University of Palermo – Physics Education Research Group

Inquiry Based Science Education & Responsible Research and Innovation in the classroom

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Summary

Responsible Research and Innovation (RRI)

Inquiry Based Science Education (IBSE)

“Traditional” Science Education and “Inquiry Based Science Education”

The “5E model” in IBSE and the 6E model

Various IBSE approaches

Some examples of IBSE and RRI in the classroom :

The IRRESISTIBLE and ESTABLISH EU Projects

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Science and Technology in Society

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Science and Technology in Society

Why?

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Science and Technology in Society

Why?

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Science and Technology in Society

What?

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How?

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Science and Technology in Society

The European Commission's "Science and Society" Program, born in 2007, addressed the involvement from a variety of perspectives, such as encouraging dialogue between scientists and other members of the public, promoting ethical standards, developing tools to allow everyone to access the research results.

The SiS program also supporteds new ways to engage young people in science and careers and new ways to achieve better gender equality in the scientific sphere.

from: http://ec.europa.eu/research/science-society/index.cfm?fuseaction=public.topic&id=1223&lang=1

A new idea…

Responsible Research and Innovation

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Responsible Research and Innovation

An evolving concept...

The forerunners (near and far)

The Italian Constitution (1948)

« Private business initiative is free. It can not contradict social utility or damage security, freedom, and human dignity. The law sets the appropriate programs and controls so that public and private business can be addressed and coordinated for social purposes. **» (**Section 41)

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An evolving concept...

The forerunners (near and far)

The business world (business, corporations)

FROM A PURELY ECONOMIC APPROACH TO A MORE "ETHICAL" ONE

- *Shareholders theory*, 1970
- *Stakeholders* theory (all the concerned people, even potentially), 1984
- Union for an Environmental Responsible Economy, Principles (*CERES Principles*), 1989
- *Business for Social Responsibility* (BSR), 1992
- *Global Reporting Initiative*(*GRI*), 1997
- *Triple Bottom Line* (anche *3BL*), 1998
- *AA1000 AccountAbility Framework Standards*, 1999
- *Corporate Social Responsibility* (Responsabilità Sociale d'Impresa) ~2000
- *Sustainability Reporting Guidelines*, 2000
- *AA1000 Stakeholder Engagement Standard*, 2005
- (Principle of inclusivity & Stakeholders Engagement)

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Responsible Research and Innovation

The term "Responsible Research and Innovation" was initially debated within the European and Anglo-American communities concerned with **the policies of Science, Technology and Innovation**. The RRI is part of a general approach to governance in science and technology that aims at linking the impact of innovation with the questions and values of society.

from Technopolis Group – Fraunhofer ISI December 2012

"First Producers" of Research and Innovation*:*

Universities and Companies involved in Technological Development

"Intermediaries" for the Production and Distribution of Research and Innovation:

Providers of financial instruments, information and communication technology experts, public policy makers, responsible for community innovations in the areas of distribution, services or system

RRI ≡ To connect the involved communities

Private Groups and Non-Governmental Organizations *:*

Business and business community; Groups interested in sustainable development, Defense of human rights, Consumer protection

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Responsible Research and Innovation

RRI is a process through which all the "actors" of society (researchers, citizens, politicians, industry ...) work together during all Research, Development and Information activities to align Research and Development to the values and expectations of the Civil Society

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Responsible Research and Innovation

Starting from 2012, within the framework of 2014-2020 planning, the European Commission uses the term "Responsible Research and Innovation" (RRI) to conceptualize the challenges already tackled in the SiS theme. Therefore, RRI can be considered as an evolution of the FP7 SiS line that leads to transforming the themes pursued by the SiS programs into the underpinnings of Horizon 2020, the program that replaced the previous 7th Framework Programs (FP7)

Currently in Europe, the European Commission is an important supporter of the RRI concept within the European Research Area. Behind the concept of RRI is the idea of increasing European growth and creativity by evolving European research and innovation processes towards greater inclusiveness and making all actors responsible for developing appropriate solutions to European social challenges.

from Technopolis Group – Fraunhofer ISI December 2012

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A REPORT ON RESPONSIBLE RESEARCH & INNOVATION

HILARY SUTCLIFFE, DIRECTOR, MATTER

(ON THE BASIS OF MATERIAL PROVIDED BY THE SERVICES OF THE EUROPEAN COMMISSION. PREPARED FOR DG RESEARCH AND INNOVATION, EUROPEAN COMMISSION)

Report (“*a new 'action tank' dedicated to having new technologies work for us all*”) commissioned by the European Commission for Research and Innovation (DG RDT) to the private agency MATTER in order to obtain a "Brief and easily understandable“ view of the state of the art of this new field.

MATTER's director, Hilary Sutcliffe, signs the Report as a product of her own thinking, not necessarily shared nor by the European Commission, or by the Businesses Group or by the MATTER Steering Group.

http://ec.europa.eu/research/science-society/document_library/pdf_06/rri-report-hilary-sutcliffe_en.pdf

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Responsible Research and Innovation

Which activities can be considered RRI?

1. Activities that highlight the environmental and social benefits of scientific innovation
2. Activities to inspire the active involvement of the society components
3. Activities that focus on social, ethical and environmental issues
4. Activities to apply openness and transparency in research and innovation processes
5. Activities involving interested parties in active construction of conscious scientific knowledge and information exchange

Engagement **Gender Equality** **Inquiry Based Science Education** **Ethics** **Open Access**

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Inquiry Based Science Education

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Inquiry Based Science Education

An approach to Teaching / Learning Science through the application of scientific investigation strategies

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But what is actually meant by scientific inquiry?

“ A systematic process aimed at obtaining descriptions and explanations of the natural world phenomena, making them more and more adherent to what really happens around us ”

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A fairly common definition of IBSE found in the literature is the one given by Linn et al. (2004):

Inquiry is a deliberate process of **:**

- Diagnosing problems
- Critically analyzing situations
- Distinguishing among various possible alternatives
- Planning study and exploration activities
- Building conjectures
- Searching for information
- Constructing models
- Comparing ideas in a peer-to-peer context and elaborating coherent arguments

Linn, Davis, & Bell, 2004; Internet Environments for Science Education, Lawrence Erlbaum Associates

"Inquiry“ is, therefore, an active exploration process

Through it, critical, logical and creative skills are put in place to ask questions about situations of specific interest and engage in answering these questions

The Inquiry process helps to connect previous knowledge with new experiences, to modify and accommodate preconceived ideas and conceptual models, and to build new knowledge. (from Douglas Llewellyn, 2002)

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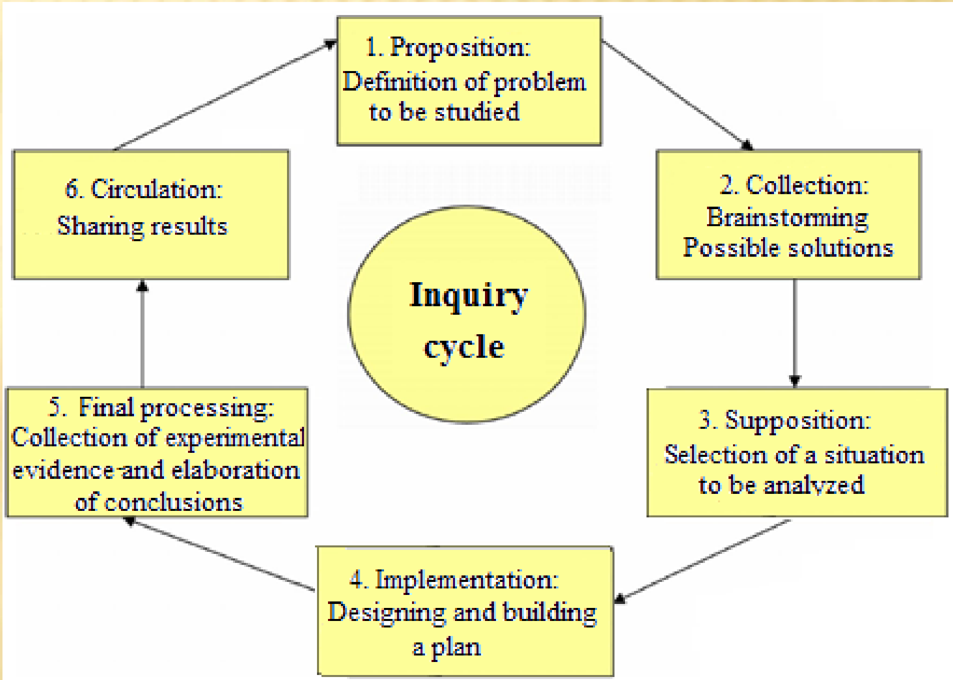
D. Llewellyn, *Inquiry Within: Implementing Inquiry-based Science Standards* (Corwin Press, Inc. Thousand Oaks, California, 2002

The National Science Education Standards (NSES), developed by National Research Council USA in 1996(www.nap.edu),

They refer explicitly to the typical mode followed by scientists to do research, defined as a "inquiry cycle", which can be represented in different idealized forms, such as those shown in the following figures:



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The National Science Education Standards (NSES), developed by National Research Council USA in 1996(www.nap.edu),

In NSES it is also stated that students of all school levels can greatly improve their learning by conducting research-like activities and understanding the methods through which scientific research is developed (p. 105):

” Scientific Survey is a basic activity for science teaching itself and is a founding principle for organizing and selecting student activities. ... Students of all school levels should be allowed to use scientific inquiry and to develop the ability to think and act through the methods associated with scientific investigation. “

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I *National Science Education Standards* (*NSES*), elaborati dal National Research Council USA nel 1996 (www.nap.edu),

Ask questions

Plan and conduct surveys

Use the most appropriate techniques and tools to collect data

Think critically and logically about the relationship between experimental evidence and its explanations

Build and analyze alternative explanations

Communicate, in a peer-to-peer context, scientific arguments

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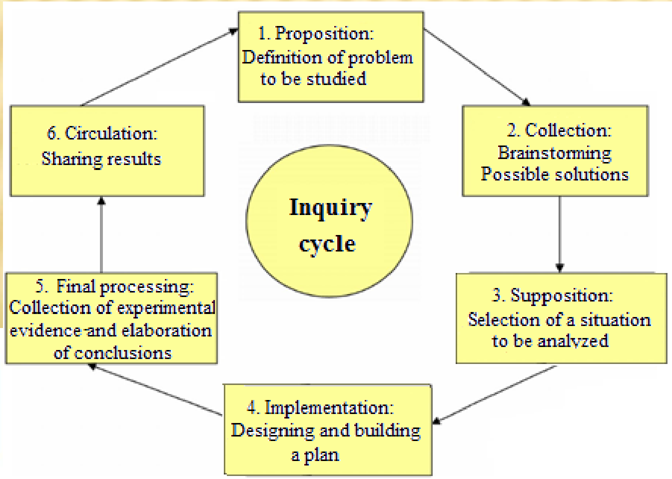
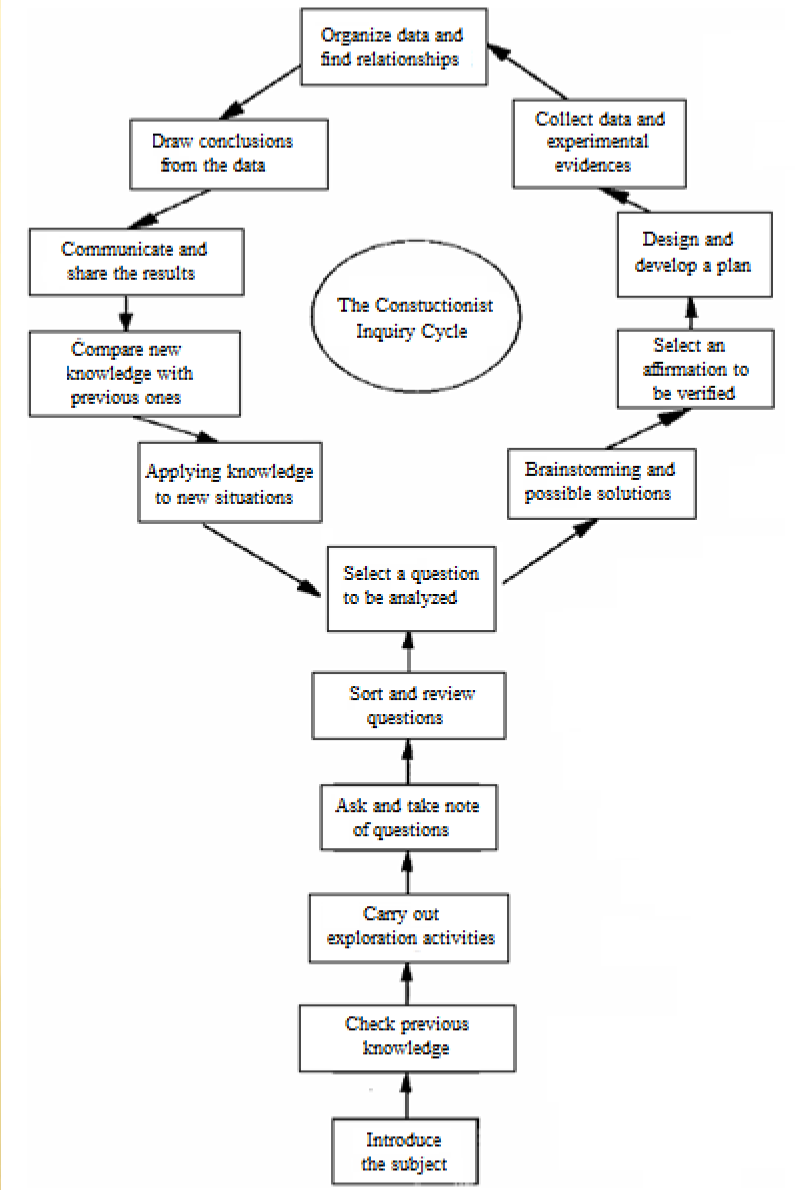
According to many authors who report about learning results based on scientific research, the basics of "Inquiry Based" methods must be sought in constructionist pedagogy(see, for example, D. Llewellyn, 2002; Inquire Within, p. 47).

