



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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Science and Technology in Society

How?



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Science and Technology in Society

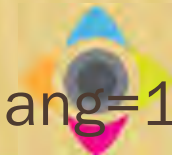
The European Commission's "Science and Society" Program, born in 2007, addressed the involvement from a variety of perspectives, such as encouraging dialogue between scientists and other members of the public, promoting ethical standards, developing tools to allow everyone to access the research results.

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



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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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Responsible Research and Innovation

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.**



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from Technopolis Group – Fraunhofer ISI December 2012



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**



Gender Equality



Inquiry Based
Science
Education



Ethics



Open
Access



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):

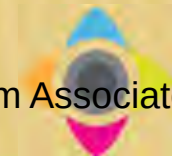
Inquiry is a deliberate process of :

- 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



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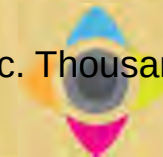
Linn, Davis, & Bell, 2004; Internet Environments for Science Education, Lawrence Erlbaum Associates



"Inquiry" is, therefore, an **active exploration process**

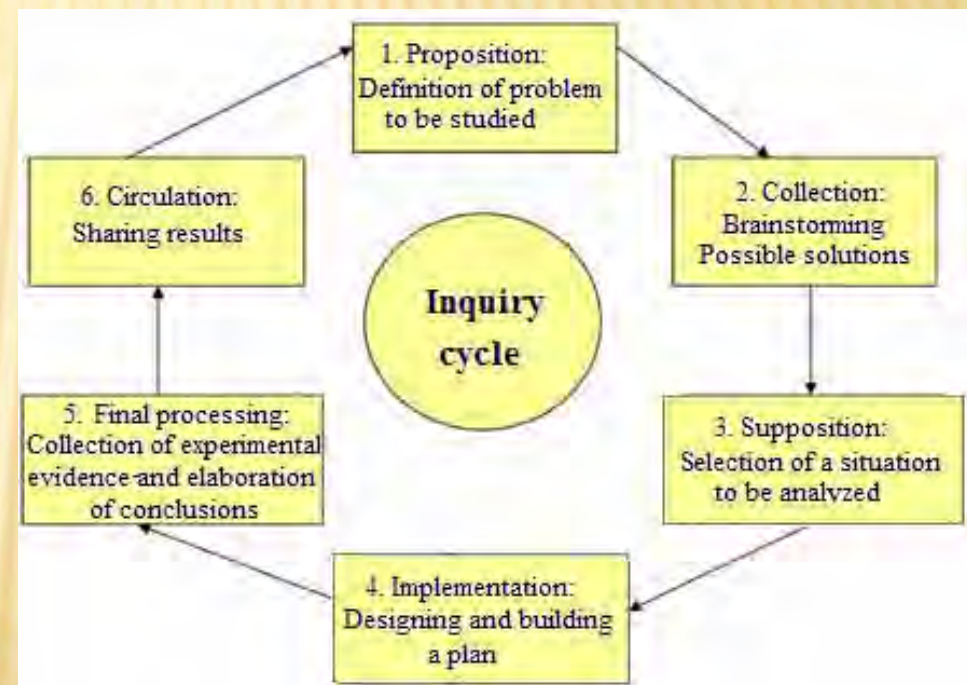
Through it, critical, logical and creative skills are put in place to ask questions about situations of specific interest and engage in answering these questions

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)



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



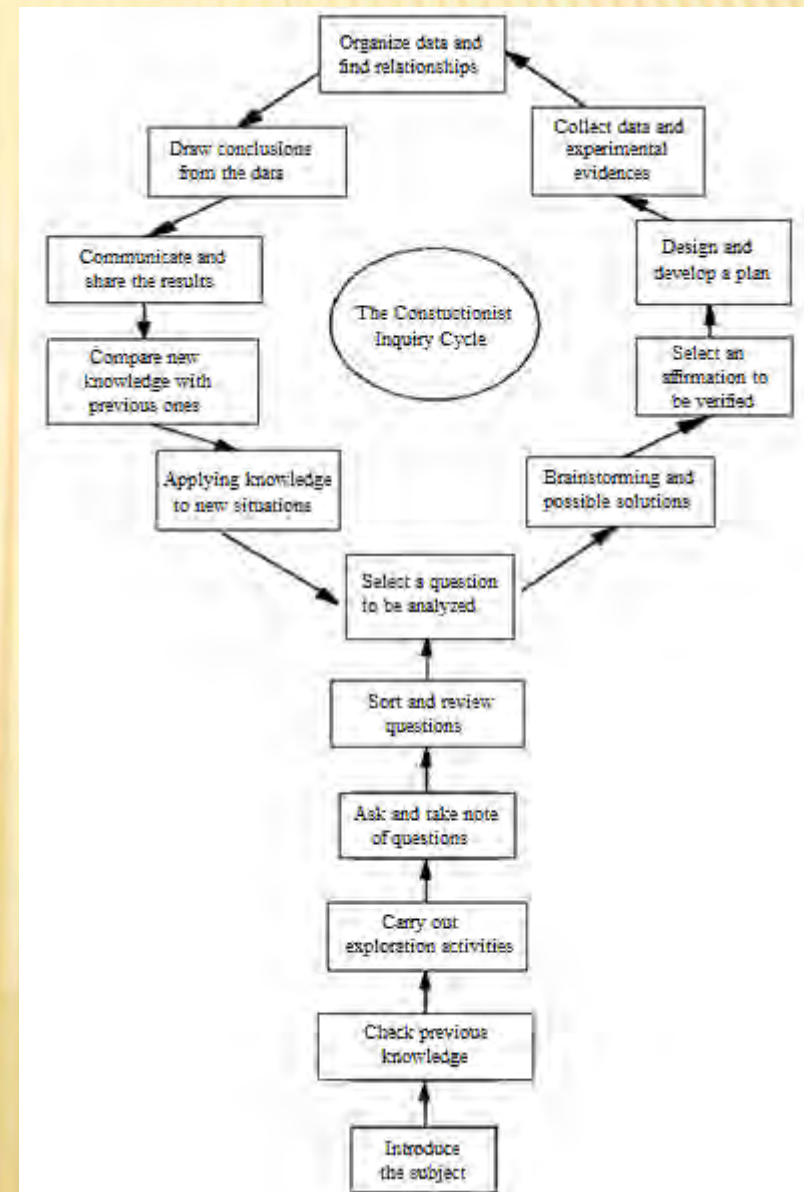
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According to many authors who report about learning results based on scientific research, the basics of "Inquiry Based" methods must be sought in constructionist pedagogy(see, for example, D. Llewellyn, 2002; Inquire Within, p. 47).

