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The 18th edition of the Multimedia in Physics Teaching and Learning Workshop

COMPUTER SIMULATIONS TO TEACH PHISYCS IN SECONDARY EDUCATION. MAIN FEATURES FOR A SUCCESSFUL LEARNING.

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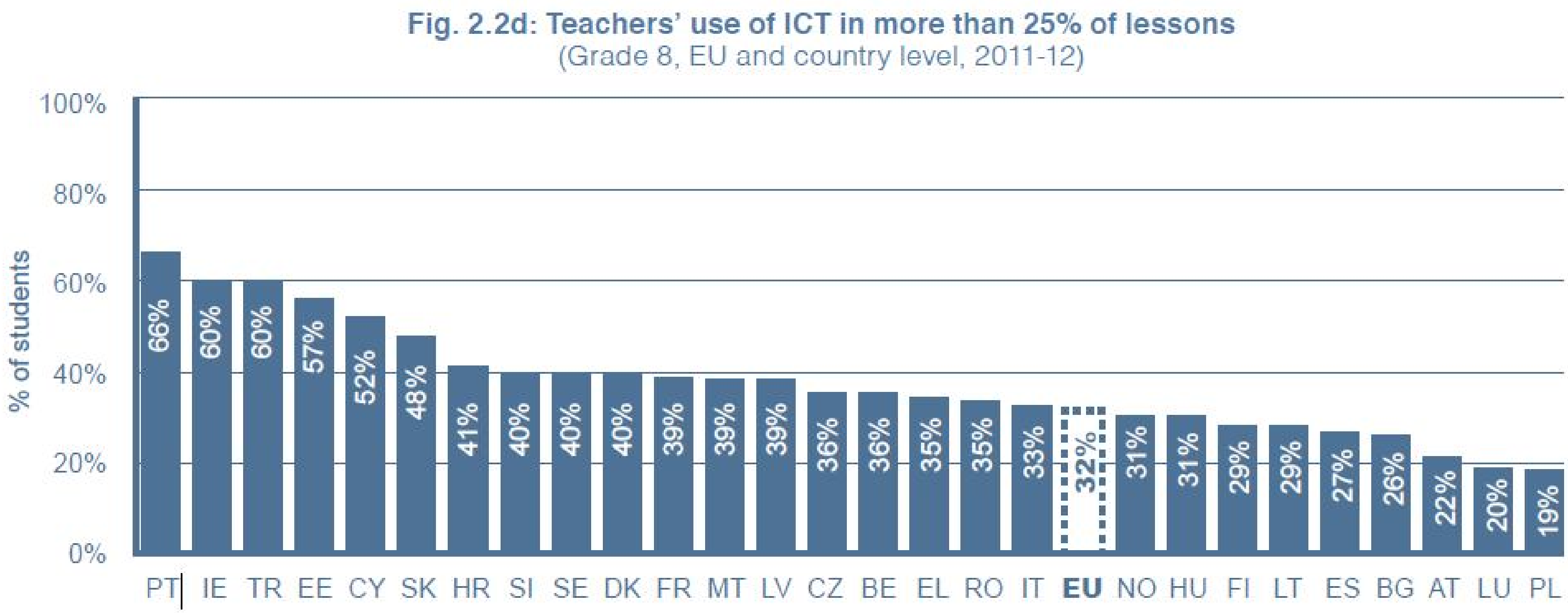
Survey of Schools: ICT in Education

BENCHMARKING ACCESS, USE AND ATTITUDES TO TECHNOLOGY IN EUROPE'S SCHOOLS

EUN.org February 2013

- There is **no correlation at EU level between level of computer provision in schools and frequency of use by students.**