Theories of constructionist learning define learning as a progressive and strongly contextualized process.

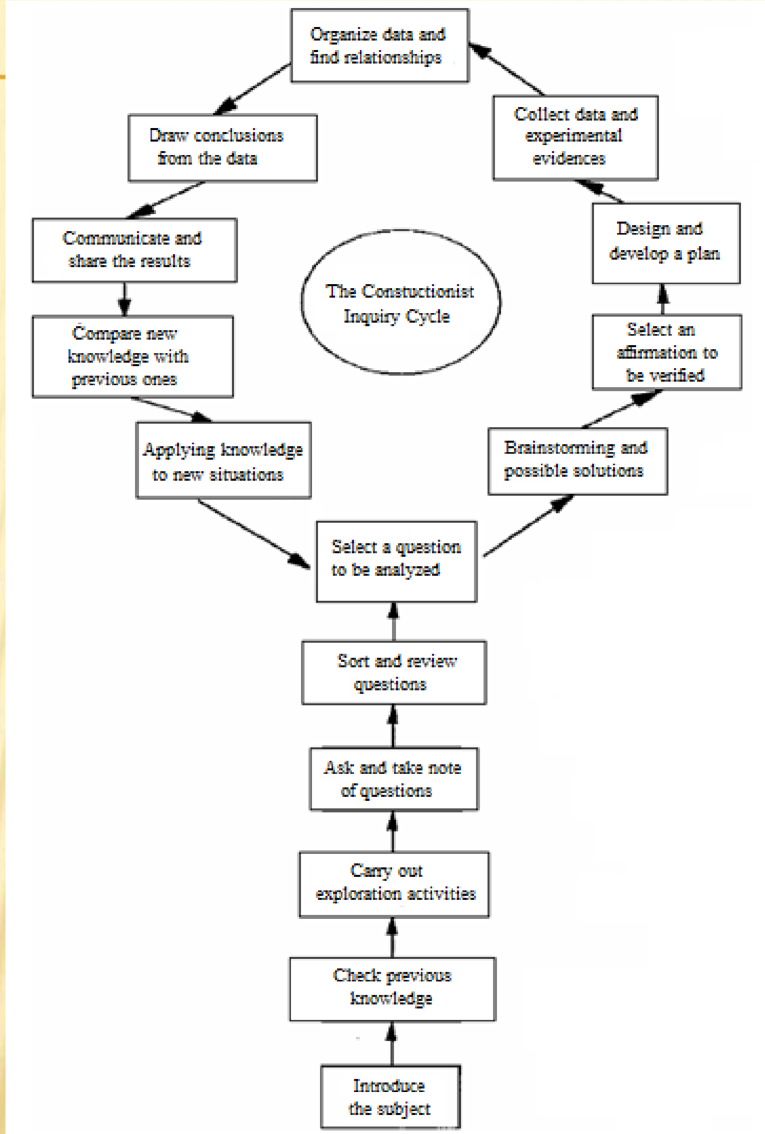
As shown in the figure on the right, which can be considered an extension to the one we already mentioned, each step corresponds to different opportunities for students to seek and build meaning from the real world experience and from reflection on it .





Through such an approach, students build their explanatory mental models while trying to reflect on their own experiences.

The construction of these models ultimately allows learners to develop cognitive skills and other skills that will be valuable throughout their lives.



Just as Scientific Investigation is intended to give answers to the questions scientists are posing, inquiry-based learning is designed to enable learners to build responses to their own questions through a clear and (possibly) rigorous scientific methodology

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The “ 5 E “ Model (Bybee, 1993)

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

The“ 5 E “ Model (Bybee, 1993)

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http://www.nasa.gov/audience/foreducators/nasaeclips/5eteachingmodels/

The“ 5 E “ Model (Bybee, 1993)

In the "**Engage**" phase, the teacher (and/or students, depending on the type of IB activity) set up the learning environment to intercept as much as possible the student's interest and generate curiosity and interest in the topic

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

The" 5 E " Model (Bybee, 1993)

"**Explore**" is the beginning of the real engagement of students in IB activity. They seek information, possibly (and hopefully ...) ask questions, develop hypotheses to be verified, collect data.

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

The“ 5 E “ Model (Bybee, 1993)

The "**Explain**" phase is the one in which students build models (descriptive or explicative), discuss the results among them and with the teacher and learn to share and communicate what they have learned.

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

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The“ 5 E “ Model (Bybee, 1993)

In "**Extend**“ students enrich the concepts and ideas they have developed before, build relationships with other concepts and ideas first and try to apply their understanding to different phenomena, generalizing their knowledge.

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

The" 5 E " Model (Bybee, 1993)

During the "**Evaluate**" phase which, in spite of its position at the end of the "5E" list, should be carried out throughout the course of IB activity, students and teachers carry out an evaluation of their work.

Students analyze, judge and evaluate their results, comparing them with what was done by their comrades.

This last phase is the one that allows the teacher to determine the effectiveness of IB activity in shaping a "meaningful and authentic" knowledge in students.

R. W. Bybee, An instructional model for science education, in *Developing Biological Literacy* (Biological Sciences Curriculum Study, Colorado Springs, CO, 1993).

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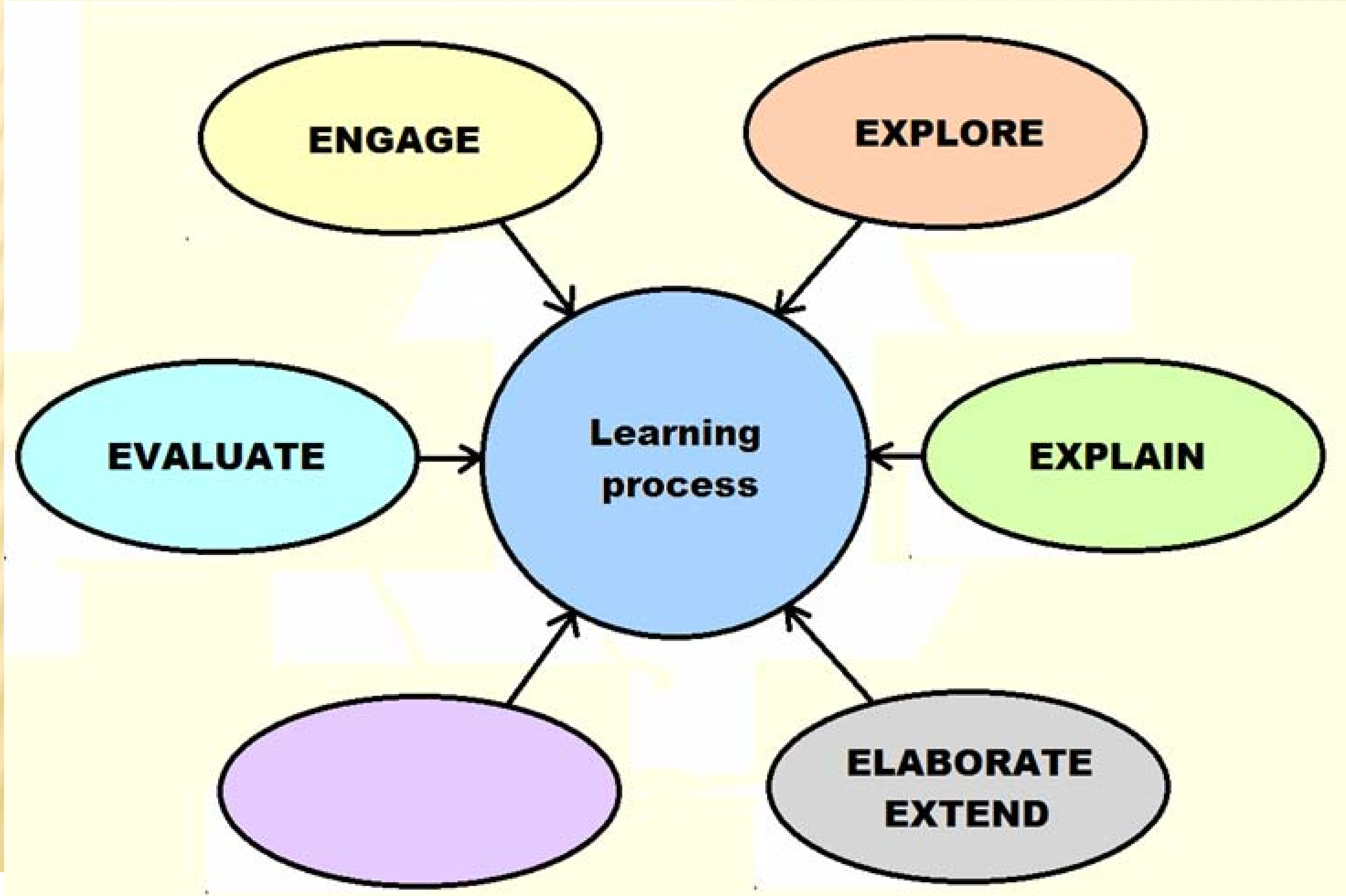
From 5 E to 6 E



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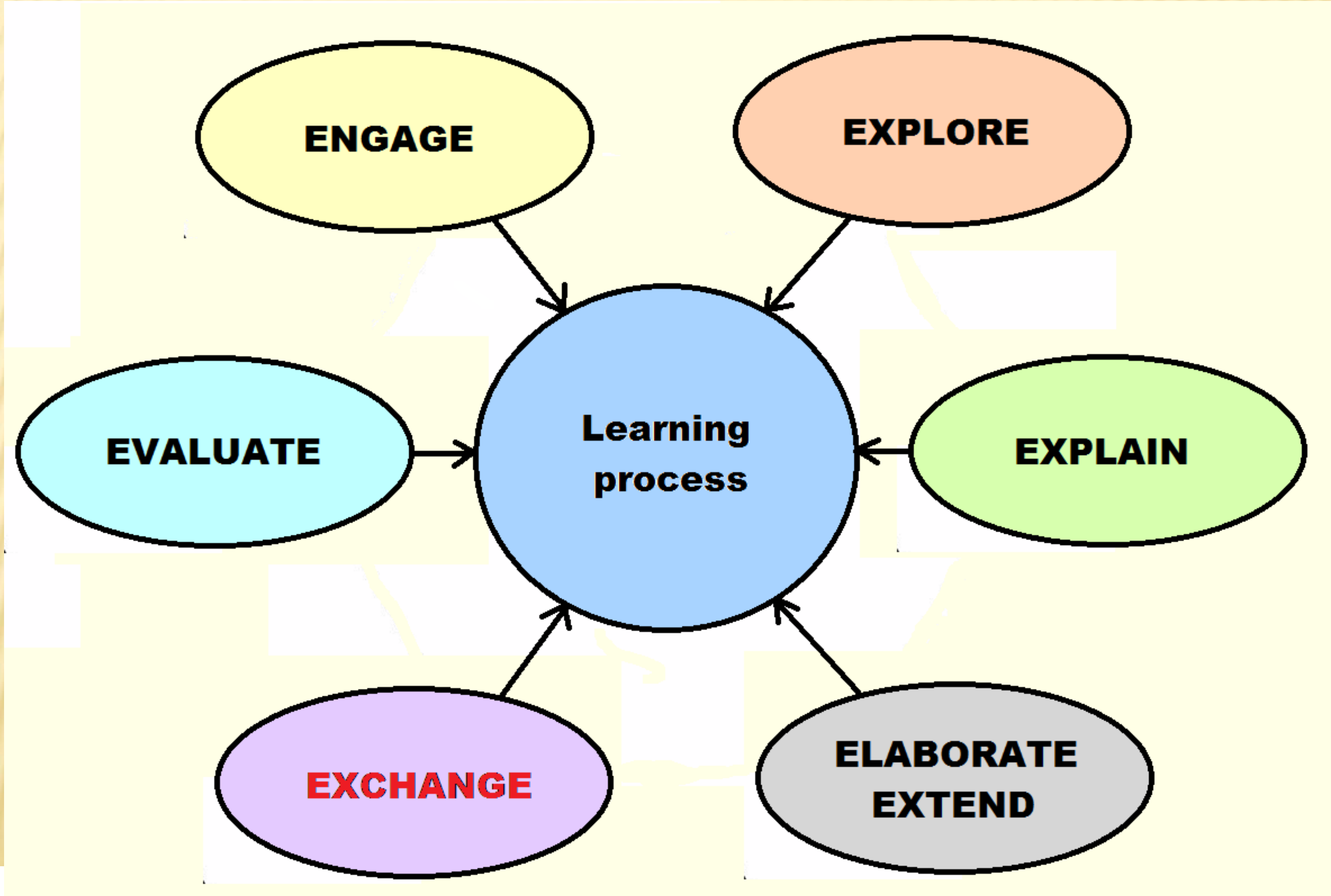
From 5 E to 6 E



