ECO-SMART PROJECT

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INTRODUCTION

This curriculum is designed to transform high schools into Eco-Smart schools so that the education and training affairs are planned, programmed and beneficial for the country. And it offers this in a curriculum structure growth strategy are included. Our schools are the places where this curriculum structure is applied. Our schools are institutions that provide education and training services students using this curriculum. The curriculum prepared is suitable for all high schools. It includes lesson plans planned in 1-hour activities on the basis of STEAM courses. It will raise awareness of high school level students on the issues. With this curriculum, students will reinforce their learning by covering the activities in both mathematics, science and art classes under the specified titles for one academic year.

In this curriculum study, the task of preparing the modules and lesson plans was determined as follows:

1. Environmental and Social Knowledge- Olemisen Balanssia ry
2. Electricty and School Heating- Fablab
3. Water Consumption- Ertev
4. Carbon Foodprint- Innovation Frontiers
5. Climate Change- OMEM
6. Waste Management- Permacultura Cantabria
7. Energy Action Plan Strategy- Lycée les Pannevelles

PARTNERS INTRODUCTION

Lycée Les Pannevelles is a polyvalent (general and vocational education) high school with skills in HVAC, civil engineering, mechanical maintenance, building construction, woodwork and heavy equipment driving for the vocational part. The high school welcomes every year about 1200 students, aged 15 to 20 years supervised by 120 teachers and 20 administrative staff. The high school prepares students for several levels of graduation such as the certificate of professional competence, vocational, technical and general baccalaureates and advanced vocational diplomas. Our high school has several workshops equipped with pedagogical installations related to the studied disciplines. In addition, we have numerical equipment such as 3D printers, numerical milling machines, Arduino makers, Raspberry Pi cards, CAD software (Revit, AutoCAD, Solidworks…) to transform our workshops into makerspaces.

This curriculum will give to the teachers and students all the theoretical concepts that are important to meet the Eco Smart Schools philosophy.

Organized around 7 key modules it presents the knowledge and skills to be studied in class. To make it more entertaining and because fighting against climate change, reducing energy consumption and changing occupant's behavior is made by action, we tried to design practical activities where students are practicing and discovering contents by experimentation and observation on the field or in class through concrete activities.

ERTEV aims to prepare individuals for the changing nature of work and emerging new technologies related to industry 4.0 and digitalization through improving the quality and relevance of basic education with STEM skills and developing technical and professional skills. ERTEV has been organizing vocational courses and trainings, training of trainers on emerging technologies and new manufacturing technologies and their applications in the classroom. ERTEV is a foundation which contributes to basic education, including technical and vocational education, provided by the state and aims to impact on individuals, who need technical and professional skills, to raise rational, prudent and creative citizens that society needs. ERTEV is one of the first entity that is striving to support individuals, teachers and public bodies to embrace new technologies and assist them to acquire future skills that digitalization transformation requires. In this context, ERTEV

establishes partnership with NGOs, Private Sector and Public Sector to widen its impact. The ultimate purpose of ERTEV is to reduce skills mismatch, which is caused by new technologies, through training qualified individuals who are compatible with emerging technologies. That's why expanding its operations is crucial for ERTEV. In this context, know-how transfer and mobilization are essential components for ERTEV and its operations. Therefore, ERTEV does not only implement projects but creates systems/projects that can be copied/transferred to other locations. To set an example, ERTEV owns a caravan called Maker Caravan which is a fully equipped Mobile STEAM Unit used for project outreach activities all around Turkey to reach disadvantaged locations and people. ERTEV also has an incubation center which is dedicated to young entrepreneurs and inventors who are unable to build up their projects and/or ideas due to lack of experience, tools, know-how.

This innovative curriculum makes students and teachers to gain Eco-Smart literacy. Environmental literacy, energy and energy saving form Eco -Smart literacy under one roof. Students understand the importance of the environment, energy, recycling, waste management and saving. Students who make the connection between these concepts gain knowledge, responsibility and autonomy. They understand how to apply these concepts in their schools.

Innovation Frontiers: Innovation Frontiers IKE is an innovative educational technology research company that specializes in creating educational, engaging, and entertaining learning experiences that incorporate innovation, creativity, and gamification to enhance flow for learners. Our company offers a wide spectrum of solutions, including interactive custom eLearning, Serious Games, Open Educational Resources, Training Simulations, Educational Animations and Mobile Learning. We combine game design, game technology, instructional design and psychology to master the art of crafting learning games, simulations and training. All developments are tailored precisely to our clients' individual needs. Moreover, the company integrates the implications of educational neuroscience in the classroom so as to improve the efficiency of learning and teaching.

The world around us changes day by day and the climate crisis has sadly become a reality. The Eco-Smart curriculum offers schools and students the opportunity to acquire the knowledge needed to deal with a lot of important issues via a wholistic approach. Its innovation element consists of the practical aspect of the curriculum, allowing students to actually change their school for the better.

OMEM: Osmangazi District of National Education Directorate is a public body under the Ministry of National Education. Our Directorate established on 15.08.1988 is the official education authority responsible for the monitoring, evaluation and development of all official and private education institutions in Osmangazi, which is the largest city with a population of 850.000 in the center of Bursa. There are 257 public and 186 private education institutions, including 25 vocational high schools within the scope of our directorate.

Depending on the duties and responsibilities under the Ministry of National Education Directorate, we have 8 departmental manager and one District Director of National Education in fields of education and training. Our directorate has been carrying out its activities in such areas; strategy development, human resources and management, guidance and supervision, primary-secondary and high school and vocational education, media and cooperation, measurement and evaluation, examination services and lifelong learning for adults. Our Directorate also plays an active role in creating educational policy while conducting projects for the students, teachers, adults and parents involved in education. In addition, they organize seminars, conferences, in-service training courses, creating educational resources, materials and e-learning applications.

Eco-smart curriculum has been put forward as a comprehensive curriculum study by taking 7 basic headings. students will be able to apply this curriculum in their classrooms with their teachers and peers in STEAM lessons. In this way, students' awareness of issues such as climate change, carbon footprint, garbage management, water consumption, heat management will increase and they will be able to implement lesson plans based on in-class experiments and observations.

The Cultural and Environmental Association Permacultura Cantabria develops its main activity in the Pasiegan Valleys (Cantabria, northern Spain). Like other rural areas of the country, Cantabria is characterized by an aging and declining population, high rates of unemployment and scarce opportunities for the social participation or learning of its inhabitants.

In this beautiful setting, more than 15 years ago, a group of professionals began to meet and organize activities in their community. Their goals were to investigate alternatives to achieve a sustainable culture, to take care of each other and to enjoy what they did. The intention of Permacultura Cantabria was to, little by little, create an international reference platform, based on ecological and healthy systems, which could help to generate enthusiasm and enrich society, which they appreciated as numb and without hope, due to the lack of references. In order to do so, they created an experimental, sustainable and self-sufficient property, in which they have hosted many volunteers, organised many courses and group activities.

https://www.permaculturacantabria/

With this curriculum students will experience real life learning, real issues will be tackled. Schools will be more energy efficient, more sustainable. Being part of the activities will engage students, teachers and other staff and it will revert to the community.

FabLab Nordvest is a classic fablab, (abbreviated from English fabrication laboratory) and thus a creative makerspace-workshop where there are digital and analog tools that non-technical people can use to create things, allowing everyone to learn about technology and realize their own good ideas. Fablabs is found all over the world and each Fablab is equipped with the same digital tools, such as laser cutters, 3D printers, CNC milling machines and microcontrollers etc. FabLab Nordvest relates to Fablab Foundation which is the main non-profit organization of all Fablab around the world. The Fablab Foundation started in 2009 and runs, among other things, FabAcademy, which is a training in practical use of tools in a Fablab.

Since its establishment in 2013 FabLab Nordvest has participated in several educational project aiming to train youth in technology, innovation, design-thinking and STEM topics. In the recent years, sustainability has become an important topic which corresponds perfectly with central ideas from the maker movement eg. being able to repair things and technology. Among sustainability projects are found a plastic recycling lab and repair-café activities.

Ecological awareness is probably the most important subject to teach students these days, and what better way to do it than to make the observe and improve their surroundings, namely their school. A school with its buildings, installations, electric-, heating- HVAC- and waste systems represent a manageable case to study, track and optimize with a curriculum created to do so. That is the aim of this project.

Olemisen Balanssia ry is a research-based entity founded in year 2014 in Raisio, Southwest Finland. The main focus of our work is the definition of educational needs, with activities focussed on data collection, structured research, detecting right digital pedagogies and experimental assessment on results through digital piloting. Inspired by the Finnish educational model, we prioritise 21st century competences and result-oriented learning outcomes alongside cutting-edge educational technologies. We believe that everyone should be prepared for today's workforce and understand the complex world in which we live and so we need to raise standards, providing a solid education in science, mathematics, and technology and developing the transversal skills to work collaboratively and creatively with others.

Olemisen has proven it is success by being a member of world-wide organisations such as Anna Lindh foundation.4000 world-wide organisations and over 100.000 members.

Olemisen also a member of Interkulttuurinen Foorumi in the regional context, one the core member of 8 organisations within the region Varsinais-Suomi. Olemisen also puts effort together with Turku Municipality, Turku University Applied Science department and with some private companies to create disruptive changes and impacts. Olemisen has a productive co-operation with Turku City government's social department as well.

Eco-Smart project aimed at STEAM teachers to gain knowledge, skills, attitudes, and values about Eco-Smart literacy which we developed in IO1.By taking competencies in the framework, now IO2 it is more practice-oriented and hand-on approach to stimulate real engagement in the class.Entire curriculum will define the borders and general approach on how to plan a semester by providing teachers extracurricular lessons plans to use in their lessons.

IMPLEMENTATION AND INFORMATION

- The program is designed for 1 academic year. The high school curriculum consists of 7 MODULES and each activity consists of 1 or 2 hours lesson. But the length and the content can be freely modified and adapted by the teachers regarding the local specificities.

- The achievements of this curriculum have been prepared in accordance with IO1 Eco-smart Literacy.

- Each module consists of separate activities for STEAM courses. Modules will be covered simultaneously in steam courses.

- The curriculum supports individuals aged 15-18 to increase their awareness of climate change and change their behaviour in this regard.

- Students will begin to understand how to do it by trying to change a few of themselves to facilitate change in others high impact behaviours first. They will be guided through various interactions.

- Activities developed based on effective behaviour change.

- Techniques defined by more than one discipline and theme-based practices will be applied in partner schools. Students will learn the techniques experimentally and will do these activities in their schools based on a design process.

- Compatibility: in the implementation of the activities in the program, the regional and sectoral needs, the equipment of the school, the teacher status and physical capacity, and the interests and needs of the students should be continued.

- Occupational health: occupational health and safety measures should be taken while achieving course and learning unit acquisitions.

COMPETENCIES

The competencies field can be divided in 2 parts, general and specific.

GENERAL PURPOSES

1) COMMUNICATION IN THE MOTHER TONGUE: Using concepts, thoughts, opinions, feelings and facts both verbally and in writing expressing and interpreting (listening, speaking, reading and writing); education and training, work to engage in linguistic interaction in a way that is appropriate and able to develop new ideas in all kinds of social and cultural contexts such as place, home and entertainment.

2) COMMUNICATION IN FOREIGN LANGUAGES: Usually the basic skill dimensions of communication in the mother tongue sharing feelings, thoughts, concepts, facts and opinions both verbally and in writing. a suitable series of education, training, workplace, home and entertainment according to the wishes and needs of the person.

It is based on the ability to understand, express and interpret in social and cultural contexts. It also requires skills of communication, mediation and intercultural understanding in foreign languages. Depending on the level of competence, social and cultural background, environment, needs and interests of the individual, it will change and develop between different languages with the dimensions of listening, speaking, reading, and writing.

3) DIGITAL COMPETENCE: It covers the safe and critical use of information communication technologies for business, daily life and communication. This competence is supported by basic skills such as access to information and the use of computers for evaluation, storage, production, presentation and exchange of information, as well as engaging in common networks and communicating via the Internet.

4) LEARNING TO LEARN: Individuals will be able to use their own learning actions to manage effective time and information. This competence is to be aware of the learning needs and processes for a knowing and successful learning action.

It includes the ability to cope with difficulties. To acquire new knowledge and skills are process and means seeking and making use of guidance support as well as self-adaptation. Learning to learn, knowledge and skills in a variety of environments such as home, workplace, education and training previous learning and life experiences for use and application in contexts it mobilizes learners towards endurance.

SPECIAL PURPOSES

1- Environmental sensitivity or appreciation, in terms of responsible attitudes toward pollution, technology, economics, conservation, and environmental action, and a willingness to recognize and choose among differing value perspectives associated with problems and issues. Motivation to actively participate in environmental improvement and protection, desire to clarify one's own values, and confidence to make decisions and judgments about environmental issues according to one's sense of morality (MODULE 1)

2- To recognize the combination of responsible electricity and heating consumption awareness, knowledge, skills, responsibility and attitude needed to make electricity and heating consumption related decisions and ultimately take actions to reduce the adverse effect of electricity and heating consumption. To understand and apply the correct and sustainable mindset required to reduce the individual and institutional electricity and heating consumption. (MODULE 2)

3- To recognize the combination of responsible water consumption awareness, knowledge, skills, responsibility and attitude needed to make water consumption related decisions and ultimately take actions to reduce the adverse effect of water consumption. To understand and apply the correct and sustainable mindset required to reduce the individual and institutional water consumption. (MODULE 3)

4- To enhance awareness on the impact and usefulness of carbon footprint in the environment, and to acquire knowledge, skills, responsibility and motivation needed to make less carbon emissions related decisions and ultimately take actions to reduce the adverse effect of carbon. To understand and apply the correct and sustainable mindset required to reduce the individual and school carbon by means of carbon footprints. In this way, students start discovering and learning about the interaction among human activities footprints, the environment and human well-being. (MODULE 4)

5- Climate Change and Influence to Human Health: to promote student discovery and learning about the complex interactions between climate change, the environment and human health. (MODULE 5)

6- To raise awareness in students, teachers and staff for waste management and how they can responsibly manage waste. To acquire the knowledge, skills, mindset, motivation and sense of commitment to work individually or collaboratively to solve environmental problems and to prevent them through effective waste management. (MODULE 6)

7- Develop an awareness about the interest and efficiency of developing a clearly organized and well-defined mode of action. To set up structured teams whose role is clearly defined and to set clear and achievable objectives. To think about the tools and strategies that must be put in place to achieve the desired goals. To organize in a practical way a methodology allowing efficiency and precision in measurements and information records as well as in their analysis. To master as much as possible the technologies, the equipment but also the environmental, climatic and societal issues in order to understand the issues related to an energy audit. To transmit clear information to all stakeholders in order to set up measures allowing energy efficiency, maximum use of renewable energy sources (RES) and behavior change. (MODULE 7)

TIMELINE OF THE PROGRAM

The program is designed for 1 academic year. The program consists of 7 modules. In the implementation of the activities in the program, the regional and sectoral require school equipment, teacher status and physical capacity, and interests and needs of the students should be assessed. Occupational health and safety measures should be taken while achieving course and learning unit acquisitions.

Timeline proposition

1- October-Creation of ESET teams in schools

2- November - Environmental and Social Knowledge (Module 1) (Giving theoretical information to students)

3- December- Energy Action Plan Strategy (Module 7) (ESET teams in schools practice and create energy plans)

4- January-February- Water Consumption (Module 3) and Electricity and school Heating (Module 2) (for conducting studies on electricity, heat and water consumption in winter months)

5- March- Carbon Footprint (Module 4) (works to reduce carbon footprint can be done more easily in the first spring months)

6-April- Climate Change (Module 5) (it can be done more easily in the spring months of the greenhouse prototype in the school garden in the lesson plans)

7-May- Waste Management (Module 6) (School garbage accumulation-composting requires longer work, so this module can be closed at the end)

PRINCIPLES OF THE TEACHING PROGRAM

Module 1: Environmental & social knowledge

Olemisen is responsible for the development of Environmental and Social Knowledge.Finnish education system and Finnish citizens are quite strong with environmental responsibility and shaping their daily life based on maximum protection of our nature and living in peace with nature. Olemisen framed it is studies under this section:

- To gain environment-friendly behavior in the class
- to explore and be equipped with learning materials in the context of Environmental and Social Knowledge.

We followed an interdisciplinary approach to combine STEAM subjects and split into some disciplines to provide practical lessons that domain teachers can use in their lessons. We hope our learning content will be useful and inspire students to protect our environment and flight with climate change and beyond.

Module 2: Electricity & school heating

FabLab Nordvest has created the heat and electricity module and in that created lessons elaborating the heat and electricity systems and their importance for maintaining a society and allowing people all over the world to reach a developed societal state. Both heat and electricity are types of energy and as such central for everything humans do. At the same time students must understand that both heating and electricity must be preserved and their sources converted into sustainable types in order to keep our collective use within the carrying capacity of the earth.

Module 3: Water consumption

Water is an indispensable resource for life. So, it is important to prevent the waste of water for both today and the future. Therefore, this curriculum has been developed to raise awareness among students about water consumption and encourage them to conserve water which is important to raise environmental awareness. Within this scope, 3 different lesson plans were prepared to be applied in mathematics, engineering and design courses. Lesson plans are based on slideshows, teacher-led demonstrations, student- led research and group analysis of data. Brainstorming, discussion, observation and exhibition techniques were used in the project for calculate and evaluate water footprint, analyze water consumption and encourages others to act towards responsible water consumption.

Module 4: Carbon footprint

Carbon footprint is a very important concept amidst the climate crisis we are experiencing. Understanding how our carbon footprint works will help students realise the impact of their everyday choices, but also give them solid ideas about what they can do in order to minimize it. The lesson plans are ready to use, so teachers only have to acquire the resources necessary (such as the Jenga blocks or the shells). For the students, the concepts are easy to follow and quite fun to implement, so we believe it will be an effective lesson module.

Module 5: Climate change

As OMEM, we have prepared lesson plans on climate change in accordance with the curriculum. Since the issue of climate change is perhaps the most comprehensive topic covering all other topics, we tried to explain the issue at the high school level. In the climate change module, lesson plans were prepared in accordance with Art-Mathematics-Engineering courses. In the lesson plans, experiments and observations that students can make in the classroom about climate change are included. We look forward to the observations and reports of our teachers while they are implementing the lesson plans with curiosity and excitement.

Module 6: Waste management

Permacultura Cantabria has elaborated a Waste Management module, we have provided lessons linked to Science, Engineering, Arts and Maths. This is an excellent opportunity for learning about real issues (waste treatment, waste quantities generated, etc). It is also an opportunity to take part in tackling the waste problem from school or from home.

Module 7: Energy Action Plan Strategy

Raising awareness on climate change, RES, reducing energy consumption, behavior change requires a clear and precise organization. Energy audit demands scientific and technical knowledge and a methodical approach in its implementation to be effective. The idea of this module is to prepare students through concrete small-scale activities to familiarize them with the knowledge and strategies to be implemented. They will subsequently be reproduced on a larger scale in the school. Questions related to group work and organization are also bringed up.

LESSON: SCIENCE

WHERE DO MY WASTE GO?

Purpose/ Learning objective

- Differentiate two types of waste: organic and inorganic
- Understand how organic waste goes back to nature and inorganic does not gain an understanding of life cycles, decomposition, and organic materials
- The correlation of pollution & environmental problems with littering
- Understand the importance of reducing consumption and also prompt them to reuse
- Explain environmental processes and systems
- Explain ecosystem dynamics and the environmental, social, economic and ethical impact of climate change

Intersecting objectives

- Encourages others to act and protect climate
- Collaborates with others and to develop commonly agreed up-on strategies to deal with climate change
- Explains environmental processes and systems

Facilitation

- Create the right environment
- Ensure the expected objective/s are clear
- Energize the classroom & groups through the lesson/activities
- Manage participation

Ideas for follow-up

As the eco code & campaign needs to be shared with your entire school community, it should be prominently displayed throughout the school: place a copy in classrooms and communal areas, on notice boards, near entrances, and in the staffroom. If possible, feature the code on your school website too.

- Students can bring their reusable items and refill them at the canteen/cafeteria (stainless steel water bottles, utensils, lunch boxes etc)
- The school can work with a stainless-steel water bottle producer to sell them at the canteen for a low price.

Resources required

- Student's stationary including notepads and writing materials
- Internet
- Laptop/Smartboard/Projector
- Links for the videos
- Annex 1

Source/The day of the lesson: Materials & Class prep.

https://www.ceeindia.org/
https://www.youtube.com/watch?v=YhHDrv0EO7o
https://www.youtube.com/watch?v=_6xINyWPpB8
https://coral.org/this-global-recycling-day-consider-the-coral-reefs/?gclid=CjwKCAjwqvyFBhB7EiwAER786YePMWCsdk1f7KJVE2_oywl28q9dB_KsR0D4Q0l6kk540jrbdYK2mzBoCM-UQAvD_BwE
https://www.teachengineering.org/lessons/view/duk_landfill_music_less

Implementation

Timing	Instructions step by step
10 min	Pre-activity: Ask students to record/document the different type of plastic they use over 2 days with details of the purpose of use, including advantages & disadvantages & alternatives.
10 min	Screen the "Life Cycle of a Plastic Bottle" and "FoodWaste Convert" • Facilitate a discussion with students about the problems associated with littering and how it leads to plastic pollution. • Ask your students the difference of the waste's types in these videos
20 min	• Divide the class into individual groups • Ask the member of the group to share their consolidated lists
30 min	• Engage students in a discussion on different ways plastic products which could be avoided Annex 1 • Ask the students to display the list on the Eco-smart bulletin • Ask students to create an Eco-code to reduce the plastic waste • Ask the students to display Eco-code on the Eco-smart bulletin and start a signature campaign. *An Eco Code is an environmental mission statement. It should demonstrate your school's commitment to being sustainable, and it needs to be visible, memorable and fun, to everyone in your school.

Annexes

Annex 1:

1. Where does plastic come from?
2. How does plastic get in our oceans?
3. What scene from the film most personally affected you? Why?
4. What does business and industry need to do to help our plastic pollution problem?
5. What does government need to do to help our plastic pollution problem?
6. What do we as a society need to do to help reduce our plastic pollution?
7. What are some ways we can galvanize our community to solve our plastic pollution problem? (i.e. call representatives, letter writing campaign, Plastic Free Pledges etc.)
8. How can we reduce our plastic use on this campus?
9. What can we do personally? (Also See Page 21 of the FAQ for Ideas)
10. How can we creatively and effectively spread this message?

LESSON: ENGINEERING/SCIENCE/TECHNOLOGY

ENVIRONMENTAL POLLUTION

Purpose/Learning objective

- Learning about the different forms of environmental pollution
- Discovering ways to reduce environmental pollution
- Developing the use of descriptive and comparative
- words and research skills

Intersecting objectives

- Explains environmental processes and systems
- Understands the current climate change as an anthropogenic phenomenon resulting from the increased green gas and carbon emissions
- Knows about the main ecological, social, cultural, economic consequences of climate change locally, nationally and globally

Facilitation

- Prepare pictures for students to compare.
- Print photos or project them so they can see them.
- Set up a computer or projector to show videos.

Ideas for follow-up

- As an educator, we support and direct students' positive energies and make sure that they are not helpless. You have the power to help them believe, this change is possible and students can continue this change.
  - "I Can" project, which is a Design course for change, the children to act, to change for themselves and invite them to share with children around the world. Students can bring their reusable items and refill them at the canteen/cafeteria (stainless steel water bottles, utensils, lunch boxes etc)
  - The school can work with a stainless-steel water bottle producer to sell them at the canteen for a low price.