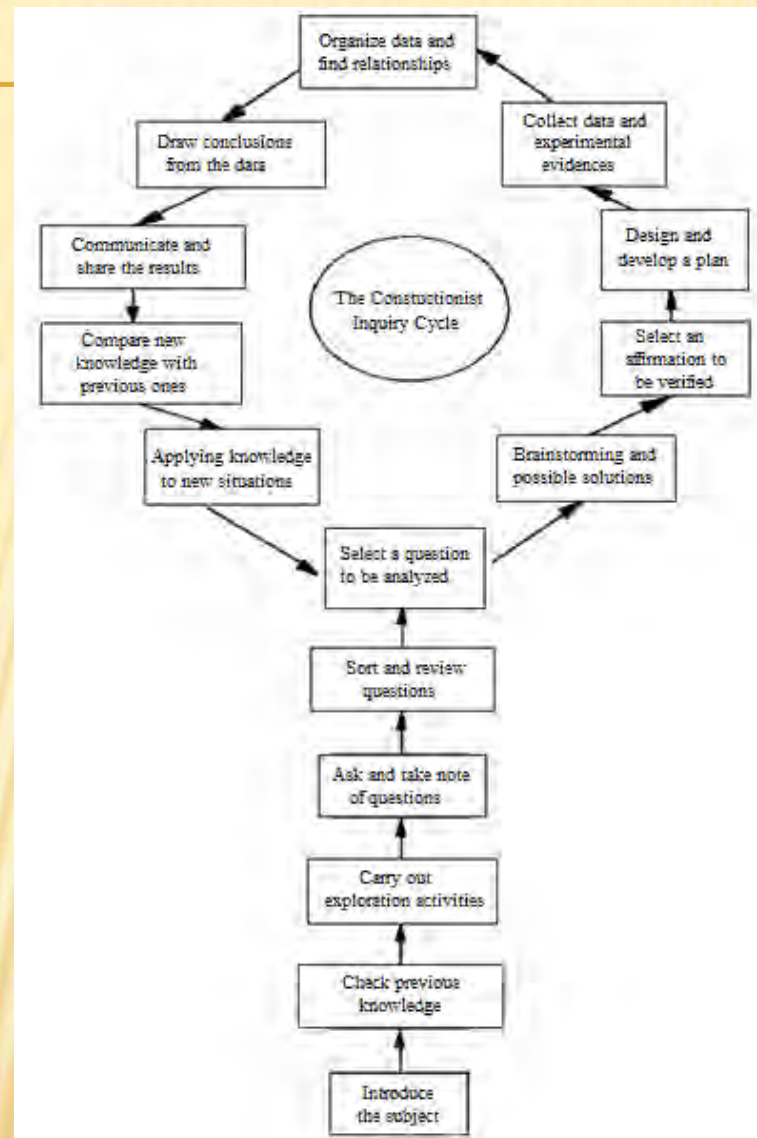
Theories of constructionist learning define learning as a **progressive and strongly contextualized process**.

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



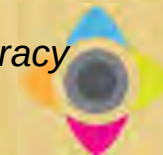
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The “ 5 E “ Model (Bybee, 1993)



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)



The screenshot shows the NASA eClips website. The top navigation bar includes links for NEWS, MISSIONS, MULTIMEDIA, CONNECT, and ABOUT NASA. The main content area is titled 'NASA eClips™' and features a banner for 'Innovative Real World Learning'. Below the banner, there is a section for '5E Teaching Model' with links to 'Grades K-5 (Our World)', 'Grades 6-8 (Real World)', 'Grades 9-12 (Launchpad)', 'NASA 360 For General Public', '5E Teaching Model', and 'NASA eClips™ FAQ'. The 'Connect' section includes links to Twitter, Facebook, and YouTube. The 'Educator Guides' section features a 'New!' badge and a link to 'These guides use video segments as an instructional tool'. The 'Teacher Toolbox' section includes a link to 'Find resources for using NASA eClips™ in the classroom'. The main content area on the right is titled '5Es Overview: "The 5E instructional model"' and contains the following text:

What is a 5E instructional model?
This model describes a teaching sequence that can be used for entire programs, specific units and individual lessons. NASA eClips™ supports the 5E instructional learning cycle, helping students build their own understanding from experiences and new ideas.

What are the 5Es?
The 5Es represent five stages of a sequence for teaching and learning: **Engage**, **Explore**, **Explain**, **Extend** (or **Elaborate**), and **Evaluate**.

ENGAGE: The purpose for the ENGAGE stage is to pique student interest and get them personally involved in the lesson, while pre-assessing prior understanding. During this experience, students first encounter and identify the instructional task. During the ENGAGE stage, students make connections between past and present learning experiences, setting the organizational ground work for upcoming activities. NASA eClips™ are designed to ENGAGE students. Through discussions, the videos may be used to uncover students' prior understanding. The video format arouses students' curiosity and encourages them to ask their own questions.



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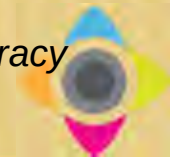
<http://www.nasa.gov/audience/foreducators/nasaeclips/5eteachingmodels/>



The "5 E" Model (Bybee, 1993)



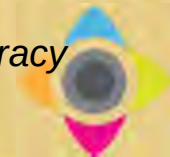
In the "**Engage**" phase, the teacher (and/or students, depending on the type of IB activity) set up the learning environment to intercept as much as possible the student's interest and generate curiosity and interest in the topic



The “ 5 E “ Model (Bybee, 1993)



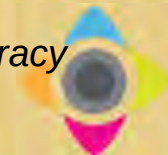
"**Explore**" is the beginning of the real engagement of students in IB activity. They seek information, possibly (and hopefully ...) ask questions, develop hypotheses to be verified, collect data.



The "5 E" Model (Bybee, 1993)



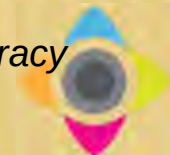
The "**Explain**" phase is the one in which students build models (descriptive or explicative), discuss the results among them and with the teacher and learn to share and communicate what they have learned.



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.



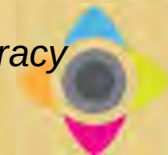
The "5 E" Model (Bybee, 1993)