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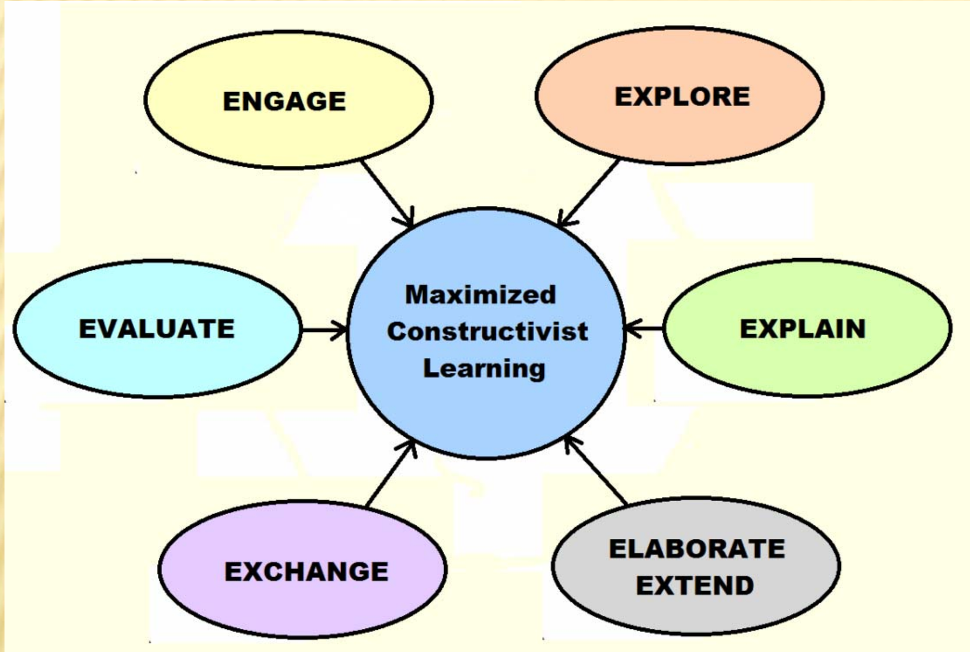
From 5 E to 6 E



The "**Exchange**" phase engages the students in designing and developing a scientific exhibit.
In this phase, the above procedures will be applied again (ask questions, build arguments and explanations, analyze alternative options based on results, communicate scientific arguments), to transform science from process to product (Hawkey 2001) and maximize the effect on students learning.

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R. Hawkey, Innovation, inspiration, interpretation: museums, science and learning, Ways of Knowing Journal, 1(1), 2001.

What's really new in the use of Sciecific Inquiry Strategies compared to the traditional lab-based science teaching?

Traditional teaching approach	Inquiry-Bases Teaching
The teacher is the primary provider of information	The teacher facilitates the search for information, which is mainly done by students
In the lab, students are mainly engaged in verifying physical laws and models	Students build (at different levels) their work plan
Students work in groups under the guidance of teaching material provided by the teacher	In the lab, students focus their attention on collecting, processing and analyzing the data required by their plan
The final construction of "knowledge" is always entrusted to the teacher	Students draw new conclusions and formulate principles, and laws from the data

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Students’ role in Inquiry-Based educational activities

Students:

are committed to answering questions that lead them to empirical research, to gather and use data to develop explanations for the scientific phenomena they are studying;

give particular importance to experimental evidence and use it as a starting point for building explanations of natural phenomena;

build models aimed to answer science-oriented questions and, as a consequence, build high-level cognitive skills;

communicate and discuss, in a peer context, their explanation models, developing critical information review skills, crucial at all times in their future life.

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Teachers’ role in Inquiry-Based educational activities

Teachers:

plan a scientific inquiry program for their students by selecting strategies that support student understanding and building a learning community by choosing content and contexts that may meet students' interests, skills, and experiences;

facilitate learning, focusing on scientific research, organizing working groups and discussions, challenging students to accept and share the responsibilities associated with their own learning, recognizing diversity among learners and enhancing them;

activate continuous assessment strategies of their teaching and student learning, trying to constantly inspect student understanding, guiding student self-evaluation, reflecting and improving teaching practice;

manage learning environments by structuring student work times, setting work to support scientific inquiry, identifying resources in and out of school and making these resources accessible to students;

encourage the development of communities devoted to scientific learning in their classes, highlighting the different ideas, skills and experiences of learners, entrusting students with responsibility, facilitating collaboration between students.

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But are all educational activities based on Inquiry the same?

It is possible to introduce a sort of "hierarchy" into inquiry-based teaching activities, based on the level of intellectual sophistication and student participation

Level 1: Interactive demonstation

The teacher conducts the scientific demonstrations and manages the experimental apparatus, but asks questions to the students, asking for predictions about what may happen by operating in a certain way and asking for explanations of what has been observed. In this way, he/she tries to lead the students to the construction of correct scientific conclusions.

In such an activity, Inquiry is mainly related to the answers and explanations given by the students.

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Level 2: Guided Discovery

Similar to Interactive Demonstrations but, in this case, students conduct the experiments previously introduced by the teacher.

This is basically a traditional laboratory activity conducted under the guidance of a worksheets given by the teacher and containing instructions for conducting the experiments. In order to develop communication skills in learners, the laboratory work is divided in "small group“ and "large group" activities. During the latter, great importance is given to the critical review of information obtained from small group work and information previously communicated by the teacher.

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Level 3: Guided Inquiry

In this case, students work in small groups on experiments identified by the teacher based on well-defined goals: "Find this ...", "Determine that ...".

There is no predetermined response or result and the conclusions are based only on the students' results. However, students are provided with hints and instructions on how to operate with the lab tools, and the teacher can guide activities through questions and problems to be posed while developing activities.

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Level 4: Bounded Inquiry

Similar to Guided Inquiry, but in this case, students are expected to plan and conduct the experiment with little or no guidance from the teacher and limited pre-laboratory preparation. The research problem to be solved is provided by the teacher but the students are responsible for designing and conducting the work, collecting data and building descriptions and explanations of what it is observed

Level 5: Open Inquiry

At this last level, it is expected that student will propose and develop their own research questions and design and assemble their experimental apparatus.

It is evident that this is an activity for students with proven IB experience and skills. Example: "Set up a study aimed at sound analysis or speech recognition". Students will be able to compare high and low tones, male and female voices, sounds produced by musical instruments, noises, etc.

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Some examples in the classroom …

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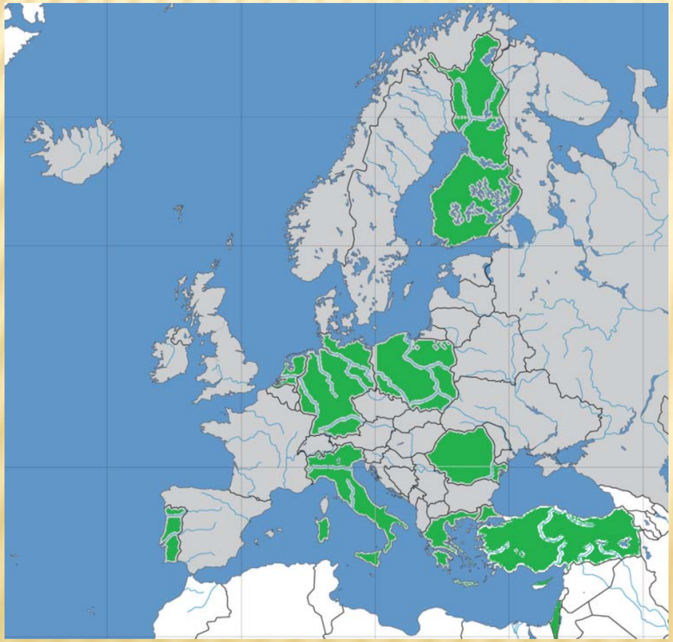
The FP7 “IRRESISTIBLE” Project

14 Universities and Science Museums from 10 European Countries, for a 36-month commitment starting from November 2013



To promote and develop RRI through the construction and testing of IB teaching/learning pathways in Secondary Schools and in Science Museums

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The FP7 "IRRESISTIBLE" Project

In Palermo ...

Phase 1: Creation of a Community of Learners (C.O.L.) made by university researchers and Secondary School teachers. Development of a Teaching/Learning pathway on Nanotechnology and "Sustainable" Solar Power Generation. Pilot trialling of the pathway with Secondary School students

Phase 2: C.O.L. spreading out and dissemination of the pathway with all the students of the schools involved.

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The FP7 "IRRESISTIBLE" Project

Structure of the T/L pathway

- Pre test — Engage
- Introduction to RRI and discussion — Engage
- Sustainability of energy transformation processes — Engage
- Experimental activities on thermal and electrical effects of light in a university lab — Engage- Explore- Explain- Elaborate.
-

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The FP7 “IRRESISTIBLE” Project

- Research activities on renewable and non-renewable energy sources. Explore- Engage
- Production of materials and sharing. Elaborate
- Assembling a "Graetzel Cell" and measurements. Explore
- Preparation and presentation of a exhibit to a "Science Fair“. Elaborate-Exchange-Evaluate
- Post test. Evaluate

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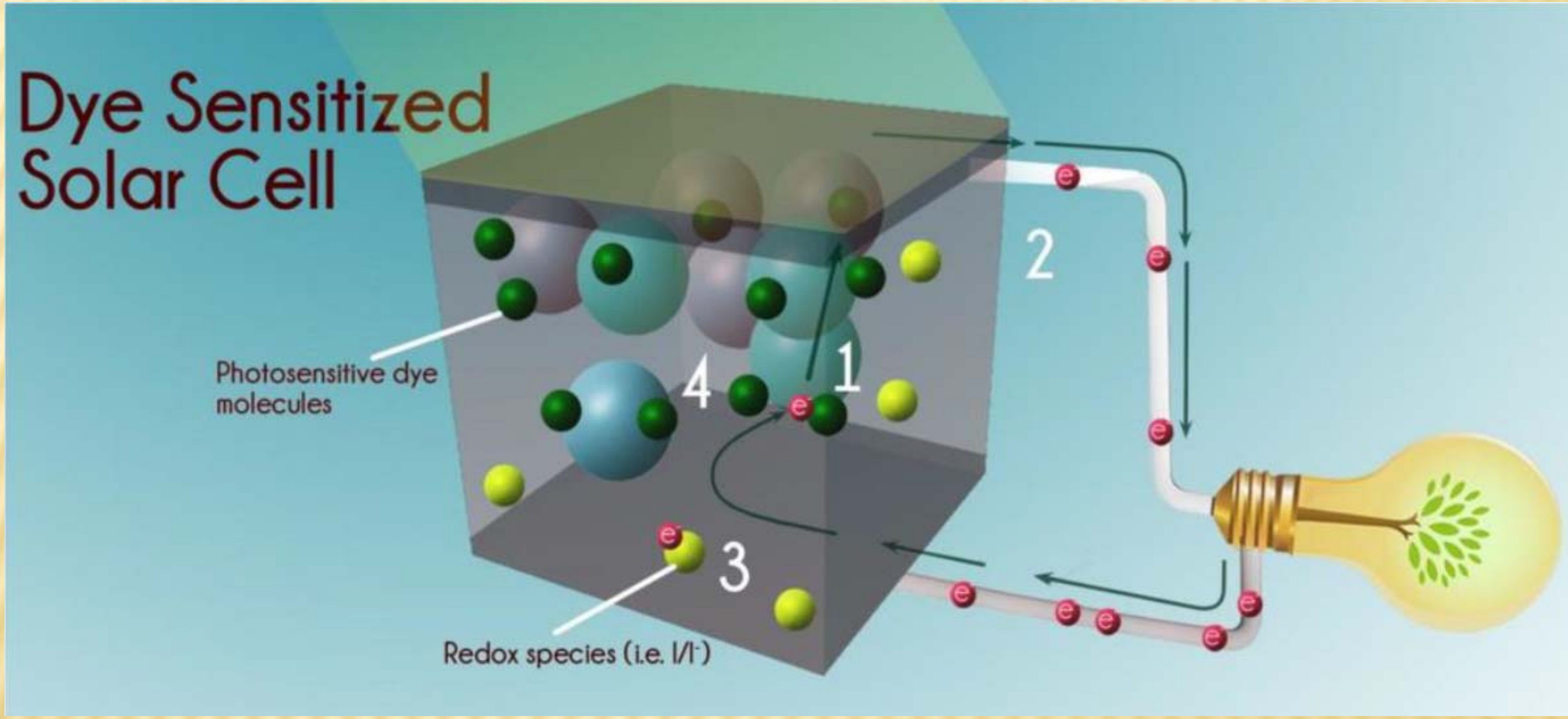
A Sustainable Solar Cell: Graetzel Cell or "Dye Sensitized Solar Cell"



Grätzel cells (or DSSCs or DSCs) are particular photoelectrochemical cells consisting of two conducting glasses, which act as electrodes, separated from the active material and the electrolytic solution by a layer of titanium dioxide (TiO2),.