Resources required

- Annex 1
- Annex 2
- Internet
- Computer or Projection

Source/The day of the lesson: Materials & Class prep.

Oil Spill

Gulf of Mexico BP oil spill: https://www.bbc.co.uk/bitesize/subjects/zkw76sg

Oil spills are accumulating in the seas: https://ypte.org.uk/factsheets/oil-pollution-case-study/print

Vehicle Exhausts

Transport systems that cause air pollution (Not an event, but explains air pollution caused by transport vehicles): http://www.ecofriendlykids.co.uk/transportairpollution.html

Fossil Fuel Energy Stations

On the Benefits and Harm of Fossil Fuels: https://www.tes.co.uk/teaching- resource/fossilfuels-nuclear-power--pros-cons-case-study-6087890

Fuels for Power Stations: https://www.bbc.co.uk/bitesize/guides/zs29v9q/revision/2

Airplane Travel

Heathrow Airport Pollution: https://www.theguardian.com/environment/2012/oct/12/heathrow-third-runway-air-pollution

Chemicals Used for Agriculture

Use of pesticides in Vietnam: http://www1.american.edu/ted/vietpest.htm

Water Pollution Caused by Industrial Wastes

Water pollution in China: https://www.bsr.org/en/our-insights/case-study-view/cleaning-up-industrial-water-pollution-in-southern-china

Ganges River in India:https://www.who.int/water_sanitation_health/resourcesquality/wpccasestudy1.pdf

Hidden Consequences of Water Pollution: https://wayback.archive-it.org/9650/20200401091714/http://p3-raw.greenpeace.org/international/Global/international/publications/toxics/Water%202011/Hidden%20Consequences.pdf

Environmental Pollution Cases in India: https://www.coolgeography.co.uk/GCSE/AQA/Changing%20Urban/Urbanisation&environment/Urbanisation&environment.htm

Implementation

Timing	Instructions step by step
10 min	Have your students watch a short video about environmental pollution**.** **https://www.youtube.com/watch?v=_6zIGYK7GME (Annex 1)** Ask your students to write down all the different pollution and ways they affect the environment they see in the video. Ask your students to think about whether any of these types of pollution exist where they live. Are there any other types of pollution they haven't seen in the video but come across locally?
20 min	Divide students into groups of four. Each student in the group has a different case describing the causes and consequences of a type of pollution such as oil spill, vehicle exhausts, plastic bags, landfill, fossil fuel power plants, air travel, agrochemicals, and industrial water pollution. They should read these cases individually from the links provided in *Annex 1 and underline the descriptive words. Give students a few minutes to help each other out for words they do not know and to find the place where the case occurred on the world map *(Annex 2). Later, students can take turns describing the cases they have read to their groups. During this work, encourage students to take notes.
10 min	Continue the lesson by asking each group to write down two things they can do on a daily basis to prevent environmental pollution where they live. Ideas can be written so that they can remind each other in the coming days or weeks.
30 min	Ask each group to come up with ideas that will prevent the type of pollution they are reading about. Ask them to find solutions that focus as much as possible on stopping the cause of the pollution, rather than just addressing the effects of pollution. Let students be creative and support them by providing pollution prevention ideas. Ask students to draw a graph showing the effects of acting to prevent pollution. Students can use words, symbols or pictures. For example: Using fewer plastic bags> Less plastic waste in the sea> Marine life thrives

Annex 2:

LESSON: ENGINEERING/SCIENCE/TECHNOLOGY

ENVIRONMENTAL POLLUTION – CLEANING THE AIR

Purpose/ Learning objective

- Use the engineering design process to create a model indoor air filter.
- Understand how engineers construct air filters toclean air pollution.

Intersecting objectives

- Explains environmental processes and systems
- Understands the current climate change as an anthropogenic phenomenon resulting from the increased green gas and carbon emissions
- Knows about the main ecological, social, cultural, economic consequences of climate change locally, nationally and globally

Facilitation

- If students have trouble thinking of what to build, show them an example.
- If students are having difficulty building a successful filter, encourage them to redesign and test their filter frequently.

Ideas for follow-up

As an educator, we support and direct students' positive energies and make sure that they are not helpless. You have the power to help them believe, this change is possible and students can continue this change.

Resources required

- Annex 1
- Annex 2
- Internet
- Computer or Projection

Source/The day of the lesson: Materials & Class prep.

- Each group should have:
- 2-3 index cards or construction paper
- clear packaging tape
- scissors
- a variety of filter-making supplies (i.e., pipe cleaners, cotton balls, cloth, tape, tissue paper, etc.)
- Copies of the Cleaning the Air Worksheet -Annex1
- For the classroom to share:
- shoebox
- tape
- string
- aluminium foil
- black pepper, sand or similar small particles
- large container (such as a trash can or cardboard box)
- protractor
- hair dryer

Implementation

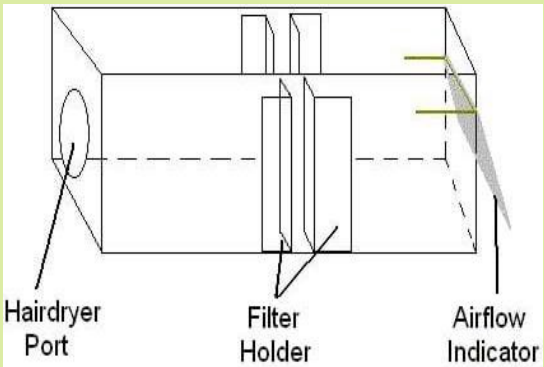
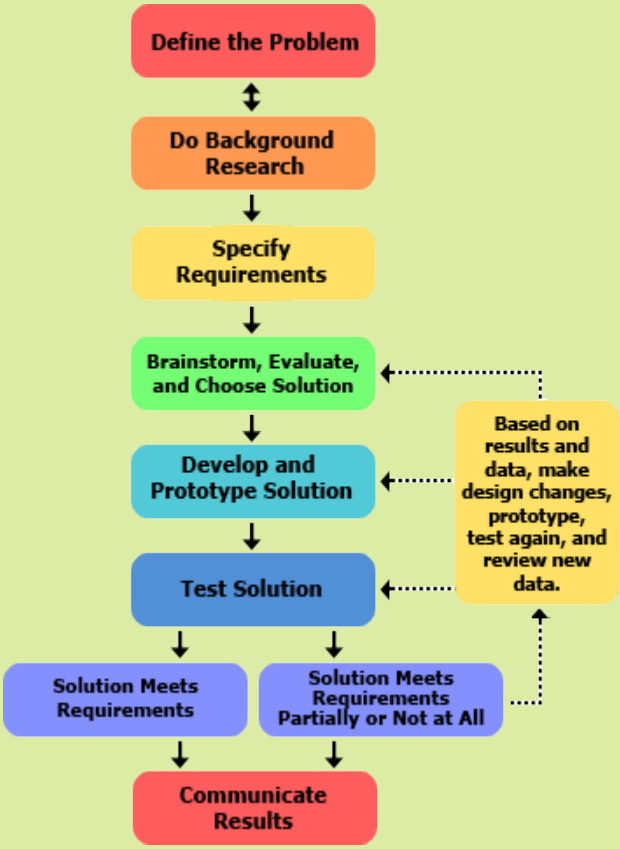
Timing	Instructions step by step
10 min	• Remind the previous lesson's learnings & outcomes to your students. • Review the graphs showing the effects of acting to prevent pollution with your students. • Explain mechanical and environmental engineers develop new technologies using the engineering design process to control the problems that pollution creates. For example, engineers have created air filtration systems that are now common appliances found in homes and businesses. Filtration systems are designed to scrub the air clean of harmful particles and chemicals. Using a variety of filtering techniques, these machines circulate the air several times each hour capturing harmful particles and making the air safe to breath. • Introduce the activity of creating/developing indoor air filter
30 min	Construct the testing apparatus as follows: 1. Cut a hole in the end of a shoebox. The hole should be sized so that the narrow end of a hair dryer fits into it. 2. Cut out the opposite end of the shoebox so it is completely open. 3. Tape a piece of string so that it extends horizontally across the top of the cut-out end. 4. Fold a piece of aluminum foil in half and hang it over the string. The deflection of the foil when the hair dryer is on will be used to indicate the amount of air flow. This will be measured with a protractor. 5. Fold four index cards into an "l" (L) shape. Tape these halfway down the length of the shoebox on the inside to hold the students' filters (see Figure 1).  Figure 1. The filter testing apparatus. 6. Set up the testing apparatus in a location to which students have easy access. Position the hair dryer through the first hole cut in the shoebox (a ring stand may be useful for holding the hairdryer). Set a large container on its side at the other end of the apparatus to catch particles. If you are using a long container, such as a trash can, you may need to place the entire apparatus inside the container so that students will be able to capture particles with a pollution collector (see Figure 2).

Figure 2. Pictures of the testing apparatus confined within a large plastic container.

7. Make enough copies of the Cleaning the Air Worksheet (Annex 1) so that each student has one.

10 min

Write the steps of the engineering design process on the whiteboard and explain how engineers use this process to solve complex problems.



What do you think engineers do first when they begin to create a new product, say a new type of a new filtration system? That's right, the first thing engineers do is ask; that is, they ask what the product will do, what need they are addressing and what others have done. This also requires conducting research of the problem.

Then, an engineer imagines all the possible features and qualities of the product. This takes a lot of creative brainstorming! After an engineer has made a list and some sketches of her/his ideas, all of the engineers in a team get together and share what they have come up with. As a team, they plan on one

	design by working with the best ideas. Once the details of the design have been decided, the team creates the product; then they get to test it out! Tests are made on models of the product or device, which are often at a smaller than full- scale size. In the testing phase, the team pays attention to what needs to be changed to the model to make the product work better. The last step of the engineering design process is to improve the design.
30 min	1. Divide students into groups of two or three depending on how your class works best. 2. Pass out the Cleaning the Air Worksheets to the students. 3. Write the following challenge on the board: Design an air filter that filters out the most particulate matter without blocking the air flow. 4. Show students the testing apparatus. Explain to students that there are two slots that will hold a filter and so students can design two filters if they want, but it must fit into the testing apparatus' filter slots. 5. Ask students if they know what an ammeter is? (Answer: An ammeter is a device that is used to measure air flow.) Show students the ammeter on the testing apparatus — the aluminium foil. Turn the hair dryer on and tell students this is full air flow. Put an index card into the testing apparatus that fully blocks the air flow. There is no air. 6. Explain to the students that their air filters cannot block more than 50% of the air flow. Ask students what the ammeter will look like when 50% of the air is blocked. (Answer: the ammeter — i.e., the foil — will come up to half of the angle it was at when air blew through the box with no filter installed.) 7. Explain that there are four criteria for the air filters that the students build (These are also indicated on the Air Pollution Background Sheet.) • They can only use materials that are provided by the teacher. • The filter cannot block more than 50% of the air. • The filter must be designed to fit into the testing apparatus filter slots. • All students must test the filter at least once. 8. Review the Cleaning the Air Worksheet with the students. Make sure students understand their challenge and the four filter criteria; ask students to copy the four criteria and challenge them down on their worksheets. 9. Give the students the remainder of the period to work in groups and design their filter. There is no building, but they should focus on the first couple steps of the engineering design process and imagine different ideas and plans by drawing a picture of their filter design.

Annex 1:

Name: _____ **Date:** _____

Cleaning the Air Activity – Cleaning the Air Worksheet

Introduction

Define the Challenge. Write a description of the challenge you are asked to solve.

Define the Criteria. Write the criteria for your filter here.

1.

2.

3.

4.

Develop solutions. Use the space below and on the back of this page to sketch and make notes of possible solutions.

Annex 2

Name: _____ **Date:** _____

Conclusion / Results

1. Count the particles in four different squares in the center of the collector.

Square	Number of particles
#1	
#2	
#3	
#4	
Total	
Average: = Total/4	

2. Describe what happened when you tested your filter. What would you do to improve your filter? (If you test your filter multiple times you should list each test.)

LESSON: SCIENCE

WALK IN THE FARM (Place-based approach)

Purpose/ Learning objective

- Name distinctive plants/crops/animals in farms.
- Relate the learnings to the concept of seasons and the variety of
- activities of the living world accordingly.
- Acknowledge and appreciate the importance of acting responsibly
- towards the environment/agriculture/animals.
- Raise awareness for climate change impacts on farms & agriculture
- Reflects his/her opinion on climate change and its effects on environment, especially farms

Intersecting objectives

- Explains ecosystem dynamics and the environmental, social, economic and ethical impact of climate change
- Recognises the significance of environmental literacy
- Explains environmental processes and systems

Facilitation

https://hardwickagriculture.org/community-programs/food-access-equity

https://www.ecoagtube.org/

Ideas for follow-up

- Garden Organic Project

Start and maintain an organic food growing garden at school

Teachers could facilitate this website to create & maintain organic gardens or green areas at school.

https://www.gardenorganic.org.uk/schools

Resources required

- Camera, projector, project canvas, computer, smart board
- Board paper

Source/The day of the lesson: Materials & Class prep.

Institute for education of Montenegro, Regional centre for life environment Montenegro (2015): METHODOLOGICAL MANUAL for IMPLEMENTATIONS of programmes, Education for sustainable development, Podgorica.

Raičević, N. (2014): Preserve the values of nature for general good of Society and future generations – Project Education for sustainable development at West Balkan, Educational work, Podgorica.

Sharma, P. and Andreou, N. (2018): Positive Actions for the Sustainable and Development Goals.

Implementation

Timing	Instructions step by step
10 min	Introduction: This lesson plan aims to take students to a farm and introduce them to the knowledge of eco-diversity and social environment. Moreover, emphasis is placed on our ways of living, respect for nature and sustainable development and impact of climate change on farm living & productivity Preparation: • Teacher will inform students about the mini journey to farm and explain the objective & activities clearly in advance • Teacher will give some research tasks about climate change impacts on environment and especially on farms & farm living • The teacher introduces the activity. Students will go to a farm and observe plants/animals/farming/agricultural procedures
20 min	• Other activities: students are to observe agricultural procedures and notice the effect of climate change on farming & agriculture. They'll observe the environment. One group of students will observe animals/ livestock and other will plants & crops
30 min	• Students explore the key scientific idea of impact of global climate change on environment/farming/animals • The teacher asks students to collect evidence, materials etc. Students will take photos-videos, collect materials, talk with farm workers, take notes, draw etc. • Students work in groups and gather the materials/things that they collect from the farm and present in the classroom with a technique or material they choose. • Finally, the teacher facilitates a whole class reflection about changes in the living world, seasons, the nature cycles, importance of biodiversity and farming because of the climate change
30 min	• Engage students in a discussion on different ways plastic products which could be avoided Annex 1 • Ask the students to display the list on the Eco-smart bulletin • Ask students to create an Eco-code to reduce the plastic waste • Ask the students to display Eco-code on the Eco-smart bulletin and start a signature campaign. *An Eco Code is an environmental mission statement. It should demonstrate your school's commitment to being sustainable, and it needs to be visible, memorable and fun, to everyone in your school.

LESSON: SCIENCE

Electricity, heat and personal electricity footprint

Purpose/ Learning objective

- Explains the importance of electricity and heat to humans.
- Explains the effects of changing living conditions on electricity and heating resources
- Prepares a poster about electricity and heating consumption.
- Develops projects by measuring and evaluating heat and electricity use, effectiveness and saving

Intersecting objectives

- Calculates and evaluates the person's heat and electricity footprint
- Encourages others to act towards responsible heat and electricity consumption
- Collaborate with peers to identify action plans to reduce electricity and heat consumption in the school and in private
- Obtain an understanding of the effects of heat and electricity consumption on the environment
- Understand the components that electricity and heating consumption
- Asks relevant questions about electricity and heating consumption conditions and problems
- Knows the importance of electricity and heating consumption footprint
- Understands the concept of responsible electricity and heating consumption

Facilitation

- Create the right environment
- Ensure the expected objective/s are clear

Ideas for follow-up

- Track consumption over time by repeating the mapping exercise at home
- Monthly mappings
- Challenge on how to save the most
- Map entire school and compare result to electricity bill

Resources required

- Computers with excel
- Optional: clamp on ampere meter and line splitter

Source/The day of the lesson: Materials & Class prep.

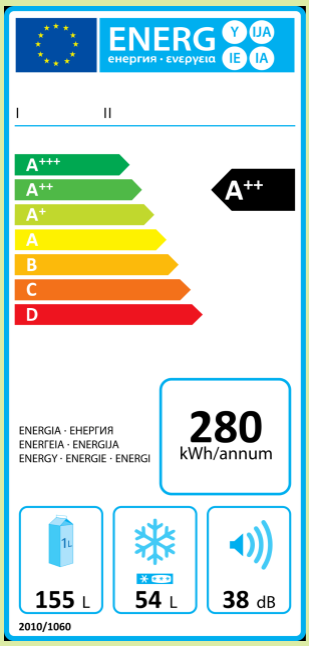
Electrical Grid theory

Home Heating Systems

Order or borrow a Clamp on ampere meter

Implementation

Timing	Instructions step by step
10 min	This lesson deals with electricity and how to measure, calculate and become aware of one's own use of it. This knowledge can then be put to use in the school context. Understand these concepts before the lesson and be able to discuss them with students: • Electricity and its history • Basic units to measure and calculate electric data: • Ampere (A) - the measure of the amount of electric charge passing through the product (or cable or circuit etc.) Can be measured with an amperemeter. • Volt (V) - the measure of the strength of the electric charge or electric potential difference in an electric source. Low voltage ie. 1.5 V can be found in a simple battery electric source, higher voltage like 230 V is used in most European households can be measured with a voltmeter. • Watt (W) - the measure used to quantify the amount of energy transferred. It is calculated as 1 W = 1 V x 1 A • kWh - the measure of the amount of energy transferred over time as kW (1000 W) per hour. This measure is used to calculate household usage of electricity and can also be used to measure device usage. • AC - alternating current. Current which periodically reverses direction and changes its magnitude continuously with time. Alternating current is the form in which electric power is delivered to schools and residences, and it is the form of electrical energy that consumers typically use when they plug kitchen appliances, televisions, fans and electric lamps into a wall socket. In EU the current alternates 50 times per second ie. 50 Hz from 0-230 V • DC - Direct current, that does not alternate. A common source of DC power is a battery cell in a flashlight. Power grid and electric distribution • Renewable and fossil ways to make electricity • How to calculate power consumption • The differences between old and new appliances ie. LED ligting, heat-pumps etc • How to read rating plates and declarations on electric appliances  Above picture shows a rating plate from a coffee brewer

	● The meaning of energy efficiency rating labels  Image above shows an energy efficiency rating label.
30 min	**Module 1. Desk research, discussion and presentation** Introduce topic Divide class into groups of 4 Make students reflect on these questions: - What is electric power? - How is it made? - What is a power grid? - What is the difference between power from sustainable sources and from fossil? - Draw the power grid of the future - Why is saving electricity important? Their answers are collected and discussed in class. The groups are instructed to make a presentation poster about electric energy
55 min	**Module 2. Measure, map and analyze school or classroom power consumption** The task in module 2 is to identify power consumption of the environment. In groups of 4 students identify all electric equipment in the classroom. If possible, this can be conducted in a school kitchen or other room with more appliances. The purpose is to obtain awareness about the power consumption of the environment and to learn ● how to find the power consumption of products (effect, wattage) ● the difference between power W and power over time, kWh, and the cost of power ● that different products have different power consumption ● that newer technology can bring power savings ie. LED ● that some devices have stand by consumption

The students use a spreadsheet to calculate power use and the cost thereof. This can be done as a homework assignment.

Electric energy mapping

Used by:	Mr. Grugsaard	Contact:	
Address:	FabLab Nordvest	Emergency:	
Cost	€ 0,30	per kilowatt-hour (kWh)	select unit price as per your location

Appliance	Quantity	Watts/unit	TOTAL watts	Hours/Day used	Cost/day to use	Cost/month to use	Cost/year to use
Desktop computer & monitor	2	140	280	12	€ 1,01	€ 30,24	€ 367,92
Laptop computer	3	25	75	8	€ 0,18	€ 5,40	€ 65,70
Printer	2	180	360	1	€ 0,11	€ 3,24	€ 39,42
Xbox 360	1	165	165	2	€ 0,10	€ 2,97	€ 36,14
LCD television (42")	2	250	500	6	€ 0,90	€ 27,00	€ 328,50
Electric fan	5	125	625	14	€ 2,63	€ 78,75	€ 958,13
AC-1	1	2000	2000	6	€ 3,60	€ 108,00	€ 1.314,00
			0		€ -	€ -	€ -
			0		€ -	€ -	€ -
			0		€ -	€ -	€ -
			0		€ -	€ -	€ -
			0		€ -	€ -	€ -
				Total energy cost	€ 8,52	€ 255,60	€ 3.109,80

Above image shows an example of a spreadsheet used to calculate electric cost

Make students look for and interpret rating plates on devices

Use a clamp meter and a line separator to measure current in different applications

Image shows a line splitter and an clamp ampere meter.

When mapping of electric usage is finished, reflect and discuss results.

- Make students compare their usage to others: https://ourworldindata.org/grapher/per-capita-energy-use
- Make students come up with suggestions on how to reduce their consumption at home and in the school.
- Make students a timeline with the development and maturing of a technology. For example lighting: from incandescent light bulb to LED and identify major breakthroughs

Discussion: how well does the school perform? Does it use energy efficient lamps? Are computers and other electronic equipment configured to save power? Is there a strategic plan in place to save electricity?

How does the school perform compared to other schools? What policies regulate school performance - if any?

Annexes

Annex 1:

Spreadsheet for calculating electric cost

LESSON: SCIENCE

Heating systems

Purpose/ Learning objective

- Understand heating systems and their sustainability performance.
- Investigate heating systems in order to benchmark the system installed in the school.

Intersecting objectives

- New behavior towards responsible use of heating

Facilitation

- For a more detailed background on European heating systems see: https://ec.europa.eu/energy/content/space-heating-heterogenous-among-european-countries_en

Ideas for follow-up

- Have students work in groups to design a heating system for a building
- Have teams evaluate their models with other energy sources in mind or other geographic settings
- Arrange a visit to a district heating plant or similar infrastructure

Resources required

- Arduino and peripherals or IR thermometer and clock
- Pipes with and without isolation
- Hot water

Source/The day of the lesson: Materials & Class prep.

- This type of activity is dependent on available equipment and prior competences with coding and Arduino. If these are limited conduct the experiments and track the temperature in Excel or on graph paper.

Implementation

Timing	Instructions step by step
	Educators should familiarize themselves with the principles of heating systems and HVAC terms to be able to discuss with students. HVAC is an engineering term which stands for heating, ventilation, and air conditioning. Educators should also assess principles and performance of the applied heating system at the school and at home in order to bring perspective to the talk. Understand these concepts before the lesson and be able to discuss them with students: - Principles of heat transfer - Principles of heating systems - Power sources, ie. fuels, solar. district, heat pumps
30 min	Introduce the topic and divide the class into groups of four Instruct each group to research a 'heat source' topic and a 'distribution system' topic. These heat sources exist: ● Furnace ● Boiler ● Heat pump ● Solar heating ● Electric (resistance) heating ● ... These distribution systems exist: ● Steam radian ● Radiant heating ● Hot water baseboards ● Electric baseboard ● Forced air system ● ... Each group should present findings about the given source and distribution technology in a poster session. Discuss pros and cons for each item and try to understand the workings of the different systems Discuss efficiency of the systems Try to discover energy-saving-tips for each technology. An example could be thermostats, cleaning of air filters etc. Experiment: Effectiveness of insulation of heating pipes.