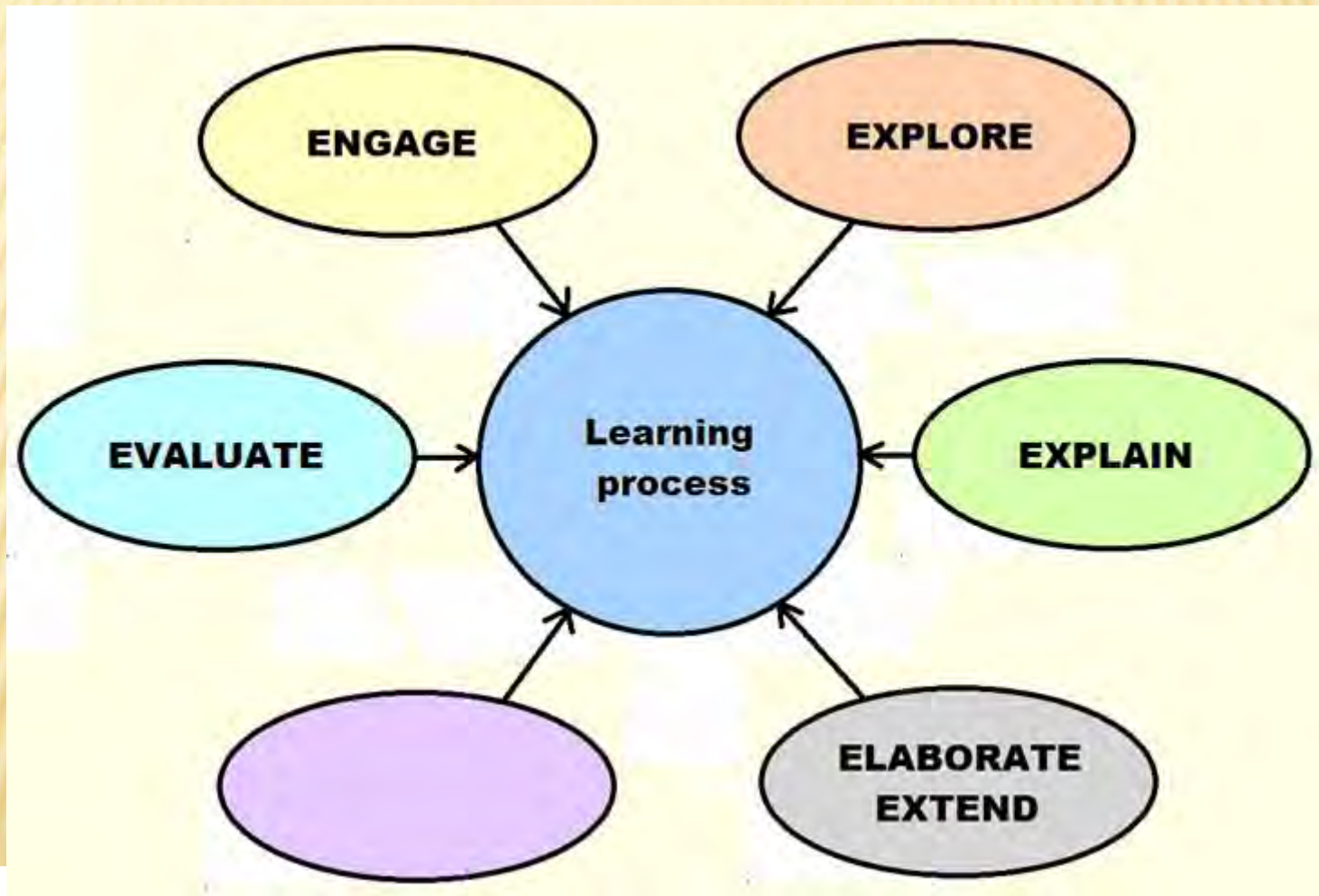
During the "**Evaluate**" phase which, in spite of its position at the end of the "5E" list, should be carried out throughout the course of IB activity, students and teachers carry out an evaluation of their work.

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.



