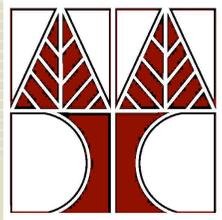


Inquiry-oriented Science Teaching: the role of *Design-Based Research*

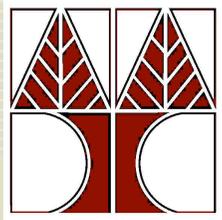
C. P. Constantinou
Learning in Science Group
Department of Educational Sciences
University of Cyprus

Creative Little Scientists International Conference, Athens, 22-23 March 2014



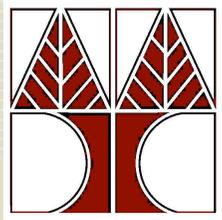
OUTLINE

- Background
 - *Where am I coming from?*
- Science in Society
 - *What have we achieved? What next?*
- Implications and potential contributions from Design Based Research



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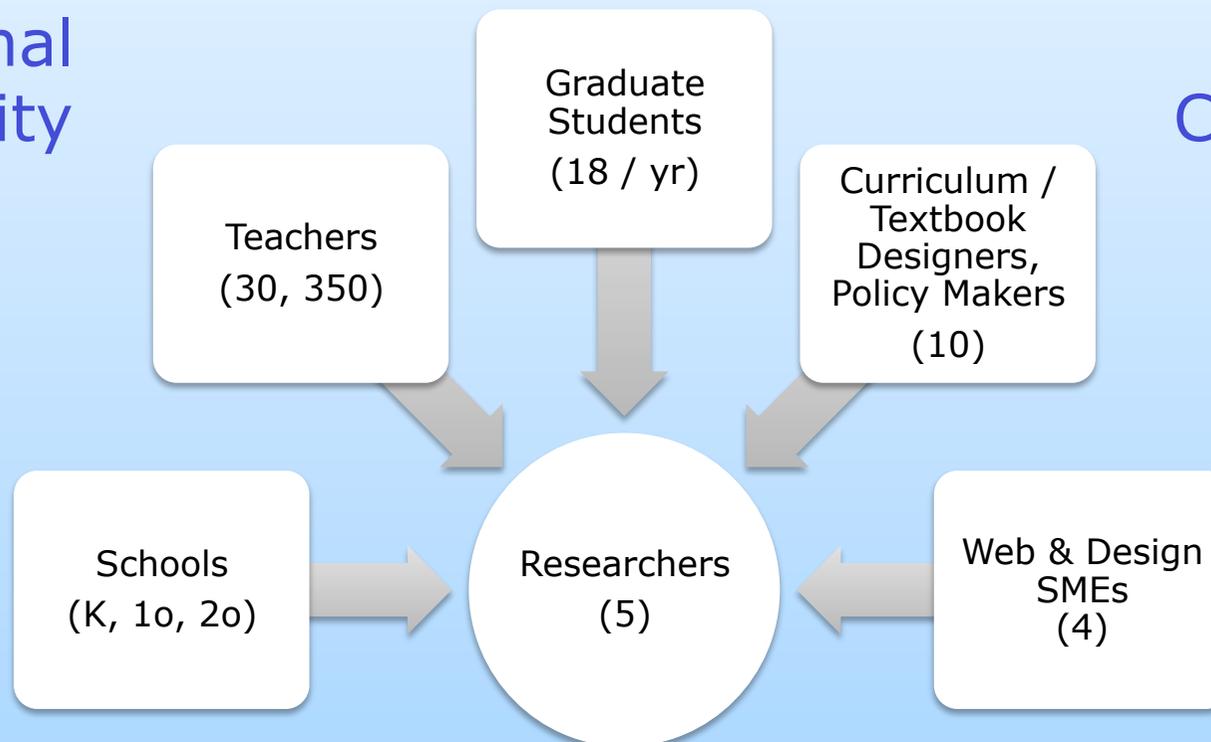


