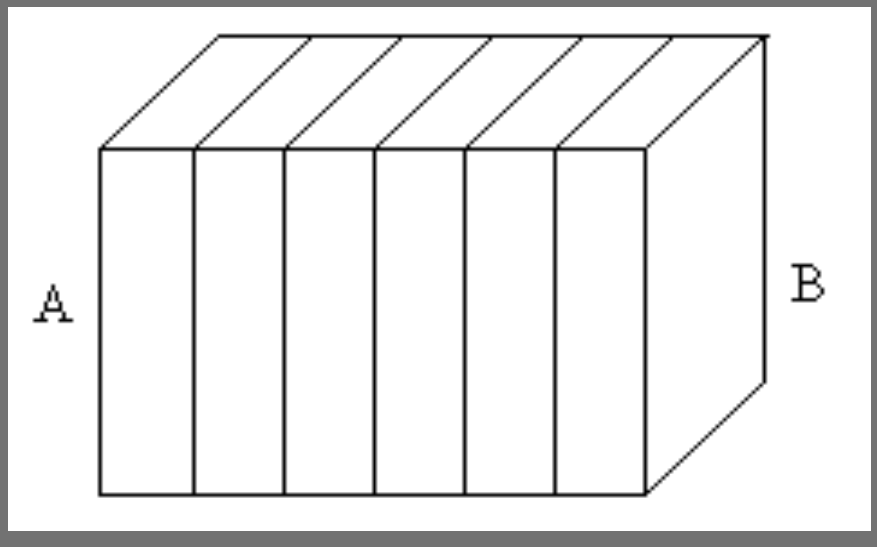
Design Brief: Transport problem, Magnetic Trains

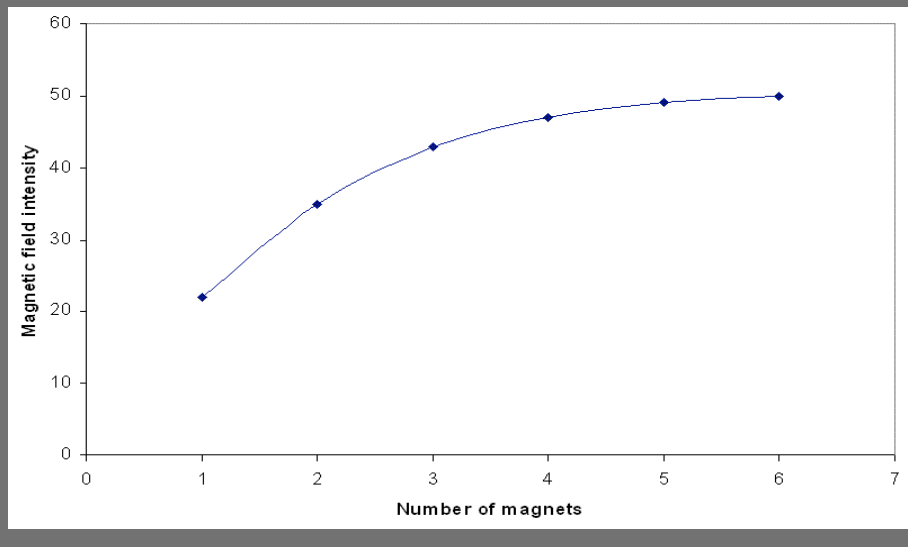
Phenomena	Conceptual Models
No interaction/ Attraction/Repulsion	Magnetic Interactions
Repulsion/Attraction forces at a distance (compass as a measurement instrument)	Magnetic Field
Magnetization/Demagnetization Electromagnetism	Magnetic domains model

Technological Design Activity:
Construct & Evaluate a magnetic train (propulsion, levitation, shielding)

Example of an Extended Inquiry Activity

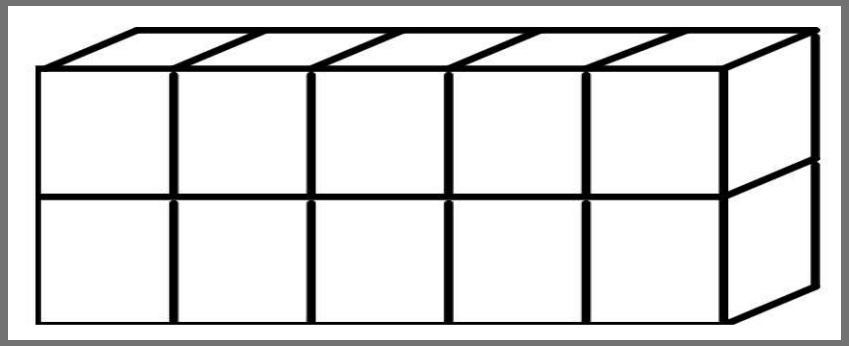
- Obtain a small set of magnets assembled into a magnetic stack. Explore its behaviour. Identify similarities and differences between the stack and a single magnet.
- To examine what happens when a magnet is broken into small pieces, can we use the magnet stack rather than break a magnet?
- Remove one small magnet at a time from the stack and each time use the sensor to measure the intensity of the magnetic field. Plot a graph to represent your measurements.

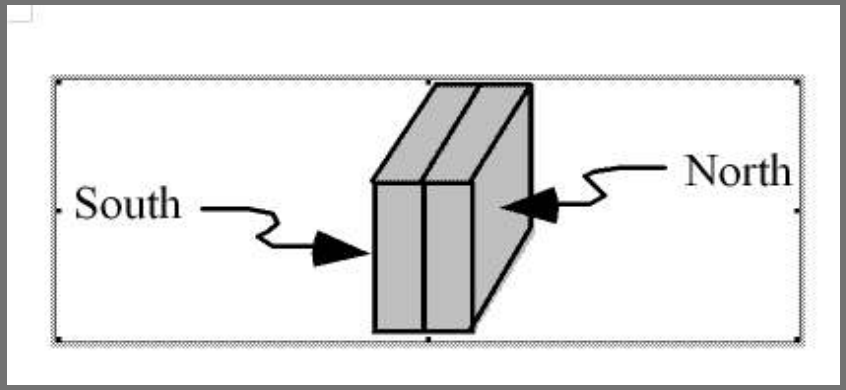


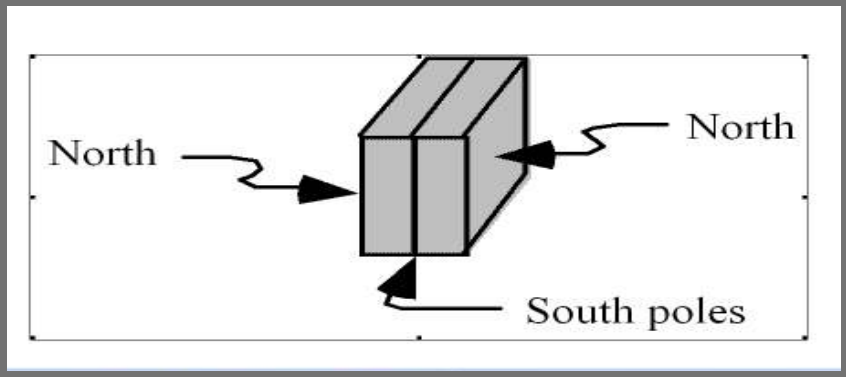


Example of an Inquiry Activity

- Using small magnets, produce the strongest possible magnetic stack, by selecting the proper arrangement.