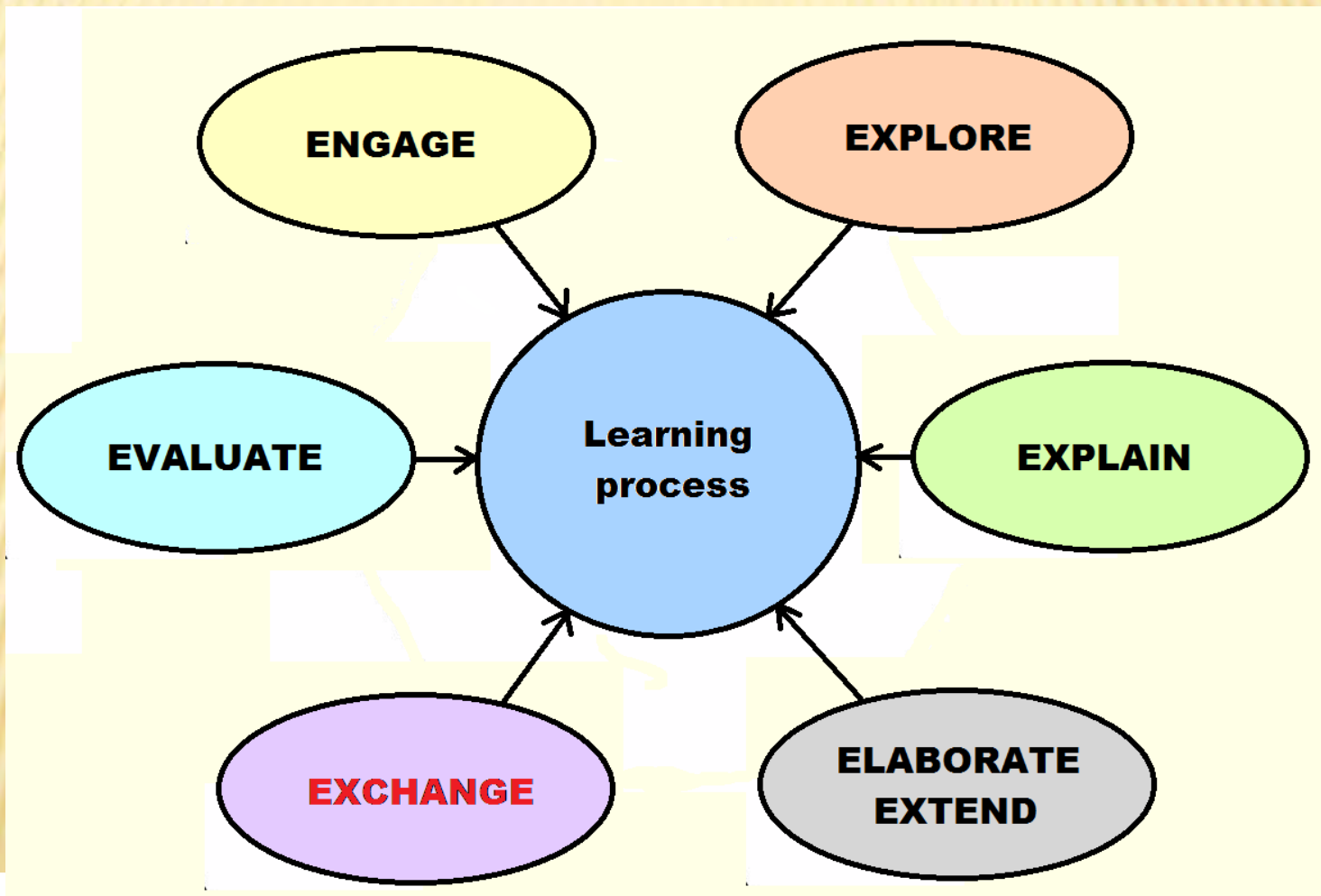
From 5 E to 6 E



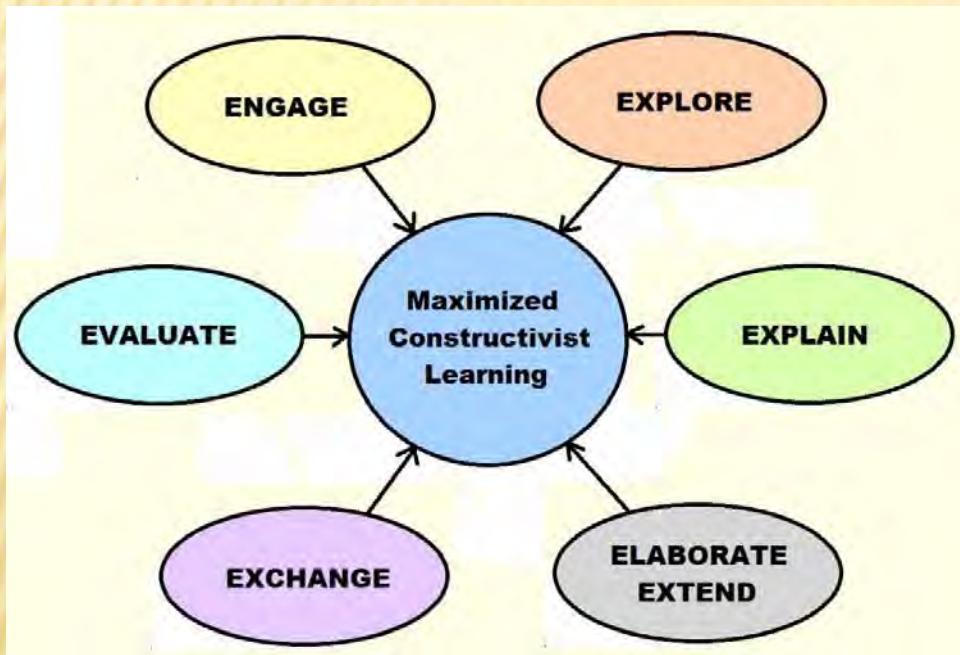
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From 5 E to 6 E



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.



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

Traditional teaching approach

The teacher is the primary provider of information

In the lab, students are mainly engaged in verifying physical laws and models

Students work in groups under the guidance of teaching material provided by the teacher

The final construction of "knowledge" is always entrusted to the teacher

Inquiry-Based Teaching

The teacher facilitates the search for information, which is mainly done by students

Students build (at different levels) their work plan

In the lab, students focus their attention on collecting, processing and analyzing the data required by their plan

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 demonstration

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



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Some examples in the classroom ...



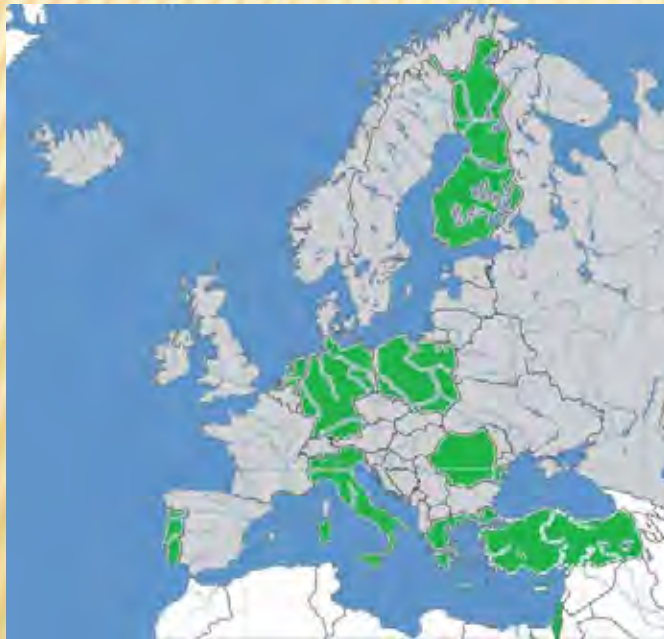
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The FP7 “IRRESISTIBLE” Project