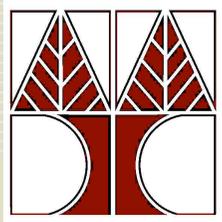
The Learning in Science Group @ UCY

Structure, Networking and Activities

Educational
Community

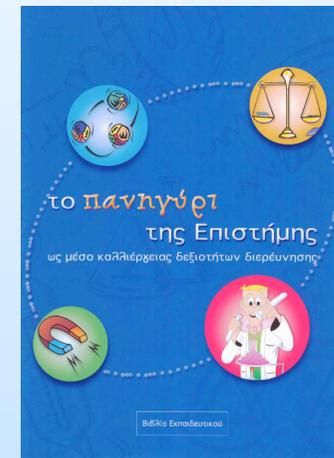
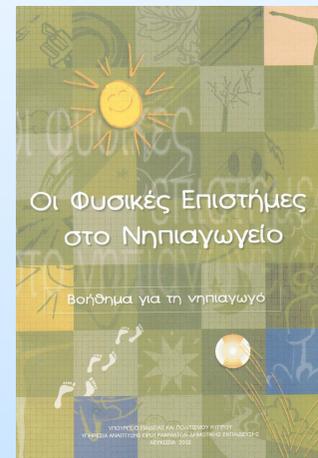
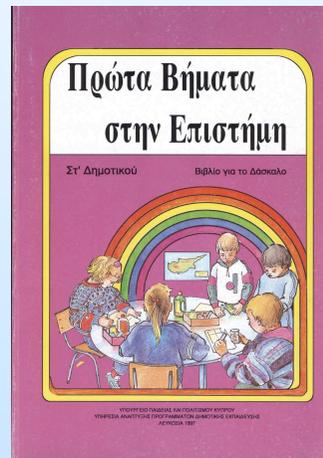
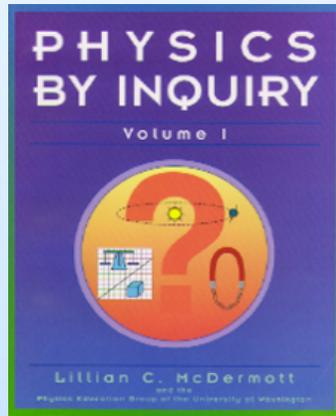
Research
Community



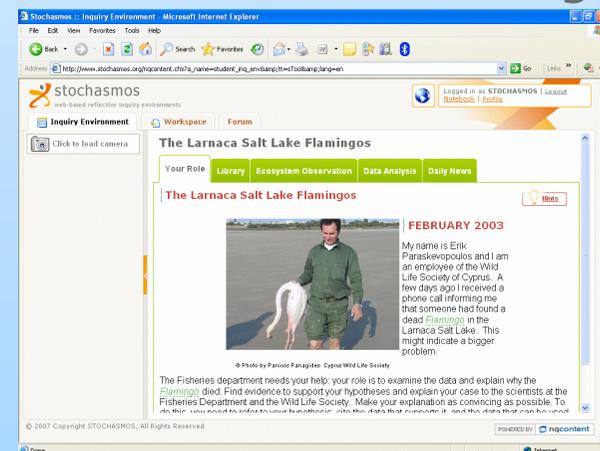


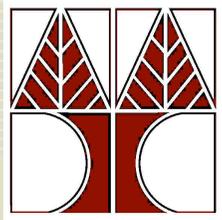
Learning in Science Group, UCY

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

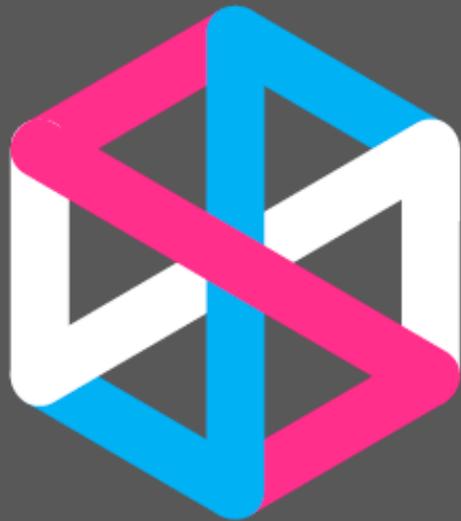


www.stochasmos.org

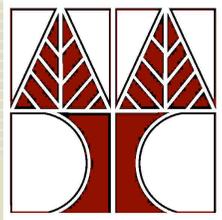




FP6: University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties (2006-2009)
<http://lsg.ucy.ac.cy/materialsscience/>