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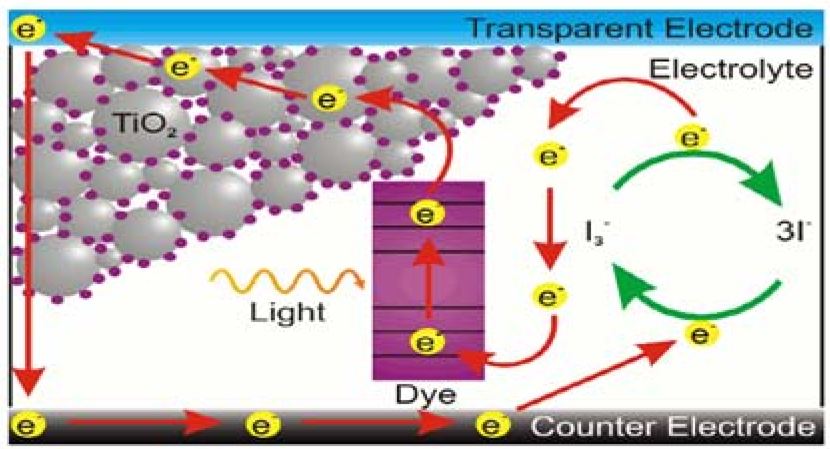
The FP7 “IRRESISTIBLE” Project

The active material is a dye which transfers electrons to titanium dioxide following absorption of photons.

TiO2 is a semiconductor, used as a base on which a large number of dye molecules are bound. To improve performance, the TiO2 layer is heated in a furnace to form a structure with nanostructured porosity to increase the surface to which the dye can be fixed, increasing the active area.

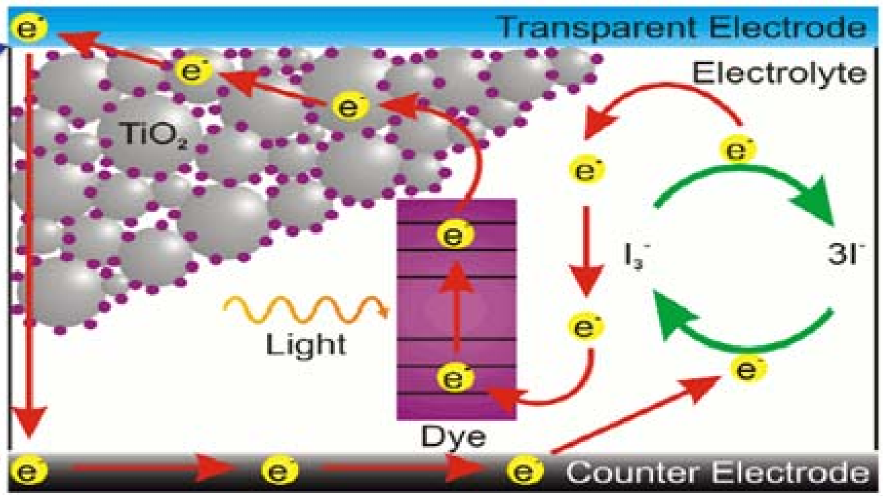


- A dye is adsorbed by porous titanium dioxide
- A dye molecule absorbs a photon forming an excited state (dye*)
- The excited state can be thought of as an electron-hole pair (exciton)

The FP7 "IRRESISTIBLE" Project

The electrolyte solution, generally based on iodine (I2) and potassium iodide (KI), has the task of allowing the transport of the electron hole formed at the same time as the electron emission when the dye molecule interacts with a photon. In this way the electron lost through oxidation is returned to the dye and the cycle can then be repeated indefinitely

- The electrons collected by TiO2 migrate to the cathode
- The anode is covered by a catalyst (graphite) and injects electrons into the cell, regenerating iodide



- The REDOX mediator is iodide/triodide (I^-/ I_3^-)

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- The cell can be made using dyes obtained from blueberries, blackberries, red oranges, pomegranates or eggplants!

- https://www.youtube.com/watch?v=Qbsl1NP5uZI

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Some examples of lab work

Heating of different substances by light radiation

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Measuring the resistance of the faces of the Graetzel cell slides to determine what the conducting face is

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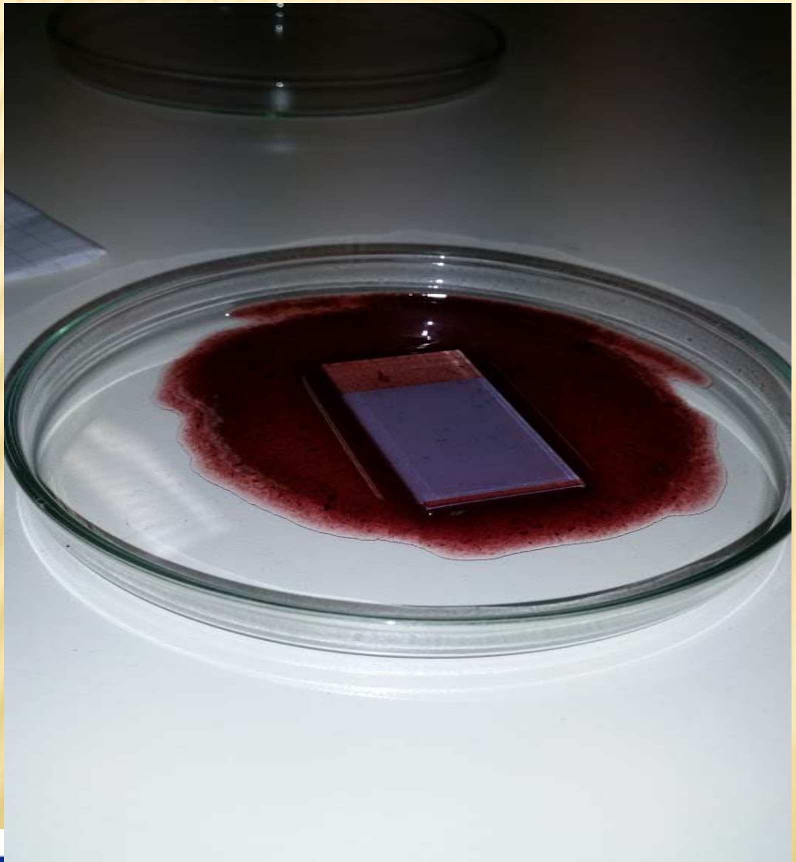
The FP7 “IRRESISTIBLE” Project



Immersion of titanium dioxide covered slide in blueberry juice

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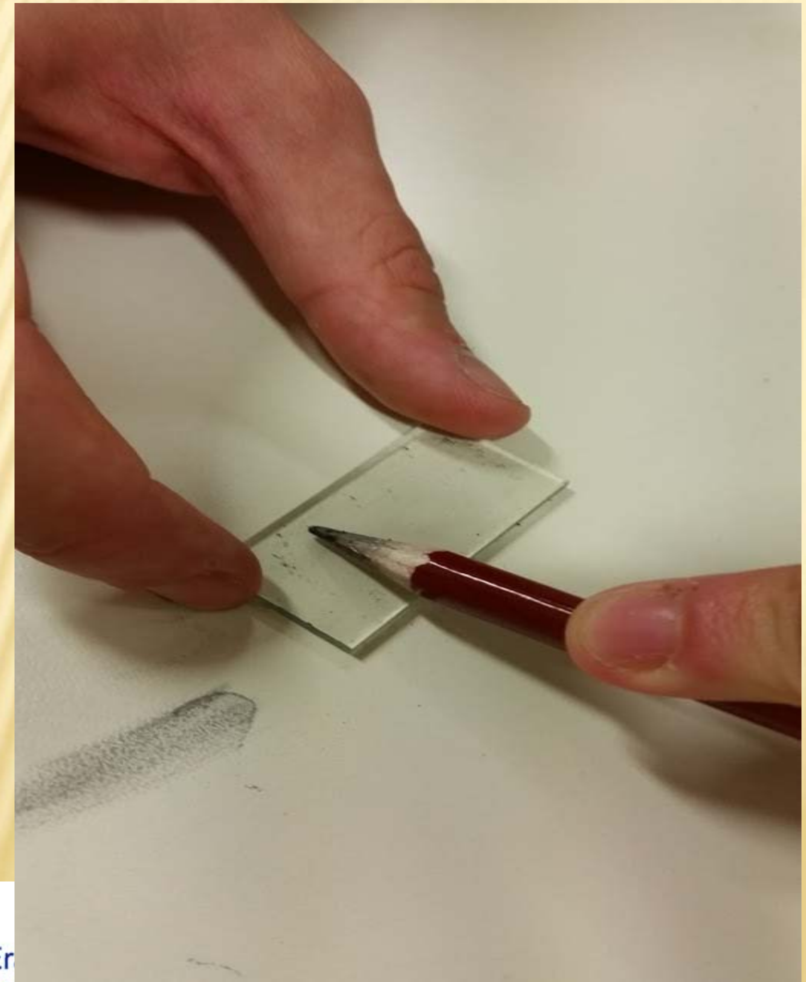
The FP7 “IRRESISTIBLE” Project

irresistible



Preparation of the counter electrode: A layer of graphite is deposited on the conductive part of the slide

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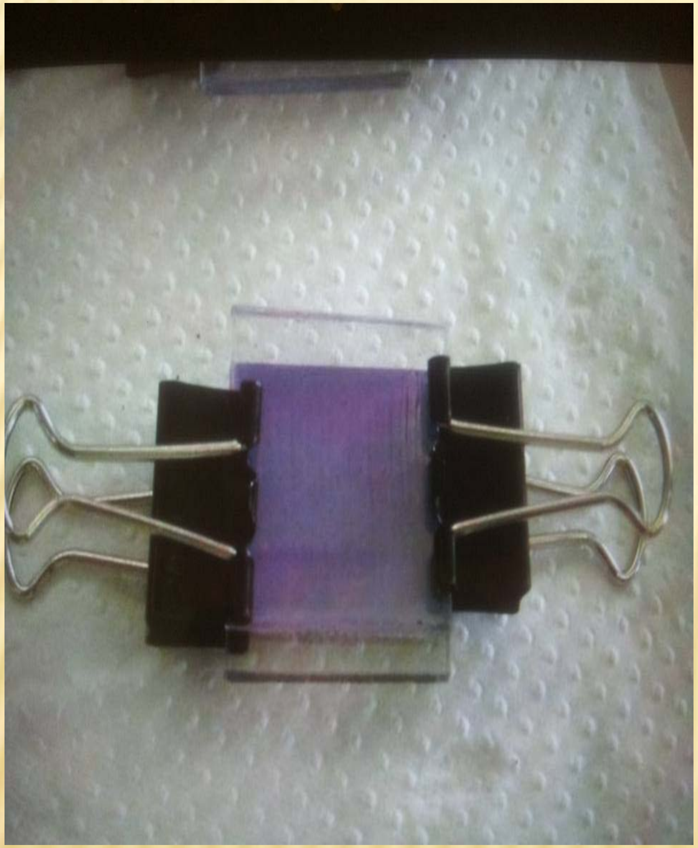
The FP7 “IRRESISTIBLE” Project



The assembled cell:
The two electrodes are superimposed after some electrolyte drops have been deposited between them