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

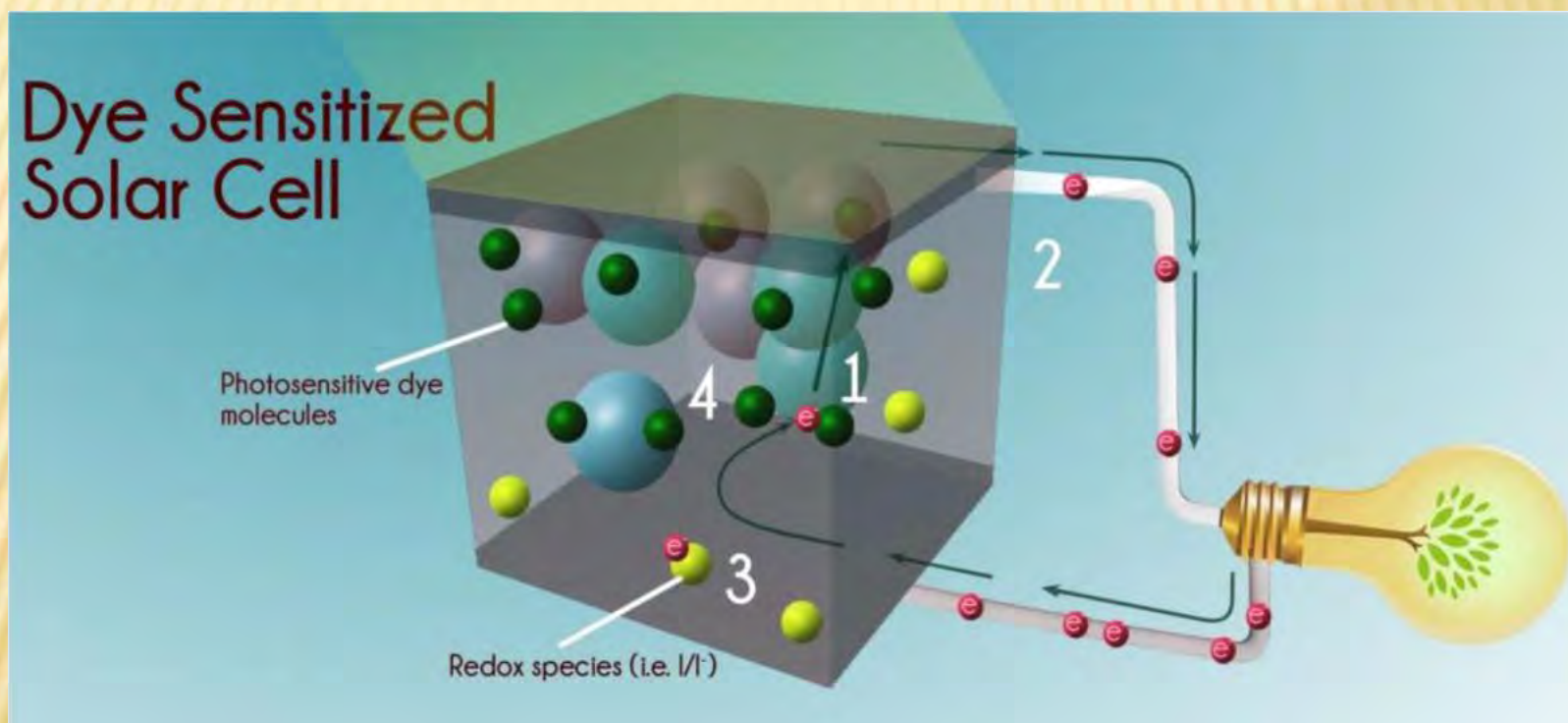


- Research activities on renewable and non-renewable energy sources. **Explore- Engage**
- Production of materials and sharing. **Elaborate**
- Assembling a "Graetzel Cell" and measurements. **Explore**
- Preparation and presentation of a exhibit to a "Science Fair". **Elaborate-Exchange-Evaluate**

The FP7 “IRRESISTIBLE” Project



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 (TiO_2).



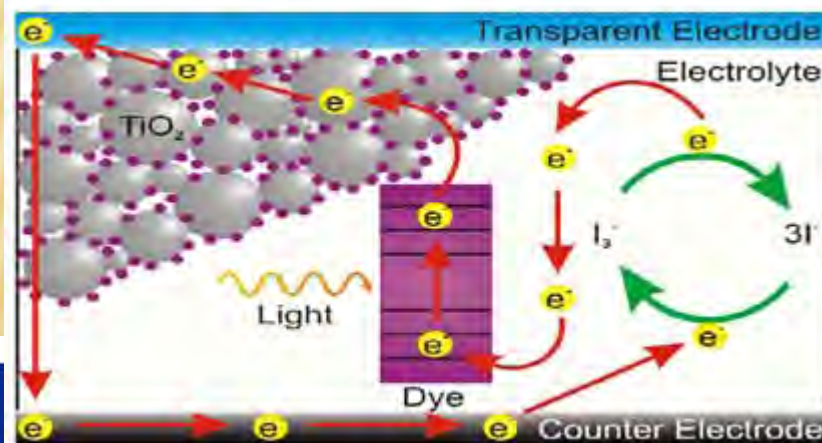
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The active material is a dye which transfers electrons to titanium dioxide following absorption of photons.

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 **nanostuctured** 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)

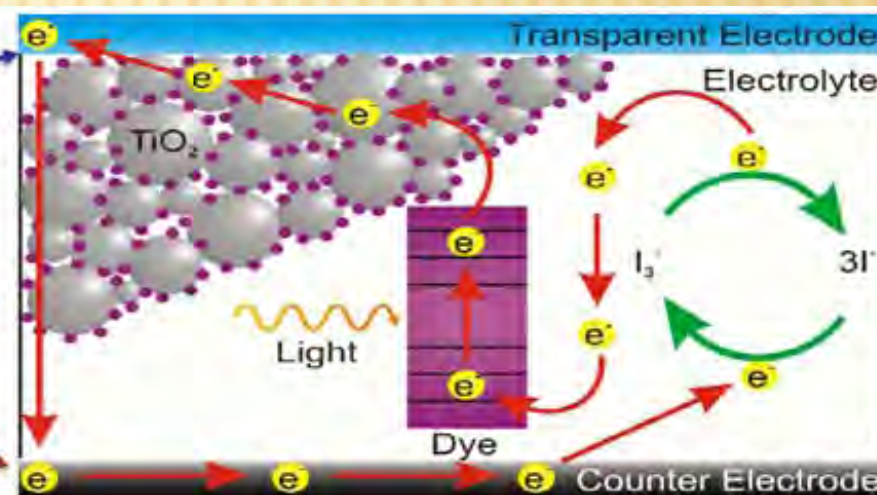


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The electrolyte solution, generally based on iodine (I_2) and potassium iodide (KI), has the task of allowing the transport of the electron hole formed at the same time as the electron emission when the dye molecule interacts with a photon. In this way the electron lost through oxidation is returned to the dye and the cycle can then be repeated indefinitely

- The electrons collected by TiO_2 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/triiodide (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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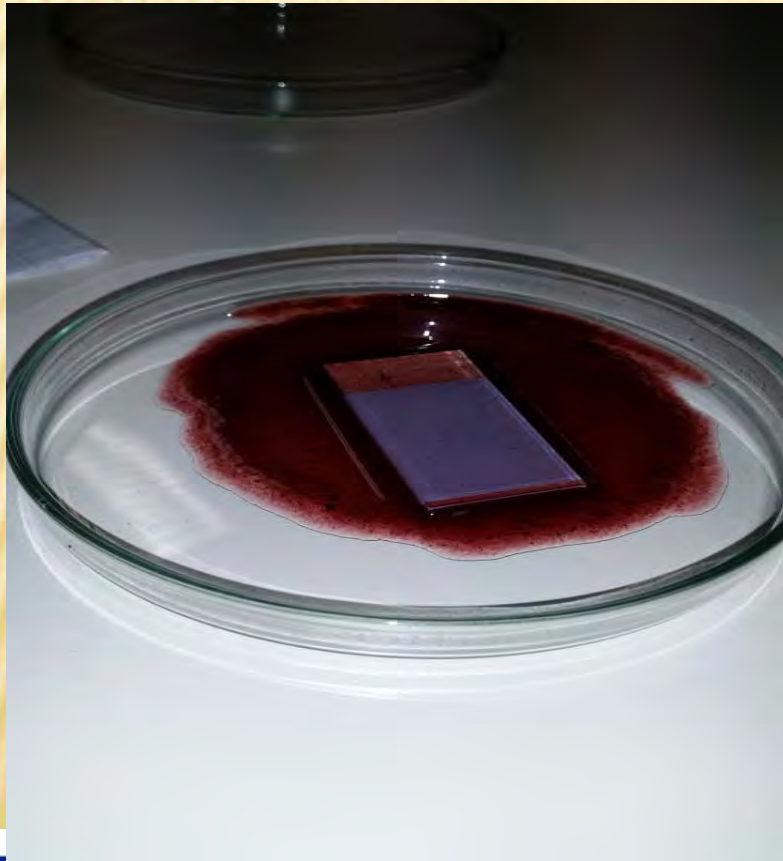
Measuring the resistance of the faces of the Graetzel cell slides to determine what the conducting face is