MATERIALS
SCIENCE



FP7: Digital support for Inquiry, Collaboration, and Reflection on Socio-Scientific Debates (2008-2011)
<http://www.coreflect.org/>





S-TEAM

S-TEAM: FIRING UP SCIENCE EDUCATION

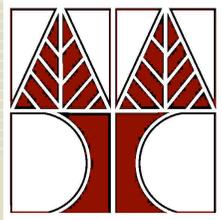


FP7: Dissemination of IBSE <http://www.s-teamproject.eu/>

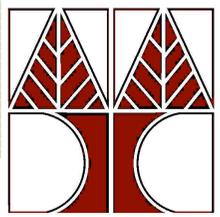
CHANGING THE WAY SCIENCE IS TAUGHT



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.



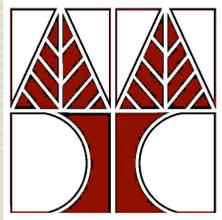
A personal perspective on the *Science in Society* Programme



Europe needs more scientists!
(Gago et al., 2004)

“School education should assure a good foundation of scientific literacy for all students. Looking at the world from a scientific perspective enriches the understanding and interaction with phenomena in nature and technology, enables students (and therefore future adults) to take part in societal discussions and decision-making processes, and gives them an additional element from which to form interests and attitudes.”



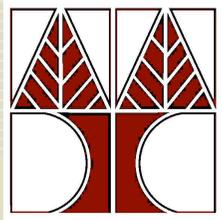


Science is Primary Conference (Dutch Presidency, 15-16 Oct 2004)

“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



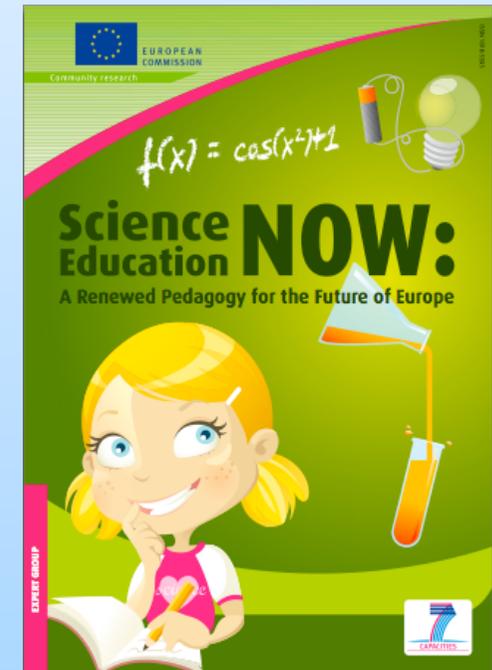
Rocard Report, FP7: Science in Society, 2007, DG Research:
“A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods *provides the means to increase the interest in science.*”

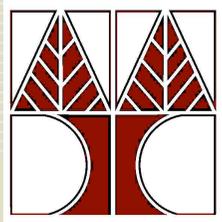
cf. NRC 2006 and Minner, Levy and Century,
JRST 47(4), pp. 474-496.

Rocard Report (pp. 6)

What is meant by science?

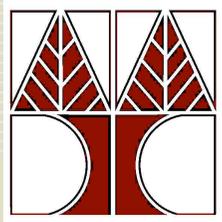
Science, in the broadest sense, refers to any system of knowledge which attempts to model *objective reality*. In a more restricted sense, science refers to a system of acquiring knowledge *based on the scientific method*, as well as to the organized body of knowledge gained through such research.





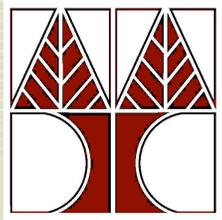
To attain sustainable educational change...