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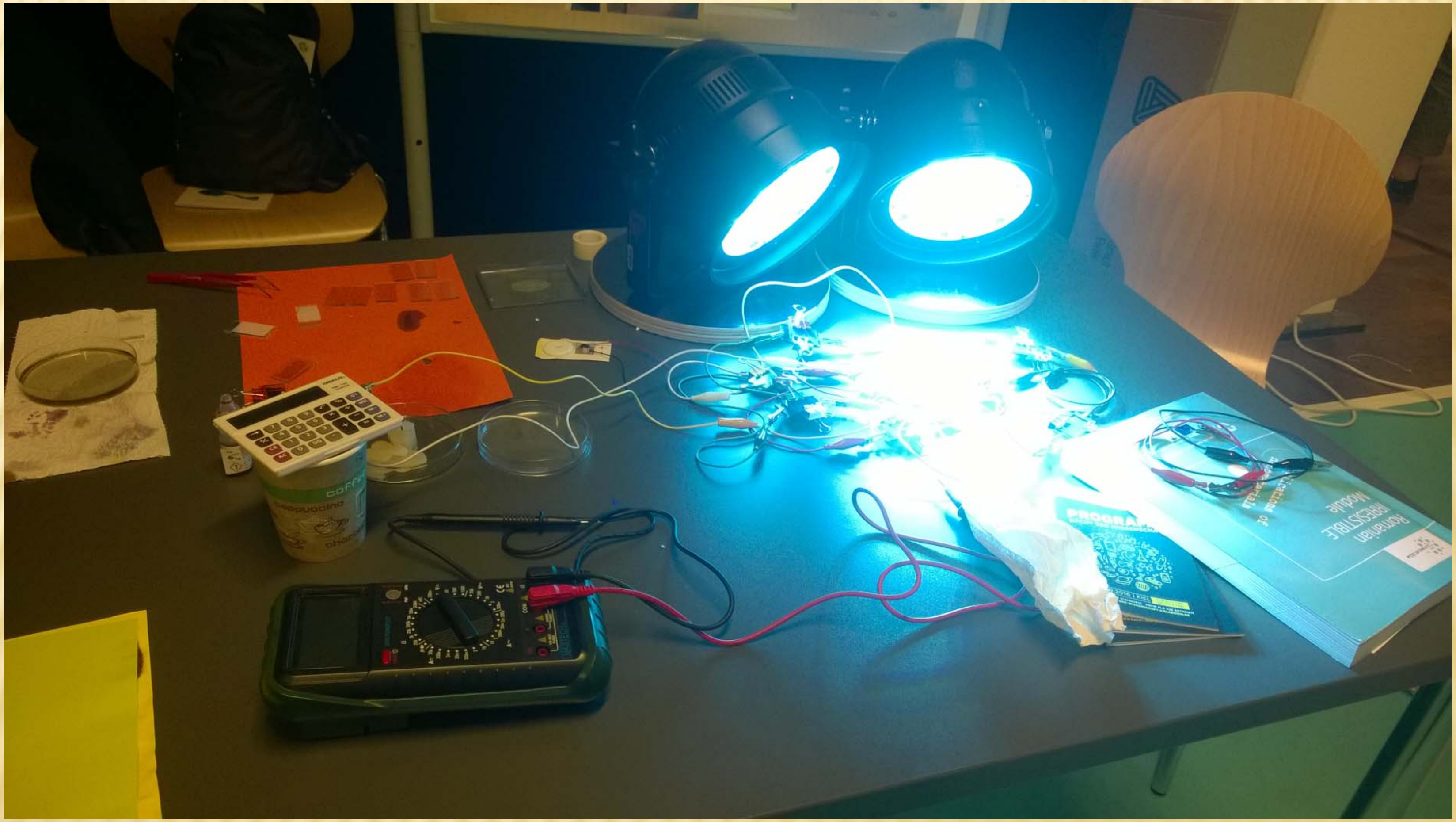
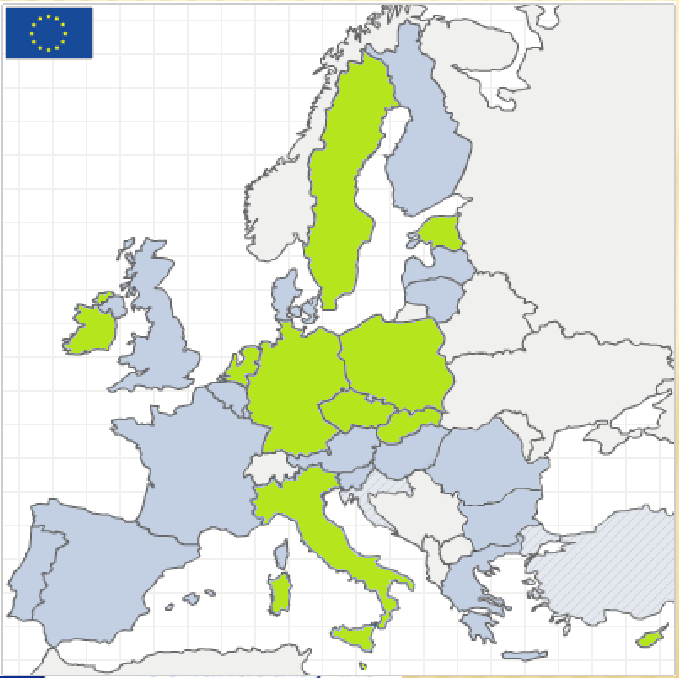


The FP7 "IRRESISTIBLE" Project

The FP7 “ESTABLISH” Project

14 Universities and Research Centres from 11 European Countries, for a 48-month commitment starting from January 2010



Promote and develop Inquiry-Based Science Education strategies in Lower and Upper Secondary Schools

Erasmus+ Programme of the European Union

The FP7 “ESTABLISH” Project

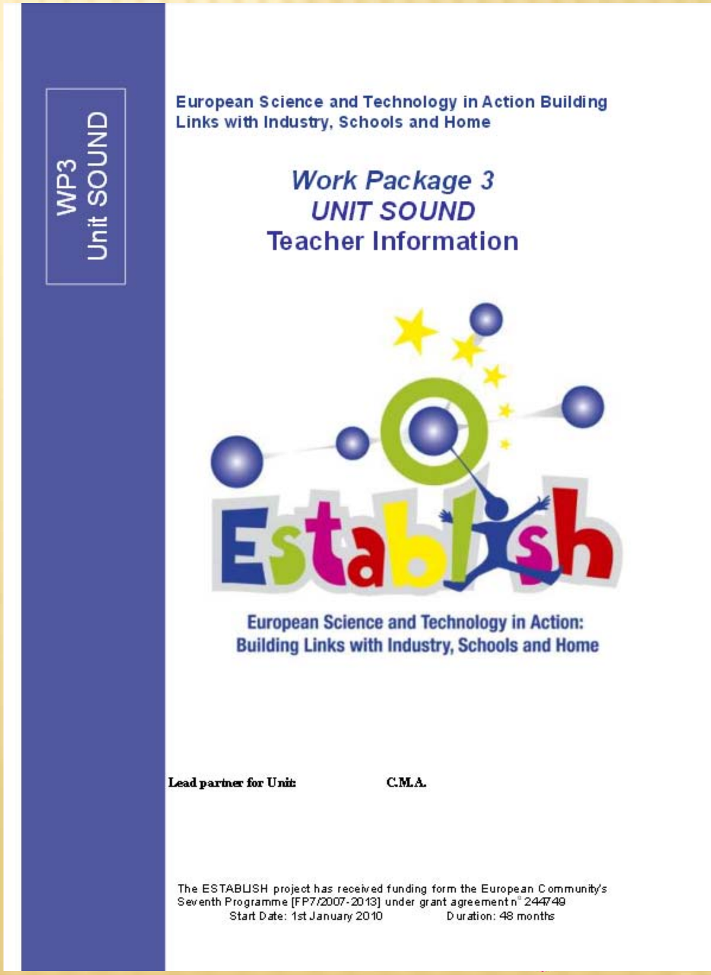
Inquiry-Based teacher training activities at the University of Palermo

Introduction to Inquiry-Based Methods.

Critical analysis of a work unit submitted by partners:

Sound

22 Secondary School teachers during School Year 2010/2011


WP3
Unit SOUND

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

Work Package 3
UNIT SOUND
Teacher Information

Establish

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

Lead partner for Unit: C.M.A.

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n° 244749
Start Date: 1st January 2010 Duration: 48 months

Co-funded by the Erasmus+ Programme of the European Union

The FP7 "ESTABLISH" Project

Inquiry-Based teacher activities at the University of Palermo

Development and trialling of a T/L unit::

Designing a Low Energy Home: Heating and Cooling

An Inquiry-Based Approach to Thermal Phenomena for Secondary School students

22 Secondary School teachers during School Years 2010/2011 and 2011/2012

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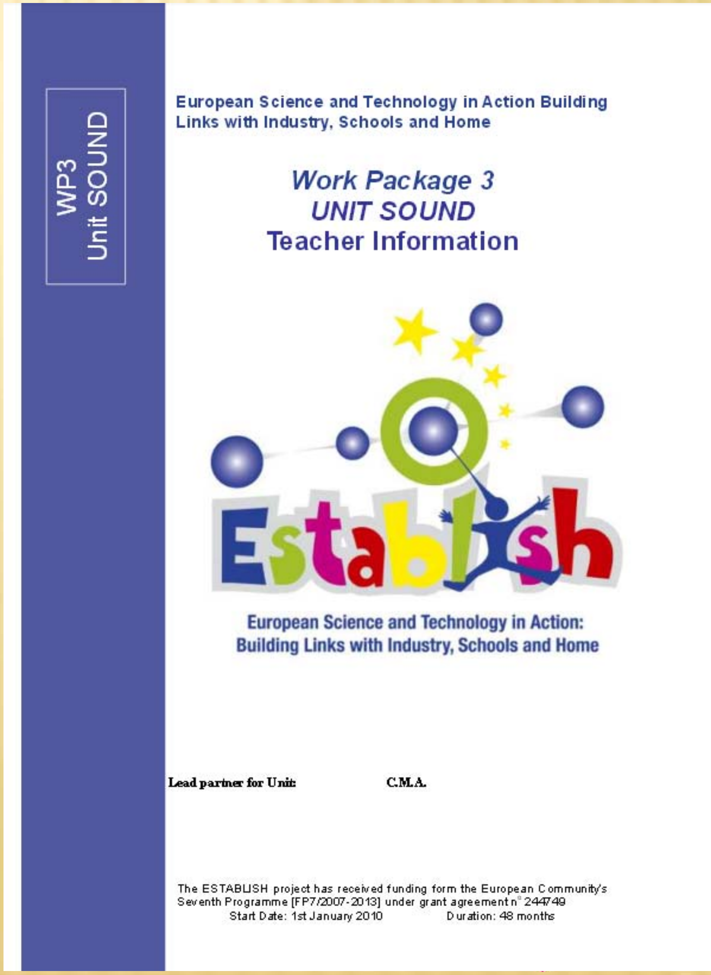
WP3 Unit SOUND

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

Work Package 3
UNIT SOUND
Teacher Information

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

Lead partner for Unit: C.M.A.

The ESTABLISH project has received funding form the European Community's Seventh Programme [FP7/2007-2013] under grant agreement n° 244749
Start Date: 1st January 2010 Duration: 48 months

The FP7 "ESTABLISH" Project

Inquiry-Based teacher activities at the University of Palermo

Trialling of three T/L units:

Blood Donation

Direct Current Electricity

University of Kosice (Slovakia)

Light

Dublin City University (Ireland)

22 Secondary School teachers during School Years 2012/2013

Co-funded by the Erasmus+ Programme of the European Union

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

Framework for IBSE Teaching and Learning Units

UNIT TITLE

A. Teacher Information

I. Unit description

Introduce the topic to capture the main idea behind the unit.

Additional specify:
Student level:

Discipline(s) involved:

Estimated duration:

II. IBSE Character

Highlight the IBSE nature of this unit.
Specify the type of inquiry and types of IBSE skills involved (for definitions and terminology which to be used see 'Guide for developing ESTABLISH Teaching and Learning Units, II. The science inquiry-based approach').

III. Pedagogical Content Knowledge

Provide background to the science theory including pre-requisite knowledge required and science concepts developed in the unit.
Highlight relevant students' difficulties.

IV. Industrial Content Knowledge

Highlight the relevance of/to industry. Specify the type of industry link(s) involved (for definitions and terminology to be used see 'Guide for developing Establish Teaching and Learning Units, III. Industrial Content Knowledge').

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V. *Learning Path(s)*

Describe way(s) in which student learning activities are connected to each other, with references to the 5E model of the Learning Cycle (for description of the 5E Learning Cycle see 'Guide for developing Establish Teaching and Learning Units, IV. Learning Paths').

Present a complete list of student learning activities included in the unit.

VI. *Assessment*

Provide items and suggestions for student assessment.

VII. *Student Learning Activities*

Give detailed descriptions for each Student Learning Activity.

The following elements should be included per activity:
Activity: *Activity title*

Learning Aim: *Specify what the learning goal of the activity is.*

Materials: *Specify materials needed and technology used (if any)*

Suggestions for use: *Give suggestions on:*
- *how to carry out the activity,*
- *how to use materials,*
- *how to link to industry*
- *how to make it inquiry-based*
- *exemplary questions for this activity*

B. Classroom Materials

Provide materials which teachers can use with their students in implementing this unit in the classroom. The extent of these materials are depends on the particular activity and student level.
Suggestions for materials include (but are not limited to):
- *student worksheets*
- *background information*
- *laboratory notes*
- *assessment sheets*
- *reference materials*

WP3
Designing a Low Energy Home: heating and

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

Work Package 3

Designing a Low Energy Home: Heating and Cooling

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

Lead partner for deliverable: **UNIPA**

Version: 1.3

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A. Teacher Information

I. Unit description

The Unit is aimed at engaging high school students in designing and building an energy-efficient scale model house through the understanding of relevant concepts in the content area of energy flow in thermal systems. It is developed into 4 sub-Units that analyse the different processes of thermal energy transfer (conduction, convection and radiation). The project intends also to introduce pupils to **infrared thermography, thermal imaging and thermograms**, i. e. **infrared imaging science**.

The content area of the Unit is energy and power in thermal systems. The sub-units are mainly devoted to 14-16 year old students and deepening is also designed for 16-18 year old students involving mathematization of data analysis and theoretical formalization.

The estimated duration of the whole unit is 30 hours. However, it can be used partially and at different deepening levels. Details of partial times are supplied for the single subunits.

The Unit uses hands-on activities, scientific simulations and probe-ware measurements as tools to develop an Inquiry Based Approach.

II. IBSE character

This unit can be used to develop students' ability to plan investigations, develop hypothesis, distinguish alternatives, searching for information, constructing models and debating with peers. It covers different types of inquiry activities, from interactive demonstration to open inquiry. The main problem dealt with the unit is divided in sub-problems faced in the different subunits that develop by increasing student participation and independence.

The unit can be implemented in different ways, and for each sub-unit emphasis can be placed on different elements of inquiry. However, in each sub-unit a progression in assigning autonomy to student is foreseen by making the suggested questions more general.

In each subunit, the teacher may start with either a series of questions or with an interactive demonstration, like in subunit 2, where the initial demonstration poses the problem to be investigated and inquiry can be developed in different steps (some of them are suggested by the activities that lead to questions for further investigations). All the activities may be guided, bounded or lead into open inquiry settings. However, the initial activities given in each sub-unit will form the background for further open inquiry activities to be performed by students.