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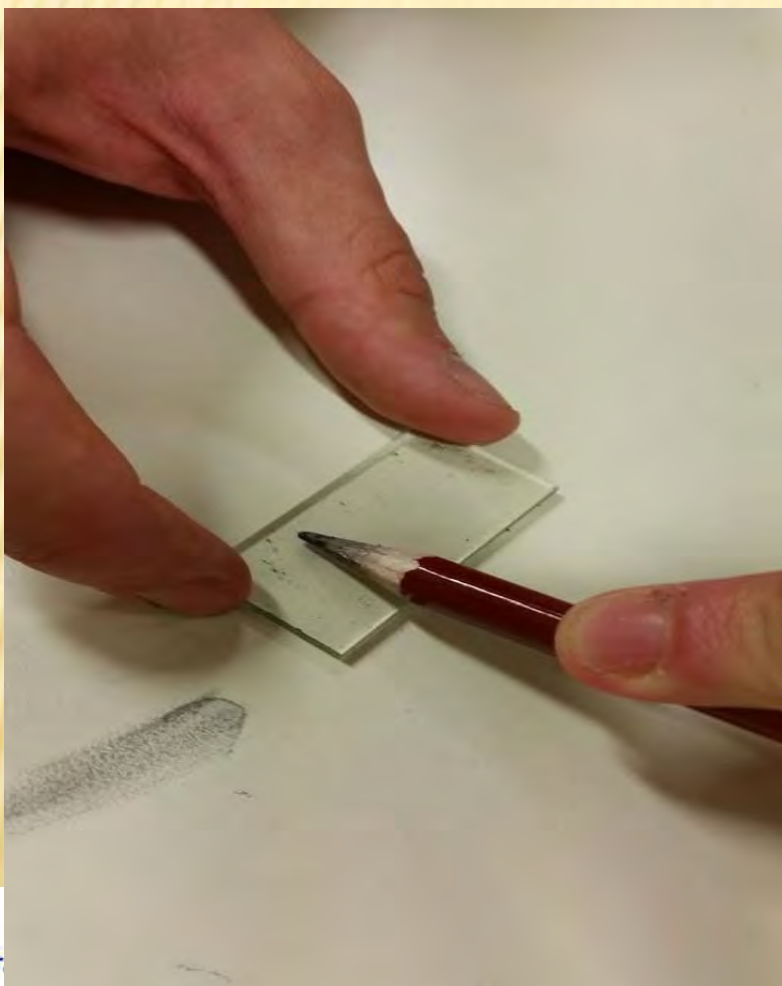
Immersion of titanium
dioxide covered slide
in blueberry juice



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The FP7 “IRRESISTIBLE” Project



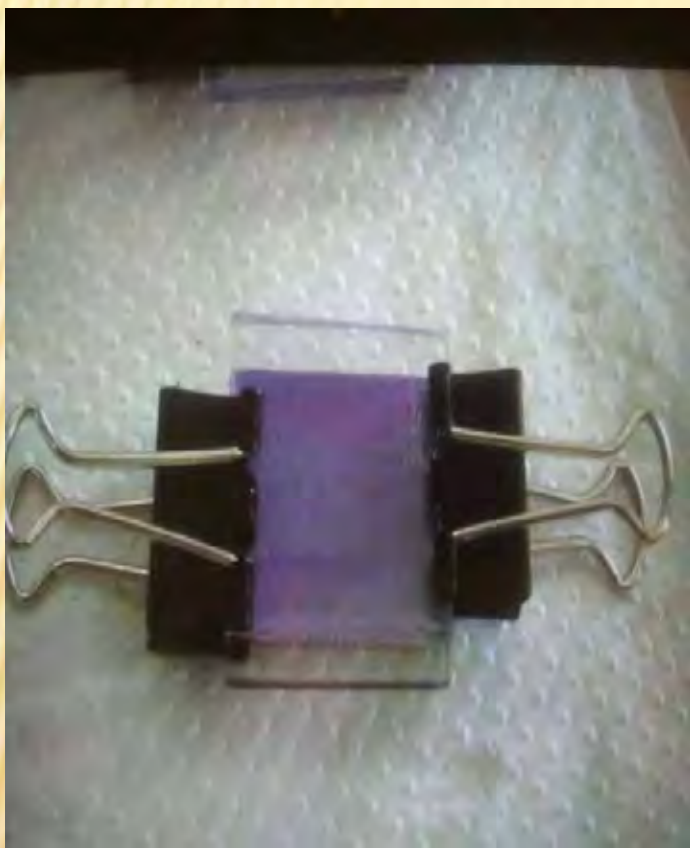
Preparation of the counter electrode: A layer of graphite is deposited on the conductive part of the slide



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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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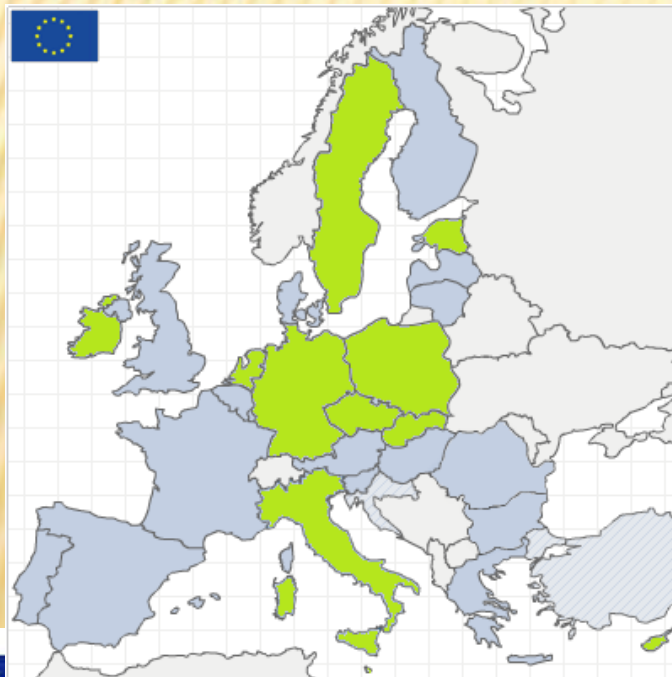
The FP7 “IRRESISTIBLE” Project



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



The FP7 “ESTABLISH” Project



Inquiry-Based teacher training activities at the University of Palermo

Introduction to Inquiry-Based Methods.