	Distribution of heat throughout buildings is often done using a pipe system that carries heated water. The water is heated by the above mentioned sources and the heat is released where it is needed, for example in a radiator. To ensure that the heat is not lost on its way to the radiator, pipes must be insulated. In fact, this is one of the most important ways to make a heating system more efficient.   Image shows an isolated copper tube.
55 min	Make students create a system in the Makerspace using metal pipes, forexample copper pipes or iron pipes. Setup a temperature logging system either by using an arduino system likethis

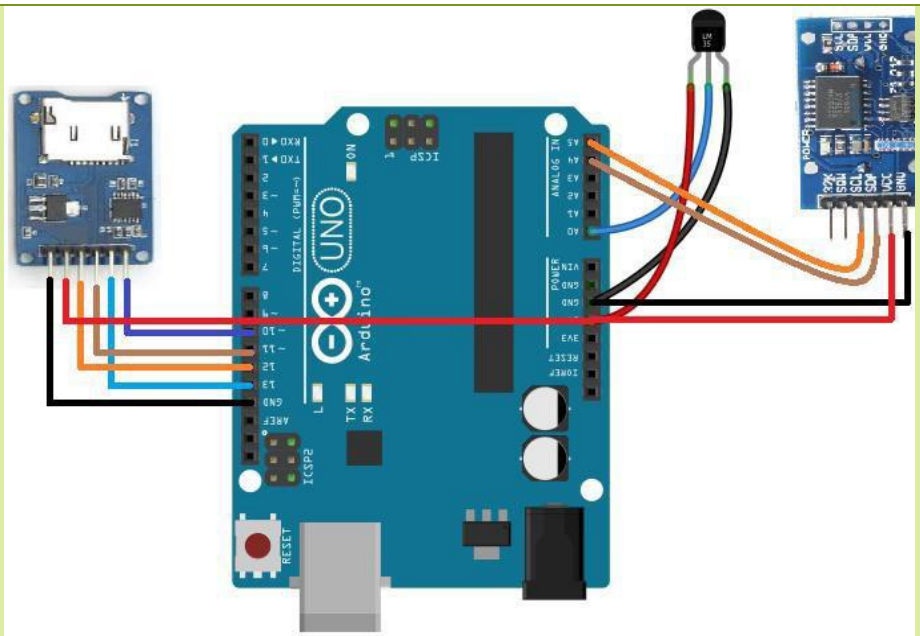


Image shows suggested wiring of an Arduino UNO to obtain an temperature logger.

Documentation here: https://maker.pro/arduino/projects/make-arduino-temperature-data-logger

Or create a manual logging system using an IR thermometer and a temp/time tracking which is done in Excel by the students

Image shows an IR Thermometer

	Isolated pipe					**Unisolated pipe**		
	Interval		00:10:00	minutes		Interval		00:10:00 minutes
	Time		Temperature			Time		Temperature
	00:00	hh:mm	44	degrees		00:00	hh:mm	44 degrees
	00:10	hh:mm	43	degrees		00:10	hh:mm	40 degrees
	00:20	hh:mm	42	degrees		00:20	hh:mm	36 degrees
	00:30	hh:mm	41	degrees		00:30	hh:mm	32 degrees
	00:40	hh:mm	40	degrees		00:40	hh:mm	28 degrees
	00:50	hh:mm	39	degrees		00:50	hh:mm	27 degrees
0	01:00	hh:mm	38	degrees		01:00	hh:mm	26 degrees
1	01:10	hh:mm	37	degrees		01:10	hh:mm	25 degrees
2	01:20	hh:mm	36	degrees		01:20	hh:mm	25 degrees

Image shows how the Excel sheet can be constructed. A graph can be made with the time/temp values.

Use the measurements done by Arduino or the manual thermometer to createa theory about heat loss and isolation.

Image shows how to use an IR thermometer.

See https://sciencing.com/calculate-hydraulic-flow-7155002.html forreferences on how to calculate heat loss.

LESSON: SCIENCE

The importance of Insulation of buildings

Purpose/ Learning objective

- Educate on the importance of insulation of buildings and the effect of behaviors in order to save energy

Intersecting objectives

- Heating systems
- Insulation materials

Facilitation

- Have students discuss energy preservation
- Explain IR thermography tools

Ideas for follow-up

- Measure buildings and objects with thermography camera and identify heat loss
- Use digital temperature logger or Arduino to measure temperature.

Resources required

- Plastic bottles
- Different insulation materials
- Thermometer
- Hot water
- If available: thermographic camera

Source/The day of the lesson: Materials & Class prep.

- This type of activity is dependent on available equipment.
- Read about thermography here: https://en.wikipedia.org/wiki/Thermography

Implementation

Timing	Instructions step by step
	The educators should familiarize themselves with the concept of insulation and understand that all thermal insulation materials work on a single basic principle: heat moves from warmer to colder areas. Therefore, on cold days, heat from inside a building seeks to get outside. And on warmer days, the heat from outside the building seeks to get inside. Insulation is the material which slows this process. This lesson tests the insulation performance of different materials by comparing these in an experiment. The educators should understand and prepare so they can engage in a discussion on the basic principles: - heat transfer - conduction - convection - radiation - the inhibitions of conduction, convection and radiation
55 min	The students will conduct an experiment to test insulation materials. The test is based on comparing four bottles, wrapped in four different insulation materials and filled with boiling water. The temperature is measured after 10 and 15 minutes. The difference equates to the quality of the insulation wrapped around the bottle.  Image showing two bottles, left without isolation, right with isolation. ● Wrap 4 equal plastic bottles in insulation material. E.g. silver foil, paper, mineral wool, plastic bag, woolen sock ● Pour boiling water and close with cap ● wait 15 minutes. ● Measure temperature in the four bottles ● Map temperatures to time in graph: time on X-axis and temperature on Y-axis. ● Compare and evaluate insulation properties based on performance ● Compare insulation materials based on sustainability ie. aluminium to paper.

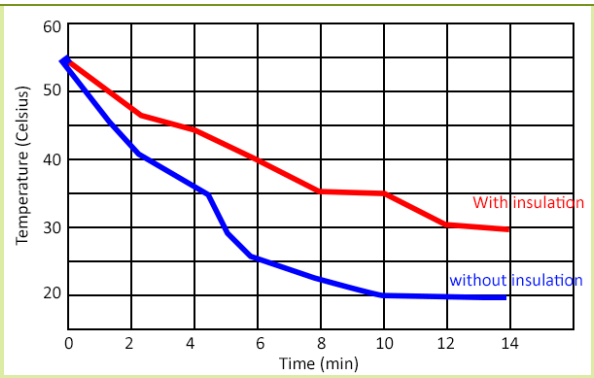


Image shows an example of time vs. temp graph.

If an infrared camera is available also measure the exterior of the bottle.
Continue/end the lesson with a discussion of the importance of insulation materials

Follow up activity can be made with IR camera.
Let students create thermographic images of the school to discover where heat is lost and insulation poor.

Discuss where insulation can easily be added and where it is difficult to add insulation.

LESSON: SCIENCE, TECHNOLOGY, MATHEMATIC

Calculating water consumption

Purpose/ Learning objective

- Explains the importance of water for living creatures.
- Explains the effects of changing living conditions on water resources
- Prepares a poster about water consumption.
- Develops projects by utilizing technology to save water
- Uses sensors in the project developed for water saving

Intersecting objectives

- Calculates and evaluates the person's water footprint
- Encourages others to act towards responsible water consumption
- Collaborate with peers to identify action plans to increase responsible water
- consumption in their families, circles of friends and schools
- Have an understanding of the effects of water consumption on the environment
- Understands the components that affect water consumption
- Asks relevant questions about water consumption conditions and problems
- Knows the importance of water footprint
- Understands the concept of responsible water consumption

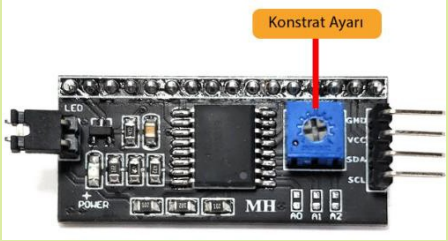
Facilitation

Things to consider while preparing the project circuit

The working logic and formula of the sensor should be understood. Since the pulse signal is a simple square wave, recording and converting liters/min (using the formula below) can be done easily.

Formula: Pulse frequency (Hz) / 7.5 = flow rate (liter/min)

The image is sharpened by turning the potentiometer on the contrast setting of the 2x16 LCD I2C display with a pointed screwdriver.



Visual 6

By paying attention to the cable colors of the sensor, it is ensured that it is attached to the correct pins.

Cable plugging and unplugging should not be done while the Arduino is connected to power. This may cause a short circuit.

Breadboard is supported for duplication of pins on Arduino.

The contact of the Arduino circuit with water should be prevented. Taping is done for the isolation of the cable connections.

The pin names used in the sensor connections on the Arduino must match the pins in the code file.

For the connection of the water flow sensor and LCD (16x2) with Arduino, the given image should be followed. (Image 2)

Click on the link for the detailed picture of Image 1. Link: https://dosya.co/4jq2gn6kcqew/mat.png.html

Click on the link for detailed specifications of the Yfs 201 water flow sensor.

https://dosya.co/o1jatfnotvcf/yfs_201_sensor.rtf.html

Ideas for follow-up

Water Control

To find out how your school uses water, how much water is used and how you can reduce it:

- Students can be divided into teams to walk around the school counting and listing everything that uses water.

- Students can research how much water each device uses and brainstorm ideas to reduce it.

Water uses

All results are put together in tables and graphs and/or on a poster.

If possible, the created posters can be displayed on the school boards.

An example of a school related to the studies carried out on water consumption can be viewed from the link below.

Link: https://greenschoolsireland.org/themes/water

The following website can be examined to raise awareness about the conscious consumption of water.

Link: https://waterfootprint.org/en

Students can observe how much water they use in daily life. They can research technological systems that reduce water consumption on how to control this.

HOME TASK 1: The students are asked how many liters of drinking and potable water they use daily. The results are noted. Students are asked to measure the amount of water they consume daily using the project they did in the math class.

Estimated and measured water quantities are compared during the lesson.

Resources required

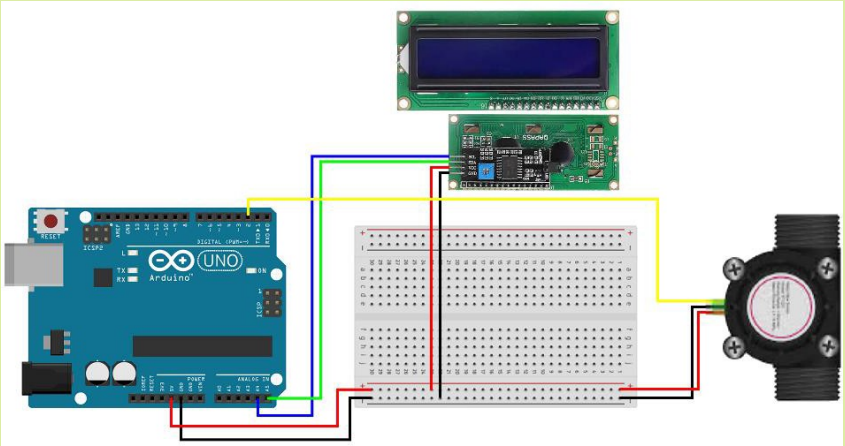
- Smart board or projector
- A3 paper
- Pens
- Internet connection

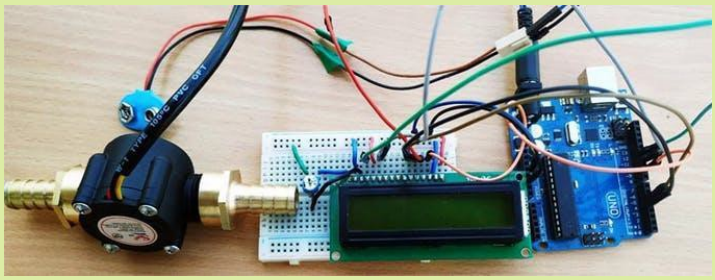
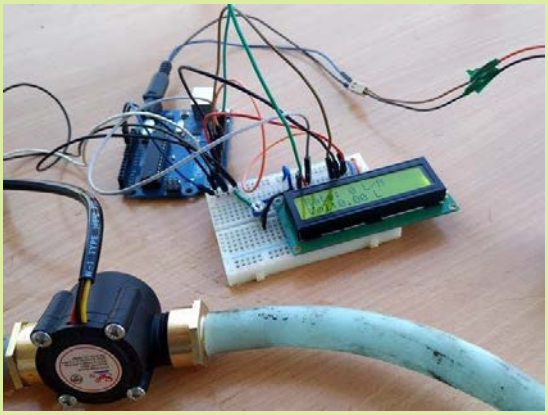
Source/The day of the lesson: Materials & Class prep.

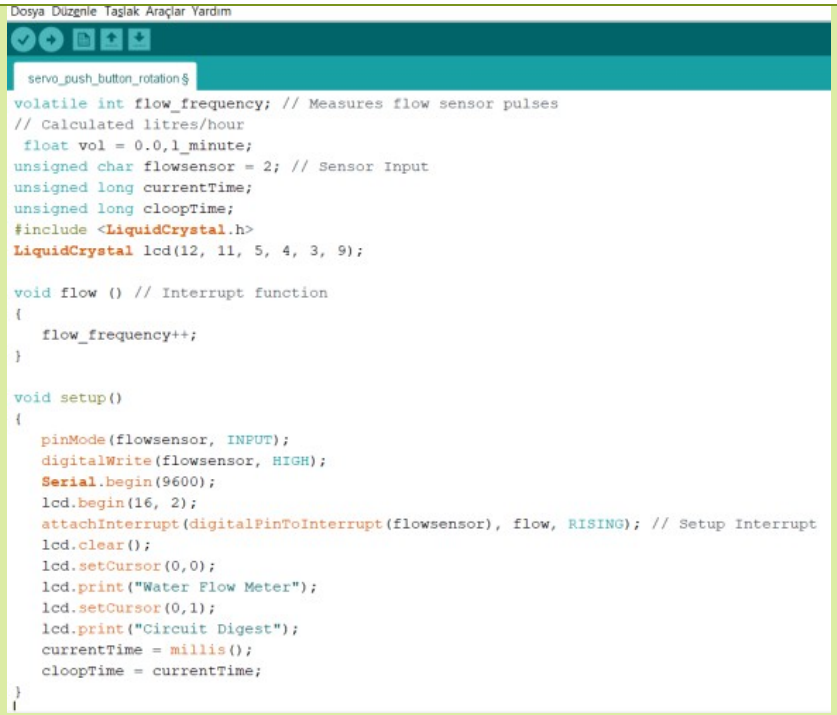
- Tablet or computer where project codes will be written
- Arduino Uno
- YF-S201 Water Flow Sensor
- LCD Screen 2x16 I2C
- Hose (12.7mm)
- Jump cables
- Silicone Gun
- Hot Silicone
- Cable Tie(150x3mm)
- Breadboard
- Insulating tape
- Arduino IDE

Implementation

Timing	Instructions step by step
	This lesson is divided in 3 major parts Before the lesson students are asked to observe the water consumption in the schoolwashrooms.
PART 1	
30 min	**Water Consumption Debate** Divide the class into pairs or small groups, give each group a worksheet, ask thefollowing questions: The students will conduct an experiment to test insulation materials. - What are the approaches you used during your observations and what results did you reach? - What is the importance of water for living things? - What are the problems caused by the reduction of water resources? **Water Consumption Discussion Outcome** Their answers are collected and displayed on one page. The subject is checked and discussed.
Optional	You can show a movie about water consumption. https://www.youtube.com/watch?v=BCHhwxvQqxg
45 min	Have students design and put together an informational poster with their answers. Place the above questions and answers around the school.
Optional	To raise awareness in the school, relevant movies can be played onmonitors around the school during lunch hours during a water awareness week.
PART 2	
	Students are asked: How much water do you think we waste when we forget to turn on the tap while brushing our teeth?
20 min	An example tooth brushing scenario is considered and the formula for the amount of water that unnecessarily flows from the fountain during tooth brushing is as follows. Q = A x V Q: Amount of water spent A: The area of the spout V: Speed of flowing water. A= π.r2 r: Radius of the spout The following method can be used to calculate the amount of water consumed in a practical way: Step 1: Put a large bowl under the tap. Step 2: The stopwatch is prepared and the tap is opened for 10 seconds. Step 3: The amount of water flowing in 10 seconds is measured and calculated in minutes. Step 4: An average tooth brushing time is determined. (x minutes) Step 5: The amount of water flowing for x minutes is subtracted from the amount of water turned off while brushing teeth and the amount of water saved is found.
20 min	Can water flowing from taps be controlled? With this question, students are provided to realize the problem Arduino is briefly mentioned to raise awareness of students.

	Arduino is an open-source microcontroller platform developed for easy use by anyone who is interested in electronics. Arduino can read signals from various sensors, flashlights, start motors; In short, it can make all electronic applications you can think of.
20 min	Can the flow of water flowing from the tap be measured and controlled using a sensor using Arduino? With questions such as, students are provided to think about the subject. Then, the materials to be used for the project that will solve the problem of excessive water consumption are introduced by using the arduino and sensors that were designed before. • Students are divided into their groups in the 1st lesson. (4 people depending on the class) • The necessary materials for their designs are provided to the groups by the teacher.
PART 3	
30 min	**Creation of the Project**  Visual 1 • A jumper cable is attached from the gnd pin of the Arduino to the (-) negative pole of the breadboard. • A jumper cable is attached from the 5v pin of the Arduino tothe (+) plus pole of the breadboard. • Thus, the limited 5v and gnd pins on the Arduino are replicated with the help of the breadboard. • Connection of Yfs 201 water flow sensor cables: - Red wire: to the (+) terminal of the breadboard - Black cable: To the (-) pole of the breadboard - Yellow cable: The sensor connection is completed by attaching it to pin 2 of the Arduino's digital pwm pins. • 2x16 LCD I2C display connection: - SCL: Arduino's Analog IN pins to A5 - SDA: Arduino's Analog IN pins to A4 - VCC: To the (+) pole of the breadboard - GND: To the (-) pole of the breadboard - screen connection is completed. • One end of the Yfs 201 water flow sensor is connected to the end of the tap with a hose and tightened with a cable tie to prevent water leakage. If necessary, it is supported with hot

	silicone. • A hose is attached to the other end of the Yfs 201 water flow sensor and the water is allowed to flow from there.  Visual 2
25 min	**Coding of the Project** After completing the project circuit, the arduino board is connected to the computer.  Visual 3 After the connection of the Arduino board is completed, the project codes are transferred to the Arduino IDE program and the code is uploaded to the Arduino board. Click the link below for the code. CODE https://dosya.co/7x8ymomja6r9/matematik-dersi-kod.rtf.html  Visual 4 Students are informed about the codes and the project is completed.

<table>
<tr>
<td></td>
<td>


Visual 5
</td>
</tr>
<tr>
<td>15 min</td>
<td>
Explaining the Project

For example, what the project aims at, what it will test and how it will be executed.

The project will provide savings by reducing the water used by consumers.

Thanks to the project created, water will be saved by ensuring that the water flowing from the taps flows in a controlled manner.

In the project, the water flow sensor is connected to a pipe. If the outlet valve of the pipe is closed, the output of the water flow sensor is zero (No Pulse). There will be no interrupt signals seen on pin 2 of the Arduino and the flow frequency count will be zero. In this case, the code written inside the else loop will work.

If the pipe's outlet valve opens, water flows through the sensor and turns the impeller inside the sensor. In this case, we can observe the pulses generated from the sensor. These pulses will act as an interrupt signal to the Arduino UNO. For each interrupt signal (rising edge), the number of the flow frequency variable will be increased by one. The variable Current time and Cycle Duration provides the flow frequency value per second to calculate the flow rate and volume. After the calculation is finished, the flow frequency variable is set to zero and the whole procedure is started over.
</td>
</tr>
</table>

LESSON: ENGINEERING

Creating a water control system

Purpose/ Learning objective

- Generates ideas on the protection, improvement and use of water resources
- Realizes what needs to be considered in water use in daily life.
- Develops projects by utilizing technology to save water

Intersecting objectives

- Identify and analyze environmental issues related to water consumption
- Encourages others to act towards responsible water consumption
- Collaborate with peers to identify action plans to increase responsible water
- consumption in their families, circles of friends and schools
- Have an understanding of the effects of water consumption on the environment
- Understands the components that affect water consumption
- Asks relevant questions about water consumption conditions and problems
- Understands the concept of responsible water consumption

Facilitation

Things to consider while preparing the project circuit

- By paying attention to the colors of the servo motor, it is ensured that it is attached to the correct pins.

- Cable plugging and unplugging should not be done while Arduino is connected to power. This may cause a short circuit.

- Breadboard can be supported for duplication of pins on Arduino.

- The contact of the Arduino circuit with water should be prevented.

- The pin names used in the button and servo motor connections on the Arduino must match the pins in the code file.

Taping is done for the isolation of the cable

-The servo motor bracket is screwed to the end of the servo motor. (Visual4)

Visual 4

You can click on the link for the detailed picture of Image 1.

Link: https://dosya.co/hp4rdxbijqkn/button-kontrollü-servo.png.html

Ideas for follow-up

- Students observe the system in their daily life which has this mechanism.
- Students develop new projects by using electronic components.

Resources required

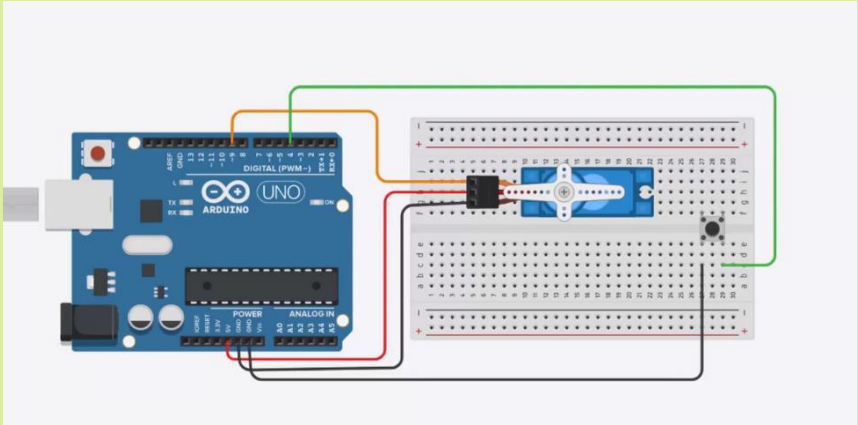
- Tablet or computer where project codes will be written.
- Arduino Uno
- SG90 Servo Motor
- 9v Battery

- Arduino 9v Connector 2.1mm
- Push button
- Male-Male Jumper cables
- Breadboard
- •Insulating tape
- Arduino IDE

Source/The day of the lesson: Materials & Class prep.