In order to focus on the different skills connected with the inquiry process, the starting point of each activity is a well defined problem whose solution requires students' engagement, raising questions and developing hypotheses. The teacher control of students' activities is mainly connected with students' expertise in autonomous work and during the succession of the proposed activities the degree of teacher's guidance decreases.

Details about the inquiry types and E-emphasis will be supplied for each sub-unit.

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III. Content Knowledge

Core physics concepts of this study are: thermal energy, heat and temperature. Such concepts involve many difficulties that often are connected with different definitions in textbooks. For this reason we, here, clarify the main definitions of the involved concepts.

In the Unit we discuss about Thermal Energy arising from the fact that particles of matter are in constant motion and that this motion relates directly to the state of matter of the object (solids, liquids, or gases). Temperature affects how fast these particles move. The higher the temperature the faster the particles move. Moving particles possess kinetic energy.

Temperature is defined as a measure of the *average kinetic energy of the particles of an object.*

Thermal Energy is the total sum of all the energies of the object particles.

As a consequence, thermal energy and temperature are related though different: temperature is proportional to the average kinetic energy of the particles; thermal energy is the total amount of the kinetic energy of the object particles.

Transfer of thermal energy between systems can happen through three different processes:

Conduction – *direct contact*

Convection – *through a fluid*

Radiation – *by electromagnetic waves*

The term **heat** involves the quantity of energy transferred from one place in a body or thermodynamic system to another place, or beyond the boundary of one system to another one due to thermal contact when the systems are at different temperatures. In this description, it is an energy transfer to the body in any other way than the mechanical work performed on the body

Transfer by conduction is the transfer of thermal energy between regions of matter due to a temperature gradient. Heat spontaneously flows from a region of higher temperature to a region of lower temperature, temperature differences approaching thermal equilibrium..

On a microscopic scale, conduction occurs as rapidly moving or vibrating atoms and molecules interact with neighboring particles, transferring some of their kinetic energy. Heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from one atom to another. Conduction is the most significant mean of heat transfer within a solid or between solid objects in thermal contact. Conduction is greater in solids because the network of relatively fixed spatial bounds between atoms helps to transfer energy between them by vibration.

Transfer by convection is the transfer of thermal energy through a substance by mean of currents of fluids (liquids and gases).

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Transfer by radiation is transfer by electromagnetic waves. These waves may pass through all matter states and also through the vacuum space by transferring energy called radiant energy.

Transfer by conduction and convection involves a direct contact between bodies at different temperatures. In this case we say that heat is exchanged between the two bodies. Transfer by radiation involves interaction between one body and the electromagnetic radiation emitted by the other body.

Concerning the specific content objectives, these involve the ability to:

- Differentiate between heat and temperature;
- Understand the concept of thermal equilibrium and thermal process;
- Differentiate among conduction, convection, and radiation;
- Give examples of how conduction, convection, and radiation are considered in choosing materials for buildings and designing an house model;
- Explain how environmental factors such as wind, solar radiation, and temperature affect the design of an house and the choice of the materials.

IV. Pedagogical Content Knowledge

PCK involved in the Unit is related to the analysed physics topics, as well as to its IB approach. With reference to the domain of physics topics, relevant elements are the following:

- To make teachers aware of expected difficulties, misconceptions and/or alternative conceptions in the understanding of the content (as for example "*Heat as energy contained in a body", "Temperature as a measure of heat in a body", "Different bodies placed in the same environment have different temperatures"…………………..),*
- To gain ability in using Scientific Instructional Representations (models, mathematical representations,.....) by connecting them and making evident their rationale to fit students' reasoning.
- To be aware of students' learning difficulties in sketching microscopic behaviours.
- To connect physics concepts with everyday phenomena.
- To relate observation of phenomena with students' representations and models.

With regard to the features of IB approach, teachers especially need to gain pedagogical content knowledge enabling them to "engage students in asking and answering scientific questions, designing and conducting investigations, collecting and analyzing data, developing explanations based on evidence, and communicating and justifying findings" . This mainly involves to make teachers able to:

- Provide questions to frame unit and questions for discussion
- Suggest approaches for using technologies as laboratory and cognitive tools.
- Suggest approaches for collecting and analysing data.
- Support students in designing their own investigations.
- Suggest approaches to help students construct explanations Based on Evidence

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- Provide approaches for promoting science communication Baseline feature.

V. Industrial Content Knowledge

Thermal insulation has a lot of industrial applications, as it reduces of the effects of the various processes of heat transfer between objects in thermal contact or in range of radiative influence. Examples go from building construction and mechanical insulation for pipes, aircrafts and refrigerators to clothing.

V.1: Related Industrial Topics

- Building materials: concrete, insulators, films, rigid structural foam, pipes and conduits, barrier layers (water, air, radon)
- Solar thermal technologies, control systems, storage of heat, heat recovery
- Photovoltaic panels, storage systems (batteries), thermo-cameras, inverters, links to electricity grid
- Measurement of heat conductivity, heat loss; thermal imaging
- External cladding

V.2: Industry Link: Building Materials – Insulation Properties, Thermocameras

Focal Organisations: Cement Roadstone Holdings, Istituto Giordano S.p.A., R&D innovAction, FLIR Systems, inc.

Cement Roadstone Holdings (CRH) is a leading international building materials manufacturer and distributor. The company was founded in Ireland in 1970 by the merger of Irish Cement Ltd. and Roadstone Ltd. and now operates in 35 countries globally with annual sales of over €20 billion. CRH shares are listed on the Irish, London and New York stock exchanges. The product range is vast and includes cement, lime, aggregates, asphalt, ready-mixed concrete, pre-cast concrete products, clay products, glass and insulation materials. Energy efficiency is a major focus of the European Construction Industry and some of the most efficient buildings in the world are being constructed using products manufactured by **CRH** companies.

Istituto Giordano S.p.A. (IG) is a Contract Research Organisation, classified as a "Centre of Excellence" in the assistance of Industrial SMEs in R&D, Innovation and Technology Transfer activities.

Established in 1959, IG today employs 120 employees (50% graduates) + 130 inspectors. IG 2010 turnover was more than11 Million Euros. More than 285 thousands certificates and test reports issued up to July 2011. IG's fields of activity comprise: Testing. R&D and TT on Building/Construction Materials & Components, Heat Technology, Fire Safety, Thermo-mechanical and Plants, Transportation, Electric, Chemistry, Naval.

R&D innovAction (**R&DI**) aims at identifying innovative solutions to improve the competitive advantages of its customers in terms of compliance with technical and economic sustainability. Based in Milan (Italy), it carries out research, development, industrialization and commercialization of innovative products and services at high technological content, mainly in the field of Materials, Process, Energy Efficiency, Renewables and Environment. R&D innovAction cooperates with leading companies in Italy and abroad to develop new Services for energy efficiency by monitoring consumption and providing Energy Management support to identify inefficiencies.

FLIR Systems, Inc. is a leading manufacturer of innovative imaging systems that include infrared cameras, aerial broadcast cameras and machine vision systems. Pioneers in the commercial infrared camera industry, the company has been supplying thermography and night vision equipment to science, industry, law enforcement and the military for over 50 years. From predictive maintenance, condition monitoring, non-destructive testing, R&D, medical science, temperature measurement and thermal testing to law enforcement, surveillance, security and manufacturing process control, FLIR offers the widest selection of infrared cameras for beginners to pros.

Examples of ICK application on Thermal insulation

1. Heating and Insulation in the home

An effective way to save energy in the home is to reduce heating costs. In terms of construction, this can be achieved by:

- building a structure that is free of draughts.
- improving insulation levels
- avoiding large temperature fluctuations by utilising the *thermal mass*.of materials.

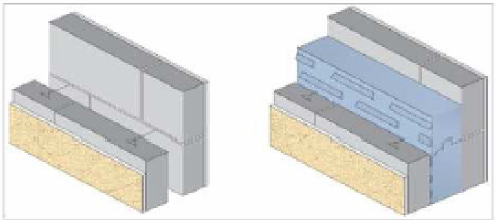
Building materials providers supply products to assist with all of these measures.

2. Heat Loss from a House

Much heat is lost from a house by conduction through the material of the floor, walls, windows, doors and roof. The *conductive efficiency* of materials is usually expressed in terms of their *U-values, expressed as* watts per square metre kelvin (W/m^2K). A material with high *thermal resistance* has a low U-value. The inverse of the U-value is called the R-value.

3. Avoiding Temperature Fluctuations

A standard way of constructing external walls of houses is to use two layers of concrete block with a cavity between them. The cavity may contain a suitable insulating material. The temperature of the outer layer of the wall varies with the external temperature. The insulated inner layer acts as a heat store. It absorbs heat when the inside temperature rises during the day and releases it when the temperature drops at night. By using the *thermal mass* of



Uninsulated cavity wall, U-value 1.76 $W\ m^{-2}\ K$; and insulated with 140 mm modern insulation: U-value 0.20 $W\ m^{-2}\ K$

concrete in this way, the inside air temperature is maintained at a relatively stable level, resulting in a more comfortable living environment and a more efficient use of energy. Another form of construction is the *externally insulated* single leaf concrete block wall.

4. Insulation in refrigerators

The best way to make efficient refrigerators is to use different types of thermal insulators in their construction. Depending on the type of refrigeration device, the insulator may be a vacuum, styrofoam or a type of fiberglass. The main aim of a refrigerator insulator is to keep outside thermal energy from getting in the refrigerator, which is, therefore, kept cold with less electric power consumption. The insulation is generally in a place we can't see it, i.e. inside the refrigerator walls. Thermal energy outside the refrigerator has a very hard time permeating the wall of the refrigerator, extending the duration of food inside the refrigerator in case of electric blackout.
Low-cost home refrigerators are mainly equipped with rigid foam board insulation, as it provides affordable, adequate protection against thermal energy loss from the appliance. Rigid foam board insulation is typically made from polystyrene or polyurethane. These insulating boards are resistant to moisture and have a high thermal resistance (R) value. R is a rating for the insulation's efficiency: the higher it is, the more effective the product will be in reducing thermal energy loss.
Another widely method used for reducing thermal energy loss in domestic refrigerator/freezers and improve their energy efficiency is to use Gas-Filled Panel thermal insulation technology. Gas-Filled panels contain a low-conductivity, inert gas at atmospheric pressure and employ a reflective baffle to suppress radiation and convection within the gas. (see B. T. Griffith, D. Arasteh, and D. Türler paper (link below) for more details).

5. Infrared Thermography

Infrared thermography, i.e. the measurement of surface temperature by means of specially designed, infrared-sensitive thermo-cameras, can provide remarkable, nondestructive information about construction details and building performance. These include validation of structural details, verification of energy performance (thermal conduction, air leakage, i.e. convection, and radiation from windows), location of moisture intrusion, thermal bridges.

Surface temperature has started to play a major role in both audits and energy surveys, as it can be used to evaluate the condition of the building itself as well as the electrical, mechanical, and plumbing systems.

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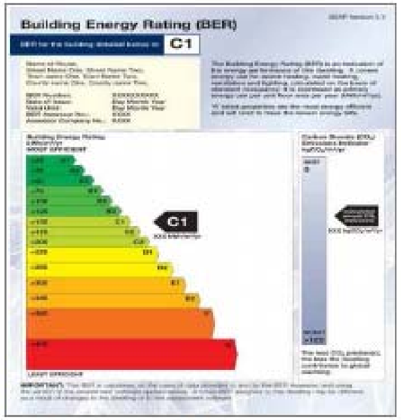
Energy Performance Certificates
EU Directive 2002/91/EC calls on .Member States to *'ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant...'*



A Building Energy Rating Certificate as issued in the Republic of Ireland

V.3: References and Links

- The CRH website - www.crh.ie
- The IG website - www.giordano.it
- The R&DI website - www.rd-innovaction.com/en
- Then FLIR website – www.flir.com
- http://vimeo.com/40214470 - a video titled BER for homeowners explained from the Sustainable Energy Authority of Ireland (www.seai.ie)
- Directive 2002/91/EC of the European Parliment on the energy performance of buildings contains a range of provisions aimed at improving energy performance of residential and non-residential buildings, both new-build and existing
- From 2013, the EPBD will be superseded by the Recast EPBD. Recast Energy Performance of Buildings Directive
- Implementation of the Energy Performance of Buildings Directive in other Member States 2010
- B. T. Griffith, D. Arasteh, and D. Türler, Energy Efficiency Improvements for Refrigerator/Freezers Using Prototype Doors Containing Gas-Filled Panel Insulating Systems, Proceedings of the 46th International Appliance Technical Conference held May 15-17, 1995 at the University of Illinois at Urbana-Champaign – LINK: http://gfp.lbl.gov/papers/lbl-36658.pdf

The following relevant items are all available in *Science and Technology in Action (www.sta.ie)*.

- The Energy Efficient Building - CRH
- Technologies Protecting the Environment - EPA
- Enzymes and Biofuels - EI Biotech
- Climate Change - EPA

In each part of the Designing a Low Energy Home Unit, examples will be supplied about how conduction, convection, and radiation are considered in choosing materials for buildings and designing a heating system and in explaining how environmental factors such as wind, solar angle, and temperature affect design of houses.

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VI. Learning paths

The learning path is developed through 4 sub-units that face the different aspects of constructing an energy-efficient scale model house.

Sub-Unit_1 guides students in the construction of a model house and in making explicit the different factors that contribute in heat dispersion and energy consumption to maintain warm the house. Each factor is analysed in the other sub-units that are also developed around a particular problem that guides the inquiry.