2006 VS 2012

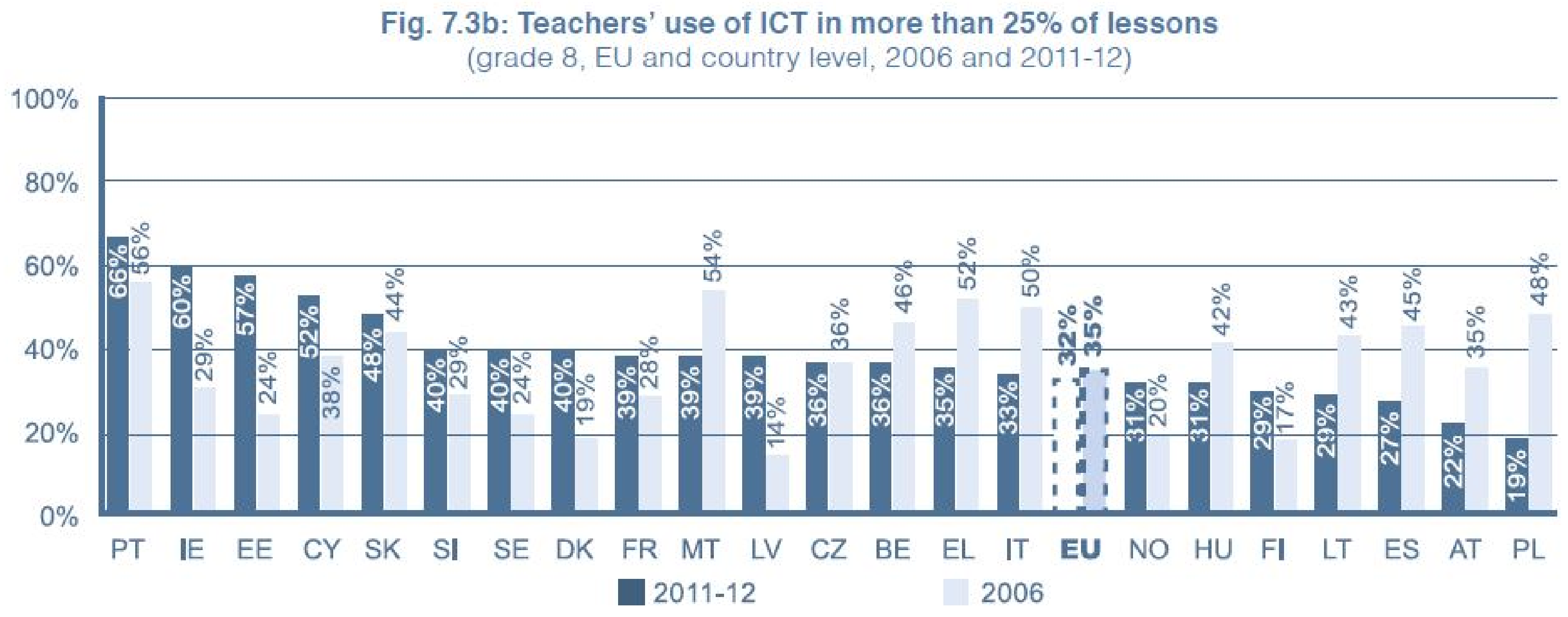
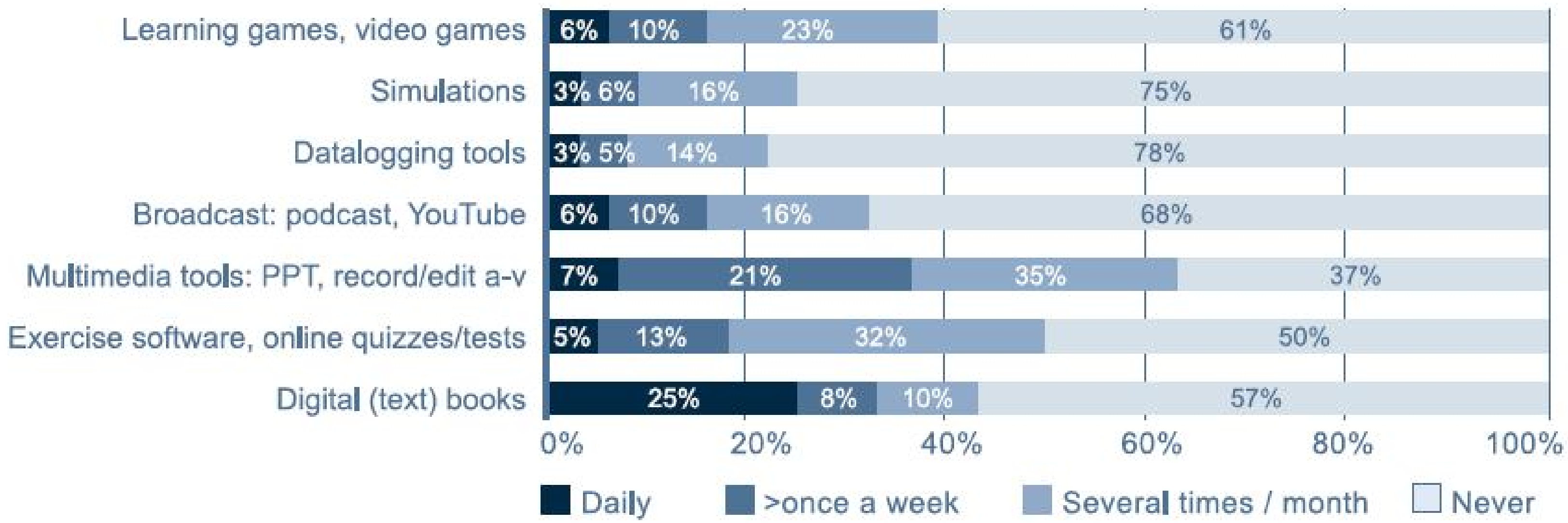