- Investigate first, which of the two combinations produces the strongest magnetic stack
- OBJECTIVE: to develop the magnetic domains model for magnetization and demagnetization

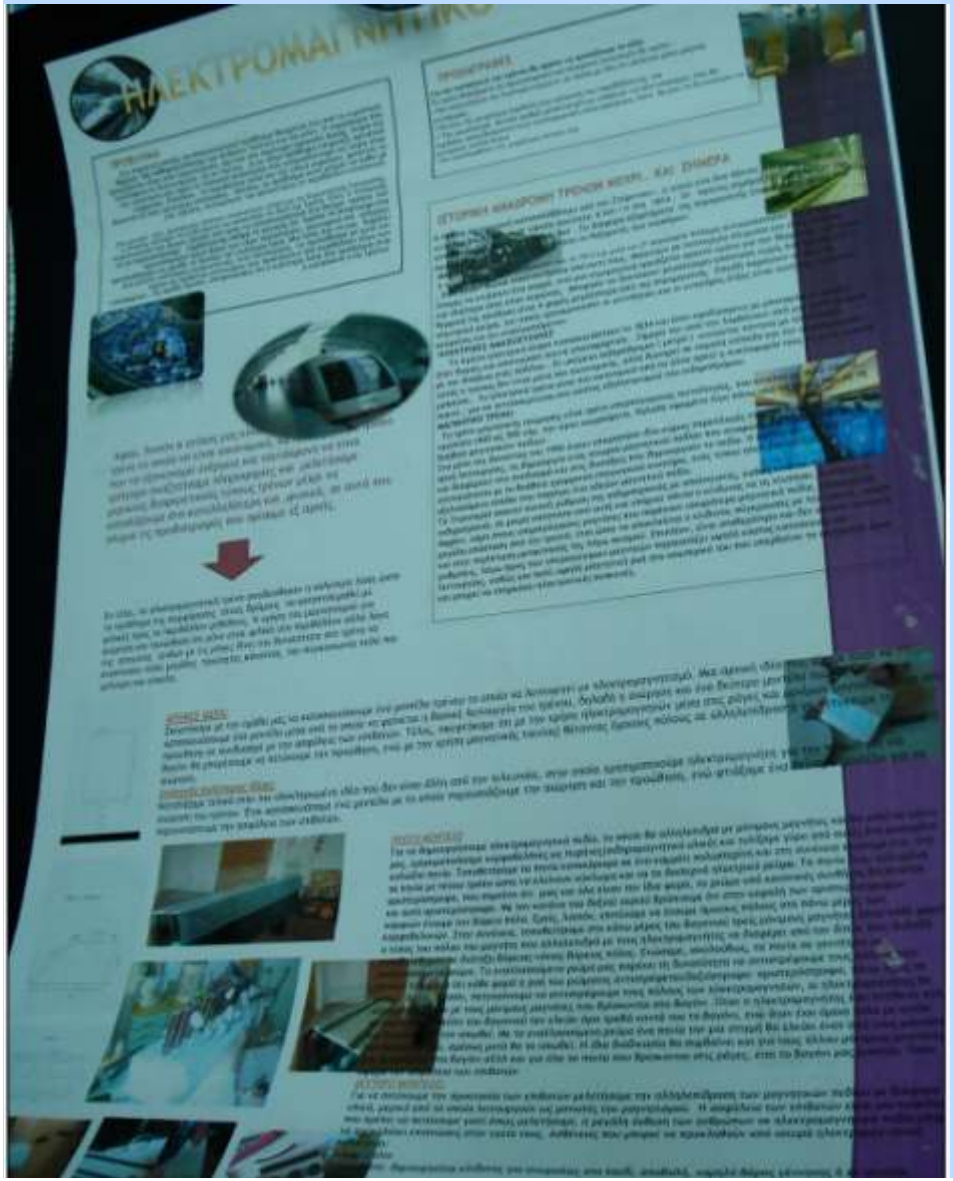
Assessment of conceptual understanding

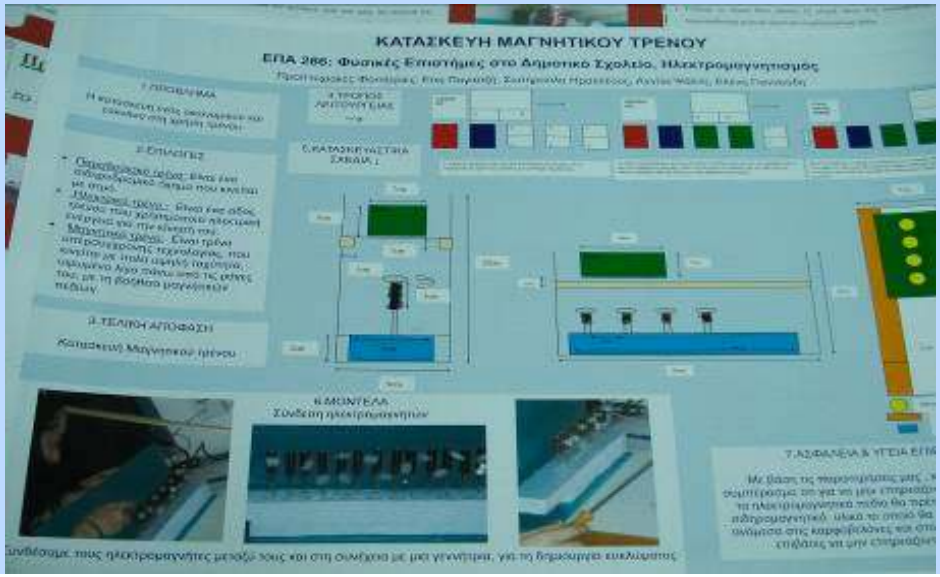
- The mystery box

	End I	End II	End I	End II	End I	End II
A	*None*	*None*	*None*	*None*	*None*	*None*
B	*Attr-n*	*Rplsn*	*Rplsn*	*Attr-n*	*Rplsn*	*Attr-n*
C	*Attr-n*	*Attr-n*	*Attr-n*	*Attr-n*	*Attr-n*	*Attrn*
D	*Rplsn*	*Attr-n*	*Attr-n*	*Rplsn*	*Attr-n*	*Rplsn*
E	*None*	*None*	*None*	*None*	*None*	*None*
F	*Attr-n*	*Rplsn*	*Rplsn*	*Attr-n*	*Rplsn*	*Attr-n*