- 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



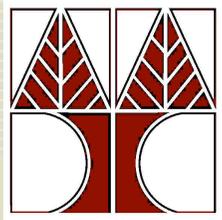
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A problem in science education

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



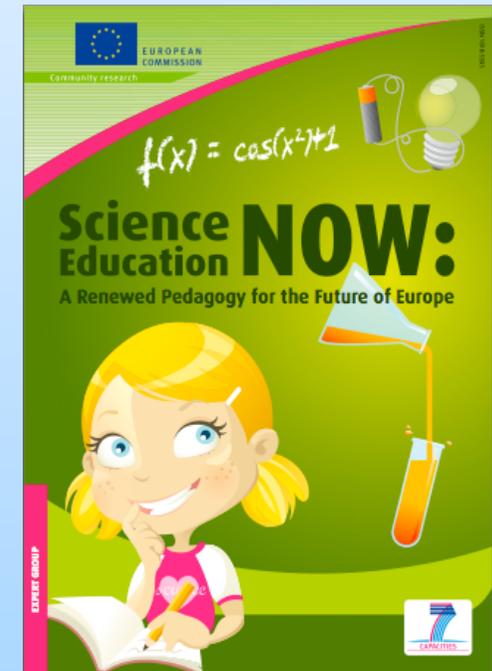
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S-TEAM

S-TEAM: FIRING UP SCIENCE EDUCATION

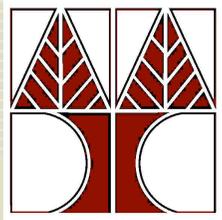


<http://www.s-teamproject.eu/>

WHAT IS INQUIRY BASED SCIENCE TEACHING?

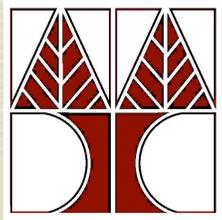


A project involving countries from all over Europe faces the challenge of developing a common terminology and a common understanding of its basic ideas. Although the roots of IBST (inquiry-based science teaching) as the main approach to improving science teaching and learning in S-TEAM lead back to the 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.



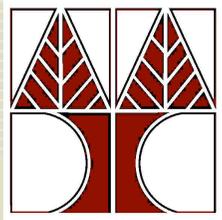
An example of widespread confusion:

Inquiry Vs Investigation



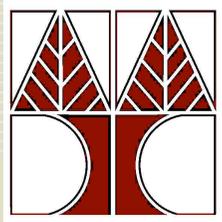
Small comment

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



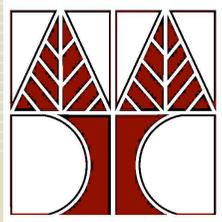
A History of Science Education Research (George de Boer, 1990)

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



To attain sustainable educational change...

- Credible, Reliable Knowledge (science education research)
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Theoretical credibility undermined...

Cognitive constructivism *Vs* the Nuffield primary science program

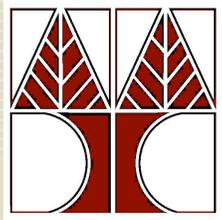
Social Constructivism (Irzik, 2000, 2001)

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



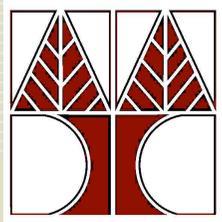
Some effects of discrediting theoretical ideas in science education

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 & Pikkariainen, 1999)

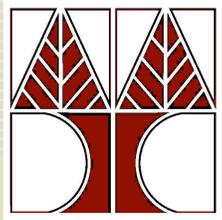
Lethal mutations of educational innovations (Collins, 2004; Pinto, 2005)



The problem reformulated...

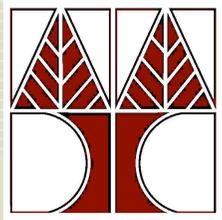
Discrediting theory is a symptom of the failure to find rigorous (educational) implementations of coherent (teaching and learning) theory