Fig. 7.3b: Teachers' use of ICT in more than 25% of lessons
(grade 8, EU and country level, 2006 and 2011-12)
100%
80%
60%
40%
20%
0%
PT IE EE CY SK SI SE DK FR MT LV CZ BE EL IT EU NO HU FI LT ES AT PL
66% 56%
60% 29%
57% 24%
52% 38%
48% 44%
40% 29%
40% 24%
40% 19%
39% 28%
39% 54%
39% 14%
36% 36%
36% 46%
35% 52%
33% 50%
32% 35%
31% 20%
31% 42%
29% 17%
29% 43%
27% 45%
22% 35%
19% 48%
2011-12
2006

- **Simulations and data-logging tools are very rarely used on a regular basis (daily or once a week)**.
- This situation could be the result of a **lack of existing good quality material** related to the curriculum**, insufficient information** provided to teachers, **lack of skills to use and integrate** them into teaching, or **lack of time** to become fully familiar with them and feel comfortable to use them in the classroom with the students.

Fig. 3.7a : Use of resources and tools during lessons at grade 8

(in % of students, EU level, 2011-12)



- But, what kind of use we want?
- http://www.youtube.com/watch?v=OINa46HeWg8&feature=youtu.be

- Thomas (2001), 12 years ago, proposed a way to incorporate ICT in education, highlighting:

- (a) pedagogy should be strongly informed by appropriate theoretical orientations,
- (b) the importance of models in science should be acknowledged in pedagogy and in software development,
- (c) developing students' metacognition during instruction involving computers should be focussed upon, and
- (d) teachers' and students' beliefs and epistemologies should be recognised as key factors in educational change involving computer implementation and use.

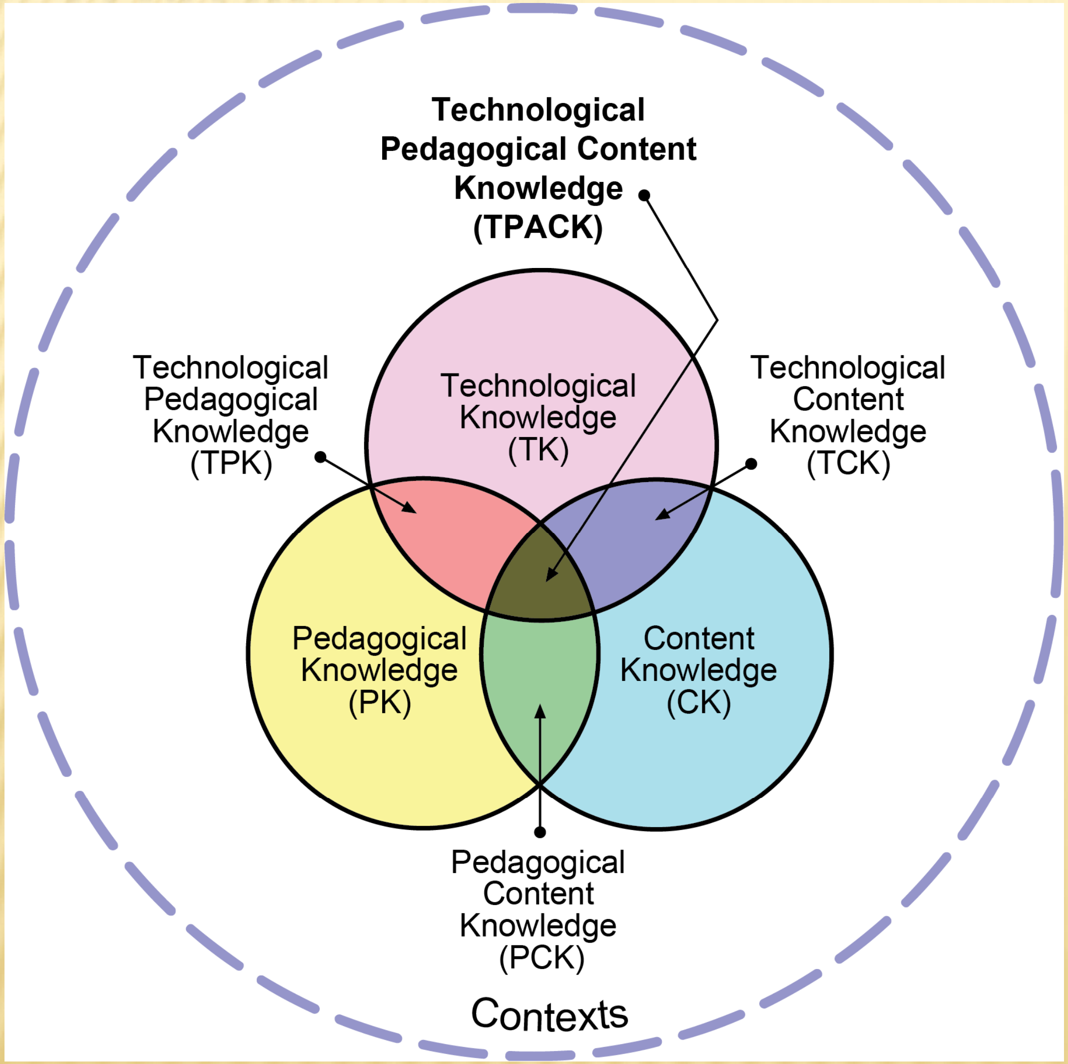
- Voogt (2012) proposes a way to integrate ICT in schools:

- “Four actions are called for which concern teaching and learning processes. They deal with the relationship between (1) ICT and 21st century learning; (2) restructuring schools to be able to use technology in addressing individual needs of students; (3) the need for new assessment structures to be able to measure outcomes of technology-rich experiences; and (4) the relationship between formal and informal learning experiences and its implications for formal learning.

- *Action 1: To establish a clear view on the role of ICT in 21st century learning and its implications for formal and informal learning*

- *Action 5: To develop and use models for teacher learning on technology use in schools and classrooms at the pre and in-service levels*

TPACK



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TPASK

Table 1
Pedagogical science knowledge (PSK).

Knowledge components	Descriptive components
Scientific knowledge	•Structure of Science (disciplinary) •Facts, theories and practices •History and Philosophy of Science •Nature of Science •Relationships among Science, Technology and Society
Science curriculum	•General purposes of Science Education •Specific learning goals for various units •Philosophy of Science Education Curriculum •Resources available
Transformation of scientific knowledge	•Organizing scientific knowledge (facts, theories, practices) •Multiple representations of scientific knowledge (pictorial, graphical, vector, mathematical) •Teaching Nature of Science •Teaching Science, Technology and Society
Students' learning difficulties about specific scientific fields	•Students' prior knowledge •Students' misconceptions •Students' cognitive barriers •Students' scientific method skills •Students' learning profile
Learning strategies	•Promoting student motivation and engagement •Using student experimental-practical work •Use of scientific inquiry •Use of scientific explanation •Use of constructivist approaches •Use of cognitive conflict situations •Use of conceptual change strategies
General pedagogy	•Knowing basic pedagogy •Developing pedagogical philosophy •Knowing pedagogical strategies
Educational context	•Educational purposes

Table 2
Technological science knowledge (TSK).

Knowledge components	Descriptive components
Resources and tools available for science subjects	•Simulations •Modeling tools •Spreadsheets •Conceptual mapping tools •MBL settings •Multimedia, encyclopaedias •Applications on the Web •Scientific Web resources •Web 2.0 applications
Operational and technical skills related to specific Scientific Knowledge	•Effective use of simulation software to model specific content (e.g. Interactive Physics, Modellus, Edison etc.) •Effective use of conceptual mapping software to model specific content •Effective use of MBL settings to support experimentation in specific subject content
Transformation of Scientific Knowledge	•Dynamic representations of specific scientific knowledge •Simulations of specific scientific knowledge (macroscopic and microscopic) •Virtual experimentation •Experimentation using MBL •Conceptual mapping in specific areas •Geospatial technologies in Geography (e.g. Google Earth) •Changes in Nature of Science
Transformation of scientific processes	•ICT-based problem solving approaches in science •New methods used to solve problems in science (e.g. using spreadsheets or modeling tools in physics) •New methods used to analyse experimental data •Modeling and simulation methods of specific content in physics, chemistry, biology (e.g. concepts, processes, principles)

Table 3
Technological pedagogical knowledge.

Knowledge components	Descriptive components
Affordances of ICT tools	•Knowledge of the pedagogical affordances of ICT •Knowledge and skills to identify pedagogical properties of specific software •Knowledge and skills to evaluate educational software •Ability to select tools supporting specific learning approaches
Learning strategies supported by ICT	•Supporting experimental-practical work •Use of constructivist approaches •Promoting student motivation •Fostering collaborative learning
Fostering scientific inquiry with ICT	•Use of scientific inquiry •Use of scientific explanation •Learning how to learn (autonomous learning)
Information skills	•Search and access of information in digital media (e.g. Web) •Analyse and evaluate scientific content in digital media
Student scaffolding	•Revealing and handling students' learning difficulties •Supporting students in conceptual change processes •Developing cognitive conflict situations for the students •Supporting students to develop information skills
Students' technical difficulties	•Supporting students to develop technical and operational skills for specific ICT applications •Supporting students to use modeling software in specific content

TPASK JIMOYIANNIS (2010)

Table 4
Components of the science TPASK curriculum.