- Tablet or computer where project codes will be written.
- Arduino Uno
- SG90 Servo Motor
- 9v Battery
- Arduino 9v Connector 2.1mm
- Push button
- Male-Male Jumper cables
- Breadboard
- Insulating tape
- Arduino IDE

Implementation

Timing	Instructions step by step
	This lesson is divided in 2 parts
PART 1	
30 min	**Water Consumption Debate** Divide the class into pairs or small groups, give each group a worksheet, ask thefollowing questions: - What is the importance of water saving? - How to save water in buildings? **Water Consumption Discussion Outcome** Answers are collected and displayed on one page. The subject is checked and discussed.
Optional	You can show a movie about water consumption. https://www.youtube.com/watch?v=womIxQqO2tE
45 min	Have students design and put together an informational poster with their answers. Place the above questions and answers around the school.
Optional	To raise awareness in the school, relevant movies can be played onmonitors around the school during lunch hours during a water awareness week.
PART 2	
	Students are asked the following questions: - Can the water in the tap be flowed in a controlled manner? With this question, students are provided to realize the problem. With questions such as how we can design these taps so that water does not flow unnecessarily, the students are to form an idea about the project they will do. Before starting the project, the materials determined by the teacher are brought to the class. Students are divided into predefined working groups The creation phase of the project begins. The circuit elements to be used during the project are introduced to the students. Brief examples of what it is used for are given.
20 min	**Creation of the Project**  Visual 1 • The red cable of the servo motor is connected to the 5v pin of the Arduino. • The orange cable of the servo motor is connected to the pin 9 of the Arduino's digital pwm

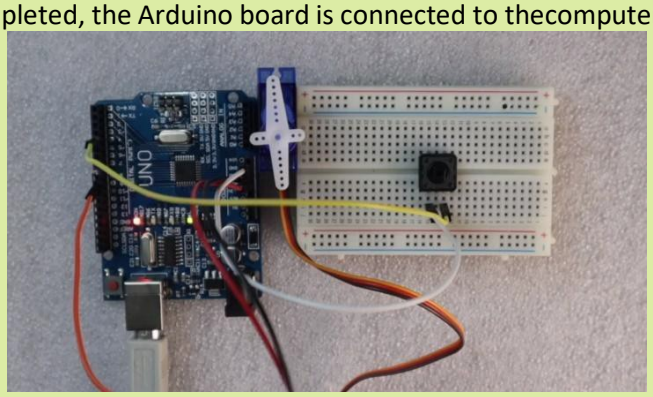
pins.

- The black cable of the servo motor is connected to the gnd pin of the Arduino.
- Push button is attached to the breadboard as in image 1.
- A line is drawn to the gnd pin of the Arduino with a male-male jumper cable from one end of the hole at the foot of the push button.
- From the other foot of the button, a line is drawn to the digital pwm pin 2 of the Arduino.
- Thus, the diagram of our circuit is completed.

20 min

Coding Phase of the Project

After the project circuit is completed, the Arduino board is connected to thecomputer.

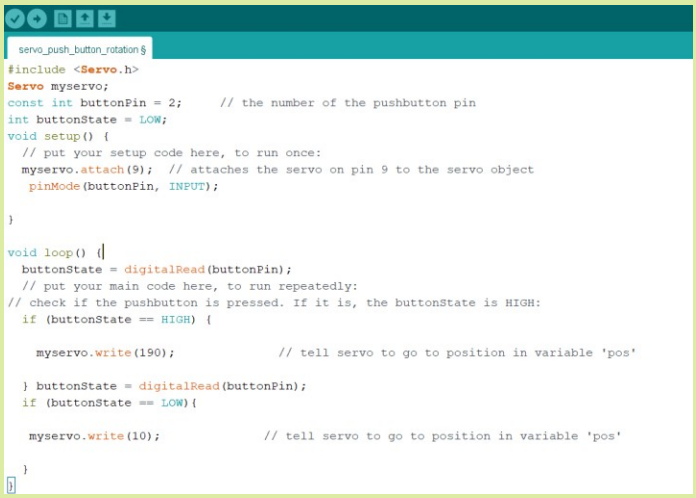


Visual 2

After completing the project circuit, the project codes are transferred to the Arduino IDE program and the code is uploaded to the Arduino card. Click the link below for the code.

Code: https://dosya.co/8yq7zgzr9umy/Mühendislik_dersi_kod.docx.html

Students are informed about the codes and the project is completed.



```
servo_push_button_rotation §
#include <Servo.h>
Servo myservo;
const int buttonPin = 2;     // the number of the pushbutton pin
int buttonState = LOW;
void setup() {
  // put your setup code here, to run once:
  myservo.attach(9);  // attaches the servo on pin 9 to the servo object
   pinMode(buttonPin, INPUT);

}

void loop() {
  buttonState = digitalRead(buttonPin);
  // put your main code here, to run repeatedly:
// check if the pushbutton is pressed. If it is, the buttonState is HIGH:
  if (buttonState == HIGH) {

    myservo.write(190);              // tell servo to go to position in variable 'pos'

  } buttonState = digitalRead(buttonPin);
  if (buttonState == LOW){

   myservo.write(10);              // tell servo to go to position in variable 'pos'

  }
}
```

Visual 3

LESSON: ENGINEERING, ARTS (Design)

Faucet knob 3D Printing manufacturing

Purpose/ Learning objective

- Generates ideas on the protection, improvement and use of water resources
- Realizes what needs to be considered in the use of water in daily life
- Develops projects by utilizing technology to save water
- Develops 3D thinking skills
- Learns and gains experience in superior subjects such as strength, planningand balance.

Intersecting objectives

- Identifies and analyzes environmental issues related to water consumption
- Encourages others to act towards responsible water consumption
- Collaborate with peers to identify action plans to increase responsible water
- consumption in their families, circles of friends and schools
- Have an understanding of the effects of water consumption on the
- environment
- Understands the components that affect water consumption
- Asks relevant questions about water consumption conditions and problems

Facilitation

Things to consider while preparing the project circuit

- Tinkercad program can be used for design. Link: https://www.tinkercad.com/
- While printing the design, the printer should be checked periodically.
- It should be noted that the temperature settings of the printer are adjusted according to the type of filament used.
- Since the printer works at high temperatures, the printer should not be interfered with during operation.
- If intervention is necessary, it should be under surveillance.
- After the assembly, the codes of the project may need to be changed according to the position of the servo motor.
- If the servo motor cable needs to be extended, jumper cable can be used.
- A new part can be designed to be able to press the button more easily.
- Double-sided tape can be used to fix the button to the ground.

Ideas for follow-up

Water Control

To find out how your school uses water, how much water is used and how you can reduce it:

- Students can be divided into teams to walk around the school counting and listing everything that uses water.

- Students can research how much water each device uses and brainstorm ideas to reduce it.

- All results are put together in tables and graphs and/or on a poster.

- If possible, the created posters can be displayed on the school boards.

- An example of a school related to the studies carried out on water consumption can be viewed at the link below.

Link: https://greenschoolsireland.org/themes/water

- The following website can be examined to raise awareness about the conscious consumption of water.

Site: https://waterfootprint.org/en

- Students can observe how much water they use in daily life. They can research technological systems that reduce water consumption on how to control this.

HOME TASK 2: With the project realized as a result of the engineering and design course, students are asked to calculate their daily water consumption.

The result is compared with the results from home task 1.

Banners, posters, etc., in order to raise awareness of the results. it can be made to benefit from the school and those around it.

Finally, the following statistical example can be presented to students.

The daily amount of drinking and utility water per person for the cities of Istanbul, Ankara and Izmir in 2018 by the Turkish Statistical Institute was calculated as 224 liters.

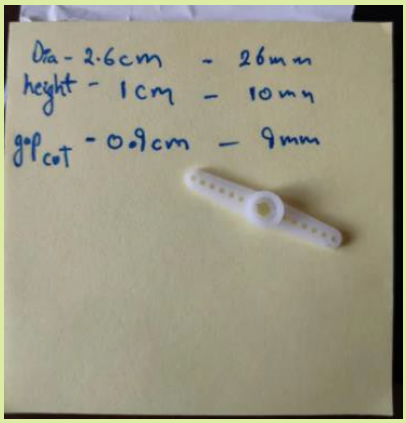
Resources required

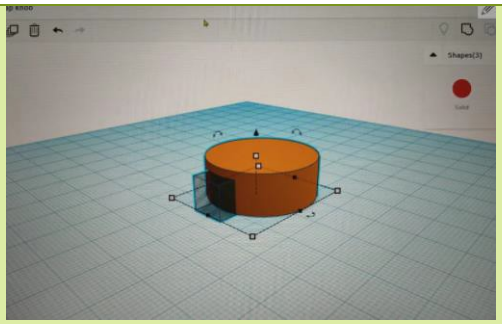
- Smart board or projector
- A3 paper
- Pens
- Internet

Source/The day of the lesson: Materials & Class prep.

- Tablet or computer where the design will be carried out
- Slicing program (Cura)
- 3D printer
- Filament
- Quick adhesive (hot silicone)
- Sandpaper

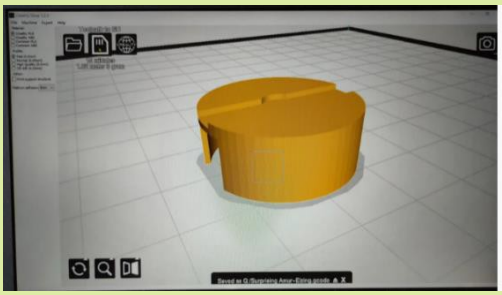
Implementation

Timing	Instructions step by step
	This lesson is divided in 3 parts
PART 1	
30 min	**Students' Prior Knowledge About 3D Design** Divide the class into pairs or small groups, give each group a worksheet, ask the following questions: - What is 3 dimensions? What is the difference between 2 and 3 dimensions? - Have you done 3D design before? If so, what programs did you use? - What is a 3D printer? What can be done with 3D printers? Collect and display the answers on one page. Check and discuss the topic.
Optional	You can show a movie about 3D printers. Website: https://www.youtube.com/watch?v=Llgko_GpXbI
PART 2	
60 min	**Making the Design** Let's design an apparatus from a 3D printer on the knob of our faucet for the Arduino project we did in the engineering class. • First, the size of the knob of the tap is measured with the help of aruler and a note is taken.  Visual 1  Visual 2 • Since the size and shape of the knob of each faucet may be different,designs are made according to the imagination and design skills of the students. • After the measurements are taken, the Tinkercad program is opened for 3D design. • While designing, it is designed a few mm larger than the predetermined dimensions. The design needs to fit on top of the bun.



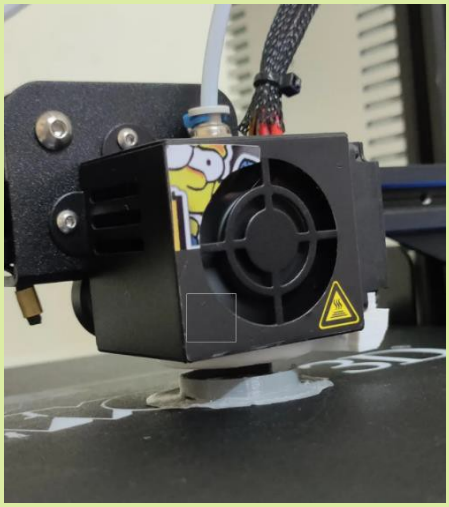
Visual 3

- After the design is completed, it is saved to the computer in .stl extension with the export design option.
- The downloaded design is transferred to the slicing program and slicing is performed according to the need.



Visual 4

- The 3D printing process is started using a 3d printer
- The printer is checked during printing. In particular, the printer is observed until the ground layer is printed properly.



Visual 5

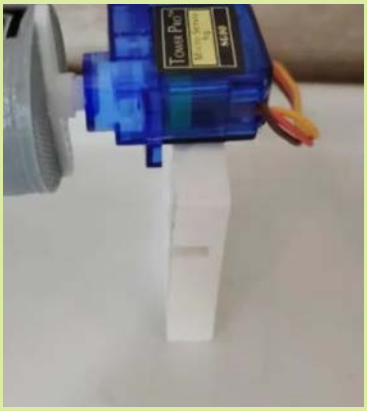
PART 3

- The design that we started in the part 2 is carefully taken from the printer after the printer has cooled down.
- The burrs on the edge of the design are removed using sandpaper

60 min	 Visual 6 The print we designed with the servo motor apparatus is adhered. While sticking, care should be taken to stick to the very center. • Fast adhesive or hot silicone can be preferred while bonding  Visual 7 The prepared part is attached to the servo motor.  Visual 8 • The piece is attached to the knob of the faucet as in the image.

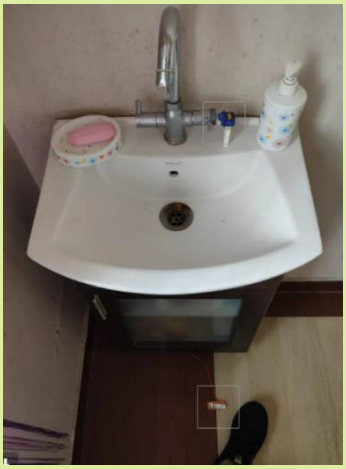
Visual 9

- A piece is placed between the servo motor and the sink to fix the servo motor. This piece can be designed and printed on a 3D printer if desired.
- Make sure that the piece adheres well to the floor. You can use hot glue to stick it to the floor.



Visual 10

- And our project is ready! When we press the button, the servo motor turns and makes the water flow. When we take our foot off the button, the servo motor returns to its initial position and prevents water from flowing.



Visual 11

	Explaining the project What does the project aim for, what will it test and how will it be executed? We have once again understood the importance of our hand hygiene due to the corona virus. To get rid of the corona virus completely, we need to wash our hands with soap for 20 seconds, and during this time the water continues to flow. Thanks to our project, water continues to flow only while washing our hands, so we save water. In our project, we have controlled the water that will flow from the fountain by using a servo motor. When we press the button with our foot, the servo motor will turn and open the tap. When we take our hand off the button, the servo motor will return to its initial position and our tap will be closed. Thanks to the project created, water will be saved by ensuring that the water flowing from the fountain flows in a controlled manner.

LESSON: SCIENCE (PHYSICS/BIOLOGY)

Carbon cycle Jenga

Purpose/ Learning objective

- Understanding the carbon cycle. This lesson is meant to be a reinforcement of the concepts of carbon sinks and sources of carbon rather than a linear review of the carbon cycle. Instead, the lesson focuses on the idea of balance as well as the importance of carbon sinks. Students will begin to observe that even small changes can have big effects.

Intersecting objectives

- Learners will be able to define the concept of carbon footprint.
- Learners will be able to list strategies (at least 6) to reduce
- their own, peers' and/or school's carbon footprints.
- Learners will be able to collaborate with peers to share and establish action plans regarding carbon offset to reduce carbon footprints in their daily life.

Facilitation

- Cards: see annex 1 (to be designed)

Ideas for follow-up

The carbon footprint tower

Students will go around the school and spot the possible carbon dioxide sinks. They will write them down and then create a tower, using clean items that were to be recycled in their home or school. They will paint each item according to the Jenga game and add an explanation note next to it. If the pieces are big, they can write on them.

Then, they will think of a solution for helping preserve each "block". The school can also implement some of the solutions, i.e.plant a tree.

Resources required

Materials

- 5 Jenga sets (or any block set)
- 4 sets of Carbon Cycle Jenga Cards shuffled and placed in a pile face down (instructions in Annex)
- paper/cartons, scissors, ruler, a marker

Source/The day of the lesson: Materials & Class prep.

- Preparation: have the students find the materials beforehand.
- Sources:
- New York Hall of Science (2012), *My Carbon Footprint High School Curriculum.*

Devon Climate Emergency, *Build your Carbon Footprint.* PDF available at Annex 2.

Implementation

Timing	Instructions step by step
	Key Terms Carbon Sink: Things that can absorb carbon dioxide. Sometimes they are natural like trees or algae, and other times they are man- made, like systems that allow humans to pump extra carbon into rocks at the bottom of the ocean. Carbon Dioxide Emission: Carbon dioxide released into the atmosphere. **Preparation** The blocks need to be colored, in order to represent different parts of the carbon cycle. This lesson is divided in 3 parts For each set you will need: Trees and plants: green (7 blocks) Ocean: blue (10 blocks) Transportation: black (8 blocks) Energy: purple (6 blocks) Factories: red (5 blocks) Shipping: orange (5 blocks) Soil: brown (5 blocks) Atmosphere: yellow (5 blocks) Animals: pink (3 blocks)
20 min	The students will be split into 4 groups, with each group getting 1 set of blocks. The blocks from the extra set may be required to supplement depending upon the cards students draw. Begin by asking students to list some common sources of carbon dioxide. Then ask students to name some common carbon sinks. You may have to spend time defining the term “carbon sink.” Break students into four groups and review the different colored blocks. Be sure to mention which factor corresponds to each color.
10 min	Have students set-up their Jenga tower as follows: Begin by mixing the trees and plants. The bottom layer should include one green block with a blue block on either side for a total of three blocks. The second layer should contain two green and one blue block, and the blocks should be placed perpendicular to the first layer. Continue this procedure using the blue, green, pink, yellow and brown blocks. Students should not include red, black, purple or orange blocks. These should be left out of the tower.
30 min	Students are now ready to play. To determine which blocks get removed or added, students will draw a card and follow the instructions. As with a regular game of Jenga, they can only use one hand to remove a block. Ask students to be aware of any changes they may notice as they remove different types of blocks. Unlike a regular game of Jenga, students should set aside any blocks they’ve removed rather than adding them back to the top of the tower. If students go through the entire stack of cards, they can shuffle and reuse. Some groups may finish before others, and you can have them play again. Ask them to take note of any changes they make when setting up their tower. After you feel that each group has had enough time to go through the procedure, you can wrap-up the lesson. Ask students what caused their tower to fall. Depending upon the order they drew the cards, they may notice that a removal or degradation of carbon sinks caused the tower to fall, or they may notice that the addition of carbon from sources like cars or factories was the cause. Emphasize that climate change is a complex idea that takes all of the factors they just saw into account. Earth’s cycles are in a delicate balance. Although we need carbon dioxide to survive, too much carbon dioxide is causing the climate to change.

Annexes

Annex 1:

Create the cards.

Have the students design the cards, using paper, scissors and a ruler. Eco-friendly tip: use to-be-recycled cartons or paper the students can find in their home. You do not have to color the cards, the students can simply write the category and the +/- sign on using a marker.

<u>Number of cards:</u>

Carbon sinks: -symbol (remove one block)

Trees and plants: 7

Ocean:10

Soil: 5

Atmosphere: 5

Animals: 3

Carbon sources: +symbol (add one block)

Transportation: 8

Energy: 6

Factories: 5

Shipping: 5

Annex 2

In the PDF attached, there is a simplified version of the game. Its goal is to help students visualize the size of their carbon footprint.

LESSON: SCIENCE (CHEMISTRY)

Carbon bath

Purpose/ Learning objective

- Acids and Bases: Ocean Acidification
- This lesson allows students to explore the concepts of acids and bases using the context of ocean acidification. Students will first complete an experiment that illustrates that the absorption of atmospheric carbon dioxide by the ocean causes the ocean to become more acidic. Then, the class will explore the effects that a change in pH might have on ocean life. This lesson should follow an introduction to acids and bases and is meant to provide a real-world application to these concepts and an opportunity to work with pH indicators.

Intersecting objectives

- Learners will be able to define the concept of carbon footprint.

Ideas for follow-up

Topic: coral bleaching.

Talk with your students about corals. Did they know they are actually considered animals? Ask them to describe a coral. The answer will probably contain some colour. Now show them a photo of a bleached reef. What caused that? Link it to acidification. What can we do to prevent this? Students can create a 2-piece collage.

In the 1st piece, there will be pictures of healthy coral reefs and everything they do for the oceans. In the 2nd piece, there will be pictures of a bleached reef and the consequences on marine life.

Link with extra info: https://www.greenpeace.org/eastasia/blog/6119/what-is-coral- what-are-the-causes-impacts-and-solutions-of-coral-bleaching/

Resources required

Materials

- Bromothymol blue pH indicator solution (available for
- purchase from any science supply company)
- 1 small cup of water for each student
- 1 straw for each student
- Pipettes
- Paper towels
- Shells or coral
- Vinegar
- Chalk of different colors, broken in half
- 2–3 Small plastic cups per student
- pH paper (available for purchase from any science supply company, pool supply store, or most pet stores)

Source/The day of the lesson: Materials & Class prep.

Andrake B., *Coral Reefs in Danger: Ocean Acidification Lesson,* Jonathan Bird's Blue World. Available at http://www.blueworldtv.com/images/uploads/lesson-plans/Lesson_plan_webisode41Acidification.pdf

Implementation

Timing	Instructions step by step
1 Day before class	**Preparation** Place a small seashell into a container with vinegar a day before the class and let it sit overnight. Directly before the lesson, place 4–5 drops of the indicator solution in a small cup of water. The water should be noticeably blue/green in colour. Prepare one cup of water and indicator solution for each student.
20 min	Explain the following key terms to the students. pH Indicator: A chemical compound that visually shows the Ph of a solution. Carbon Sink: Something that can absorb carbon. Sometimes it is natural like trees or algae, and other times it is manmade, like systems that allow humans to pump extra carbon into rocks in the bottom of the ocean. Ocean Acidification: The decrease of the ocean's pH due to increased absorption of carbon dioxide. Dissociation: The separation of a compound into simpler parts.
10 min	Direct students to put on goggles. Ask students to take note of the colour of the liquid in their cup. Tell them that they will use the straws to blow into the blue liquid for 30 seconds. Some of the water might overflow onto the table, but they should try to be neat. Instruct students to blow into the straw. Time them for 30 seconds. After 30 seconds, direct students to put their straws down. Students can now remove their goggles. Again, ask students to notice the colour of the liquid in their cup. They will notice that the liquid has turned yellow. Ask students to hypothesize why the liquid changed colour and what liquid they think was in the cup to begin with. Allow a few students to share their ideas. You can prompt them by asking what they were exhaling into the cup. After a short discussion, explain that the cup contained water with a few drops of a pH indicator solution. If necessary, review the concept of pH and pH indicators. Now that they have this information, do they have a different idea of why their liquid turned colour? Explain that students exhaled carbon dioxide into the cup, which made the water slightly more acidic causing the indicator solution to change color. If you wish, you can discuss the following equation with students: CO2 + H2O ! H2CO3 (carbonic acid) The carbon dioxide and water combine to create carbonic acid. Carbon dioxide plays a part in natural processes such as breathing, and carbon dioxide is an important part of our atmosphere. However, humans are adding carbon dioxide to our atmosphere at a faster rate than ever before through our use of fossil fuels. The ocean acts as a carbon sink. This means that the ocean absorbs carbon from the atmosphere.

	Tell students that as more carbon dioxide has been produced, the ocean has absorbed more carbon dioxide than it has in the past, and the ocean pH has begun to change, becoming more acidic. This is similar to when the students exhaled carbon dioxide into the water and the pH indicator solution showed that the liquid became slightly more acidic. Although the change in numbers may seem small, they actually represent a significant change in ocean pH over time. This is a good opportunity to remind students that a change in one whole number on the pH scale (i.e. going from a pH of 8 to a pH of 7) represents a tenfold increase in hydronium ion concentration. Ask students how a change in pH might affect ocean life. Prompt them to think about things they might have seen on TV or in magazines.

LESSON: SCIENCE (CHEMISTRY)

Eco-friendly buildings

Purpose/ Learning objective

- Understanding the impact of non-ecological buildings. Learning about new techniques about green housing.

Intersecting objectives

- Climate change, water conservation, waste management.
- Learners will be able to list strategies

(at least 6) to reduce their own, peers' and/or school's carbon footprints.