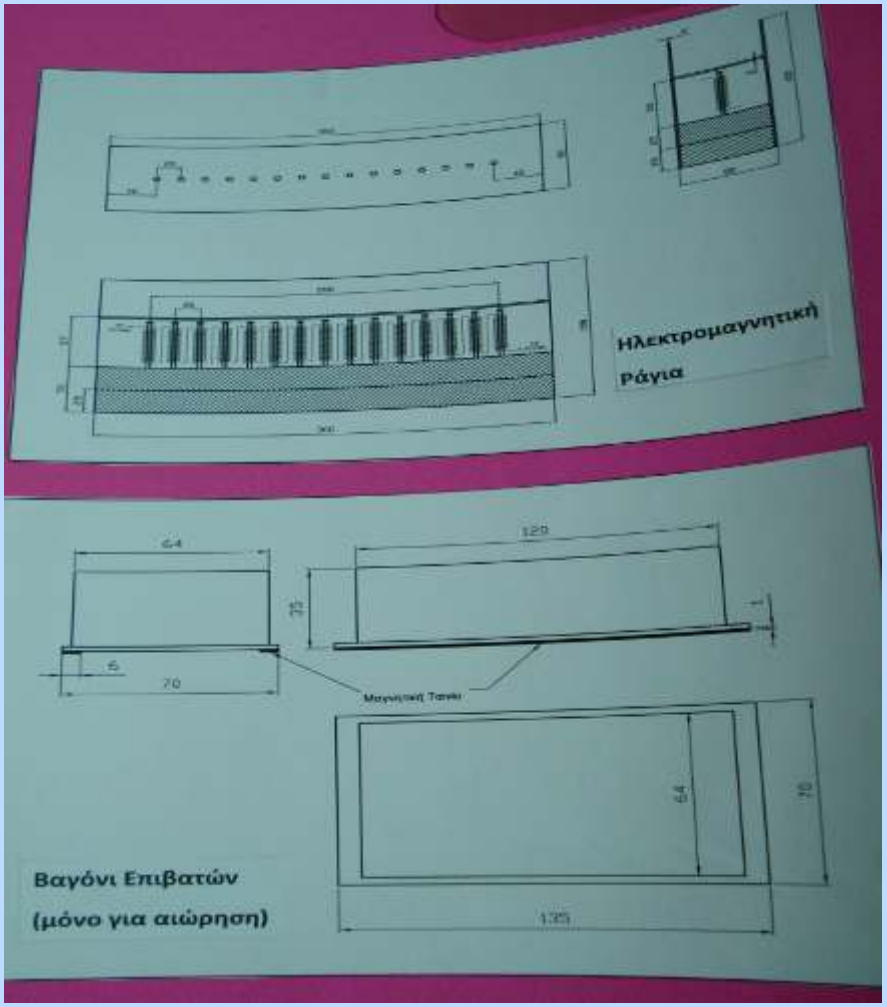
Are there any magnet ends that can be considered identical?
How many different kinds of magnet end are there?
Is it conceivable that there may be another type, not represented here?

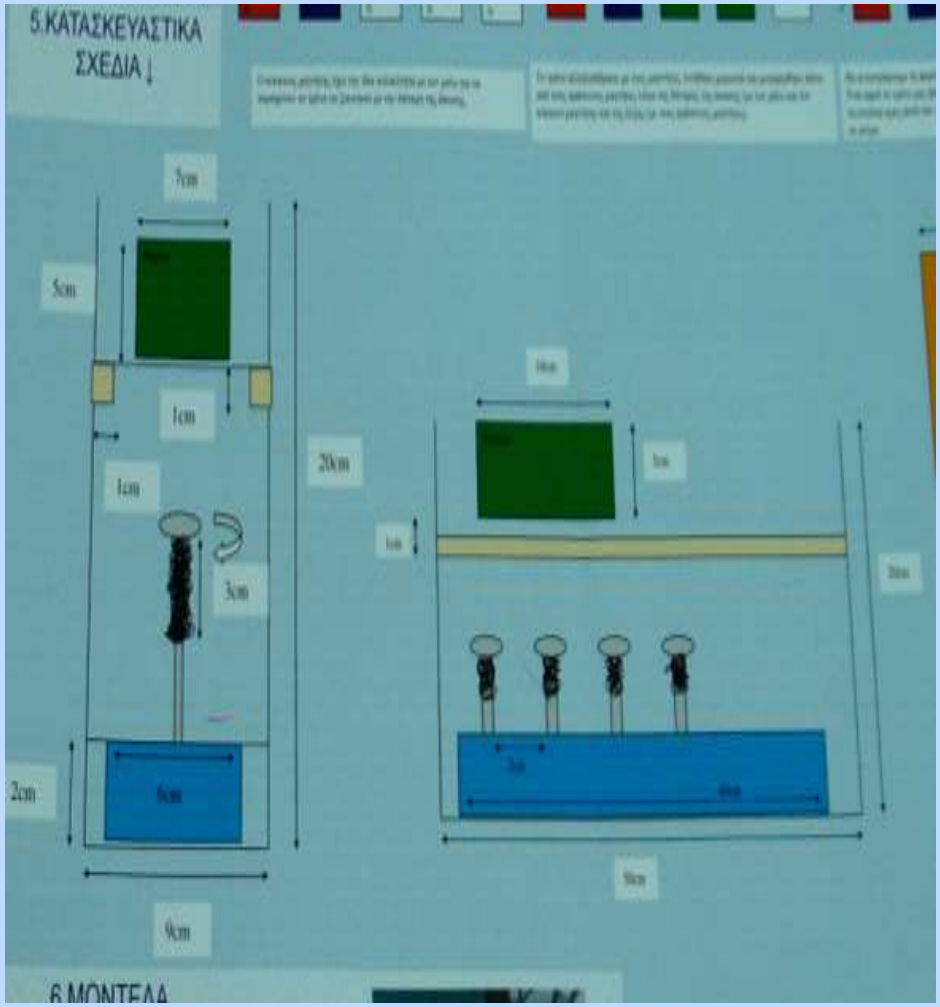
Poster Examples





Construction Designs





Dimensions of Artifact Analysis

- Problem statement & Specifications
- Initial ideas & Development of possible solutions
- Selection & Development of the best solution
- Construction Designs
- Two additional design stages were identified in a small minority of the posters:
  - Researching the problem
  - Testing and Evaluation of the solution

Construction requirements?

	Elevation	Propulsion	Passenger protection
Train 1	Placement of magnetic strips under the wagons and on the rails with the like poles face to face → Successful elevation	• Almost identical electromagnets (core material, number of wire loops, density of loops) • Right connections between electromagnets and consequently correct polarity • Stable distance among electromagnets • Relatively low density of wire loops → Low ability for movement	Ferromagnetic material in form of sheet is covering the bottom of the wagons → Significant decrease of the intensity of the magnetic field
Train 2	Placement of magnetic strips under the wagons and on the rails with the like poles face to face but not in appropriate distance between them → Elevation without good balance	• Almost identical electromagnets (core material, number of wire loops, density of loops) • Right connections between electromagnets and consequently correct polarity • High density of wire loops • Unequal distance among electromagnets and bad alignment → Propulsion is not achieved	Ferromagnetic material in form of sheet is covering the bottom of the wagons → Significant decrease of the intensity of the magnetic field

Interpretations

- It was necessary for students to construct the magnetic domains model in order to design for the oscillating magnetic field required for train propulsion.

- Students found it difficult to negotiate two mechanisms simultaneously. They tended to approach magnetic levitation and train propulsion sequentially rather than seek a solution that integrated both mechanisms. Synthetic design emerged as a scaffolding challenge.

- We found that students needed scaffolding in structuring their reports in order **to make use of the conceptual models they had developed in their design decisions** (eg material for shielding passengers from effects of electromagnetic fields).

Emergent Problem

- **Observed epistemological naivety**
  - technology as applied science
  - trial and error design
  - scientific understandings as “theory” meaning “not practice”

- This suggested the need for involving students extensively and systematically in explicit reflective discourse around the interconnection and distinction of science and technology.

  Isolated discussion is not adequate to help students to overcome epistemological difficulties.