Curriculum Components	TPACK framework	Teacher learning strategies
Introduction to basic technical skills on using ICT tools in science education (e.g. simulations, modeling, spreadsheets, presentation software, conceptual mapping, Web recourses etc.)	TK	Practical training, learning by doing, collaboration
Introduction to the affordances and the added value of ICT in science education (e.g. simulations, conceptual mapping, Web recourses etc.)	TSK	Classroom presentation, practical training, discussion, collaboration
Introduction to student-centered pedagogical approaches	PSK	Classroom presentation, discussion
Introduction to science education, including student pre-existing knowledge issues, misconceptions and learning barriers, cognitive conflict examples etc.	PSK	Classroom presentation, discussion, teacher practical knowledge, selected papers from the literature
Use of ICT-based existing educative curriculum materials (e.g. for different science topics and different ICT tools)	TPASK	Educative curriculum materials; debate and collaboration
Discussion of materials on practicality for classroom use	TPASK	Grounding learning in classroom practice, collaboration
Development of simulations for specific content by participating science teachers	TSK	Learning by design simulations (e.g. using Interactive Physics to simulate the trajectory motion of an object in the earth gravity field)
Study of how ICT can support specific pedagogical strategies and goals in the classroom (e.g. uses of simulations to foster inquiry learning)	TPK	Classroom presentation, discussion, selected papers from the literature
Discussion on specific software and environments and their uses as cognitive tools that enhance student learning in science	TPK	Grounding learning in classroom, practice and collaboration
Design and development of a complete simulation-based learning scenario by participating science teachers	TPASK	Learning by design
Design and development of complete learning scenarios by participating science teachers using various ICT tools (spreadsheets, conceptual mapping, MBL, Web Quests etc.)	TPASK	Learning by design
Science teachers' debating on their own educational materials with colleagues and their educators	TPASK	Grounding learning in classroom, practice and collaboration
Revision of the developed lesson materials based on feedback	TPASK	Feedback; debating with colleagues, educators' comments
Experimental teaching using their own lesson materials to their colleagues and the coordinator (micro-teaching)	TPASK	Feedback; debating with colleagues, coordinators' comments

THE HORIZON PROJECT

The six technologies featured in the *NMC Horizon Report: 2013 K-12 Edition* are placed along three adoption horizons that indicate likely timeframes for their entrance into mainstream use for teaching, learning, and creative inquiry.

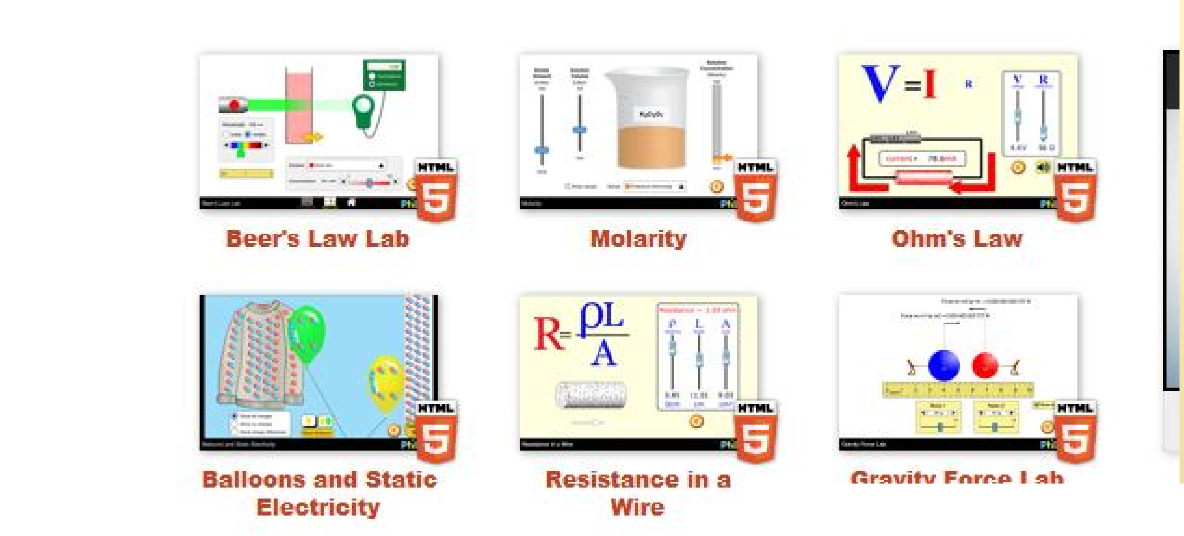
The NMC Horizon Project is currently in its 11th year, dedicated to charting the landscape of emerging technologies for teaching, learning, and creative inquiry in education globally.