- Learners will be able to calculate and evaluate their carbon footprints.
- Learners will be able to appraise the sources and assumptions behind the footprint calculations.
- Learners will be able to collaborate with peers to share and establish action plans regarding carbon offset to reduce carbon footprints in their daily life.

Facilitation

Ideas for follow-up

Students can work with their families to inspect their homes and find ideas for possible (and plausible) green improvements that will also be money-savers.

Crossover: climate change module-school inspection.

Resources required

- Maquette building materials: new and old (recyclable and clean garbage from the students' homes).
- Ask students to keep the recyclable packaging of the waste of their home, such as cartons, papers, bottles etc. All materials must be clean and checked by the teacher.
- After the class gets all their garbage, make a list with the remaining materials that are needed. Either the school will provide them or the cost will be split among the students. Choose easy materials to work with (carton, glue etc). No need for expensive or special materials.

Source/The day of the lesson: Materials & Class prep.

Class preparation: the teacher will talk about the basics of maquette building, in order to help students to organize themselves better.

Cummings E., *How to Model Eco-Friendly Houses for a School Project,* Classroom. Available at https://classroom.synonym.com/model-ecofriendly-houses-school-project-7862794.html

Stefani K. (2021), member of the Eco Smart consortium

Implementation

Timing	Instructions step by step
20 min	Discussion: what produces carbon emissions in a building? Ask the students to describe the buildings they're currently living in. What seems eco-friendly in their house? What could be improved? Ask students to describe an imaginary eco- friendly house in its entirety. What would a completely eco-friendly house look like in 50 years from now?
20 min	Help students design the imaginary house. Don't overcomplicate it: stick to the basics (effective heating and cooling, good insulation, solar panels etc).
55 min	Students create the basic frame of the maquette together. Then split them into groups that will create the eco- friendly features. Depending on what they discovered in their research, these may include solar panels, a wind turbine, a green roof, thermal pane windows, a rain barrel or other attributes. Aluminum foil works well as solar panels, fake turf or painted cotton can be used for greenery and popsicle sticks are helpful for wind turbines, trim work etc. Each group must design their basic idea on paper and then build it. For the last step, the groups will combine their parts to create the green house.

LESSON: MATHEMATICS

Food math

Purpose/ Learning objective

- Understanding the impact of everyday choices, like the food we are eating. The students will also learn how to use Excel to insert data and create graphic representations.

Intersecting objectives

- Learners will be able to list strategies (at least 6) to reduce their own, peers' and/or school's carbon footprints.
- Learners will be able to describe why it is important to have as small a footprint as possible.
- Learners will be able to calculate and evaluate their carbon footprints.
- Learners will be able to appraise the sources and assumptions behind the footprint calculations.
- Learners will be able to collaborate with peers to share and establish action plans regarding carbon offset to reduce carbon footprints in their daily life.

Facilitation

Prepare/have the Excel sheet ready on your computer

Ideas for follow-up

Split students into 4 groups and ask each group to design a vegan meal. During the next month, the students will cook one of these meals per week with their family and document the process. At the end of the month, they will present their photos and discuss their experience.

Idea for further implementation: create a cookbook containing low impact recipes (seasonal, vegan ingredients, minimal packaging or bulk options etc).

Resources required

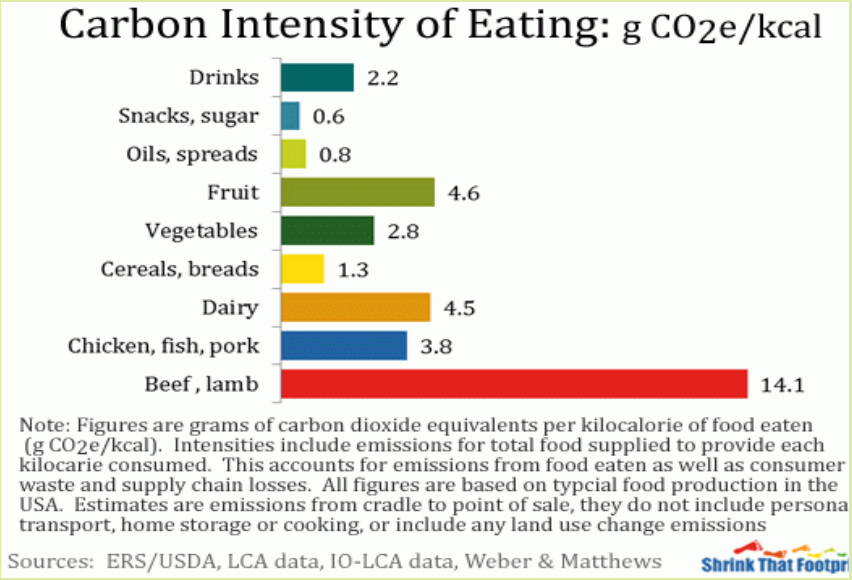
- Computers
- Excel

Source/The day of the lesson: Materials & Class prep.

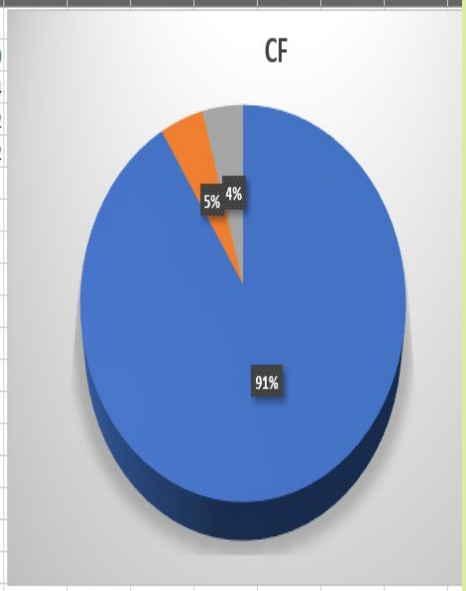
Melissakis G. (2021)

Wilson L., *The carbon foodprint of 5 diets compared.* Available at http://shrinkthatfootprint.com/food-carbon-footprint-diet?fbclid=IwAR2-W7R_DcNlPvFUkb7P5cQIX3-rcIRDIbDKFo8B4nH_CskkGZrHLX-Pa6o

Implementation

Timing	Instructions step by step
10 min	The teacher will have the following data available and explained: 
10 min	• Ask the students to research the nutritional guidelines for their age regarding the calories their lunch should contain (per average). • Ask the students to describe a meal they think is balanced. Most teenagers will probably think of a meat, a vegetable and a grain source. Split the students into 3 groups: the 1st will create a dish containing beef, grains and vegetables. The 2nd group will use fish instead of beef and the 3rd group will use legumes instead of fish.
	Now the students, using the data for the average calories their lunch should have, create the proportions of their plate. The beef, fish and legumes must offer the same calories. After the final plates are created, ask each group to insert their data into an Excel sheet. One column will contain the protein source (beef/fish/legumes), the grains and the vegetables. Create a 2nd column with the weight of each food. The 3rd column will contain the calories of each category. The 4th column will contain the carbon footprint of each food per calorie (use the data of the first image). Using the Excel tools, create a graphic design as following (check the Annex for template and instructions):

Food	Weight	Kcal	CF
Beef	200	500	7050
Veggies	200	130	364
Cereal	100	264	343.2
Total	500	894	7757.2



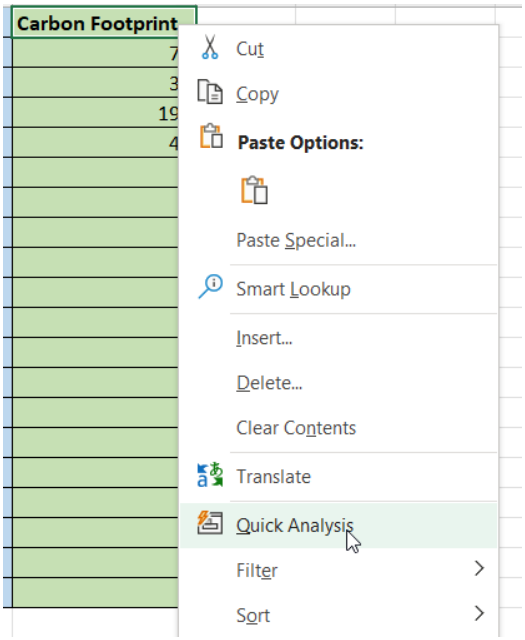
Compare the images of the 3 different plates. Is the protein sources' difference big? Did you expect that? Why do you think beef has such a carbon footprint?

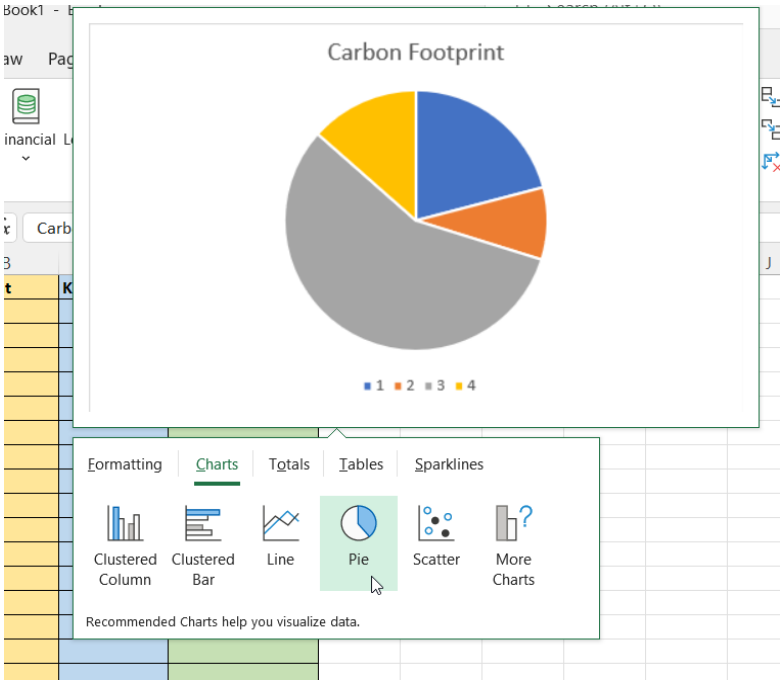
Discuss about the production of each protein source. What resources were used in each? i.e., cows have to eat large amounts of grains and drink a lot of water, fish need to be bred or caught in the wild, legumes must be watered.
What do they have in common? i.e. resources used in processing, packaging and transportation.

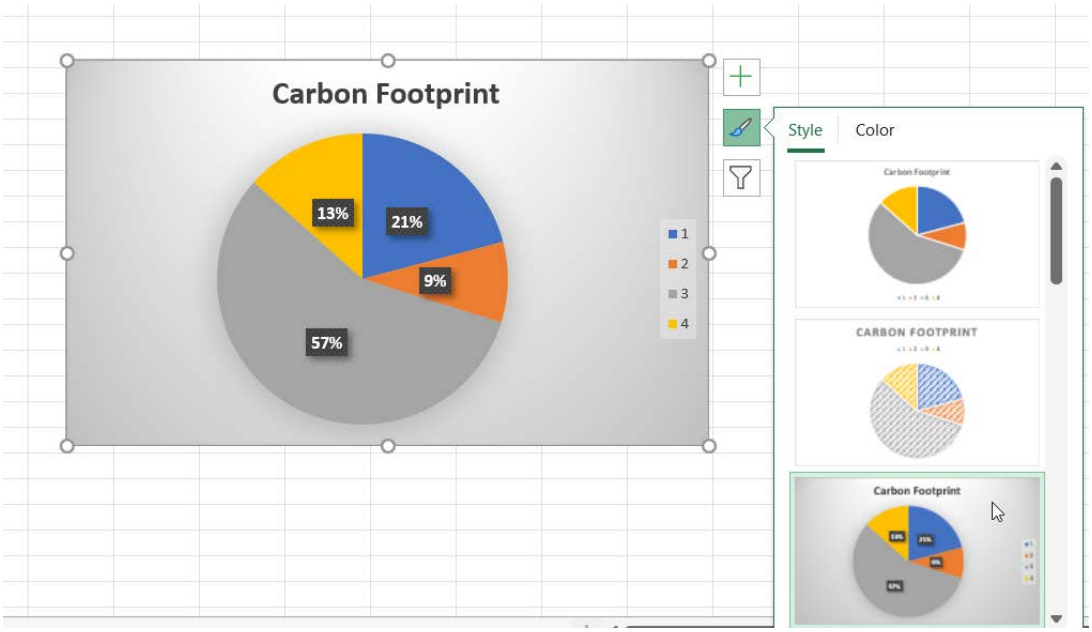
Annexes

Annex 1: “Module 4 Lesson 4 annex 1”

You can either use the Excel provided or use a new one. Here are some instructions:







LESSON: SCIENCE

Effect of greenhouse gases

Purpose/ Learning objective

- Students learn the advantages and disadvantages of the greenhouse effect.
- They build their own miniature greenhouses and discover how their designs utilize heat transfer processes to create controlled environments.
- Compare the greenhouse indoor and outdoor temperatures, record measurements and create graphs.
- Students are also introduced to global issues such as greenhouse gas emissions and their relationship to global warming.
- Recognize the effects of climate change on humans (food cultivation).

Intersecting objectives

- Describe the climatic conditions that are changing in response to a warming climate.
- Describe the impacts of these changing climatic conditions
- Demonstrate understanding of the complexities of the climate change-health effect system through construction of a visual model.

Facilitation

Vocabulary/Definitions

- absorbance: The ability of a medium to absorb radiation.
- global warming: The recent trend of increasing world surface temperatures, thought to be caused by pollutants and their "entrapment" of heat.
- greenhouse: A structure with transparent walls and roof used for the cultivation of plants under controlled conditions.
- greenhouse effect: The warming of the Earth's surface due to greenhouse gases.
- greenhouse gases: Gases that contribute to the greenhouse effect (mainly carbon dioxide, methane and water).
- model: (noun) A representation of something for imitation, comparison or analysis, sometimes on a different scale. (verb) To simulate, make or construct something to help visualize or learn about something else (as a product, process or system) that is difficult to directly observed or experimented upon.
    - radiation: Energy that is radiated or transmitted in the form of rays, waves or particles.
    - transmittance: The amount of light that passes through an object.

Ideas for follow-up

- Have students work as a class to design and build a larger greenhouse that can accommodate more plants.
- Have teams evaluate their models with solar geometry in mind and consider the sun's position relative to their greenhouse. Where do they put their greenhouse next to a house? For example, a greenhouse is best placed in an area that receives sunlight at all times of the year.
- Have students design and build a small-scale "vertical farm" by working together to create a multi-level greenhouse. You can find more information about this idea at The Vertical Farm Project, http://www.verticalfarm.com

Resources required

Each group needs:

- 6 acrylic or Plexiglas squares, approximately 10 to 12 inches (25 to 30- cm) per side
- hot glue gun and glue sticks
- soil and plant
- thermometer
- clear, wide strapping tape
- Greenhouse Design & Testing Worksheet
- (optional) structural frame made of wood, metal or plastic for the entire class to share: saws, to cut acrylic or Plexiglas

Source/The day of the lesson: Materials & Class prep.

- Greenhouse Effect. Updated December 4, 2008. Wikipedia, The Free Encyclopedia. Accessed December 4, 2008. http://www.gov.mb.ca/agriculture/crops/greenhouse/bng01s04.html
- Greenhouse Heating and Venting: A guideline for determining heating and venting requirements of a greenhouse. March 2006. Manitoba Agriculture, Food, and Rural Initiatives. Accessed December 3, 2008. http://www.gov.mb.ca/agriculture/crops/greenhouse/bng01s04.html
- The Vertical Farm Project - Agriculture for the 21st Century and Beyond. 2008. The Vertical Farm Project, Environmental Health Science of Columbia University, New York, NY. Accessed December 3, 2008. http://www.verticalfarm.com/
- https://www.teachengineering.org/content/cub_/activities/cub_housing/cub_housing_lesson03_activity2_worksheetas.pdf
- https://www.teachengineering.org/lessons/view/cub_air_lesson07

Implementation

Timing	Instructions step by step
	Before the Activity • Gather materials. • (optional) To save class time, pre-cut acrylic or Plexiglas squares.
10 min	Students are given information about greenhouse and greenhouse gases in the first 10 minutes. Students need to explain why greenhouse gases affect climate change: *Question: Have you ever noticed that after getting into a car in the sun all day, it gets very hot or even uncomfortably hot inside? It's not just hot weather; This is because the design of the car allows heat to come in, but not out. This should not be confused with the greenhouse effect. Although the situations are similar, the analogy is wrong. The greenhouse effect refers to the process by which radiation from the sun is absorbed and reflected by the Earth's surface; Some of the reflected radiation returns to the atmosphere and some is absorbed by the greenhouse gas molecules and then re-radiates the radiation in all directions in the atmosphere, warming the Earth's surface. You've probably heard many times, The process by which a greenhouse works is very different from the greenhouse effect. A greenhouse consists of a structure made of a completely transparent material such as glass or plastic. The transparent material allows heat to enter in the form of radiation, but this does not allow heat to escape (at least not very quickly). The heat is absorbed by the objects and materials inside by radiation and then released to the rest of the interior by convection. The most important aspect of a greenhouse is that one can control the indoor environment, which is helpful when growing plants, especially in climates where horticulture is not normally conducive. *Greenhouse Effect and Climate Change: The greenhouse effect is often confused with the process that occurs in a real greenhouse. The greenhouse effect refers to a process in which radiation reflected from the Earth's surface is absorbed and re- emitted by greenhouse gases, rather than being returned to the atmosphere. It prevents heat loss by radiation rather than convection as in a typical greenhouse. It is important to distinguish between the two because they can be easily confused. *Climate change refers to a significant change in the average weather patterns over a long period of time in a given region. It is attributed to various factors, such as changes in solar intensity and Earth's orbit, and more recently greenhouse gas emissions. In this lesson, we will learn how greenhouse gases cause global warming and how they cause climate change.
20 min	**Pre-Activity Assessment** Question/Answer: Have students first discuss amongst themselves, and then discuss as a class. ● What kind of heat transfer does a greenhouse use to gain heat? How is it able to do this? (Answer: The greenhouse gains heat through solar radiation. It is able to do this because radiation does not require a medium and can easily be transmitted through transparent or nearly transparent materials [such as glass].) ● What kind of heat transfer does the greenhouse prevent (between the inside and outside)? How does this help the greenhouse operate? (Answer: The greenhouse prevents convection heat transfer between the indoor and outdoor air. This allows the indoor air to be heated up while keeping it from exchanging with the cooler outdoor air. Because the greenhouse is sealed up, it only loses heat through conduction.)
10 min	How Greenhouses Work: Greenhouses work on four fundamentals: radiation, permeability, absorption, and convection. Through this process, people can harvest energy from the sun and use it to provide a warm and humid indoor environment conducive to the growth of plants.

	Step 1: Radiation and Permeability - Almost all of the heat in a greenhouse comes directly from the sun via radiation. This energy radiates from the Earth's atmosphere and is transmitted through glass (or other transparent materials) into the greenhouse. Step 2: Absorption — Once the energy from the sun reaches the inside of the greenhouse, it must be absorbed. It helps to have a surface that absorbs almost all the energy that hits it (for example, something dark; the earth works well). Whatever is inside the greenhouse continues to absorb this energy. 3. Step: Convection - After the energy is absorbed in the greenhouse, the heat is transferred to the whole area by convection. The colder air falls to the bottom and is warmed by the absorbent surface, and the process repeats. Since convection is the way the rest of the greenhouse is heated, it is important to tightly close the entire structure. Even opening the door for a short time can significantly lower the indoor temperature

LESSON: MATH, SCIENCE

Thermal expansion model

Purpose/ Learning objective

- An important part of understanding sea level rise is understanding the thermal expansion of water. Thermal expansion accounts for about half of the measured global sea level rise. Students will create a model using diary items to show that water expands when heat energy is added.

Intersecting objectives

- Describe the climatic conditions that are changing in response to a warming climate.
- Describe the impacts of these changing climatic conditions.
- Prepare a poster, brochure, infographic, video, etc that is one adaptation strategy from an economic, social and environmental perspective

Facilitation

For a more detailed background on sea level rise and a related activity, see:

https://www.jpl.nasa.gov/edu/teach/activity/graphing-sea-level- trends/

Ideas for follow-up

Evaluation

Ask students to identify the reasons for sea level rise in sufficient detail to demonstrate their understanding:

- Melting ice contributes to sea level rise. As the land ice melts, it mixes with the ocean and increases the amount of water in the ocean basins. Melting of sea ice does not contribute to sea level rise, as melted ice fills the area previously occupied by frozen sea ice.
- The ocean's heat capacity allows it to absorb a lot of energy in the form of heat as land and air temperatures rise. When water is heated, it expands and takes up more space, a phenomenon known as thermal expansion. Thermal expansion increases the volume occupied by ocean water, causing sea level rise.

Resources required

Materials

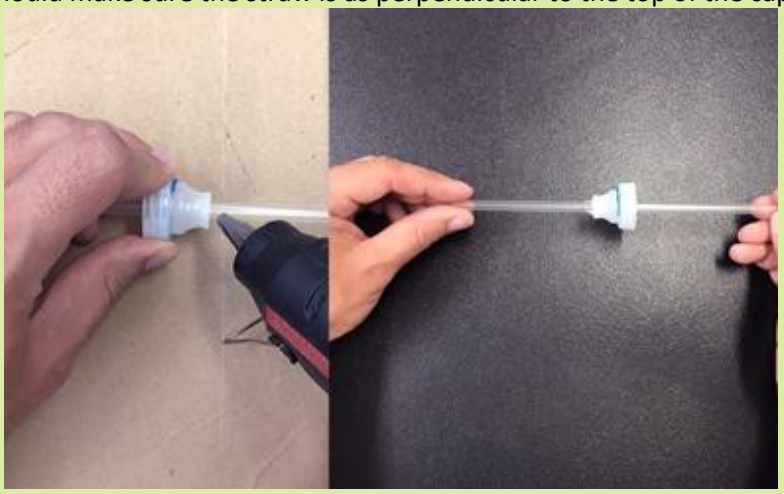
- Per group of 2-3 people:
- 1 disposable plastic water bottle with flip cap, if available. Small bottles made of thicker, stronger plastic are preferred.
- 1 clear plastic straw food coloring
- Ruler
- Cutting tool
- Dark color felt pen
- Thermometer (optional, see Management section)
- Several low temperature hot glue guns, putty or other malleable sealant
- Paper or cloth towels Goggles
- Heat sources (such as incandescent bulbs, heat lamps, heat pads or the Sun)

Source/The day of the lesson: Materials & Class prep.

https://www.jpl.nasa.gov/edu/pdfs/sealevel_graphing_worksheet.pdf

Implementation

Timing	Instructions step by step
10 min	**Students are given the following information.** Global sea level has changed significantly, especially throughout history. sea level is rising. Global tide measurements from tide gauges show that global sea level has increased by about 3.4 millimeters (0.13 inches) per year over the past century. • Sea level rise is caused by many different processes, including melting ice. But one of the biggest contributors to sea level rise is rising global temperatures, which are warming the seas and causing something called thermal expansion of water. Thermal expansion occurs when water heats up, causing the volume of water to increase. About half of the global sea level rise measured on Earth is due to warming waters and thermal expansion. • Sea level is measured by monitoring stations on the coastline and at sea. Like NASA's JASON-3 satellite, satellites collect data at sea level. There are more than 120 sea level monitoring stations in the US and 240 additional stations worldwide. By looking at data of 30 years or more from these stations, trends in individual stations can be determined and compared with other stations. This gives scientists useful information about local conditions. This data can also be used to calculate global, mean sea level and study it over time, giving scientists a picture of what is happening in the ocean on a planet-wide scale. For over a century, sea level has been measured at some stations and sea level data dating back to 1880 are provided. • Global sea level is currently rising as a result of both ocean thermal expansion and melting glaciers, each accounting for about half of observed sea level rise, and each due to recent increases in global average temperature. Between 1961 and 2003, sea level rose at a rate of 1.11 millimeters (0.04 in) per year due to thermal expansion and glacial melting (from small glaciers, glaciers, and ice sheets). Between 1993 and 2003, the contribution to sea level rise increase to 2.79 millimeters (0.11 in) per year for both sources. So, sea level isn't just rising, it's also rising faster than in the past. • Why is this happening? Scientists have discovered that the concentration of carbon dioxide in the atmosphere has increased by 39 percent since the start of the Industrial Revolution. Most of the CO2 comes from energy production from the fossil fuels we use to support our lifestyle. Some of this extra carbon dioxide is absorbed by the oceans, soils and trees, but the rest will remain in the atmosphere for thousands of years. This is important to our climate because carbon dioxide is the most important gas that controls Earth's atmospheric temperature.
20 min	Discuss climate change and sea level rise with students. Ask students to identify the causes of sea level rise. If students see melting ice as a cause of sea level rise, ask them what type of ice, land ice, or sea ice contributes more to sea level rise. Consider illustrating the contribution of land ice and sea ice to sea level rise using Causes of Sea Level Rise. *If students are not talking about thermal expansion, explain that in addition to melting ice, there is another phenomenon that contributes to sea level rise. The following activity will demonstrate this phenomenon. You can see how this process works by creating a model using everyday elements to show that water expands when heat energy is added.