- The teaching/learning sequence was revised to achieve improved understandings of the distinction and interconnections between science and technology

Constantinou et al. IJSE, 2010, 32(2) pp. 143-172

Revised Priorities

- Conceptual Understanding
- Learning by Design
- Views regarding Science & Technology (distinction and interdependence)

  (Constantinou et al. IJSE, 2010, 32(2) pp. 143-172)

Main finding of this new iteration

Epistemological awareness should be treated as a significant learning objective that has to be addressed through *explicit discourse* in the frame of specially designed learning environments

Hadjilouca, Constantinou & Papadouris, *Science & Education*, 2011

An illustration of two aspects of DBR

- Emergent activity structures
- **Methodological alignment** (Hoadley, 2004)
  As initially unpredicted observations arise among predicted ones, the approach changes with renewed theoretical input leading to intervention designs that are better fit to their intended setting and to better explanations of how they work

STOCHASMOS

STOCHASMOS: a Web-based Platform for Inquiry-Oriented Teaching and Learning with the use of authentic scientific data

http://www.stochasmos.org

Funding:

Ίδρυμα Προώθησης Έρευνας Κύπρου

European Commission
Marie Curie Actions

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CYPRUS

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Funding Agencies

Πρόγραμμα Προώθησης Έρευνας

Cyprus Research Promotion Foundation

STOCHASMOS investigates the role of new technologies in supporting middle-school students' reflective inquiry practices in science and, in specific, the role of technology-based supports in scaffolding students' reasoning with scientific data.

We have developed a web-based learning environment for supporting students' scientific reasoning through scientifically authentic investigations with an embedded authoring tool. Teachers and other instructional designers can use this system to design their own web-based investigations with reflective supports. The **STOCHASMOS**environment is available in both the **English** and the **Greek**languages.

The research part of the project examined the interactions of the students with the web-based environment following a mixed-methods approach. We investigated the extent to which the reflective scaffolding supports the construction of students' scientific explanations using quantitative as well as qualitative methods.

We are currently in the second development phase of the STOCHASMOS platform, in the context of the research and development program **"Collaborative Inquiry Learning Environments"** (project SYNERGASIA). This project is funded by the Cyprus Research Promotion Foundation.

Announcements

Talk to us during the following conferences:

» Kaleidoscope 2007 Symposium, November 26-27 2007, Berlin, Germany

» 12th Biennial Conference for Research on Learning and Instruction (EARLI), August 28-September 1, 2007, Budapest, Hungary.

» European Science Education Research Association meeting (ESERA), August 21-

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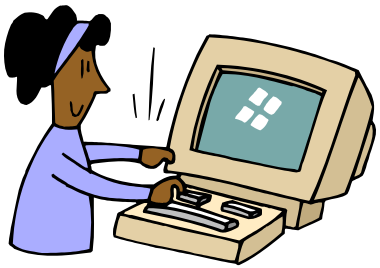
The STOCHASMOS platform

- Builds on prior technological design efforts, such as the Progress Portfolio and WISE
- **Overall goal to scaffold students' data-rich, self-regulated learning in science.**
- Design principles:
  - Making thinking visible.
  - Helping focus and organize investigations.
  - Augment opportunities for reflection through articulation.
  - Grounding articulation and reflection in the data.
  - Supporting the process of active reasoning with evidence.
  - Providing tools for communication and collaboration.

STOCHASMOS

A web-based platform to support reflective inquiry



An authoring environment for teachers

Teachers can:

- Create one or more learning environments
- Or adapt existing environments designed by others
- Customize or create new reflective templates for the WorkSpace
- Engage in embedded assessment (log, synchronous and asynchronous feedback mechanisms)
- Collaborate with other teachers

A learning environment for students

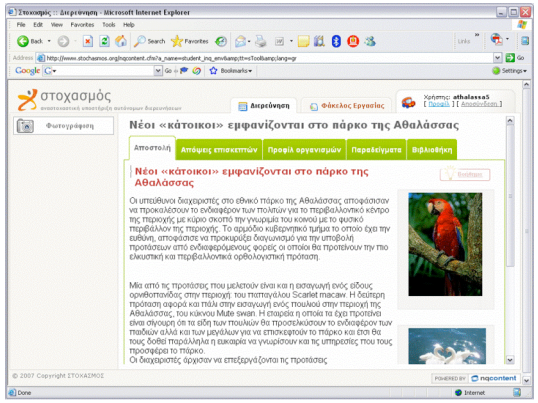
Inquiry Environment

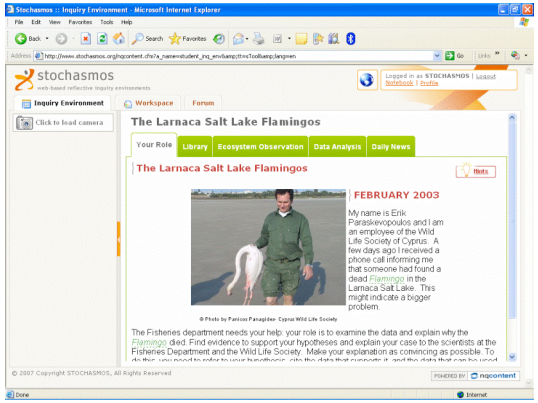
Reflective Workspace

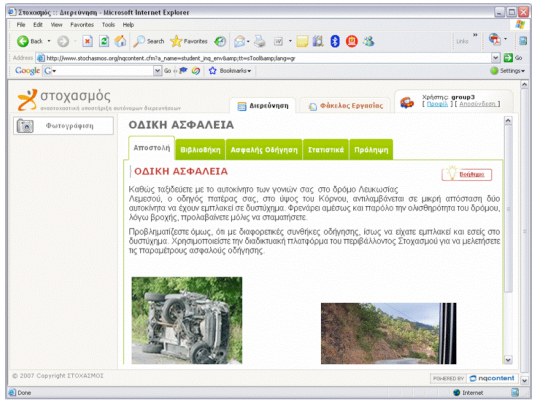
Focus on:

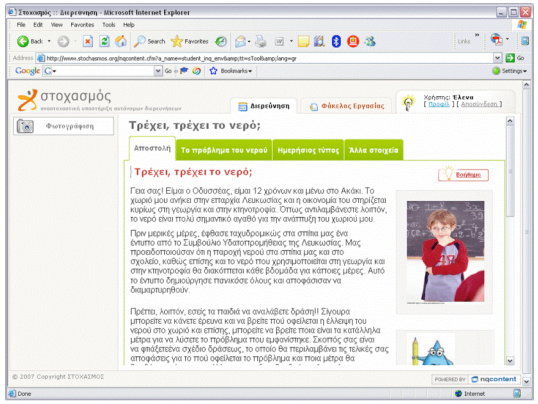
- Reflection during inquiry
- Interpretation of primary data
- Evidence-based explanation building
- Student collaboration
- Peer feedback mechanisms
  - Synchronous communication: chat
  - Asynchronous communication: forum, Workspace templates sharing, peer feedback