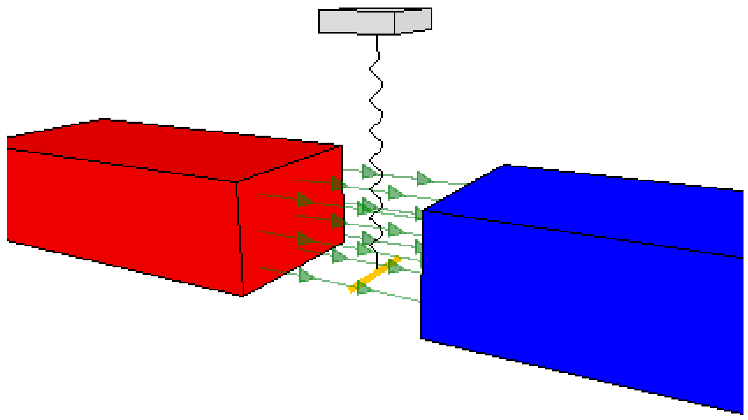
- <u>K-12 2013 report:</u>
- NMC Horizon Project Preview: 2013 K-12 Edition
- **Time-to-Adoption Horizon: One Year or Less**
- § Cloud Computing
- § Mobile Learning
- **Time-to-Adoption Horizon: Two to Three Years**
- § Learning Analytics
- § Open Content
- **Time-to-Adoption Horizon: Four to Five Years**
- § 3D Printing
- § Virtual and Remote Laboratories

Virtual and remote labs are often spoken of together as they both address the challenge of increasing access to authentic science.

Because these labs are designed to allow easy repetition of experiments, there is less pressure on students to execute perfectly the first time.

SIMULATIONS





Click on the image to start the applet.
Applet 'Lorentz force'.

file with the XML source code for this example. To inspect and run the example, you will need to have EJS installe

ADVANTAGES

- <u>Advantages for teachers:</u>
- the saving of time, allowing them to devote more time to the students instead of to the set-up and supervision of experimental equipment;
- the ease with which experimental variables can be manipulated, allowing for stating and testing hypotheses;
- and provision of ways to support understanding with varying representations, such as diagrams and graphs
- Aim for students: infer the features of the simulation’s conceptual model, which may lead to changes in the learners’ original concepts

THE GET THE BEST OF SIMULATIONS…

- Methodology must be IBL (Inquiry Based Learning).
- Simulations with traditional instruction don’t improve learning.

IBL

- Inquiry (de Jong, 2006):

- **The Inquiry Process**
- Inquiry learning mimics authentic inquiry.
- [There are some exceptions, such as the origin of the research question, the number of (known) variables, and the presence of flaws in data .

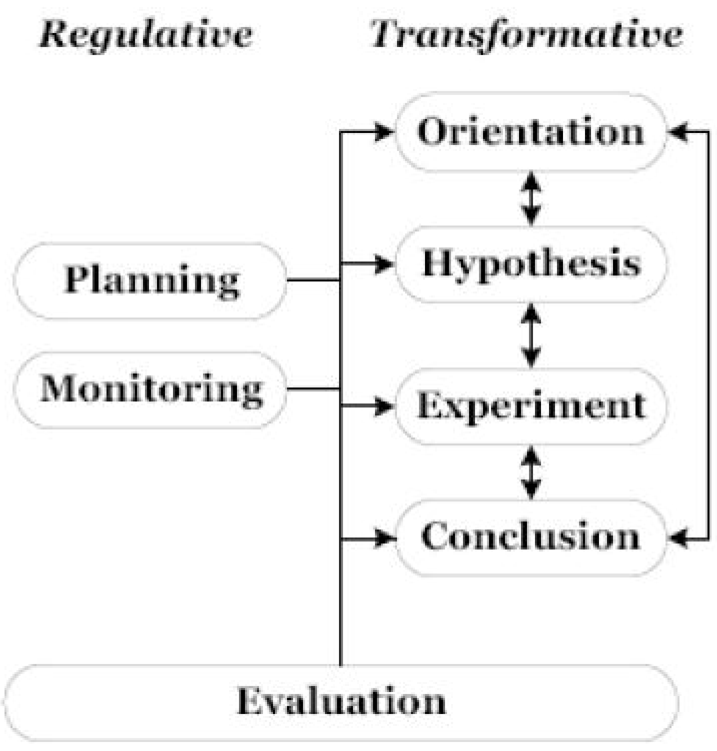


Figure 1. Processes of Inquiry (Manlove, 2007)

PROBLEMS

- However, research indicates that, overall, students have substantial problems with all of the inquiry processes listed before.