- 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



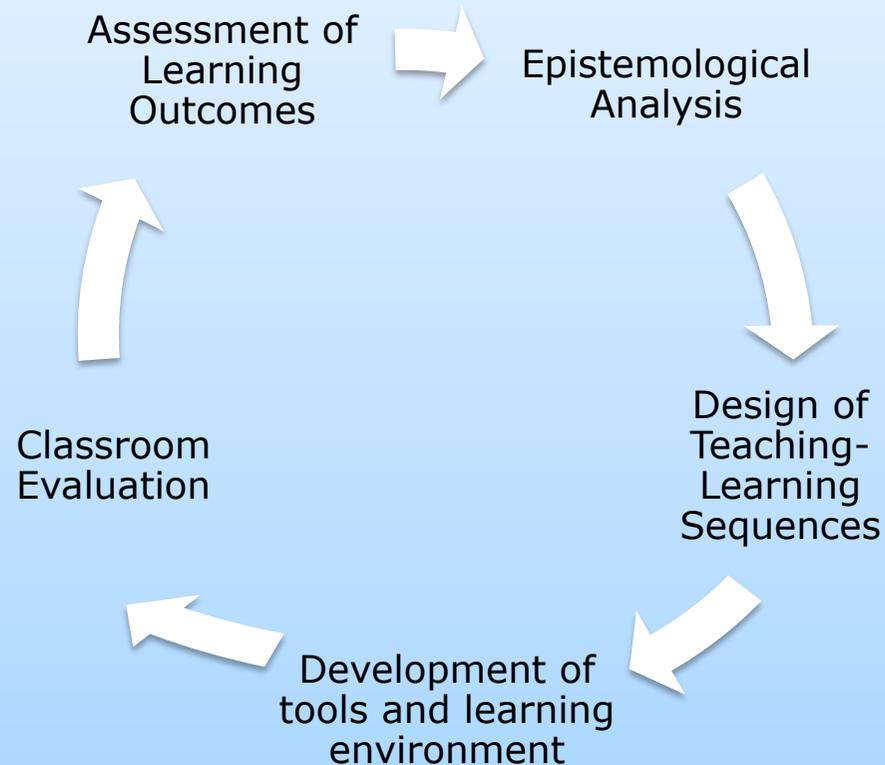
What cannot be done about the problem of combining rigour and coherence?

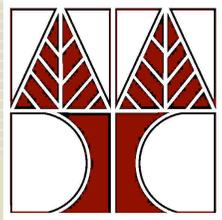
- **Design and development** (Duit, 2000) which involves evaluation, assessment but not research; it is often problem/needs centered rather than theoretically informed)
- **Design research** (A. Collins, 1992, 2004) which does not involve in-situ research
- **Design experimentation** (A.L. Brown, 1992; 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