Students' Inquiry Environments

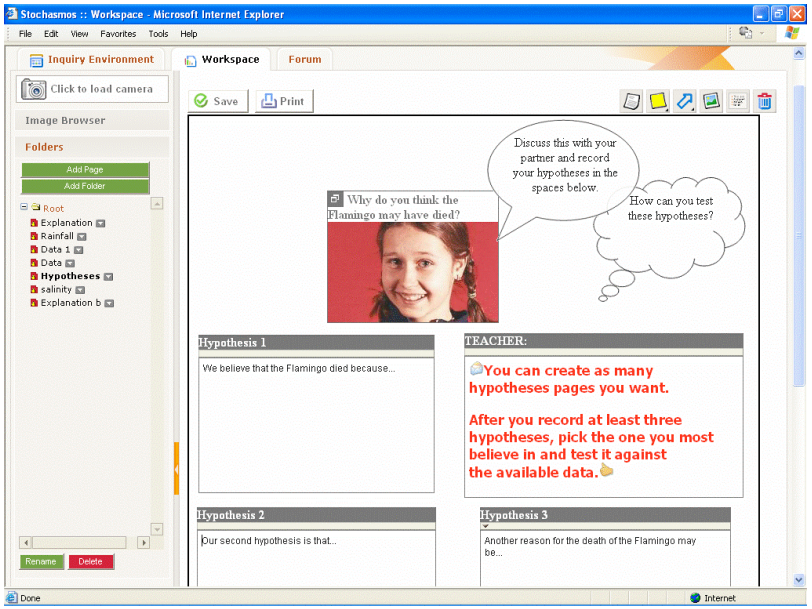


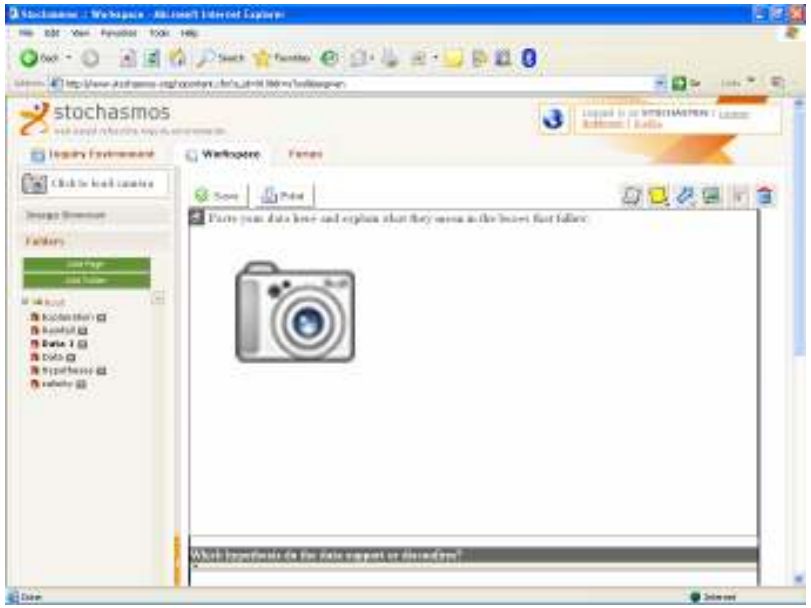


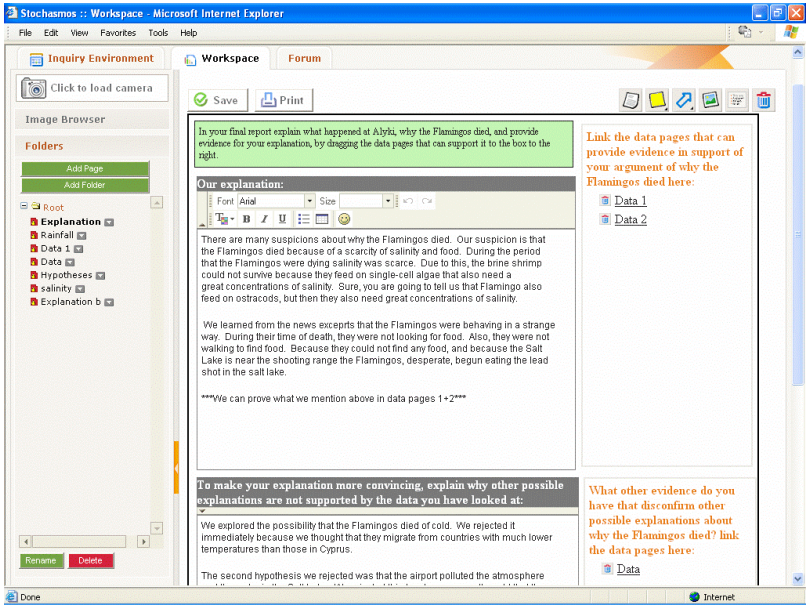


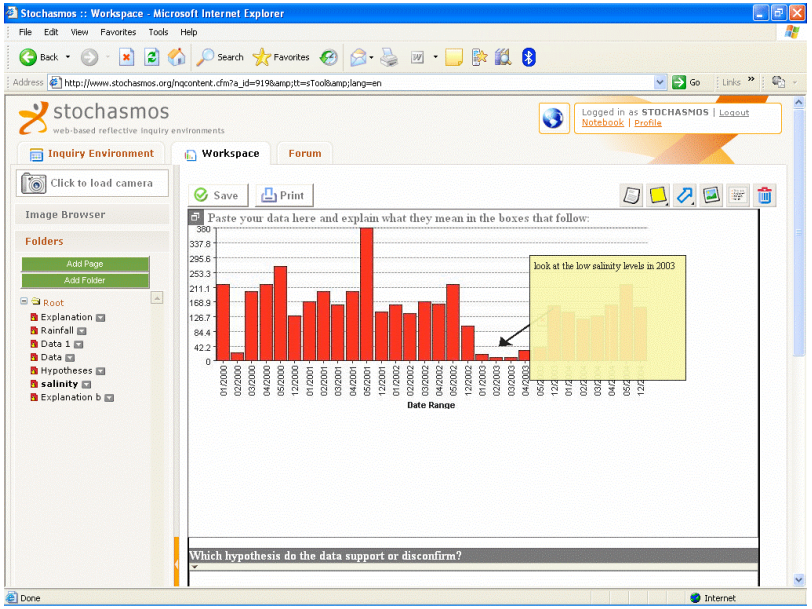


Students' WorkSpace templates









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Αποστολή | Βιβλιοθήκη | Παρατήρηση | Ανάλυση | Ημερήσιος Τύπος

Τα Φλαμίγκο της Αλυκής Λάρνακας

Βοήθημα

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ΦΕΒΡΟΥΑΡΙΟΣ 2003

Γεια σας. Ονομάζομαι Ερρίκος Παρασκευόπουλος και εργάζομαι στην Υπηρεσία Θήρας. Πριν από λίγες μέρες πήρα ένα τηλεφώνημα ότι βρέθηκε ένα νεκρό Φλαμίγκο στη μέση της Αλυκής. Αυτό το γεγονός μπορεί να είναι ένδειξη προβλή

Σημάδι ή στοιχείο. Πληροφορία που μας βοηθά να καταλάβουμε κάτι άλλο.