- Students have difficulty choosing the right variables to work with, they find it difficult to state testable hypotheses, and they do not necessarily draw the correct conclusions from experiments.
- They may have difficulty linking experimental data and hypotheses, because their pre-existing ideas tend to persist even when they are confronted with data that contradict those ideas.
- Students also struggle with basic experimental processes. They find it difficult to translate theoretical variables from their hypothesis into manipulable and observable variables in the experiment ; they design ineffective experiments, for example, by varying too many variables at one time; they may use an “engineering approach,” where they try to achieve a certain state in the simulation instead of trying to test a hypothesis; they fail to make predictions; and they make mistakes when interpreting data . Students also tend to do only short-term planning and do not adequately monitor what they have done . (de Jong, 2006)

POSSIBLE SOLUTIONS

- **Supporting the Inquiry Process**
- Research in inquiry learning currently focuses on finding scaffolds or cognitive tools that help to alleviate these problems and produce effective and efficient learning situations.
- Examples of cognitive tools are assignments (exercises that set the simulation in the appropriate state); explanations and background information; monitoring tools (to help students keep track of their experiments); hypothesis scratchpads (software tools to create hypotheses from predefined variables and relations); predefined hypotheses; experimentation hints (such as “vary one thing at a time ” or “try extreme values”); process coordinators (which guide the students through the complete inquiry cycle); and planning tools.

- Scalise et al. Looked at 79 papers about simulations and virtual labs focus on secondary education and only 3 (3.8%) showed no learning impromvemen. 20 (25,3% gave mixed results (some groups gain and others no), 14 showed better performance under several conditions (17,7%) and 42 (53,2%) gave better knowledge adquisition. Then, from this study, 96,2% of experiences gets some kind of improvement.

CATEGORIES FOR FEATURES (SCALISE ET AL., 2012)

- Software and hardware concerns of **interface** and infrastructure: Aspects of the software, hardware or interface that were found important to address for learning outcomes.
- **Representations** and media concerns: How visualizations are represented on the screen can be important.
- Scientific standards and concerns of implementation related to simulations and virtual labs: This included **guiding** students in practicing active and extended scientific inquiry; **peer** collaboration and working with others to enhance scientific process; understanding and responding to **individual** students; and continuously **assessing** understanding.

‘‘EFFECTIVE INTERFACES’’

- Focal points:
- Do NOT use step-by-step instructions trough-out the simulation or virtual lab.

- Cognitive load:
- Start with basic attention to standard interface usability characteristics. Note that for science simulations in particular, the interface should allow representations and text to be integrated where appropriate.
-
- Scaffolds:
- Employ effective scaffolds to promote learning, including teaching and encouraging students to use help functions. Basic approaches to scaffolding can include “hover” labels that appear when moused over, and clickable links to provide information.

- Hybridization:
- Do NOT use exclusively computer-based laboratory instruction. Be sure in constructing and using materials to consider when to go beyond the simulation interface and the virtual experiences.

- Infrastructure:
- Vendors should identify appropriate hardware and software for product use. Software should be reliable and platform independent. Purchasers should have what is needed.

‘‘POWERFUL VISUALIZATIONS’’

- Sense-making:
- Simple graphics with less detail can be more effective than realistic representations. Additional detail and realism can be added as students sense-making ability improves.

- Unbinding Constraints:
- In general, simulations that unbind physical constraints (size, time, energy, toxicity, waste, cost, etc.) can be especially helpful in schools.

- Differentiating Instruction:
- Allowing users to stop, start and replay visualizations as needed can allow reinspection and aid learning.

- Relevance:
- Simulations should be connected with real world target applications, and students should also explore these off-line and hands-on.

- Interpretation:
- Explicitly ask students to interpret, compare and control displays.

"ILLUMINATING INQUIRY"

- Scientifically Oriented Questions:
- Active inquiry includes identifying the study problem and writing hypotheses, so don't pose questions simple as a "given". Avoid "cookbook" science BUT have a clear purpose, ensure students know what it is, and include assessments with measures of knowledge.
- Priority to evidence:
- Students collects data, make observations, influence results, and apply information while using simulations. This includes setting and observing parameters, operating virtual equipment, and recording data. Software or teacher should model good practices.
- Design and Conduct Investigations:
- Make sure students recognize experimental outcomes as clues to scientific phenomena. Link quantitative data with conceptual displays. Include learner decision-making beyond software control, and sufficient procedural info.
- Formulate/Evaluate Explanations:
- Scaffolds are necessary to relate observations/conclusions to plausible explanations. Systematization in confirmation of hypothesis is necessary to avoid wrong conclusions.
- Communicate & Justify Findings:
- Epistemological beliefs can lead students and teachers to think truth is received from an authority figure rather than explored based on evidence. Justification helped students "think like scientists".