The Learning in Science Group @ UCY

Methodology: *Design Based Research*



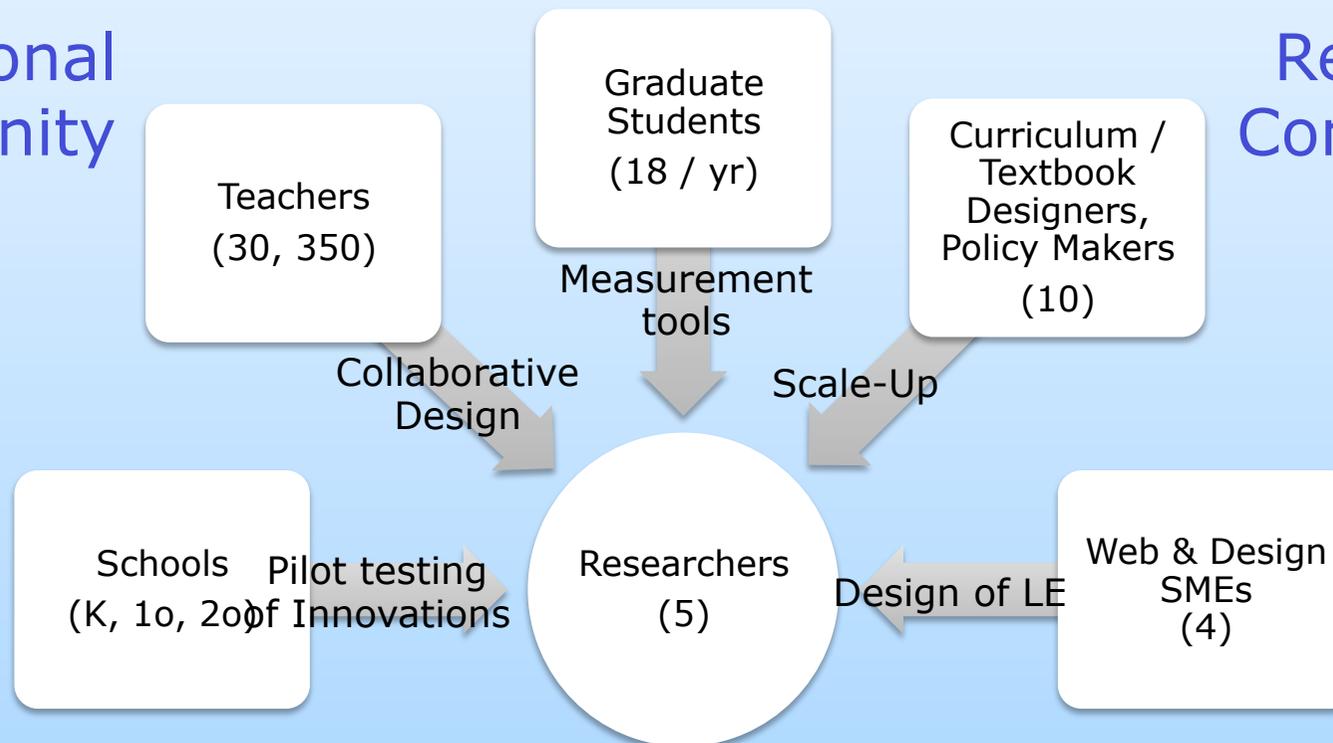


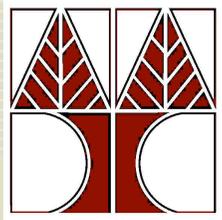
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Structure, Networking and Activities

Educational
Community

Research
Community

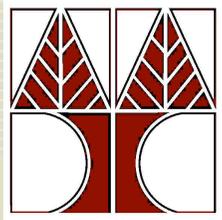




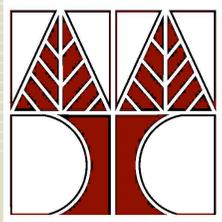
What next for Science Education in the EU?

- Systemic Reform Initiatives
 - Incentive structures
 - Professional development
 - Curricular realignment
 - Assessment reform
- Evidence validated practices
 - Instruments for gathering evidence on the inquiry practices
 - Mechanisms for collecting, analyzing data and using them in dynamic refinement of learning tools and teaching practices
 - Emphasis on assessing engagement, authentic learning outcomes and motivation for learning

Can we respond to the need to make science education more scientific?



Implications for Research

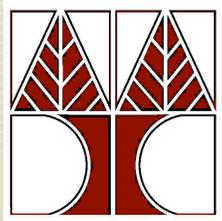


Inquiry Based Science Education

What are the defining features?

IBSE is a teaching and learning framework. As such, it builds in socio-constructivist 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 engagement and a motivational base for self-directed goal orientation and sustained self-regulation strategies



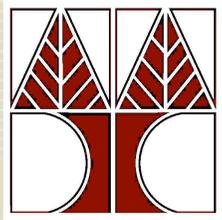
Inquiry Based Science Education

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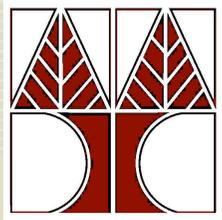
*... that also seeks to provide a **process** frame for enacting designed and validated teaching-learning sequences as a mechanism for reforming teaching practices in MST education with emphasis on **collaborative learning processes and meaningful outcomes such as key competencies and coherent conceptual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

Design Based Research provides a methodological frame for how to attain this



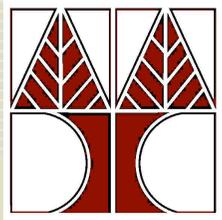
SER perspectives on the design of teaching interventions

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



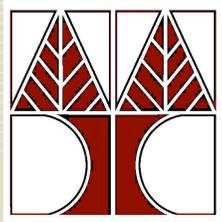
Some open issues

- 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



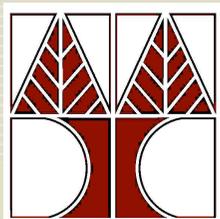
What is Design Based Research (DBR)?