Το Τμήμα Αλιείας χρειάζεται τη βοήθειά σας: ο ρόλος σας είναι να εξετάσετε τα στοιχεία που υπάρχουν και να λύσετε το πρόβλημα του θανάτου των Φλαμίγκο. Βρέστε τα στοιχεία που υποστηρίζουν τις υποθέσεις σας και γράψτε μια εξήγηση την οποία θα στείλετε στους επιστήμονες στο Τμήμα Αλιείας και στην

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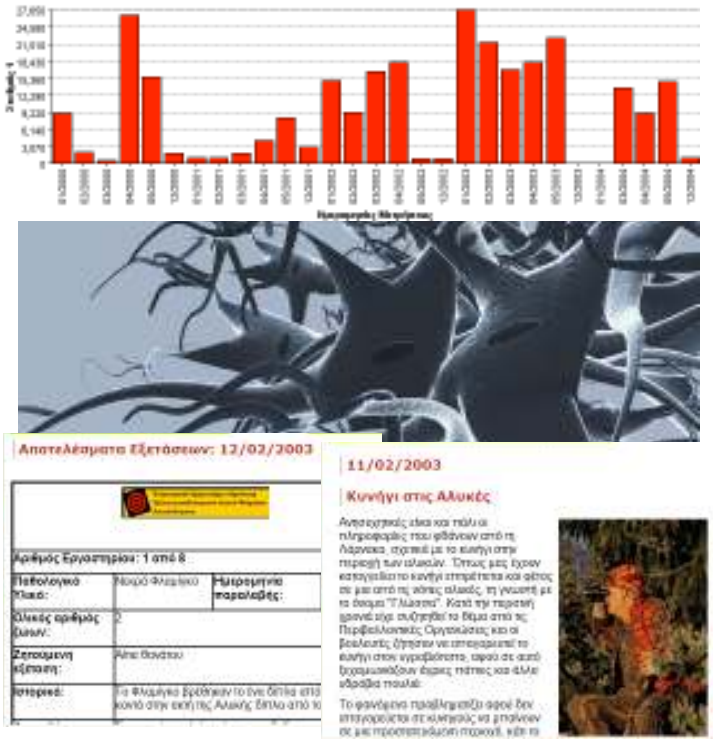
Inquiry-based learning

- The STOCHASMOS learning environments
  - designs for reflective inquiry learning:

  - Problem-based approach
  - Driving question
    (to help focus)
  - Authentic problems
    - Engaging (motivation)
    - Data-rich (complex)
    - Challenging (due to the nature of the problems)



The goal is discursive argumentation with the use of authentic scientific data as evidence

Reflective inquiry

- We define ***reflection*** as the ability to monitor and evaluate past and ongoing actions in order to help plan next steps.

- **Reflective inquiry** can be seen as a set of practices that help the inquirer adopt a systematic, critical, and evidence-based orientation to learning.
  (Kyza & Edelson, 2003; Loh *et al.*, 1998)

Design Tools for Scaffolding reflective inquiry

Examples of scaffolds that can facilitate reflective inquiry:

Doing the inquiry

- Automating routine tasks to help students focus on the conceptual aspects of inquiry
- Data boxes for storing information
- Easy access to stored and interpreted data

Reflecting on the inquiry

- Changing the nature of the task (Kyza, 2004, Loh, 2003).
- Data capture camera to support data evaluation
- Articulation prompts to support planning, monitoring, evaluating
- Annotations to allow free expression of ideas

Collaborating

- Making thinking visible
- Tasks, prompts and articulation boxes provide the basis for externalizing thinking to peers and teacher
- There is opportunity for ongoing synchronous and asynchronous feedback

Embedded Assessment

- Ongoing feedback opportunities
- Both from peers and teacher
- Chat/Forum/WorkSpace sharing

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Research Goals

- **INITIAL**
- To examine the role of software-based reflective inquiry scaffolding in supporting student inquiry with a salt lake ecosystem

- **EMERGENT**
- What is the role of the reflective inquiry scaffolding in the creation of evidence-based explanations?
  - Students' ecosystem reasoning
  - What is the interaction between group ability, reflective inquiry scaffolding, and groups' collaborative explanations?

Kyza, Constantinou & Spanoudis, IJSE, 2011, 33(18) p. 2489-2525.

Brief literature review

- Students are reported to have difficulties with both the more general aspects of **what constitutes an explanation in science** and the **domain-specific aspects** of understanding ecological concepts. e.g.
  - Do not provide evidence in support of their explanations (Sandoval, 2003).
  - Students have difficulties in reasoning about causality and noticing indirect relationships (Abrams & Southerland, 2001).

Additional scaffolding for students' explanation building

- Qualitative investigations of the discourse and actions of students of higher, medium, and lower academic ability as they work with the STOCHASMOS platform.
- The scaffolding in the tool supports students' reflective inquiry conversations about their data.
- Most of the lower ability group's reflective inquiry conversations take place in the context of working with the group.
- **This led to a hypothesis that such tools may be more necessary for lower ability students.**

Design-based methodology

PARTICIPANTS

Pilot enactment

- Three 6th grade classrooms (n=75), same science teacher, half of the dyads with WorkSpace, half of the dyads with PowerPoint.

Second enactment

- Lessons learned from pilot enactment led to the "Detective investigation" for introducing terminology, concepts, inquiry routines, and use of the system.
- Two 6th grade classrooms (n=26, 27), same science teacher, one class with WorkSpace, one with PowerPoint.
- Using the Raven's standard progressive matrices and a test measuring students' conceptual understanding of the ecosystem:
  - A two-step cluster analysis showed that students could be grouped in two clusters: those of low learning potential (M=1.43) and those of high learning potential (M=4.33).
  - Chi-square and t-test analyses showed that the two classes were equivalent.

Enactments

- Students work in groups and mostly independently
- The teacher moves around and provides just-in-time feedback
  - Teachers can also provide asynchronous feedback to groups (reviewing workspace pages, chat, forum)
- Groups engage in peer-review and peer-critiquing after the completion of certain stages in the project
- Groups make final presentations of their work to each other & to their teacher

Research Methodology

ACTIVITIES

- Students worked in dyads of high, low, and mixed ability.
- Lessons lasted for about 6 weeks and included an initial brainstorming activity, mid-investigation peer-reviews, and final class- and school-wide presentations.