30 min	1. Have students drill a hole in the cap of their waterbottle, depending on their age and ability.  2. Have students insert the straw into the hole. With the cap attached, the straw should extend approximately 2-3inches into the bottle. (Students can keep the bottle and cap separate during this step.) Seal the gaps around the straw using hot glue, putty, or other sealant. Students should avoid skin contact with the adhesive and make sure there is no glue, paste or sealant on the threads of the cap. The bottle will not close properly if the threads are not clean. As the glue dries, students should make sure the straw is as perpendicular to the top of the cap aspossible. 

3. Have students add a few drops of food coloring to the water bottle, fill the bottle to the brim with water, then filland tighten the straw and cap assembly. There may be some overflow when the cover is installed. The water in the straw should be in the lid, but low enough to allow the measurements to show how high the water rises when it rises.

4. Students need to mark the straw to indicate the bottomor zero level of the water. For each measurement, they must align the zero mark on the ruler to this mark. Once the line is marked, avoid moving or holding the bottle while the water is heating, as moving and squeezing the bottle can change its shape, internal volume, and water level. Using water bottles with thicker plastic will help minimize changes in water level that can occur when the bottle is moved.

5. Have students point a heat source into the bottle or expose the bottle to direct sunlight. Because some heat sources apply heat less intensely to the water, the time it takes to notice a change in temperature and water height can vary. Test one of these models ahead of time to get anidea of how long it will last.

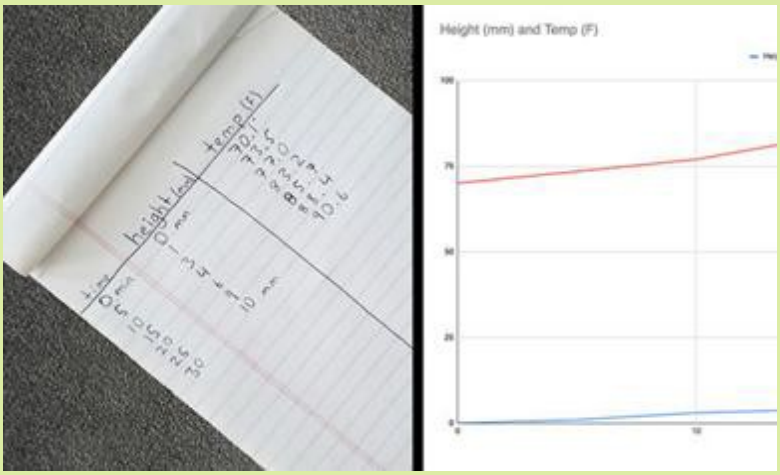
6. At consistent intervals, students should measure and record the water level in millimeters compared to the zero-mark drawn on the straw and note what happened. If thermometers are used, students should also record the temperature at these intervals.

7. Have students chart their height measurement on paper or using spreadsheet software. If thermometers areused, students should also graph this data.

- Ask students to describe what they observed on the straw and what they noticed on their graph. Students should notice that the water level rises as heat is added to the water. Explain to students that this phenomenon mentioned in Step 1 is known as thermal expansion.

Make a conclusion

- Write a description of what you observed in the straw. Graph your measurements on paper or using spreadsheetsoftware.
- What happened to the water level as heat energy was added? How does this relate to rising global temperaturesand sea level rise?



LESSON: MATH, SCIENCE

Arctic sea ice and mathematic

Purpose/ Learning objective

- learn about derivatives and their application in comparing rates
- understand the derivative function graph and related terms such as extrema, roots, and inflection points
- use function graphs to observe changes in rates of melting and the extent of Arctic Sea Ice in given datasets

Intersecting objectives

- Describe the impacts of these changing climatic conditions
- Prepare a poster, brochure, infographic, video, etc that is one adaptation strategy from an economic, social and environmental perspective

Facilitation

Expand understanding

- Use the reading "Polynomials and Their Derivatives: Polynomials, Critical Points, and Inflection Points" by Donald Byrd, Indiana University.
- Informatics to repeat mathematical concepts that will be applied in the following activity.
- Using the 'Arctic Sea Ice' classroom activity from Thomas J. Pfaff, Professor of Mathematics, Ithaca College, USA, Sustainability Math, have your students practice derivatives, polynomial differentiation, and derivatives using datasets from National. Snow and Ice Data Center (NSIDC). This class event includes three datasets on Arctic Sea Ice coverage in conjunction with NSIDC's observations from 1980 to 2017. This data is provided in an Excel spreadsheet. The classroom activity also includes a Word document with instructions on how to use different mathematical methods on the data provided. Invite your students to download the Excel file (with the dataset) and the Word document (containing instructions for using the dataset and a set of questions for analyzing the dataset).
- Continue the classroom activity and encourage your students to answer the questions by applying their understanding of the graph of functions, maximum/minima, root, and inflection points.

This can be accessed at:
http://sustainabilitymath.org/calculus-materials/#

Ideas for follow-up

1. Discuss further

Use the visualization, 'Charctic Interactive Sea Ice Graph' from NSIDC to encourage discussion amongst your students about the changes in the

extent of Arctic Sea Ice from the years 1979-2020. Discuss how these

changes could be the result of changes in the Earth's climate in recent times.

These can be accessed at:

https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/

2. Topic introduction and discussion

Use the teaching module, 'Differentiation: definition and basic derivative rules' by Khan Academy, to introduce the concept of derivatives and

differentiation. Navigate to the sub-sections within the module to explain derivative rules, the power rule, and how to differentiate polynomials.

Use the in-built practice exercises and quizzes to evaluate your students' understanding of the topics.

This can be accessed at:

https://www.khanacademy.org/math/ap-calculus-bc/bc-differentiation-1-new

3. Develop the topic further

Use the teaching module, 'Derivatives and the shape of a graph' by OpenStaxTM, Rice University, to explain to your students how related rates can be compared using derivatives. Use the sub-sections within the tool to explain various mathematical concepts for determining maxima/minima values, roots, and inflection points in the derivative function graph.

This can be accessed at:

https://openstax.org/books/calculus-volume-1/pages/4-5-derivatives-and-the-shape-of-a-graph

Resources required

https://www.khanacademy.org/math/ap-calculus-bc/bc-differentiation-1-new

https://smile.oregonstate.edu/lesson/tracking-ice-arctic-sea-ice-and-mathematics-curriculum

Source/The day of the lesson: Materials & Class prep.

All the teaching tools in our collated list are owned by the corresponding creators/authors/organizations as listed on their websites. Please view the individual copyright and ownership details for each tool by following the individual links provided.

We have selected and analyzed the tools that align with the overall objective of our project and have provided the corresponding links.

We do not claim ownership of or responsibility/liability for any of the listed tools.

1. Teaching Module; 'Differentiation: definition and basic derivative rules'

Developed by Khan Academy

2. Teaching Module; 'Derivatives and the Shape of a Graph'

Provided by OpenStaxTM, Rice University.

3. Classroom Activity; 'Arctic Sea Ice'

Provided by Sustainability Math by Thomas J. Pfaff, Professor of Mathematics, Ithaca College, USA.

4. Reading; 'Polynomials and their Derivatives'

By Donald Byrd, Indiana University Informatics.

5. Visualization; 'Charctic Interactive Sea Ice Graph' From National Snow and Ice Data Center (NSIDC)

Implementation

Timing	Instructions step by step
	This lesson plan will allow you to teach introductory derivatives, polynomial differentiation, and the application of derivatives. The lesson plan includes a hands-on computer-based classroom activity to be conducted on datasets of Arctic Ice Data (1980-2017). This activity includes a set of inquiry-based questions that will enable your students to apply their understanding of sixth degree polynomial differentiation, maxima/minima values, finding roots and inflection points. Thus, the use of this lesson plan allows you to integrate the teaching of a climate science topic with a core topic in Mathematics
20 min	Use this lesson plan to help your students find answers to: • What are derivatives and their functions? • Using an example, describe polynomial differentiation. • Is the extent of the Arctic Sea Ice decreasing since 1980? • Has the speed of melting of Arctic Sea Ice changed from 1980- 2017? • Discuss the Ice Albedo Feedback and Global Warming to explain the differences in rates of melting of and extent of Arctic Sea Ice over the past four decades.
30 min	1. 1st Teaching Module (20 min) A teaching module to explain the basics of derivatives, derivative rules, and differentiation. This can be accessed at: https://www.khanacademy.org/math/ap-calculus-bc/bc-differentiation-1-new 2. 2nd Teaching Module (20 min) A teaching module to explain the application of derivatives in comparing rates in differentiation and aspects of the function graph. This can be accessed at: https://openstax.org/books/calculus-volume-1/pages/4-5-derivatives-and-the-shape-of-a-graph
10 min	A pre-activity reading can be accessed at: 1 Contents //homes.sice.indiana.edu/donbyrd/Teach/Math/Polynomials+atives.pdf
30 min	**Classroom Activity (20 min)** A classroom activity to apply understanding of differential rates using datasets of Arctic Sea Ice Data (1980-2017). This can be accessed at: http://sustainabilitymath.org/calculus-materials/ **Visualization (5 min)** An interactive visualization of changes in the extent of Arctic Sea Ice from 1979-2020. This can be accessed at: https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/ Suggested questions/assignments for learning evaluation (5 min) • What are derivatives and their functions? • Using an example, describe polynomial differentiation • Is the extent of the Arctic Sea Ice decreasing since 1980? • Has the speed of melting of Arctic Sea Ice changed from 1980- 2017? • Discuss the Ice Albedo Feedback and Global Warming to explain the differences in rates of melting of and extent of Arctic Sea Ice over the past four decades. Here is a step-by-step guide to using this lesson plan in the classroom/laboratory. We have suggested these steps as a possible plan of action. You may customize the lesson plan according to your preferences and requirements.

LESSON: ART

Climate change in comics drawings and caricatures

Purpose/ Learning objective

- Students will explain climate change trough cartoons and comics.
- Students will learn how to make cartoons and comics

Intersecting objectives

- Prepare a poster, brochure, infographic, video, etc that is one adaptation strategy from an economic, social and environmental perspective

Facilitation

- Self-publish your comic. As tools for self-publishing become more widespread, the ease of publishing material has greatly increased. Resources such as Amazon's CreateSpace allow authors to easily.
- CreateSpace will automatically list your comic on Amazon, and will print copies to match orders.

Ideas for follow-up

- If you feel like your strip would be a good fit for newspapers, talk to a syndicate. These are publishing groups that sell their comics to papers around the world. Syndicates receive thousands of submissions every year, and typically only pick about 3-4 strips.

Resources required

https://www.createspace.com/

Source/The day of the lesson: Materials & Class prep.

http://www.wikihow.com/Make-a-Comic

Implementation

Timing	Instructions step by step
10 min	1. The students are asked which comics and cartoons they like the most. 2. Explain why cartoons and comics interest young people more than normal articles and news. (Comics have a way of making us feel. Whether it's laughter, sadness, intrigue, excitement, or any other emotion, the power of a visual story is undeniable. Creating your own comic can be a rewarding experience and can be easier than you think. Make a great comic. You'll need a story, a style that's all yours, and a format that fits both. From there, create a rough sketch and publish your final masterpiece online or in print before drawing, painting, and painting the final comic.)
20 min	Follow the link below on how to draw comics: http://www.wikihow.com/Make-a-Comic https://www.storyboardthat.com/storyboard-creator www.canva.com www.bookcreator.com 1. Development of the comic in this lesson - Write down the basics - Write what you know. - Decide on a style - Pick a format.  2. Creating the sketch - Write a script. - Sketch out the frames - Make sure your panel layout makes sense. - Experiment with different uses for text - Ask yourself if every frame matters. - Experiment with the frame structure 

3. Drawing comics
   - Create the frames
   - Start adding content to your frames
   - Draw your final lines
   - Scan the comic
   - Clean up the image
   - Create your own font
   - Add dialogue and speech bubbles in Photoshop.
   - Color your comic.

4. Publishing Your Comic topics will be taught.
   - Upload to an image host and spread the links
   - Create a DeviantArt account.
   - Create your own web comic page.
   - Self-publish your comic

Students will be able to make cartoons and comics under titles in the lesson, and those who cannot finish will be able to continue at home.

LESSON: SCIENCE/TECHNOLOGY

Getting to understand waste management

Purpose/ Learning objective

- To understand waste and waste management
- To be able to classify well founded and not well-founded information from the internet, social networks, etc.
- To understand the process of waste from home to the landfill or treatment

Intersecting objectives

- To understand waste pollution
- To understand consequences to the environment
- Behaviour and consequences towards waste management: What can you do at school or at home?
- Why it is important REDUCING, RECYCLING, REFUSING and REUSING waste
- Team work
- Climate change
- Reinforcing they ICTskills

Facilitation

- The teacher will provide as much information and guidance to the students as possible. Some explanations may be needed.

Ideas for follow-up

- Transferring the knowledge acquired to other peers

Resources required

- Computers

Source/The day of the lesson: Materials & Class prep.

Challenge based learning

A classroom guide

https://images.apple.com/education/docs/CBL_Classroom_Guide_Jan_2 011.pdf

Implementation

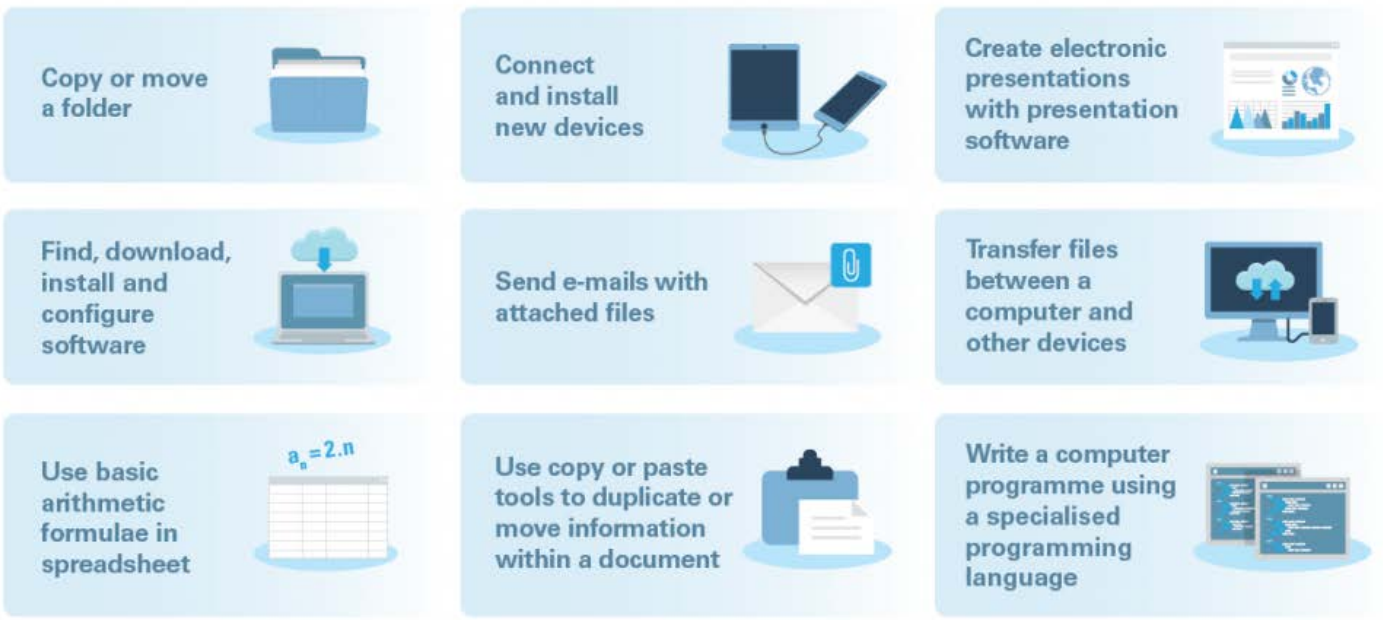
Timing	Instructions step by step
	In this lesson we are going to work with the methodology challenge based learning. We are going to follow the different steps provided in the guide. https://images.apple.com/education/docs/CBL_Classroom_Guide_Jan_2011.pdf Before Lesson: Explain to students about this methodology and also check the students´ ICT knowledge (Annex 1)
60 min	**Stage 1: From big idea to the challenge** A big idea is one that is important on a global scale and that students can work with to gain the deep multidisciplinary content knowledge and understanding that is required by the standards for their grade level. The teacher can propose a big idea. For this lesson we propose: WASTE MANAGEMENT ACTIVITY: Brainstorming Make sure every contribution is recorded Comment student's ideas
120 min	**Stage 2: Guide questions** They work in groups of four, if possible. During this second stage of the process, students identify the guiding questions (what they need to know) and identify resources and activities to answer their questions. Remind them that they have many options for their guiding activities and resources: they can use the Internet, the school or public library, their social networks, or interview local experts in person or experts located anywhere in the world via the web. Examples of guiding questions are: - What happens after I throw the rubbish? - How much waste do we generate? - Identifying biodegradable and non-biodegradable (students need to guess the degradation time of each material listed) https://www.sciencelearn.org.nz/resources/1537-biodegradability - What can we do to reduce the amount of waste at home or at school? - How can I manage my waste in order to minimize the harm to the environment?
2 x 120 min	**Stage 3: Identifying a solution** Having thoroughly researched the guiding questions, the students now have a solid foundation to begin identifying a variety of possible solutions. They should select one solution through prototyping, experimentation, or other means. Next,they fully research, document, and develop that solution andthen identify steps to carry out their implementation plan.

	Explain students about waste hierarchy 
Optional	**Stage 4: Implementation and Evaluation** After identifying their solutions together with the knowledge acquired on this lesson, the students will implement them, measure outcomes, reflect on what worked and what didn't, and determine whether they made progress in addressing the challenge. When implementation is complete, students share their work with the rest of the world. In their research plan, the students decide what they will measure and how often so they can be consistent throughout the implementation phase. For instance, if the challenge is to reduce the school's paper footprint, they might want to keep track of how much paper is used per day. Once they decide what to measure, the students can determine a baseline by taking current measurements over a few days or a week. **Stage 5: Publishing Results and Reflection** Throughout the project students document their experience using audio, video, and photography. Near the culmination of the challenge, students build their solution video and record their reflections. The three-to-five-minute solution video should include a description of the challenge, a brief description of the learning process, the solution, and the results of the implementation. Students are encouraged to keep individual written, audio, or video journals throughout the process. As a culminating event, students can be provided a series of prompts for final reflections about what they learned about the subject matter and the process.

Annexes

Annex 1:

Activities to check your pupil's ICT skills:



Fuente: UNICEF connect. https://blogs.unicef.org/evidence-for-action/ict-skills-divide-todays-youth-prepared-digital-economy/

Annex 2:

Example templates for the different steps can be found:

https://images.apple.com/education/docs/CBL_Classroom_Guide_Jan_2011.pdf

LESSON: ENGINEERING, SCIENCE

What happen with the waste after you throw it?

Purpose/ Learning objective

- Become aware of how improperly handled waste impacts the environment.
- Explain some of the major problems caused by waste disposal and use of landfills.
- Understand and explain the role of engineers in solid waste management.
- Suggest ways to reduce the amount of solid waste going to a landfill.

Intersecting objectives

- To understand the consequences to the environment
- Sustainable waste

Facilitation

- Risk Assessment
- Instructions for the group of Students

Ideas for follow-up

- Try a different experiment: Methane from the landfill.

Resources required

- Science Laboratory
- Material:
- 2-liter plastic beverage bottle
- 1 tennis ball-sized mound of modeling clay; enough to line the inside of the top half of the 2-liter bottle
- 3 cups of soil
- ¾ cup water
- ½ sheet of paper, torn into small pieces; tip: use recycled paper from Activity 1 or newspaper
- 2 lettuce leaves, torn into small pieces
- 1 apple, sliced/diced into small pieces
- 2-3 plastic food containers, cut into small pieces about
- ½ inch square; tip: use empty butter or yogurt containers
- 8 pairs of rubber or latex gloves, 2 pair per student
- 2 spoons or popsicle sticks
- set of measuring cups, specifically, 1 cup, ½ cup and ¼ cup sizes
- 4 inches of masking tape, for labeling landfills

Source/The day of the lesson: Materials & Class prep.

- https://www.teachengineering.org/curriculum/browse?q=lanfill

Implementation

Timing	Instructions step by step
	Before Lesson: Remind the students the different ways of waste disposal. Student groups will work as engineers to build and observe model landfills they make using two-liter plastic bottles. They come to understand the process and pitfalls of landfills as a waste disposal method. • Ask students to bring in 2-liter plastic beverage bottles from home to use for the activity. Tell students to wash each bottle and leave it to air dry, saving the caps. Cut each group's 2-liter bottle in half horizontally (keep the top section slightly larger). Twist the caps on securely (even over tighten them if possible). • Pick a location to keep the model landfills during the observation period. Choose a place that receives sunlight, but where the odor will not be bothersome. • Mix the food (lettuce and apples), the paper, and the plastic together into a "garbage" sample. Decaying landfill garbage can produce harmful methane gas, which is a source of fires and environmental hazards. So, engineers design gas pipe systems to collect landfill gases, including methane, carbon dioxide and sulphur dioxide, which are used to generate electricity.
60 min	Activity: Worksheet: https://www.teachengineering.org/content/cub_/activities/cub_environ/cub_environ_lesson04_activity2_worksheet_v1_sas.pdf 1. Divide the class into groups of four, students each anddistribute the supplies (activity sheets, soil, approximately ½ cup of the "garbage" sample, water, 2-liter bottles, clay, gloves, and masking tape). 2. Ask each group to write the name of their group members on the masking tape and place it on the topportion (the neck end of the bottle) of the 2-liter bottle. 3. Ask all students to put on their latex/rubber gloves. 4. Ask the groups to line the inside of the top portion of the 2-liter bottle with clay, as in Figure 1. (Discuss howthis is similar to the clay and plastic liners used in modern sanitary landfills to prevent toxins from leaching into the ground water.)