- 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.



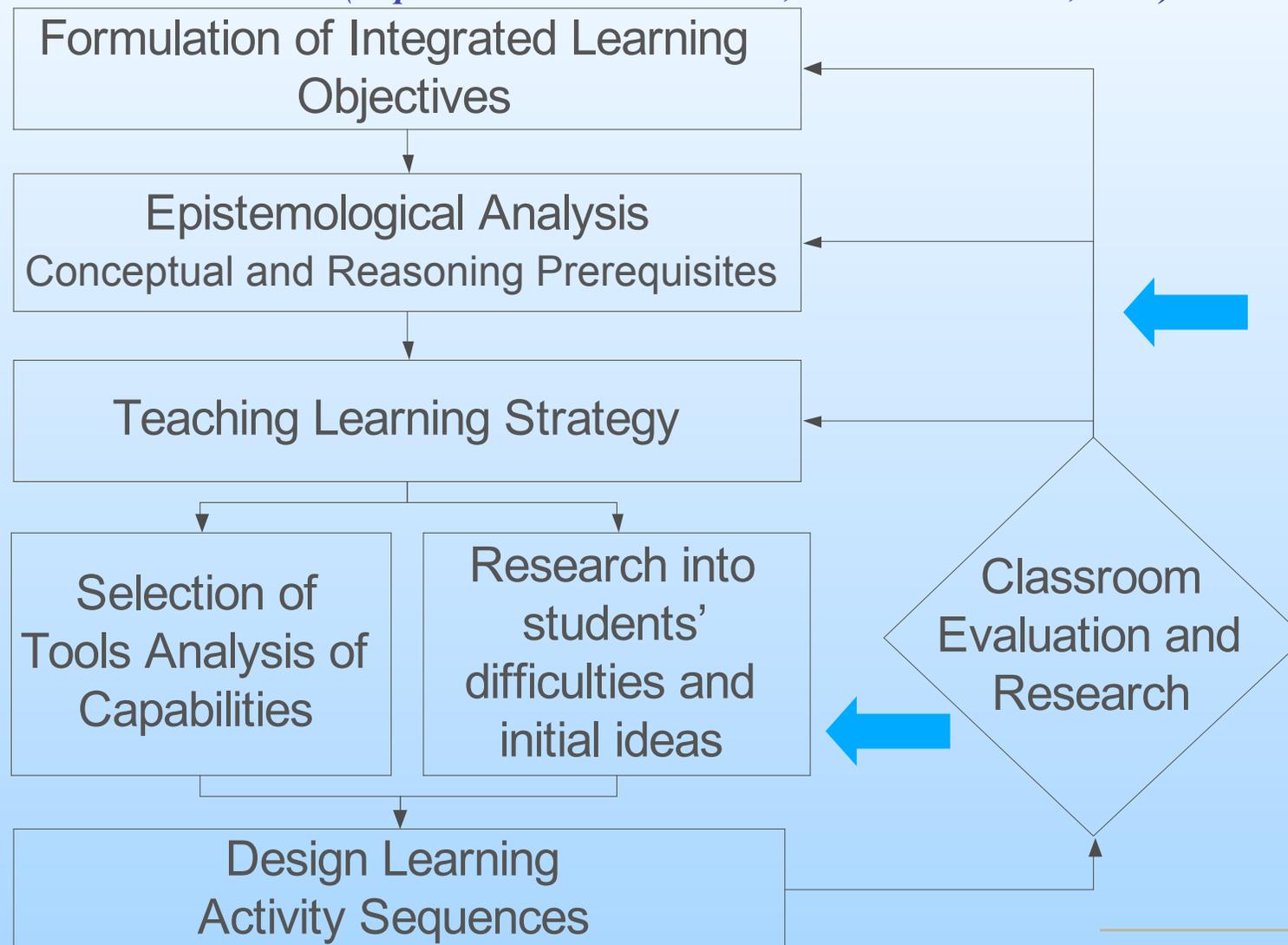
What is DBR?