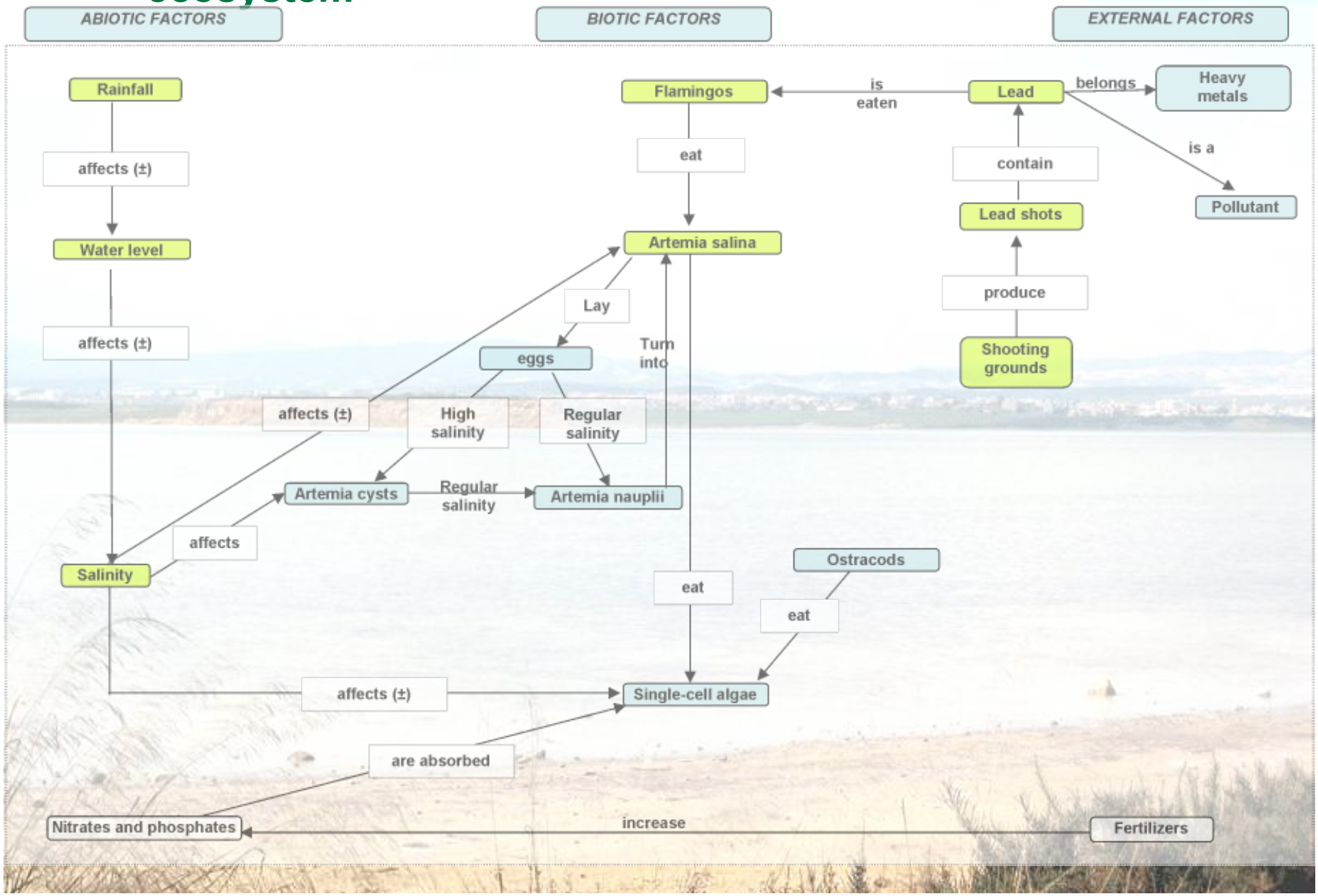
DATA COLLECTION

- Pre and post tests examining students' conceptual understanding and inquiry skills.
- Videotaped three groups' interactions with the software, teachers, and peers.
- Logbook of the students' use of the STOCHASMOS system.
- Each group's computer-generated artifacts.

ANALYSIS

- Analysis of students' final explanations.
- Statistical analyses of pre and post tests.
- Case studies of different ability groups as they work with the reflective WorkSpace or with PowerPoint.

Expert criterion map of the salt lake ecosystem



Explanations coding scheme

-Modified Toulmin's argumentation scheme

-Based on the expert criterion map

	Level					
Main explanation	**0**	**1**	**2**	**3**	**4**	**5**
Claim	The group has not provided any claim answering the problem they were asked to solve.	The group has no one definite claim and may e.g. present two claims.	The group has provided a claim stating an answer to the problem they were asked to solve.			
Reasoning	The group does not provide an explanation of the claim they have provided or provides a reasoning that is not related to the claim put forth.	The group has attempted to provide reasoning but the statement (s) provided are merely observational and describing facts. Students may provide observations or descriptions that do not provide a causal ecosystem explanation of why the flamingos died.	Students present a causal explanation that only refers to the exogenic or endogenic environmental factors that influenced the salt lake ecosystem and may have caused some flamingos to die.	Students provide an ecosystem-related mechanism for how the flamingo died, in which they explicitly mention relationships between exogenic environmental and endogenic biological factors of the ecosystem as they are related to the Flamingos. However, the mechanism is not adequately explained: for instance, two factors (biotic or abiotic, e.g. flamingo, rainfall) may be linked, but intermediate links may be ignored or not adequately explained (rainfall, water height, brine shrimp, flamingo). Some false reasoning may also exist.	Students provided an ecosystem explanation, where they explain the key ideas of how the interdependence of biotic and abiotic factors led to the death of some of the flamingos. Explanation cannot be given full marks because it may lack important comparisons such as reference to baseline data from previous and future years.	Full marks - same as #4, but explanation refers to baseline data, as well.
Evidence cited (explicitly linking the claim about the death of the flamingos with investigation data)	The group has not provided any evidence to support their claim as to why the flamingos die or may cite as evidence background data.	The group has provided evidence explicitly supporting their claim but all evidence linked is not appropriate.	The group provided some evidence but some of the evidence is contradictory or/and false. Evidence provided is not sufficient to support the claim.	The group has provided evidence in support of their claim. There is no contradictory or irrelevant evidence cited, and the evidence is all appropriate. The group has linked their claim and the evidence cited. However, the evidence is not sufficient to support the claim stated.	The group has provided evidence in support of their claim. All evidence provided is sufficient and appropriate. The group has linked the evidence cited and their claim stated.	
Rival explanations						
Listed other explanations they refuted	The group has not listed any rival explanations they have refuted.	The group has listed one or more rival explanations they have attempted to refute.				
Provided the reasoning for rejecting rival explanations	The group has not provided any reasons for refuting the rival explanations they listed.	The group has explained their reasoning as to why they refuted some or all of the rival explanations. However, the rationale provided in each case is ***irrelevant*** or ***insufficiently explained*** for **all** the refuted claims.	The group has provided a rationale as to why at least ***some*** of the rival explanations listed were refuted. However, the rationale behind rejecting some of the explanations may be **missing** or **not explained adequately**.	The group has provided a valid rationale for all the rival explanations they have refuted.		
Cited evidence in support of the refutation of these alt. explanations	The group provided no evidence to support their refutation of rival explanations	The group has provided evidence to support the reason they refuted a rival explanation but all evidence linked is not appropriate	The group provided evidence for some or for all of the alternative explanations they have refuted. One or more of the following may hold true: not all of this evidence may not be relevant, appropriate, or sufficient, based on the information existing in the database. The evidence may not be clearly connected to particular counter-claims	The group has provided evidence in support of all of their refuted explanations. There is no contradictory or irrelevant evidence cited, and the evidence is all appropriate. The group has explained the connection between the alternative explanations and the evidence cited. However, they have not provided adequate evidence for all claims stated, or the evidence may not be sufficient or well-justified to support the claim stated	The group has provided evidence in support of their refutation of alternative explanations. All evidence provided is sufficient and appropriate. The group has explained the connection between the evidence cited and the refuted claim	

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-Based on the expert criterion map