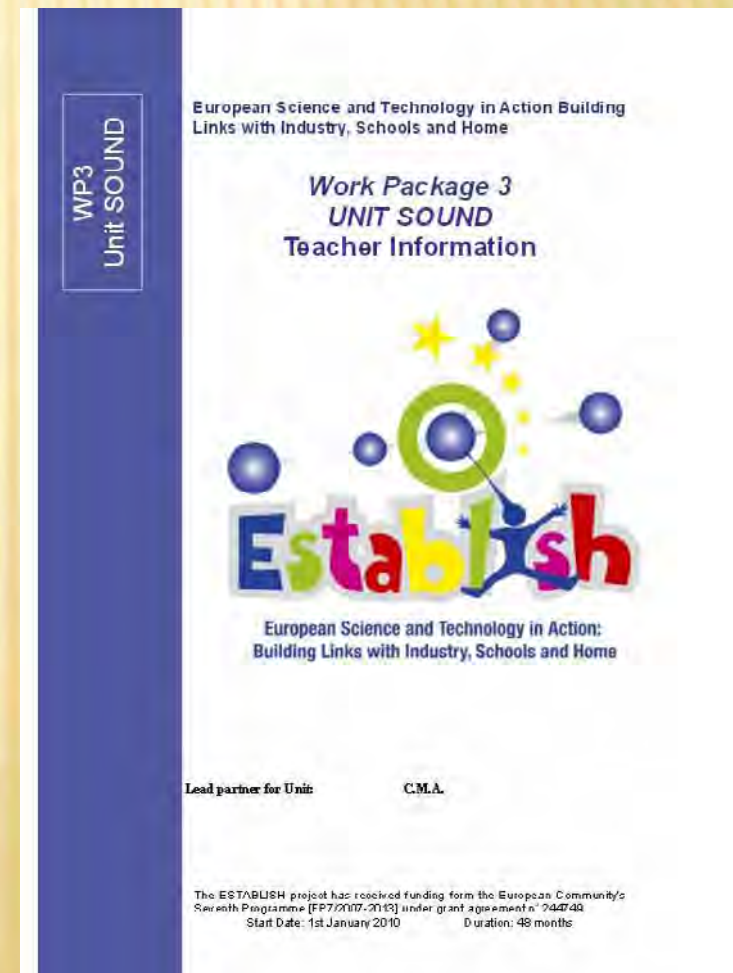
Critical analysis of a work unit submitted by partners:

Sound

22 Secondary School teachers during School Year 2010/2011



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The FP7 “ESTABLISH” Project



Inquiry-Based teacher activities at the University of Palermo

Development and trialling of a T/L unit::

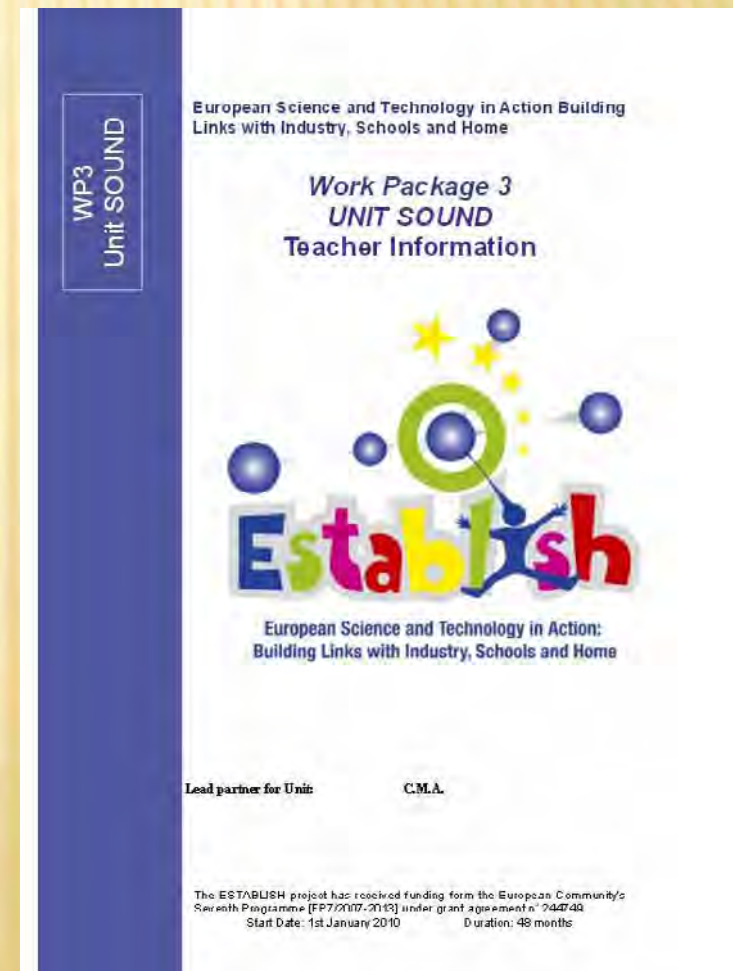
Designing a Low Energy Home: Heating and Cooling

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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The FP7 “ESTABLISH” Project



Inquiry-Based teacher activities at the University of Palermo

Trialling of three T/L units:

Blood Donation

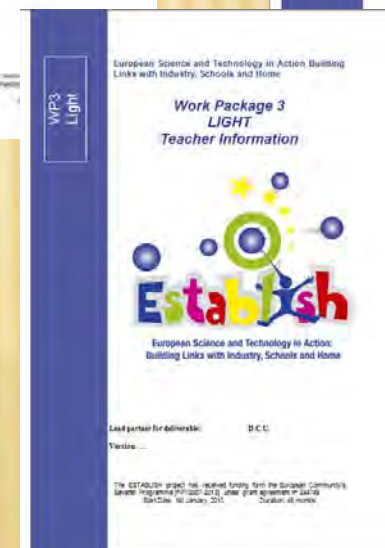
Direct Current Electricity

University of Kosice (Slovakia)

Light

Dublin City University (Ireland)

**22 Secondary School teachers during
School Years 2012/2013**



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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').





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 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



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

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



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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 than 11 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,



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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 ($\text{W/m}^2\text{K}$). 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 $1.76 \text{ W m}^{-2} \text{ K}$; and insulated with 140 mm modern insulation: U-value $0.20 \text{ W m}^{-2} \text{ K}$.



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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

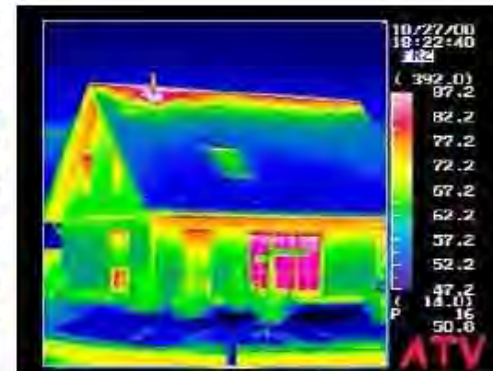
The best way to make efficient refrigerators is to use different types of thermal insulators in their construction. Depending on the type of refrigeration device, the insulator may be a vacuum, styrofoam or a type of fiberglass. The main aim of a refrigerator insulator is to keep outside thermal energy 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.