Sub-Unit_2 analyses the role of different materials in heat dispersion by developing the relevant concepts connected with energy transfer through conduction.

Sub-Unit_3 analyses energy transfer in fluid material and the main concepts connected with the convection process.

Sub-Unit_4 introduces the concept of energy transfer by radiation, analysing the different effects of solar radiation spectrum.

VII. Assessment

In all Sub-Units the students' assessment should include both a theoretical test (understanding basic concepts) as a practical assignment. Assessments of students' understanding of operative procedures such as observation, hypothesizing, explaining,.....has also to be taken into account.
Examples of prototypical question will be given in each sub-Unit.

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VIII. Student learning activities

SUB_UNIT_1: Testing a house model

Learning Path

This sub unit introduces basic concepts such as heating/cooling rates, energy conservation, conduction, convection, and radiation, and engineering elements such as insulation, glazing, thermal storage, and passive heating and cooling. It also aims at recalling previous learned concepts of heat, temperature and thermal equilibrium by taking into account the well known misconceptions held by students at this school level.

At the end of this sub unit, students should have a basic understanding of some physical processes, such as how heat transfer occurs between the house and the environment under different weather conditions.

Students will be involved in constructing a scale model house using a hands-on kit supplied by the teacher. They will learn to use sensors to measure the heat gain or loss and evaluate insulation. They will explore different heating and cooling factors using the tools provided and other low-cost materials on hand. For instance, a light bulb (covered by an aluminium foil) models the heather, the effects of wind can be simulated using an electric fan, and sun shining heating by using a lamp .

The sub-unit involves 3 student learning activities:

a. Activity 1_1 aimed at the construction of different kinds of house models and at evaluating the main difficulties in maintain them warm;

b. Activity 1_2 aimed at analysing the distribution of temperature inside the house model;

c. Activity 1_3 aimed at analysing the heating effects of light on the house models.

The following table characterises the three activities from the point of view of the required type of inquiry and considering 5E model of the Learning Cycle.

Activity	***Student Task***	***Inquiry Type***	***E-emphasis***
1_1	Discussing and experimenting how to maintain warm a house model	Interactive demonstration Guided discovery	Engage Explore
1_2	Experimenting distribution of temperature inside the house model	Guided inquiry Bounded Inquiry	Engage Explore Explain
1_3	Hypothesizing and experimenting the sunshine effects on the house model temperature	Guided inquiry Bounded Inquiry Open Inquiry is also possible	Engage Explore Extend

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Designing a Low Energy Home

The project we want to develop in this Learning Unit deals with the idea of a model house that uses less energy to heat the rooms and makes use of scientific discoveries and technological resources to minimize energy consumption. The house analysis will be the starting point to explore some important scientific concepts related to heating and cooling of bodies and to heat transfer.

Even if we will work with models of polystyrene, wood, plastic and cardboard, warmed by a light bulb placed inside, we will apply the same principles of science and engineering that are taken into account in the construction of a real house.

In many countries a large percentage of energy consumption is due to heating and cooling of buildings. Therefore, the search for more efficient methods of construction to improve the energy efficiency of buildings is extremely important. Less energy means less fossil fuels and thus a lower amount of carbon dioxide in the atmosphere. Your generation has the task of doing something about energy efficiency and then you need to know the problem to make responsible choices.

Some initial considerations

We begin our work by observing the characteristics of some houses. Then, we try to understand why they are very different from each other.

		The houses in mountainous areas are often made of wood or have very thick walls
		The Mediterranean countries and the souks of the desert have whitewashed houses and narrow streets

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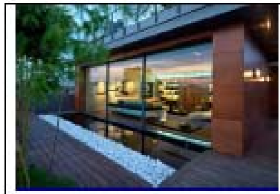
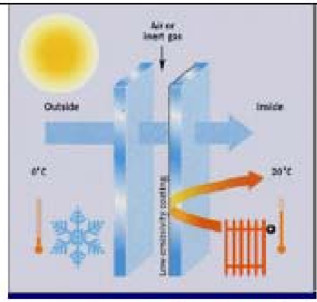
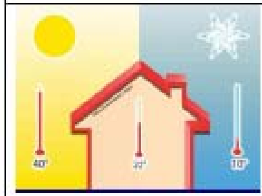
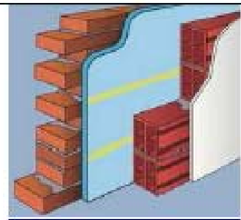
		The houses with large windows often use double (or even triple) glass window panes separated by an air or other gas filled space to reduce heat transfer across a part of the building envelope.
		Companies that sell thermal insulation material for walls show as layers of different materials can be more successful at maintaining a constant temperature inside a room than walls made of only a material
		Photocameras are available that can show and highlight the different temperature of various parts of the outer wall of a house (thermocameras).

Although our goal is to build a model home that is efficient from an energy point of view, that has a constant temperature and can also be heated by the sun, we will start working with models to familiarize with the materials, construction methods, and measures necessary to evaluate the project.

Your teacher will provide you with the models on which we will use standard procedures for measuring the thermal performance of a house.

In order to cool a house (or as it is commonly said losing heat), there must be a difference in temperature between the inside and the outside. The inside of the house must be warmer than the outside. Because you cannot cool your classroom at 0 ° C, we will try to heat your model house at 15 ° C above the environment temperature. This is done with a heating bulb placed inside the model.

As in a real home, what matters is how long the heater must stay switched on to keep the house warm. The higher the inner temperature, the more energy is used and the more you heating bill will be. To mimic this situation, we will record the percentage of time the heating lamp should stay turned on to maintain the house at 15 ° above ambient temperature. We will perform the same test in other conditions, trying to understand why different results are obtained.

Activity 1_1: How to maintain warm your house model

The problem:

In the winter we need energy to maintain warm our house. By using suitable designed house models it is possible to analyze how much energy it takes to have the inner part of each house model 15°C warmer than the air outside it.

Material needed for each group:

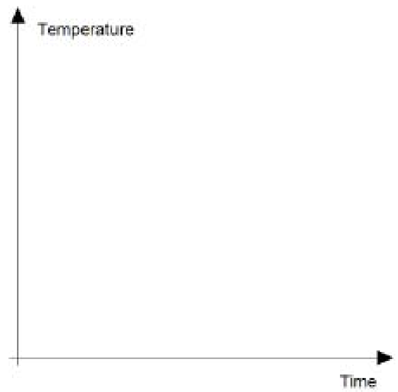
- Boxes of different materials (of equal dimensions) modeling different kinds of houses.
- Temperature sensors to put in the wall opposite to the heater.
- Heaters (light bulbs covered by aluminium sheets)

Suggestions for use:

Follow the suggestions of the teacher and place the heater and the thermometer as shown in figure.

In this experiment you will switch on the heater and start recording the inner temperature of the model house as a function of time.

Before actually performing the experiment, give your prediction of the Temperature-Time graph you are going to obtain and draw it on the right.



Now turn on the heater and record the inner temperature of the model house until it reaches a value of about +15 ° C above the external temperature, T_e. Turn off the heater so that the temperature decreases until T_e.

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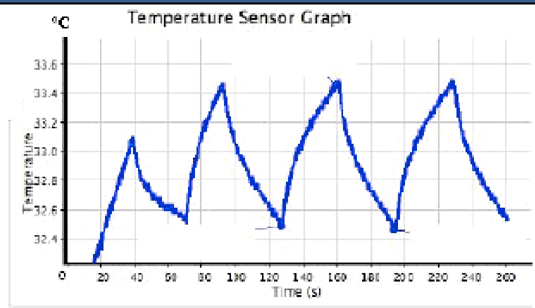
DATA ANALYSIS

Take note of the time intervals during which the heater is turned on and off and say how much energy was used to heat the house?

Compare your data with those of your schoolmates. What conclusions can you draw with regard to energy saving?

In depth analysis:



The graph above shows an experiment performed by a student that repeatedly switched on and off the heater, aiming at maintaining the temperature of the house at about 33 ° C. Try to calculate how much energy has been used if the heater was a 40W light bulb.

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ESTABLISH: sharing the results

10 teachers took part to the ESTABLISH International Teacher Conference at Dublin City Universit" (DCU) from 7th to 9° June 2012.
They discussed their results with colleagues from all the partner countries

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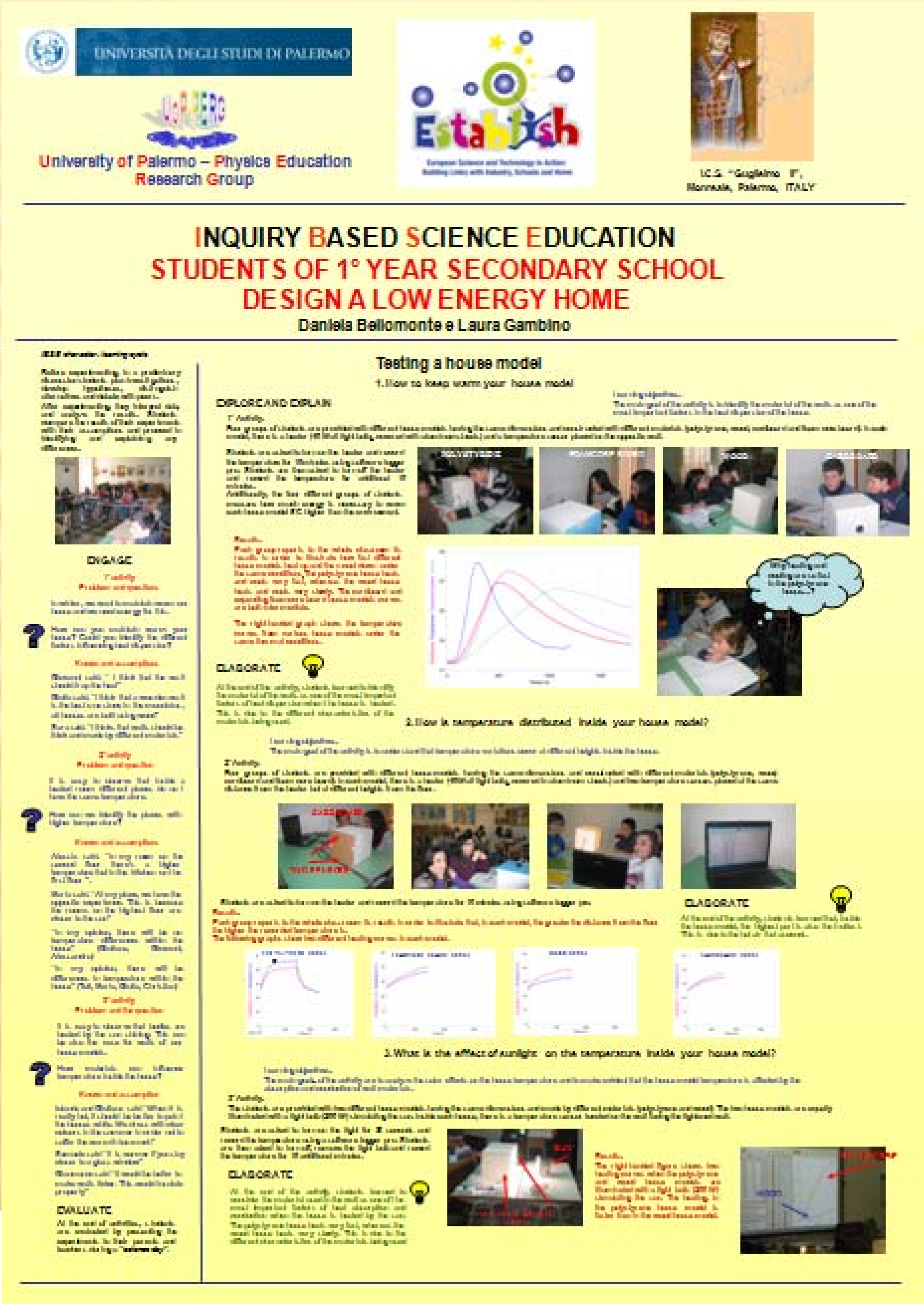
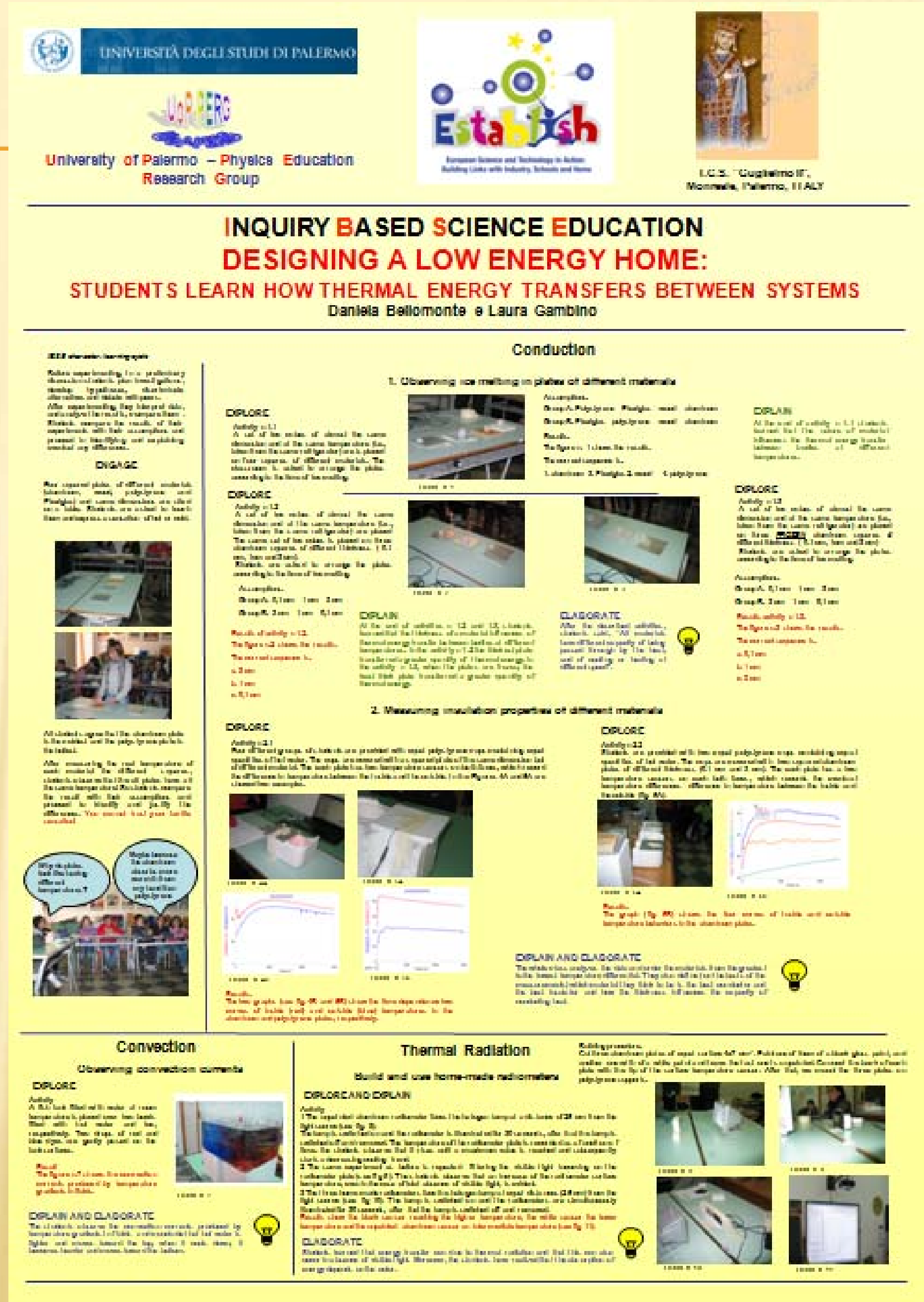