Figure 1. Clay-lined model landfill

5. Have students place the top portion of the 2-liter bottle upside down in the cut off bottom half of thebottle. (The bottom serves as a stand that will help keep the model upright.)
6. Ask students to place about 2 cups of their soil insidethe clay-lined "landfill."

Have the groups spread their "garbage" sample on topof the soil (see Figure 2).

Figure 2. A Model landfill with garbage

8. Ask students to sprinkle their remaining soil on top ofthe "garbage."
9. Have students sprinkle ¾ cup water over their landfill.(Note: Discuss that the water simulates rainfall)
10. On the accompanying activity worksheet, have students draw a diagram of their landfill and label itappropriately in Section I, Drawing.
11. For the Prediction section of the worksheet, ask students to write down their predictions about whatwill happen with their landfill over the next 4 days.
12. Place all the landfills in a location where they will getsome sunlight yet where the odor will not be bothersome to the class (or others).
13. On day two, observe the landfills as a class. Have students record their observations. Discuss what leaching is (i.e., in this case, a process whereby toxinsleak into the soil/water as a result of rains or other moisture) and look for evidence of it in the landfills.
14. Repeat the observation process on days 3 and 4. Onday 3, have students sprinkle another ¾ cup water over their landfills.
15. On day five, have students do the final steps andobservations.

	16. After students have put on a pair of rubber/latex gloves, ask them to carefully remove the cap from the bottle and let the water drain into the bottom one-halfof the 2-liter bottle. Ask them to record their observations. 17. Ask the students to use the spoon/popsicle stick to gently scrape back the top layer of dirt. What do they notice about the garbage in their landfills? Ask them torecord their observations. 18. Use the "Numbered Heads" Assessment activity todiscuss the results with student teams. 19. Ask the students to work together as a team to complete the questions in the Response section of their activity worksheets. Use the Numbered Heads procedure to discuss answers.

LESSON: ARTS

Waste to art

Purpose/ Learning objective

- To understand the reuse of waste
- Learning about the importance of recycling

Intersecting objectives

- To develop creativity
- New Behaviour towards waste management

Facilitation

- Risk Assessment
- Instructions for the group of Students

Ideas for follow-up

- Exhibition in the main hall of the school

Resources required

- Material collected at school from the recycle bins
- Scissors
- Glue
- Pliers

Source/The day of the lesson: Materials & Class prep.

- Free style work with little instructions from the teacher

Implementation

Timing	Instructions step by step
	Prior Lesson: Make the students aware about this lesson a couple of weeks in advance Students need to collect some material from the recycle bins for their artwork.
60 min	ACTIVITY 1: Play the following video to inspire students on their creation https://www.youtube.com/watch?v=SR0XtX24f8M ACTIVITY 2: Students will develop their own artwork by using the waste collected at school

LESSON: SCIENCE/MATHEMATIC

Composting at school

Purpose/ Learning objective

- To understand the reuse of waste
- Learning about the compost process
- Learning about sustainable environmental practices

Intersecting objectives

- Behaviour and consequences towards waste management: What can you do at home?
- Educating the community on collective responsibility of waste management in the school
- Analyze segregated waste quantities

Facilitation

A detailed guide for this activity can be found in the following link:
http://greenmountainfarmtoschool.org/wp-content/uploads/2016/01/Guide-to-Staring-a-School-Compost-Program.pdf

Ideas for follow-up

- Waste audits (Compost Quality)

Resources required

- - Material collected at school from the recycle bins
- - Scales
- - Buckets to collect the food scraps, tissue, paper, etc.
- - Clipboard for the record sheets
- - Sawdust
- - Cloth rags

Source/The day of the lesson: Materials & Class prep.

- http://greenmountainfarmtoschool.org/wp-content/uploads/2016/01/Guide-to-Staring-a-School-Compost-Program.pdf

Implementation

Timing	Instructions step by step
2 hours	Prior Lesson: Make sure the students are familiar with bio and non-bio degradable matter. From the first lesson they should know the conditions needed for a biodegradable/compostable material to actually biodegrade. Setting up a compost site in the school: • First thing to do is to define roles and responsibilities. • Designate the classes to be the Compost Keepers. They should empty the food scraps daily, monitor the piles, and take measurements (Annex 1). • Designate a staff member to check on the compost pile, add amendments, turn over piles regularly and add to the Green -house or the garden when needed.
1 hour a day	Check with the students the daily tasks: 1. Collect Food Scraps 2. Weigh Food 3. Transport Food Scraps Outside 4. Take Compost Temperature 5. Spread Food Scraps 6. Layer with Bulking Material 7. Clean Up COMPOST PREPARATION: 1. Place a sign above compost buckets that show students what to compost. Some food service staff use a small white board to write what lunch items can be composted each day. 2. Students scrape ALL food scraps and servillets into the buckets 3. Weigh food scraps by placing a bucket on a scale and subtracting the weight of the container. Record the amount to show savings in the disposal of solid wastes produced by the cafeteria. The weights can also be used to construct math problems or track the composting operation. 4. A designated staff or a group of students to take the buckets to the compost pile outside. 5. Take the compost temperature by placing the long probe into the center of the compost pile. Record the reading. If the temperature has dropped, decomposition has taken place or the balance of the compost needs to be adjusted. 6. Spread the food scraps onto the pile, do not pile them high. 7. Follow the specific recipe designed for your site and layer with the bulking material recommended (wood chips, wood shavings, leaves or hay). Spread with a pitchfork to cover the food completely. This will make it less attractive to animals. 8. Adjust your trash pickup schedule accordingly to reflect the diversion of food scraps and recycling. Be sure to monitor cost change to keep track of the monetary value of composting.

Annexes

ANNEX 1:

Development of STEAM-Oriented kits for better transition to Eco-Smart Schools
(2020-1-FR01-KA201-080167)

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

WEEK NUMBER_____DATE_____

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
TYPES OF FOOD					
WEIGHT (KG)					
RECORDED BY					
TOTAL WEIGHT FOR A WEEK					

WEEK NUMBER_____DATE_____

	TYPES OF FOOD	WEIGHT (Kg)	TEMPERATURE OF PILE (ºC)	OBSERVATIONS
MONDAY				
TUESDAY				
WEDNESDAY				
THURSDAY				
FRIDAY				

LESSON: SCIENCE, TECHNOLOGY, MATHEMATIC

Classroom lighting audit

Purpose/ Learning objective

- Calculate energy consumption of lighting appliances
- Discover auditing techniques
- Identify and calculate lighting energy savings
- Identify and propose lighting enhancements and recommendations

Intersecting objectives

- Energy efficiency
- Energy savings
- Electricity
- Luminosity standards for comfort

Facilitation

- Classroom lighting audit example (resource 3 bis and 4 bis)

Ideas for follow-up

Audit can be extended to specific places where lighting consumption can be significant such as gymnasium, places where lights are always on etc…

Resources required

- Resource 1: Types of lighting
- Resource 2: Lighting calculation template (Word)
- Resource 3: Lighting calculation sheet (Excel)
- Resource 3 bis: Lighting calculation sheet (Excel)
- Resource 4: Savings calculation template
- Resource 4 bis: Savings calculation template
- Resource 5: Electricity costs and CO2 emissions values

Source/The day of the lesson: Materials & Class prep.

- Types of Lighting | Department of Energy
- How Energy-Efficient Light Bulbs Compare with TraditionalIncandescents | Department of Energy
- www.energy.gov

Implementation

Timing	Instructions step by step
	Preparation before the lesson: - Review the lighting material of the classroom and be comfortable with energy consumption calculation (cfenergy and electricity module) - Instead of making students work at height to check lightspower specifications, you can ask to maintenance staff tohave a piece of the different types of lighting available in the classroom and in other parts of the buildings Be familiar with all kinds of lighting (incandescent, fluorescent, LED to allow comparison and help for calculating and proposing recommendations (checkresources)
60 min	Activity 1: Formative case: By using resources 1, 2 and 3 - Calculate the academic year consumption of different types of lighting (incandescent, fluorescent and LED bulbs) - Compare the costs between the different types After students being familiar to energy consumptions and enhancement measures pursue with activity 2
60 min	Activity 2: Classroom lighting audit - Pick up lighting modules references to determine the type and power - Count all the lamps - Calculate the consumption Compare the costs if they were replaced by LED bulbs including investment and rentability

Resource 1: Types of lighting

There are four main families of lamps, from the oldest models to the newest:

- Filament lamps
- Halogen lamps
- Compact fluorescent lamps
- LED lamps

INCANDESCENT TYPE

Incandescent lamps

The principle of incandescent lamps is heat. Indeed, any body carried above about 700 K (Kelvin) emits electromagnetic radiation in the visible, it is then called "incandescent". At the lowest temperatures the color is red / orange (cigarette end for example), then, the higher the temperature and the whiter the color emitted, to then tend towards blue. Around 6000 K for example, the color approaches sun's color. The white light emitted remains acceptable for temperatures between 3000 K (warm white) and 6500 K (cold white). The temperatures listed here refer to those of a black body.

The color of artificial light has a direct action on **comfort feeling** of the luminous atmosphere of a space. **However, it does not influence visual** performance. To qualify it, we define the color temperature (expressed in Kelvins (K)). We will generally speak of warm hue (color temperature < 3,000 K) or cold (color temperature > 3,000 K). The warmer a color is visually, the lower its thermal temperature (in degree Kelvin) is. A "warm" color light is composed mainly of red and orange radiation. This is the case for normal filament lamps.

Standard fluorescent tubes generate "cold" light consisting mainly of green, purple and blue radiation. Below, we illustrate the variation of the comfort feeling of the luminous atmosphere of a room according to the color temperature of the fluorescent tubes chosen and this for the same level of illumination.

Fig1 - Illumination of 300 lux warm light

Fig 2- Illumination of 300 lux cold light

Credit: https://energieplus-lesite.be

The filament is made of tungsten in order to withstand high temperatures. Carbon was widely used at the beginning (late nineteenth/early twentieth century) but was replaced by tungsten because of its mechanical properties (easy to stretch and wire) and its low rate of hot evaporation. Tungsten filaments are thus of 3 different shapes: straight, spiral or bi-spiral.

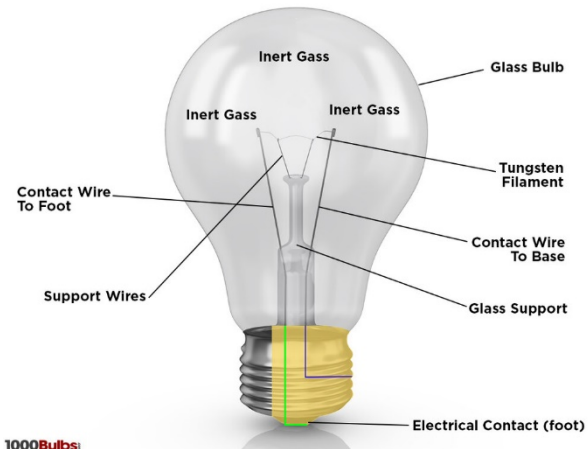


Fig.3 - Incandescent bulb constitution - Source 1000Bulbs.

However, an incandescent body brought into contact with oxygen leads to combustion and therefore volatilization of the body: it is therefore necessary to isolate the filament, which is achieved by a quartz or glass envelope filled with an inert gas (vacuum is also suitable). The most used gas is argon but krypton and xenon are also suitable, especially since they slow down the evaporation of tungsten and therefore improve light efficiency. Their use is limited by their high cost.

These lamps have in common to be cheap but also poorly performing (especially by poor service life and poor energy efficiency). Their strong point comes from their principle of incandescent operation which leads to have a continuous electromagnetic spectrum thus giving them an excellent rendering of colors.

These lamps were widely used in the twentieth century, especially by private individuals, and many models exist or rather have existed: indeed, their low energy efficiency has led the European Union to gradually ban their use since January 1, 2013.

The performance of these lamps is given in the following table and is to be compared in particular to halogen lamps, compact fluorescent lamps and especially LEDs.

Powers (W)	Luminous flux(lm)	Luminous efficiency(lm/W)	Colour T° (K)	Average lifetime (h)
25	220	8,8	2 700	1 000
40	415	10,4		
60	710	11,8		
75	935	12,5		
100	1 300	13		

Table 1: Incandescent light bulbs characteristics

Halogen lamps

The physical principle of halogen lamps is the same as incandescent lamps. A halogen compound is simply added to increase the efficiency of the lamp and the lifetime of the filament: these particles will indeed react with the tungsten filament to redeposit on the latter (unlike incandescence where the tungsten evaporates and blackens the glass) to establish what is called the "halogen cycle".

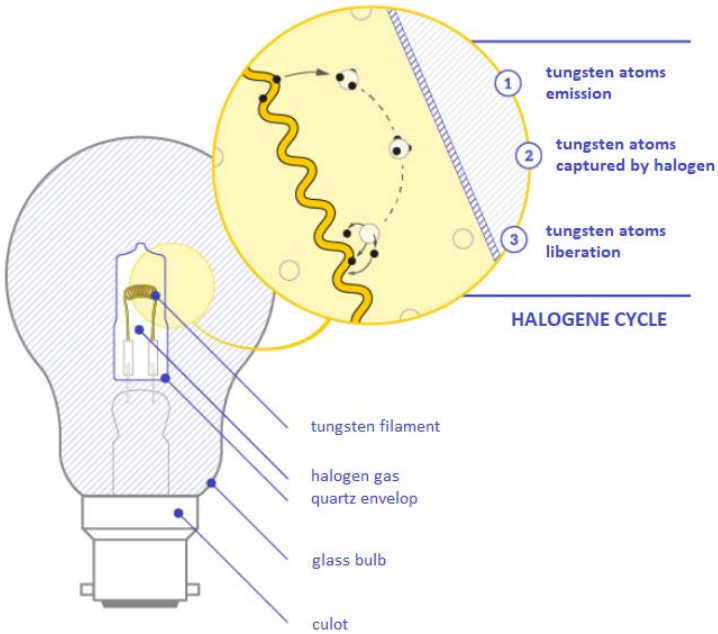


Fig 4 – View of halogen lamp constitution and halogen cycle - source leclairage.fr

Since the envelope is no longer blackened by the evaporation of tungsten, it is possible to decrease the volume and increase the pressure, which decreases the evaporation rate of tungsten and thus increases the light efficiency and service life. In order to withstand high temperatures, quartz is used for the envelope.

VLV lamps (Very Low Voltage, i.e. less than 50V) have a higher efficiency and service life than 230V lamps but require a transformer to pass the current from 230V -> 50V.

Here too, very many models exist or rather have existed: indeed, as for the incandescent lamps above (and even if the performance of halogen lamps is better), their low energy efficiency has led to a small ban on their use since September 1, 2018.

Below the performance of these lamps to be compared in particular to compact fluorescents and especially to LEDs.

Powers (W)	Luminous flux(lm)	Luminous efficiency(lm/W)	Colour T° (K)	Average lifetime (h)
40	490	12	3 000	2 000
60	820	14		
120	2 250	19		
160	3 100	19		
400	9 000	23		
1 000	22 000	22		
2 000	44 000	22		
Halogen lamp ECO version				
40	590	15	2 800	2 000
60	980	16		
120	2 300	19		
160	3 300	21		

Table 2: Halogen lamp characteristics. Basic and ECO version

LUMINESCENT TYPE

Fluorescence

Fluorescent lamps and tubes are the most widely used types of lamps in schools. Many forms exist, with one or two pellets, with or without built-in ballast. From a practical point of view these sources will be presented according to two main families: tubes (two caps) and lamps (one cap).

Figure 5 - Fluorescent tube (left) and compact fluorescent tube (CFL) (right)

Thanks to its good performance in service life and light efficiency, its good color rendering and a reasonable price, fluorescence has been the preferred source for decades in indoor lighting. Its performance is now exceeded by LEDs but it is still very used because it's cheaper. Ionized gas is a mixture of argon and mercury vapor that produces electromagnetic waves in the ultraviolet. Fluorescent powders deposited on the glass walls make it possible to convert these electromagnetic waves into the visible.

Fluorescent sources offer powers that vary from 5W to 120W and are supplied with magnetic or electronic ballast depending on the case. See the summary table of the characteristics of the different lamps.

Tubes (T8 and T5)

Fluorescent tubes have been used since the 1930s/40s on a common basis. The old tubes are tubes called T12 of 38mm diameter but these have disappeared and are only available in "relamping". The tubes still widely used today are the T8 tubes (26mm) and especially the T5 tubes (16mm). Tubes called T2 (diameter 7mm) also exist for small powers (6 to 13W) but are disappearing.

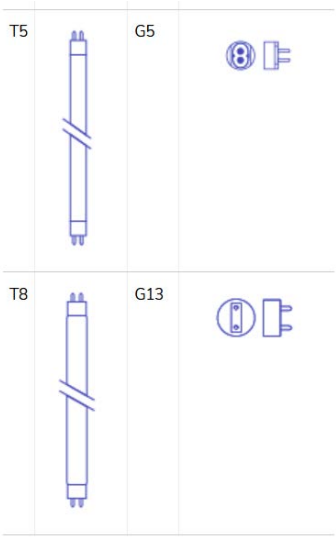
Attention

It is essential to take into account the efficiency of the lamp / ballast factor to be able to make comparisons between the tubes because the ballast according to its type has an impact on energy consumption.

T8 tubes

As a result of the T12 tubes, the T8 tubes arrived and are still in use. They have been designed for operation with a magnetic ballast and are also suitable for electronic ballasts.

T5 tubes



The T5 tubes are of a newer generation and have a design on the one hand finer – thus allowing the design of luminaire more design – and on the other hand taking into account the high temperature inside the luminaires.

These tubes have been designed for electronic ballasts only (no magnetic ballast possible for powers greater than or equal to 14W) and are roughly the size of the T8 tubes.

Summary table

These are below the main characteristics of the T5 and T8 tubes (refer to the manufacturers' data for more precision and completeness, the data varying according to the temperature and the ballasts used):

	Type	Nerve	Puiss. LampeMagn/Elec (W)	Length(mm)	Stream lamp*(lm)	Flux/metre(lm/m)	Lamp+ballast power(W)	Efficacitis (lm/W)
15 W	T8	G13	15	437	1000/1080	2471	16	67
18 W	T8	G13	18	590	1350/1300	2203	19	68
30 W	T8	G13	30	895	2400/2700	3017	31	87
36 W	T8	G13	36	1200	3350/3200	2667	36	88
58 W	T8	G13	58	1500	5200/5000	3333	55	90
4W	T5 mini	G5	4	142	140	1000	6	23
6W	T5 mini	G5	6	217	260	1198	8	32
8W	T5 mini	G5	8	293	470	1787	11	42
13 W	T5 mini	G5	13	520	1000	1923	15	66

Powers (W)	Luminous flux (lm)	Light efficiency (excludingballast) (lm/W)	T°of colour (K)	Useful life (h)	Average lifetime (h)
Ø 26 mm or T8, class 1B, at 25°C					
18	1 350	75	2 7003 0004 0006 500[1]	16,000 with electronic ballast preheating (42,000 for the long-term version)	20,000 with electronic ballast preheating (50,000 for the long-term version)
36	3 350	93			
58	5 200	90			
Ø 26 mm or T8, class 2, at 25°C					
18	1 100	64	2 9004 000	5 000	14 000
36	2 600	83			
58	4 125	83			
Ø 16 mm or T5, class 1B HE, at 35°C					
14	1 250	96	2 7003 0003 5004 0005 0006 500 [1]	19 000 (30,000 for the long-term version)	24 000 (45,000 for the long-term version)
21	1 920	100			
28	2 600	104			
35	3 300	104			
Ø 16 mm or T5, class 1B HO, at 35°C					
24	1 750	89	2 7003 0003 5004 0005 000, 6 500[1]	19 000 (30,000 for the long-term version)	24 000 (45,000 for the long-term version)
39	3 100	92			
49	4 300	99			
54	4 450	93			
80	6 550	88			

Fluorescent lamps

Fluorescent lamps are in fact only "curved" tubes. The need to have small format sources led manufacturers to develop tubes in a scale model, which was achieved by "bending" the tube, bringing the electrodes closer and keeping only one base. These lamps – according to the principle set out at the top of the page: the larger and more homogeneous the volume, the greater the efficiency – have a much lower efficiency than the tubes seen above but are widely used in small luminaires such as portholes, sconces or floor lamps.

In these lamps, two families are quite distinct:

– lamps that can not connect directly to the 230V and therefore require a separate equipment: these lamps are therefore reserved for professional use, they are lamps without integrated ballast that have a very specific base.

– lamps that can connect directly to the 230V because a ballast is integrated into the base of the lamp (which suddenly has a large volume): these lamps are used very widely by the individual and are known by him under the name of "compact fluorescent".

Energy efficiency

Fluorescent lamps have the advantage over tubes of having a small footprint but their energy efficiency is significantly worse.

Lamps without integrated ballast

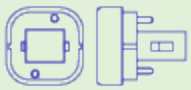
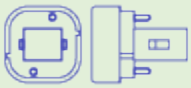
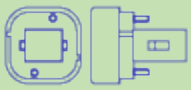
In these lamps, the ballast is separated and the very specific cap makes it possible to distinguish it without doubt any possible from a lamp with integrated ballast.

Magnetic and electronic ballast

Depending on the lamps, magnetic and or electronic ballasts can be used. One rule however: it is necessary to have 4 pins to be able to put an electronic ballast while two pins can be enough for the magnetic ballast.

These lamps can have different shapes and sizes and are available in magnetic and / or electronic version depending on the years of design:

Lamp overview:

	Flux (lm)	Formelampe	Length(mm)	magnetic			electronics		
				Type	Nerve	Cap shape	Type	Nerve	Cap shape
5W	250		83	TC	G23		TC-EL	2G7	
7W	400		113						
9W	600		145						
11 W	900		214						
10 W	600		94	TC-D	G24d 1		TC-DEL	G24q 1	
13 W	900		116						
18 W	1200		128		G24d 2			G24q 2	
26 W	1800		149		G24d 3			G24q 3	

Lamps with integrated ballast CFL

The "compact fluorescent" lamps well known to the individual must be able to be fixed directly on a screw cap (type E27) or bayonet (type B22) and therefore operate directly on the current of the network, in 230V / 50Hz.

As explained in the theory of lamps, the ionization of the gas is carried out on the one hand by generating a large potential difference via the electrodes and on the other hand by limiting the intensity of the current by an electrical component type ballast. This implies the presence of a specific apparatus intermediate between the current and the lamp, and, in the case of the individual, the necessary positioning of this component in the cap.

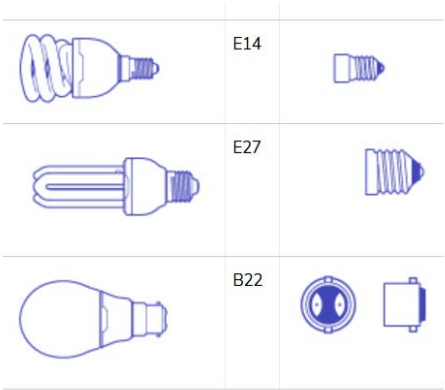


Figure 6 - CFL lamps

This explains why – even if the technique of fluorescence has existed for almost a century – it was not until the development of electronics that this type of lamp appeared much more efficient (light efficiency and service life) for individuals than incandescent or halogen lamps.