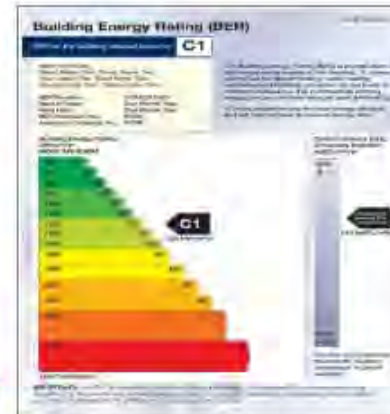


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Energy Performance Certificates

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-innovation.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 Parliament 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. Türlér, 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 heater, 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





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

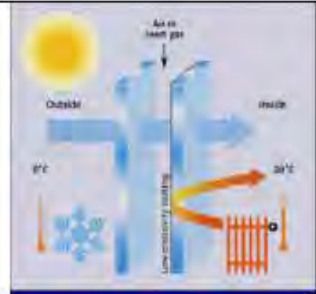
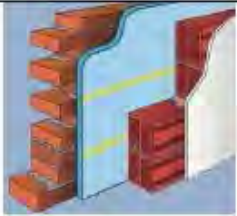
We begin our work by observing the characteristics of some houses. Then, we try to understand why they are very different from each other.

		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 your 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.



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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)

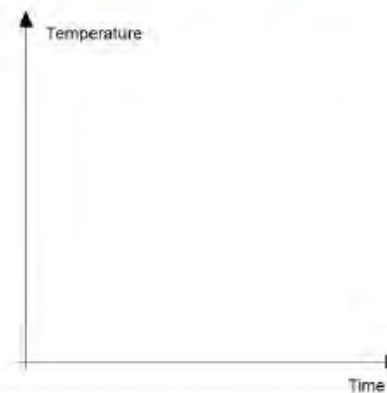
Suggestions for use:

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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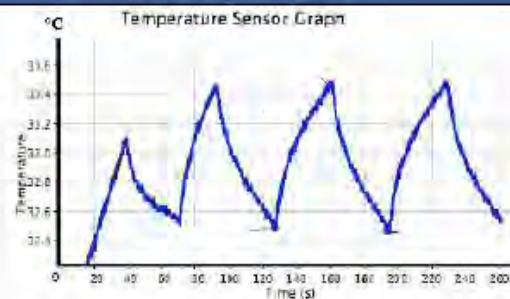


DATA ANALYSIS

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 University (DCU) from 7th to 9th June 2012.

They discussed their results with colleagues from all the partner countries



Teacher Conference - Dublin 7th-9th June 2012



Teaching at the heart of learning

Dublin City University, Ireland
7th - 9th June 2012

[Poster 1](#) [Poster 2](#) [Poster 3](#) [Poster 4](#) [Poster 5](#)



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INQUIRY BASED SCIENCE EDUCATION STUDENTS OF 1° YEAR SECONDARY SCHOOL DESIGN A LOW ENERGY HOME

Daniela Bellomonte e Laura Gambino

ISS: science-learning goals

Students participating in a preliminary science-based, problem-solving activity, identifying "problems" that require scientific understanding to solve. After understanding the problem, students design a solution, test the solution, and evaluate the solution. Students compare the results of their design with their expectations, and present to the class, and explaining any differences.



DISCUSS

Students working on a project.



How can you maintain the heat in your house? Can you identify the different factors affecting the heat loss?

Students working on a project.



How can you maintain the heat in your house? Can you identify the different factors affecting the heat loss?

Students working on a project.



How can you maintain the heat in your house? Can you identify the different factors affecting the heat loss?

Students working on a project.



How can you maintain the heat in your house? Can you identify the different factors affecting the heat loss?

Students working on a project.



How can you maintain the heat in your house? Can you identify the different factors affecting the heat loss?

Students working on a project.

Testing a house model

1. How to keep warm your house model

DISCUSS AND EXPLAIN

1. Activity

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

INQUIRY BASED SCIENCE EDUCATION DESIGNING A LOW ENERGY HOME: STUDENTS LEARN HOW THERMAL ENERGY TRANSFERS BETWEEN SYSTEMS

Daniela Bellomonte e Laura Gambino

Conduction

1. Observing ice melting in plates of different materials

DISCUSS

Activity 1.1

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Convection

Observing convection currents

DISCUSS

Activity

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

Thermal Radiation

Build and use home-made radiometers

DISCUSS AND EXPLAIN

Activity

Students working on a project.

Students working on a project.

Students working on a project.

Students working on a project.

traditional method	case
Treatments and in-depth exploration of the subject	Autonomy in building up knowledge and skills
Developing Problem Solving skills	Ability to cooperate and interact with others
	Ability to communicate (collaboration experiments)
	The students participate actively and constructively
	The students estimate decisions that encourage the creation and assessment of ideas and concepts
	Active Learning and engaged
	Constructivist acquisition of knowledge is promoted



UNIVERSITÀ DEL PALERMO



University of Palermo - Physics Education Research Group



PALERMO

From the inquiry to application

1st Class - Course in Computer Science - Academic Year 2011/2012

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The problem

Thermodynamic and energy aspects play a key role in today's world. Energy is the most valuable resource and is a key factor in the development of the world. Today many energy resources are being used and the demand for energy is increasing. The scientific community is working on the solution of these problems and is looking for new energy resources.

The use of renewable resources, that are unlimited, distributed all over the world and with a low environmental impact.

The scientific community is working on the solution of these problems and is looking for new energy resources.

The improvement of energy efficiency that in case of buildings means doing the same tasks with a reduced use of energy.

Energy resources are changing due to the increase in emission of CO₂ in the atmosphere.

Their decision and consequently the end of their economic convenience.

The experimental approach to the problem was very useful because allowed us to verify the manner in which the heat flows. The use of measuring instruments inserted with the computer allowed us to construct the graphs in real time focusing on the phenomenon and on the calculations and formulas. The plot has enabled us to see the results and to see the results on the video to have more information about the problem.

Searching on the web we found that among transport industry and buildings the greatest amount of energy is used by buildings and a large amount is wasted and dispersed in the environment.

To conduct the research, we investigated in three directions

The construction of the model of the house

The measurement of the heat flows

The construction of the model of the house

We have used some models of the house original data, in the same thickness but different materials. The heat source was a lamp of 100 W. The temperature was measured inside the model revealed the heat of temperature during heating, with a light lamp, and cooling with heating of the lamp. The temperature has changed in different ways.

The property during the heating phase of the polystyrene model is due to a small accidental opening of the model and this made us reflect on the importance of doing and avoiding that could happen in the house.

We used the model of polystyrene and two sensors placed on the wall opposite to the heat source.

The first measurement was made with the sensors at the same height. The second measurement was made with the sensors at different heights.

The measurement was made by placing a light source of 100 W at the same distance from the walls of polystyrene and with a temperature sensor from the inside of each wall.



The experiences that we have conducted allowed us to discover that some materials can improve the isolation because they carry less heat. This can be used in the coating of buildings.

One of the ways to improve the energy class of a house is to use materials of construction and construction for thermal conductive.

The plot shows that some simple and cheap solutions to reduce the heat loss can be found outside with economic and environmental benefits.



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