of the European Union

University of Palermo – Physics Education Research Group

Scuola secondaria di 1° grado "Gregorio Russo" Palermo

"Like a scientist" Experience in a Secondary School:"Gregorio Russo" Palermo, Sicily

M Tumbiolo, M.L. Modesto, C. Bianna

Introduction

Level		Age	N° of years
PRIMARY SCHOOL		6-10	5
SECONDARY SCHOOL	1° degree	11-13	3
	2° degree	14-18	3+2

The secondary school "Gregorio Russo" is situated in a poor suburban district in Palermo.
The experiment has been made with two classes of 1° degree secondary school: 13 students of 2nd year, and 14 students of the last year.

In the work package "Designing a low energy home: heating and cooling", realised by University of Palermo, teachers selected two subunits for both classes.

[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]

Due to their poor cultural background and general low ability, the students were not curious and therefore the selected subunits were modified by School teachers, in order to semplificate student's work: Prof. C. Bianna and M.Tumbiolo, realized for some subunits easier student worksheets for each activity; instead, Prof.ssa M. L. Modesto, who has younger student, decided to work by interactive demonstration for all activities.

Starting up...

The project was carried out in 5 lessons (two hours each one). Some experiments were repeated twice because they turned out too difficult for the students.

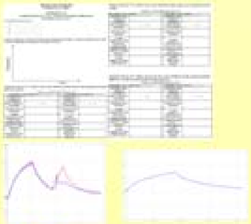
First step: Motivation
In order to increase student's involvement, teachers introduced the Establish Project, underlining the importance of student's work to implement the unit.

Second step: Instruments
Teachers organized a Preliminary Unit, aimed at engaging students in scientist's work: the scientist uses instruments to take measures, so students had the opportunity to know the software, use thermal sensors in a free activity and discuss with the teachers the resulting graphs. Moreover teachers showed a Power Point Presentation "Designing a low energy home" with pictures of different type of houses, for stimulating the students to investigate how thermal energy flows through different materials.

Experience

First lesson: Activity 1.1
Model of how to keep your house warm

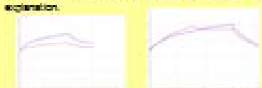
3rd class
The students were divided into two groups. Each group had to test two house models constructed with different materials (wood and polystyrene). During the activity students were given a worksheet prepared by the teachers, in order to realize an interactive demonstration.



2nd class
The teacher carried out this activity with the whole class. Six students received a special task:
• Three students helped to carry out the experiment
• Three students recorded the temperature on PC
During the activity students took notes on their exercise book

Second lesson: Activity 1.2.
How is the temperature distributed inside your house model?
3rd class
The students were divided into two groups: one group worked with a wood house model and the other with a polystyrene house model. Each group was requested to analyse temperature distribution inside the house. A guided inquiry was proposed, starting with a discussion, in order to identify factors and design an appropriate experiment. The students didn't find difficulties in imagining number and position of the thermal sensors and easily realized the experiment.

2nd class
All students had fun to assemble the model home. The teacher put to them key-questions to start the discussion and to find the way to carry out the experiments.
The students arguments were interesting, but they sometimes had no sense.
During the experiment the students were interested to follow the graphic and to touch the material and they also thought over their experience.
The teacher stimulated them to record data and then to make a representation of results and to give an explanation.



Third lesson: Activity 2.1.
Observing ice liquefying in plates of different materials

3rd class and 2nd class
Teachers planned an interactive demonstration with the whole class. Students were initially requested to make a hypothesis on ice liquefying time over each kind of substratum. Most of the students' prediction were wrong. After the demonstration, students were requested to give an explanation about the observed phenomena. The teachers guided the students to connect experimental measures to a reasonable model.
The synergic work of student was foundamental to reach the final model. This activity resulted the most difficult, for the high abstraction level required, probably will need an easier worksheet.

Forth lesson: Activity 2.2.
Measuring insulation properties of different materials

3rd class and 2nd class
The students were divided into two groups. Each group had to make insulation assessments, puting plates of different material in cups with hot water. One group worked with plates of aluminium and the other with plates of polystyrene. In order to make these activities easier and to relate its with the last one, teachers prepared a worksheet with a series of key questions in order to guide them with their research. Finally students were able to make assessments on their own about insulation material's properties in order to make a low energy home.

Istituto di Istruzione Superiore "G. Carducci" – Comiso

University of Palermo – Physics Education Research Group

Shedding light!
A comparison of two teaching methods

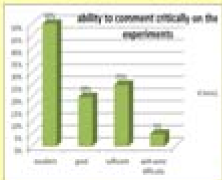
Carmelo Distefano

Introduction

Objective: to evaluate efficacy differences between the IBSE method and the traditional method of teaching

Traditional Approach
Although the discussion of this subject can be enriched with a variety of multimedia training aids and laboratory activities (almost always related to the verification of a law and hardly ever of a discovery) the teacher's explanation followed by homework plays a key role in the learning process.

Activities
1. Sources of light
2. How does light travel?
3. Understanding shadows
4. Exploring white light and filters
5. Exploring primary colours
6. Investigating mirrors
7. Investigating refraction, Investigating Snell's law
8. Investigating lenses, Studying lenses
9. Using Diffraction



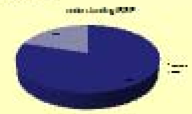
A larger amount of time spent on the subject has been widely rewarded by a deeper understanding of the fundamental concepts and by the acquisition of investigating competencies as well as of more self-awareness when verifying a given hypothesis on the basis of the cases mentioned above.

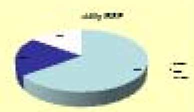
Some points for investigation

Structure

methodology	Time spent (hours)	audits
IBSE	20	3
traditional	10	3

Results





Responses have been extremely positive with an increase of about 20% for each student. These data have helped me to consider the positive effects of spending a larger amount of time on the subject since extra activities for remedial courses were no longer needed (in reality the opposite quite frequently happens) ...

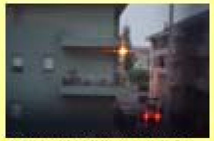
strong points

traditional method	IBSE
Treatment and in-depth exploration of the subject	Autonomy in building up your knowledge and skills
Developing Problem Solving skills	Ability to cooperate and interact with others
	Ability to comment critically on experiments
	The students participate actively and constructively
	The students stimulate discussions that encourage the creation and association of ideas and concepts
	Active Learning is encouraged
	Contextualized application of knowledge is promoted

Method of Evaluation

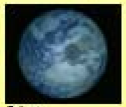
Two groups of students in their third year of high school have been taught the same topics about light.
One group has studied the topics on the textbook using the traditional method; the other group has studied the same topics on the same textbook using the IBSE method instead.
For the evaluation tests both groups of students have been given the same exercises and questions that are in their textbook

Light and shadows

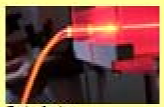


Diffraction: the light through a curtain

Lens

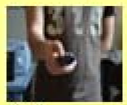


Eclipse

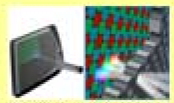


Total reflection

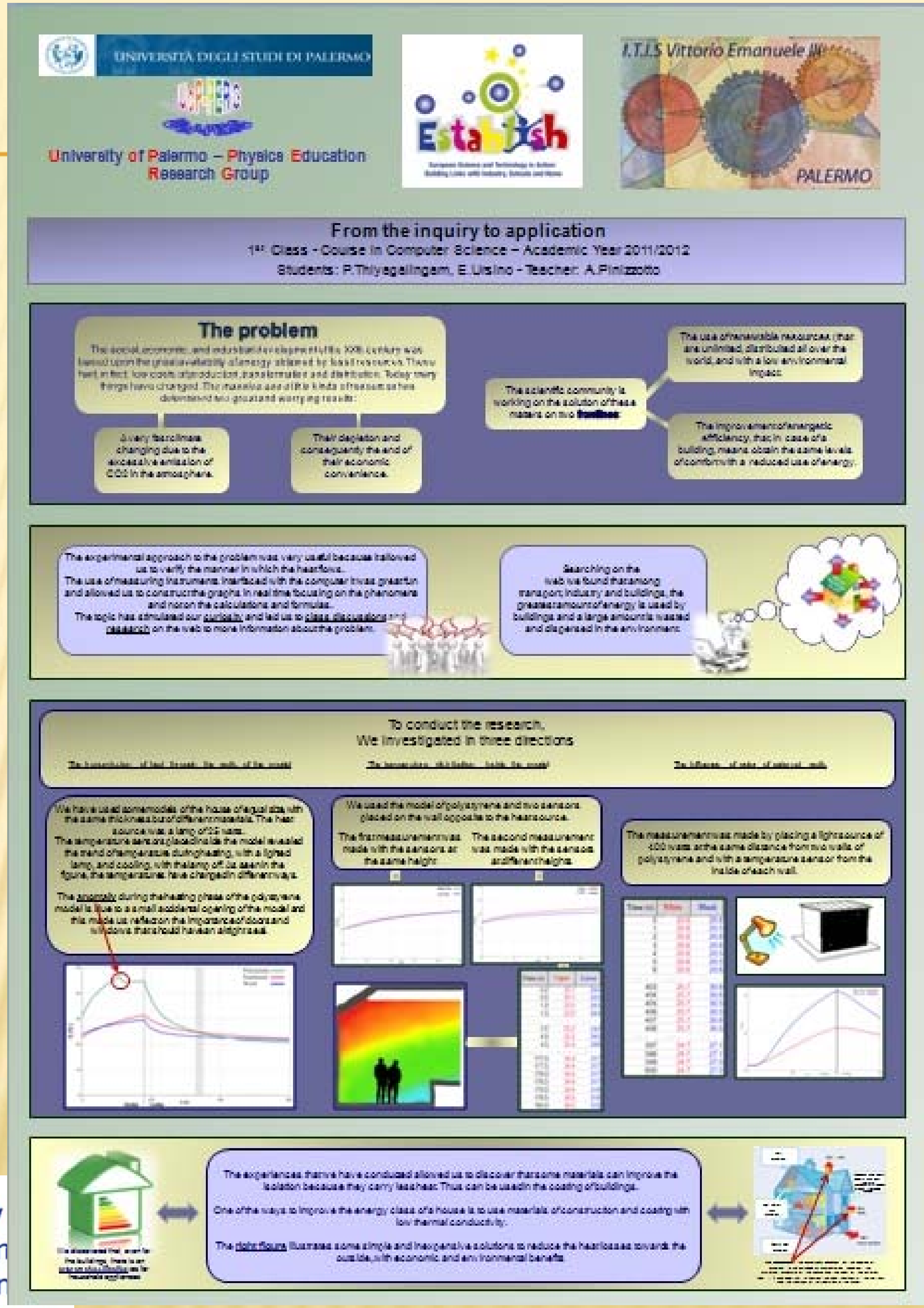
Camera



Infrared



Primary colors and technology



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