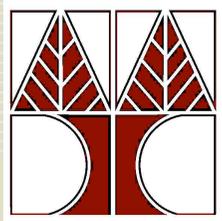
- DBR as engineering (Brown, 1992; Collins, 1992; Brown & Campione, 1998)
 - iteration
 - emergent phenomena
 - variation in developmental trajectories of intellectual growth
 - customization of teaching
 - outcome, climate and system variables (Collins, 1999)
- Generalized design knowledge
 - design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



A Methodology for designing teaching and learning materials

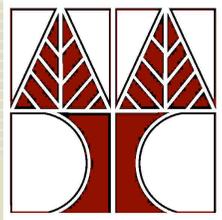
(Papadouris & Constantinou, J. Curric. Studies, 2009)





Some critical attributes of DBR

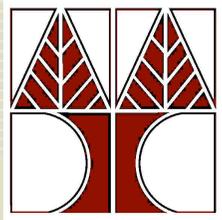
It provides a methodical framework for modifying the intervention as it unfolds (in order to respond to the dynamic, contingent nature of decision making during teaching, and thus make the intervention “work” in a complex setting) without placing at risk the need for empirical control that leads to theoretical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



Some 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)



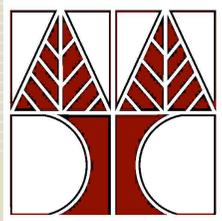
DBR in accord with the complexity of teaching – learning: two illustrative aspects

- **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**



Emergent activity structures

R. Hadjilouca, C. P. Constantinou and N. Papadouris

The rationale for a teaching innovation about the interrelationship between science and technology.

Science & Education, 2011, Vol. 20 (10), pp. 981 – 1005

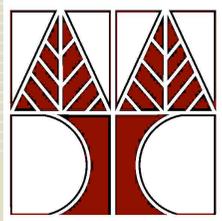
C. P. Constantinou, R. Hadjilouka and N. Papadouris

Students' Epistemological Awareness Concerning the Distinction between Science and Technology.

International Journal of Science Education, 2010, Vol. 32

(2) pp. 143 - 172.





DBR in accord with the complexity of teaching – learning: two illustrative aspects

- 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>

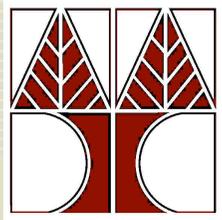
Funding:



Ίδρυμα Προώθησης
Έρευνας Κύπρου



European Commission
Marie Curie Actions



Methodological Alignment

E. Kyza, C. P. Constantinou and G. Spanoudis

Sixth graders' co-construction of explanations of a disturbance in an ecosystem: exploring relationships between grouping, reflective scaffolding and evidence-based explanations.

International Journal of Science Education, 2011, Vol. 33, No. 18, pp. 2489-2525.

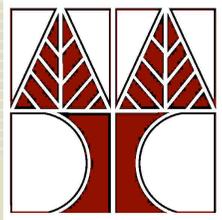
E. A. Kyza and C. P. Constantinou

A Design-Based Approach to Professional Development: The Need to See Teachers as Learners to Achieve Excellence in Inquiry-Based Science Education

In J. Zumbach, N. Schwartz, T. Seufert and L. Kester (editors) *Beyond Knowledge: The Legacy of Competence*, 2008, Springer, The Netherlands, pp. 173-181, ISBN: 978-1-4020-8827-8



STOCHASMOS



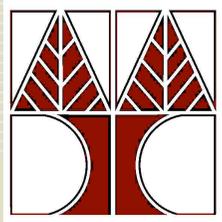
DBR: a constraint

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, SSE, 2014



Synopsis...

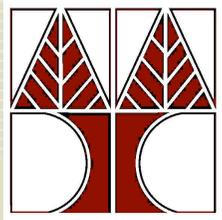
Discrediting theory is a symptom of the failure to facilitate rigorous (educational) enactments of coherent (teaching and learning) theory

- 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.

Team Learning as a pre-requisite to Practitioner Inquiries

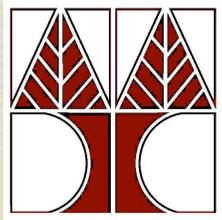


Synopsis...

As a community, we need to create the space for more critical reflection on ideas and educational enactments.

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

in promoting better quality teaching and learning



Thank you for your attention!

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