	Level					
Main explanation	**0**	**1**	**2**	**3**	**4**	**5**
Claim	The group has not provided any claim answering the problem they were asked to solve.	The group has no one definite claim and may e.g. present two claims.	The group has provided a claim stating an answer to the problem they were asked to solve.			
Reasoning	The group does not provide an explanation of the claim they have provided or provides a reasoning that is not related to the claim put forth.	The group has attempted to provide reasoning but the statement (s) provided are merely observational and describing facts. Students may provide observations or descriptions that do not provide a causal ecosystem explanation of why the flamingos died.	Students present a causal explanation that only refers to the exogenic or endogenic environmental factors that influenced the salt lake ecosystem and may have caused some flamingos to die.	Students provide an ecosystem-related mechanism for how the flamingo died, in which they explicitly mention relationships between exogenic environmental and endogenic biological factors of the ecosystem as they are related to the Flamingos. However, the mechanism is not adequately explained: for instance, two factors (biotic or abiotic, e.g. flamingo, rainfall) may be linked, but intermediate links may be ignored or not adequately explained (rainfall, water height, brine shrimp, flamingo). Some false reasoning may also exist.	Students provided an ecosystem explanation, where they explain the key ideas of how the interdependence of biotic and abiotic factors led to the death of some of the flamingos. Explanation cannot be given full marks because it may lack important comparisons such as reference to baseline data from previous and future years.	Full marks - same as #4, but explanation refers to baseline data, as well.
Supporting evidence						
Evidence cited (explicitly linking the claim about the death of the flamingos with investigation data)	The group has not provided any evidence to support their claim as to why the flamingos die or may cite as evidence background data.	The group has provided evidence explicitly supporting their claim but all evidence linked is not appropriate.	The group provided some evidence but some of the evidence is contradictory or/and false. Evidence provided is not sufficient to support the claim.	The group has provided evidence in support of their claim. There is no contradictory or irrelevant evidence cited, and the evidence is all appropriate. The group has linked their claim and the evidence cited. However, the evidence is not sufficient to support the claim stated.	The group has provided evidence in support of their claim. All evidence provided is sufficient and appropriate. The group has linked the evidence cited and their claim stated.	
Rival explanations						
Refuted explanations		The group has listed one				
Reasoning for rejecting alternative explanations		The group has explained their reasoning as to why they refuted some or all of the rival	The group has provided a rationale as to why at least some of the rival			
ing for rejecting rival explanations	refuting the rival explanations they listed.	*plained* for **all** the refuted claims.	may be **missing** or **not explained adequately**.	explanations they have refuted.		
Supporting evidence						
Cited evidence in support of the refutation of these alt. explanations	The group provided no evidence to support their refutation of rival explanations	The group has provided evidence to support the reason they refuted a rival explanation but all evidence linked is not appropriate	The group provided evidence for some or for all of the alternative explanations they have refuted. One or more of the following may hold true: not all of this evidence may not be relevant, appropriate, or sufficient, based on the information existing in the database. The evidence may not be clearly connected to particular counter-claims	The group has provided evidence in support of all of their refuted explanations. There is no contradictory or irrelevant evidence cited, and the evidence is all appropriate. The group has explained the connection between the alternative explanations and the evidence cited. However, they have not provided adequate evidence for all claims stated, or the evidence may not be sufficient or well-justified to support the claim stated	The group has provided evidence in support of their refutation of alternative explanations. All evidence provided is sufficient and appropriate. The group has explained the connection between the evidence cited and the refuted claim	

Findings

- Students of lower achievement benefited significantly more from the use of scaffolding tools
- Within an extended intervention they were able to
  - Formulate explanations of comparable quality, and
  - Show signs of emergent autonomy (faded scaffolding had no impact)

Kyza, Constantinou & Spanoudis, IJSE, 2011, 33(18) p. 2489-2525.

DBR: a constraint

Measurement instruments have a strong influence on the process and on the convergence of the iteration

- Good quality instruments are specific in what they probe, and highly discriminating

Examples from our energy work:

- Papadouris, Constantinou & Kyratsi, JRST, 2008, 45(4), pp. 444-469
- Constantinou & Papadouris, JRST, 2011

Synopsis…

Discrediting theory is a symptom of the failure to find rigorous (educational) implementations of coherent (teaching and learning) theory

- There is a need for intermediate theoretical frameworks such as **inquiry oriented teaching and learning**

  Authenticity, epistemic anchoring, emergent autonomy

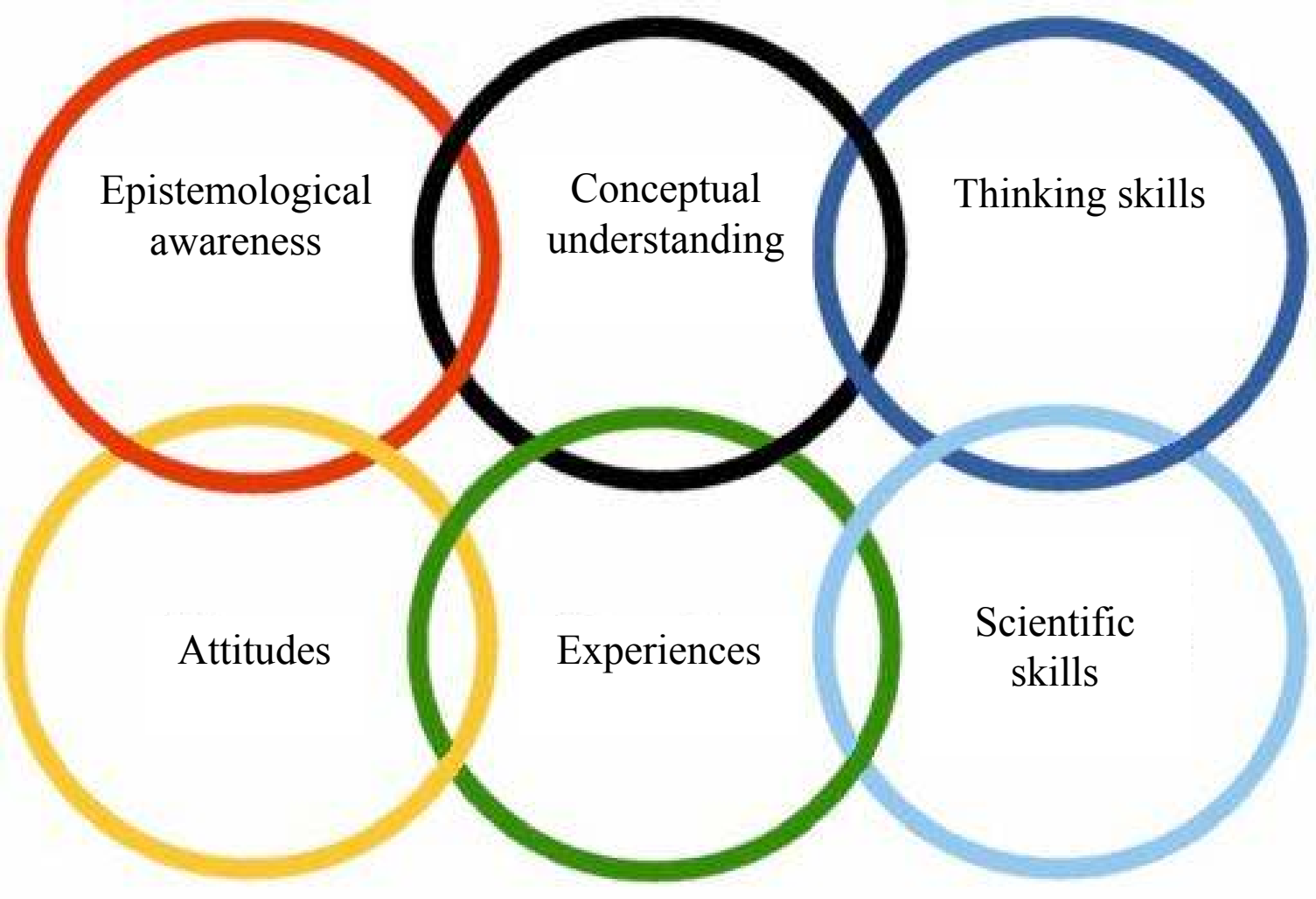
- **Design based research** provides a **methodological framework** that safeguards the need for rigour without sacrificing coherence.

Synopsis…

As a community, we need to be more critical of ideas and educational enactments.

And we should do that so that we do not lose sight of what is important…

Integrated Learning Goals



Concluding Remark…

Professional (Moral?) Responsibility in school (science) education:

In our efforts to get students to University we often forget the more **important goal of enabling young people to take charge of their own lives**.

Education as a self-serving institution

Unemployability is not just a social phenomenon or an outcome variable in Economics. It is also a symptom of a **deficit in our educational systems**.

Thank you for your attention!

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