TECHNIQUES FOR GUIDANCE IN SIMULATIONS

- Incorporate Explanations
- Encourage Reflection
- Manage Complexity
- Optimize Interface Fidelity
- Provide Instructional Support

(Clark and Mayer, 2008)

SCAFFOLDING FOR INQUIRY BASED LEARNING

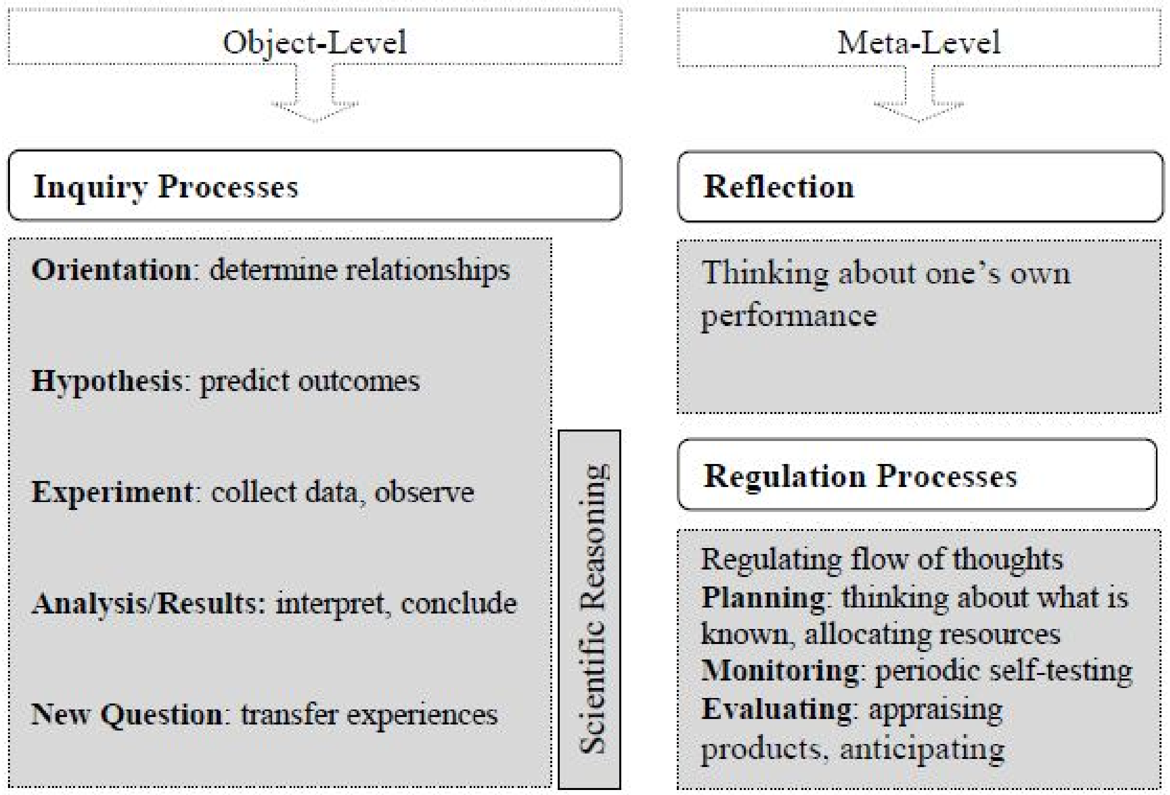


Figure 3. Processes During Inquiry Learning

TYPES OF SUPPORT (WICHMANN, 2010)

Table 2. Types of Support

Types of Support	Examples
Inquiry Support	*Basic:* Pre-defined workflows, pre-defined goals (Manlove, 2007) *Advanced:* Pre-structure for specific inquiry tasks in form of template (de Jong & Njoo, 1992), e.g., to facilitate the formulation of a syntactically correct hypothesis (Chen & Klahr, 1999).
Explanation Support	*Meta-level support:* Prompting or requests for explanations → provoking thought
Regulation Support	*Meta-level support:* Prompts and hints for planning, monitoring and evaluation → regulating flow of thought

ABOUT VIRTUAL LABS VS PHYSICAL LABS

- Students are observed to have several general problems in a physical laboratory. Hofstein and Lunetta (2004) indicated that students are often occupied by manipulating materials and procedural issues, and do not pay as much attention to elaborating on the underlying theory or constructing concepts. Moreover, a high percentage of students manipulate irrelevant variables (van Joolingen & de Jong, 1991) or pay unnecessary attention to trivial matters such as the colors of the wires in simple DC circuits (Finkelstein et al., 2005). Furthermore, students usually focus on getting desirable results, and fail to utilize the complete experimental information or think deeply into the underlying theories (Schauble, Klopfer, & Raghavan, 1991). VLs can considerably reduce these distractions/drudgeries by constraining the learners' interaction with the learning environment or scaffolding an optimal inquiry path for the learners. Almost all published VLs for K-12 have been designed in accordance with these principles.

NEXT STEPS...

- Design didactic sequences to try these features.
  - Graphs and movements
  - Bouyancy
  - Electric circuits

- Thank you for your attention!

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