These lamps nevertheless have much lower characteristics (always in light efficiency and service life) than compact fluorescent lamps with offset ballast studied above and are therefore very little used in professional lighting.

Powers (W)	Luminous flux (lm)	Light efficiency (excludingballast) (lm/W)	T°of colour (K)	Useful life (h)	Average lifetime (h)
Screw cap lamp (replacement of a filament lamp) with conventional ballast.					
9	350	39	2 700		15 000
13	550	42			
18	850	47			
25	1 200	48			
Screw cap lamp (replacement of a filament lamp) with electronic ballast.					
5	240	48	2 700		20 000
7	400	57			
11	640	58			
15	900	60			
20	1 260	63			
23	1 600	70			
Pin cap lamp (2 or 4).					
5	250	50	2700 3000 3500 4000 6500	6000 to 10000 (electronic ballast).	8,000 to 14,000 (electronic ballast).22,000 for the long-lasting version.
7	400	57			
9	600	67			
11	900	82			
18	1 200	67			
26	1 800	69			
32	2 400	75			
36	2 900	81			
40	3 500	88			
55	4 800	87			

Fluorescent lamps form a vast family that the technical characteristics (light efficiency, service life, CRI, proximal color temperature ...) and the price make particularly interesting. Since the 1980s, electronics have enabled the development of new innovative products (compact fluorescent lamp with integrated ballast) and more efficient products (T5 tubes). This family is losing momentum in favor of the LED.

The very varied products can adapt to many situations according to the needs and the choice is always a compromise between:
– light efficiency
– the cost
– congestion
– professional use (remote ballast) or for private individuals (built-in ballast)
– the need for gradation
– the service life
– IRC
– the temperature of proximal color.

The following is a summary of the main uses and features:

Type of sources	Type of building	Light fixtures	Type of need
Tube T5/T8	Tertiary and professional industrial (see architectural)	Linear or surface type: recessed, ceiling light, suspension, strip, waterproof	High efficiency, large flow, large dimensions
Compact fluorescent lamp with remote ballast	Tertiary and professional architectural	Porthole, downlight, wall lamp, floor lamp	Small dimensions
Compact fluorescent lamp with integrated ballast	Special housing	Suspension, table lamp, desk lamp	Adaptable to 230V/50Hz current

LED

LEDs (Light Emitting Diode) whose principle is known since the beginning of the XX century have experienced a strong development in signage from the 1970s/80s thanks to red LEDs. Professor Nakamura having discovered the possibility of creating blue LEDs in 1991, made it possible to create white LEDs that are at the origin of the current rise of this light source.

The logic of Moore's Law is respected: performance is doubled very regularly and prices fall significantly, which leads to a very strong current evolution of the market.

Their use is changing very rapidly and current performance has surpassed all other white light sources.

The LED (Light Emitting Diode) is an optoelectronic component that, on one hand, allows the electric current to pass only in one direction (definition of the diode) and on the other hand, emits light.

LED has a relatively recent history compared to other lighting sources: it began to develop from an industrial point of view initially in signage from the 1970s and has really spread in general lighting since the years 2000/2010. Here are some pointers:

– 1907: discovery of the "curious phenomenon" by Henry Round

– 1962 : Nick Holonyak realizes an LED emitting in the red

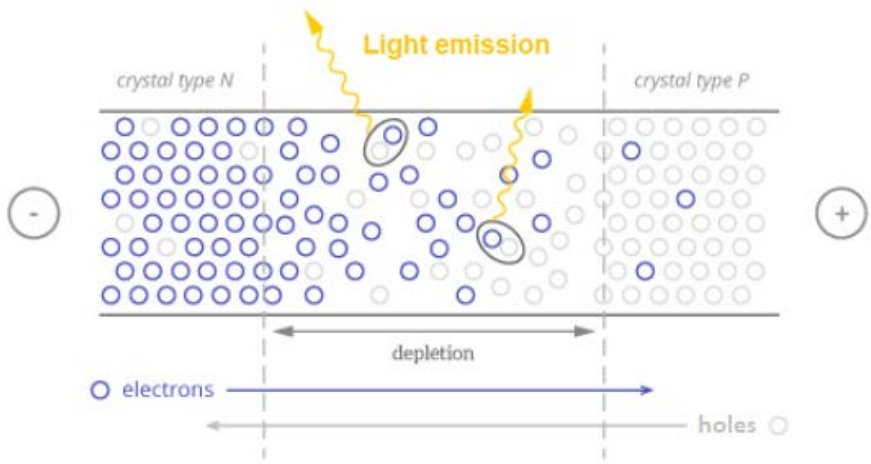
– 1991: Shuji Nakamura develops the blue LED that makes it possible to produce white LEDs

– 2000s: start of the production of power LEDs

– 2013: the efficiency of the LEDs marketed exceeds that of the best fluorescent tubes

Operation

LEDs work according to the principle of luminescence and more precisely electroluminescence, since the light is emitted following the passage of an electric current. The principle is to produce an electron deficit in one area (doped material p) and a surplus in another (doped material n): at the junction between the two materials, the electron "holes" recombine with the electrons and generate a photon.



The light-emitting diode lamp is intended to replace all other existing lamps and are used in all proposals for solutions to reduce the energy consumption of buildings.

In the beginning, these lamps were used in signal lights because they produce almost no heat unlike incandescent lamps and they consume very little energy, making them products of choice for operating lights.

With a very high service life, they have grown and now we find LEDs in all areas and sizes. Their lifespan is counted in tens of thousands of hours. Their old age is characterized by a decline in their yield. It is therefore more common for the electronic components of the LED to fail before the light-emitting diodes themselves.

This type of lamp also shows a high resistance to changes in state on or off without wearing out or damaging itself unlike a usual incandescent bulb. Finally, they allow a full instantaneous light power.

There are, however, some drawbacks to the use of LEDs. Indeed, theprice remains as much higher than traditional lamps but in the long term, the profitability in terms of operating and maintenance costs make it an economic and ecological solution.

Advantages and disadvantages of the types of bulbs

Depending on their characteristics, not all bulbs are intended for the same use. To set up efficient and economical lighting, it is important to consider the characteristics of each equipment for appropriate use.

Here is more precisely a comparative table of the characteristics of all the different types of bulbs and LEDs:

Characteristics	Low-energy (or compact fluorescent) bulb	Incandescent (or filament) bulb	Halogen bulb	Ampoule LED
Lifetime	average (6,000 to 15,000 hours)	short (1,000 hours) up to 1,500 hours if an inert gas (argon, krypton or xenon) is added	short (3,000 hours)	very long (> to 15,000 hours, up to 50,000)
fragility	Yes	Yes	Yes	Not
Energy performance	A or B	E, F or G	B, C or D	A+
	The energy class of a light source is graduated from: A++ (very economical) to G (not very economical).			
ignition	progressive	instantaneous	instantaneous	snapshot (< 1/2 second)
Light output	good (60 to 75 lm/W)	low (9 to 15 lm/W)	medium (20 to 35 lm/W)	excellent (100 lm/W)
Color of light	glare possible, can change colors	warm and natural (close to daylight)	warm (close to that of the sun)	no glare, does not change the colors, many possible colors as seen previously
Resistance to switching cycles (on/off)	weak	-	weak	good
Heating	weak	yes (up to 150°C)	Yes	Not
consumption	average	energy-intensive	energy-intensive	low

	The consumption of LED bulbs is 3-5 times < low-energy bulbs, 8-10 times < incandescent bulbs and 6 times < to halogen bulbs.			
Purchase price	moderate (< 10 €)	low (< 5 €)	moderate (< 10 €)	high (> 10 €)
Possibility of recycling	no (presence of mercury)	Not	Not	Yes
Other features	UV emission	Only 5-8% of the energy consumed is used for lighting	compatible with a dimmer (light too strong to be used directly)	blue tint not recommended for the eyes (a distance of 20 cm for the eyes is essential)
		prohibited from sale since January 1, 2013	**prohibited from sale from September 2018**	

Characteristics by source type

Here is a summary of the characteristics of the lamps used in professional lighting (data taken from the catalogs of the largest European brands):

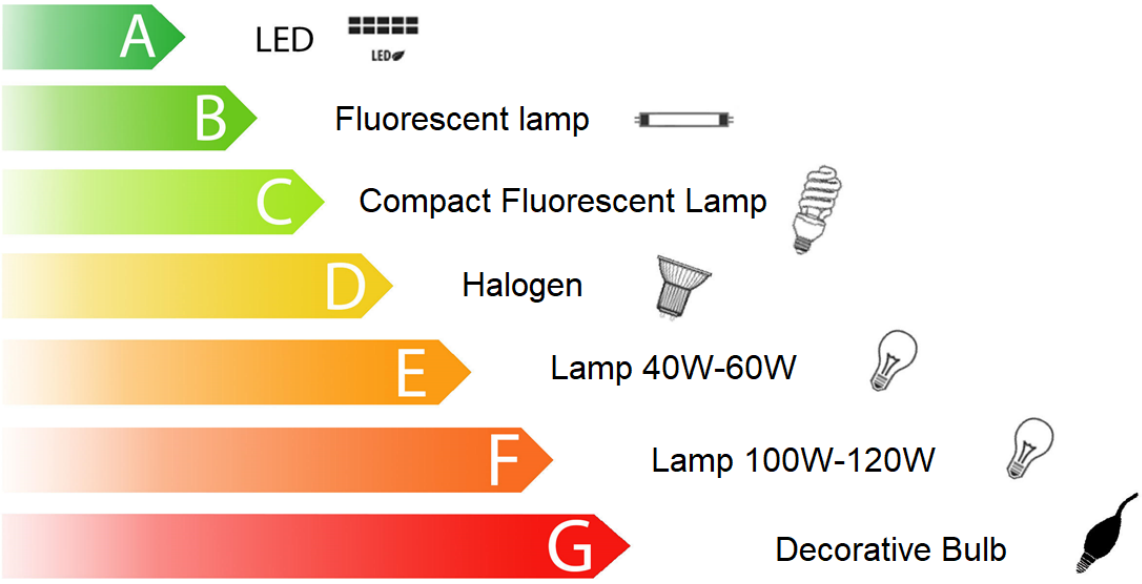
Type of sources	cost	Efficiency (lm/W)	Lifetime (h)	IRC	Puiss. - (W) Mr President,	Appar.	Gradation	specific
incandescence	Excellent market	<15	1,000 to 2,000	100	5 to 100	Not	Phase clipping	–
halogen	Very cheap	10 to 30	2,000 to 5,000	100	5 to 2000	Not	Phase clipping	–
Tube T5/T8	cheap	80 to 115	20 to 35,000	50 to 100	14 to 120	Yes	Electronics,decreased efficiency	Large footprint
Compact fluorescent with remote ballast	cheap	50 to 90	6 to 10,000	50 to 100	5 to 120	Yes	Electronics following lamp, decrease in efficiency	Large footprint
Compact fluorescent with integrated ballast	cheap	40 to 75	6 to 20,000	50 to 100	5 to 75	Not	Specific lamp	Large footprint
LED	high	150 to 220	50 000	Up to 90	Up to 3	Yes	Electronics,increased efficiency	Watch out for warm-up and glare

Uses by source type: LED's domination

Here is also a summary of the main uses of these lamps (and on the dedicated page a use of the different sources by type of luminaire):

Type of sources	Main features	Type of building	Light fixtures	Type of need
incandescence	Inexpensive, very low efficiency, low service life, excellent IRC	Almost unused now, see standard	Old or very specific luminaires (high temperature)	Specific applications such as very high temperatures
halogen	Inexpensive, low efficiency, low service life, excellent IRC	Very little used, special housing	Architectural suspension	Low cost, low footprint
Tube T5/T8	Cheap, very good efficiency, long service life, good CRI	No longer used		Only relamping on existing installation
Compact fluorescent	Cheap, good efficiency, good service life, good CRI	No longer used		
LED	Expensive, excellent efficiency, very good service life, good CRI, spot lighting (beware of glare and warm-up)	Tertiary, architectural, industrial, housing	Any application except high heat	Very good efficiency, long service life, all dimensions

Energy classification



Sources : leclairage.fr, energieplus-lesite.be.

Resource 3: Lighting audit template

Measurement									Energy Consumption and Costs		
Location	Lamp type	Lamp Power [W]	Lamps per fixture	Power per fixture [W]	Number of room fixtures	Total power [kW]	Operating hours per day	Annual Operating Hours (hrs/yr)	Energy Use (kWh/yr)	Annual Energy Cost (€)	Annual CO_2 Emissions [$kgCO_2/kWh$]
	A	B	C	D	E	F	G	H	I	J	K
	Halogen, T12, T8, T5, CFL, LED etc...	On site measure or use lamps characteristics tables: Resource 1		B X C		D x E/1000		School days per year x G (France academic year: 180 days)	H x F	I x Electricity cost Cf. Resource 5	I x electricity production type CO_2 per kWh Cf. Resource 5
				TOTAL							

Resource 3: Lighting audit template (example)

Measurement									Energy Consumption and Costs		
Location	Lamp type	Lamp Power [W]	Lamps per fixture	Power per fixture [W]	Number of room fixtures	Total power [kW]	Operating hours per day	Annual Operating Hours (hrs/yr)	Energy Use (kWh/yr)	Annual Energy Cost (€)	Annual CO_2 Emissions [kgCO_2/kWh]
	A	B	C	D	E	F	G	H	I	J	K
	Halogen, T12, T8, T5, CFL, LED etc...	On site measure or use lamps characteristics tables: Resource 1		B X C		D x E/1000		School Days per year x G (France academic year: 180 days)	H x F	I x Electricity cost Cf. Resource 5	I x electricity production type kg of CO_2 per kWh Cf. Resource 5
Classroom 011	T8	36	2	72	8	0,576	8	1440	829,44	94,56	82,94
Classroom 011	T5	28	1	28	2	0,056	8	1440	80,64	9,19	8,06
Classroom 011	Halogen	40	1	40	1	0,04	8	1440	57,6	6,57	5,76
				TOTAL					967,68 kWh	110,32 €	96,77 kgCO_2/kWh

Resource 4: Savings calculation template

Measurement									Energy Consumption and Costs		
	Lamp type	Lamp Power [W]	Lamps per fixture	Power per fixture [W]	Number of room fixtures	Total power [kW]	Operating hours per day	Annual Operating Hours (hrs/yr)	Energy Use (kWh/yr)	Annual Energy Cost (€)	Annual CO_2 Emissions [$kgCO_2/kWh$]
	A	B	C	D	E	F	G	H	I	J	K
	Halogen, T12, T8, T5, CFL, LED etc...	**On site measure or use lamps characteristics tables: Resource 1**		**B X C**		**D x E/1000**		**School days per year x G (France academic year: 180 days)**	**H x F**	**I x Electricity cost** Cf. Resource 5	**I x electricity production type CO_2 per kWh** Cf. Resource 5
Existing Lamp Model											
New Lamp Model											
				SAVINGS = existing lamp item – new lamp item							
				% of savings = savings/existing lamp item							

Resource 4 Bis: Savings calculation template

Measurement									Energy Consumption and Costs		
	Lamp type	Lamp Power [W]	Lamps per fixture	Power per fixture [W]	Number of room fixtures	Total power [kW]	Operating hours per day	Annual Operating Hours (hrs/yr)	Energy Use (kWh/yr)	Annual Energy Cost (€)	Annual CO_2 Emissions [$kgCO_2/kWh$]
	A	B	C	D	E	F	G	H	I	J	K
	Halogen, T12, T8, T5, CFL, LED etc...	On site measure or use lamps characteristics tables: Resource 1		B X C		D x E/1000		School days per year x G (France academic year: 180 days)	H x F	I x Electricity cost Cf. Resource 5	I x electricity production type CO_2 per kWh Cf. Resource 5
Existing Lamp Model	T8	36	2	72	8	0,576	8	1440	829,44	94,56	82,94
New Lamp Model	T8 LED	20	2	40	8	0,320	8	1440	460,80	52,53	46,08
				ANNUAL SAVINGS = existing lamp item – new lamp item					368,64 kWh	42,03 €	36.86 $kgCO_2/kWh$
				% of savings = (savings/existing lamp item) x 100					44.4 %		

Resource 5: Electricity costs and CO2 emissions values (Source Eurostat)

Electricity prices for household consumers (All taxes and levies included)

Country	Price per kWh [€/kWh]
Denmark	0.282 €/kWh
Finland	0.177 €/kWh
France	0.196 €/kWh
Greece	0.164 €/kWh
Spain	0.23 €/kWh
Turkey	0.082 €/kWh

Electricity prices for non-household consumers (All taxes and levies included)

Country	Price per kWh [€/kWh]
Denmark	0.235 €/kWh
Finland	0.094 €/kWh
France	0.114 €/kWh
Greece	0.112 €/kWh
Spain	0.1422 €/kWh
Turkey	0.076 €/kWh

Electricity CO2 emissions per kWh

Energy source	Unit	CO_2 per kWh [$kgCO_2$/kWh]
Electricity (nuclear plant)	1 kWh	0.1 $kgCO_2$/kWh
Electricity (gas-fired plants)	1 kWh	0.43 $kgCO_2$/kWh
Electricity (oil-fired plants)	1 kWh	0.78 $kgCO_2$/kWh
Electricity (coal-fired plants)	1 kWh	0.97 $kgCO_2$/kWh

LESSON: SCIENCE/TECHNOLOGY/MATHEMATIC/ENGINEERING

Building envelope survey

Purpose/ Learning objective

- Develop a planned and structured measurement methodology
- Establish a structured work organization
- Collecting datas

Intersecting objectives

- Building architecture
- Insulating materials
- Comfort

Facilitation

- Most common thermal insulating material (resource 2)
- Example of classroom envelop audit
- Example of building envelop audit

Ideas for follow-up

Thermal envelop analysis is applied to all building constructions including students houses. All closed premises need this analysis to estimate the heating and cooling needs.

Resources required

- Resource 1: Insulating materials
- Resource 2: Insulating material comparison table
- Resource 3: Envelop and energy audit spreadsheet (Excel file)
- Resource 4: Insulations and heat losses explanation

Source/The day of the lesson: Materials & Class prep.

Guide technique d'audit énergétique (Marchio D., Krarti M.)

Implementation

Timing	Instructions step by step
	Preparation before the lesson: - Depending on the size of your establishment, think about the buildings to study according to the size of the buildings and the number of students in groups. - Students will work in groups, provide mixed and balanced groups. - Retrieve the school plans or draw them if they are unavailable (if time allows a simplified plan can be produced by the students). All the geometric data (length, height, surfaces, etc.) collected will be reusable during the audit.
60 min	Activity 1: Discovering insulating material: By using resources 1 to 4 - Calculate the classroom or another premise/area the heating and/or cooling needs according to the wall and roof envelop - Comparing insulating solutions and find the best one according to costs and energy efficiency
120 min	Activity 2: Building envelop audit Go on the field with your students. Group can be formed and different measurement can be ask to each group to gain time - Pick up all geometrical datas - Analyze structural elements (glazing, doors etc…) - Calculate energy loss - Determine energy ratios

RESOURCE 1: INSULATION MATERIALS USED IN BUILDING

Mineral insulators

Glass wool is obtained by melting, centrifuging, and blowing recovered glass until a mattress of tangled wool that traps air is made.

It comes in the form of rolls or panels. It is used for the insulation of attics, partitions, siding and floors.

Advantages:

- very good thermal and acoustic insulation
- permeable to water vapor
- one of the cheapest insulators on the market.

Disadvantages:

- rolls of wool settle over time and can lose, after a few years, half of their thickness, especially in attic insulation
- its thermal performance is greatly reduced by humidity
- glass wool contains breathable fibers that are very irritating for the handyman who has to handle them.

Elle se présente sous forme de rouleaux ou de panneaux. Elle est utilisée pour l'isolation des combles, des cloisons, des bardages et des planchers.

Rock wool is made from basalt rock. Its manufacturing process involves melting and fiberizing rock, resulting in a mattress of tangled wool that traps air.

It comes in the form of rolls or panels and is used for insulation of attics, partitions, siding and floors.

Advantages:

- very good quality of thermal and acoustic insulation (better sound insulation than glass wool)
- permeable to water vapor
- one of the cheapest insulators on the market
- good fire behavior.

Disadvantages:

- rolls of wool settle over time and may lose half of their thickness after a few years, especially in attic insulation
- its thermal performance is greatly reduced by humidity
- rock wool contains breathable fibers that are very irritating for the handyman who has to handle them.

Cellular glass is made from carbon and glass. The foam contains an inert gas in its micro-cells, giving it insulating power.

In the form of panels, cellular glass is used for flat and pitched roofs.

In the form of blocks, they are placed under the masonry and thus prevent thermal bridges.

Advantages:

- very good thermal insulation
- excellent resistance to humidity
- very good mechanical resistance
- completely non-flammable.

Disadvantages:

- not recommended on irregular surfaces (poor adhesion is detrimental to insulation)
- proves to be fragile if the sheet of cellular glass foam is too thin
- not very ecological manufacturing method.

Synthetic insulation

Extruded polystyrene (EPX) is, like expanded polystyrene, made from crude oil, and of a uniform foam.

Better quality than expanded polystyrene, it comes in the form of panels and is mainly used in screed insulation and exterior insulation.

advantages:

- better insulation performance than expanded polystyrene
- more resistant to compression and humidity than expanded polystyrene
- very light material
- high mechanical resistance
- easy to work.

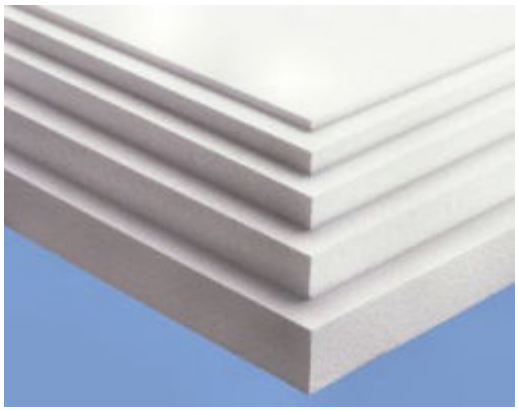
Disadvantages:

- poor sound insulation
- more expensive than expanded polystyrene
- subject to delamination during hot weather
- polluting manufacturing method
- release of toxic gases in the event of fire.

Expanded polystyrene (EPS) is made from crude oil. Its manufacturing process consists in binding together a multitude of balls by compression during a molding which will trap the still dry air.

Expanded polystyrene is mainly used in interior insulation panels and in bulk for lightweight concrete.

Advantages:



- good insulation capacity
- permeability to water vapor
- very light material
- high mechanical resistance
- easy to work
- economic

Disadvantages:

- poor sound insulation
- low longevity
- polluting manufacturing method
- release of toxic gases in the event of fire.

Polyurethane (PU) is a honeycomb structure containing a gas that is even more insulating than air.

In panels, it is used in insulation of screeds and in exterior insulation. It can also be used as a foam for caulking joints or as sleeves to insulate pipes.

Advantages:

- good thermal and acoustic insulation capacity
- high mechanical resistance
- good resistance to humidity
- Interesting cost regarding its performances

Disadvantages:

- low longevity
- possible irritations by contact
- release of toxic gases in the event of fire
- not recyclable.

Natural insulators

Natural insulators are products of plant, animal or mineral origin. Beyond their thermal and / or acoustic performance, they are distinguished by their environmental characteristics.

Expanded cork

We can, among other things, distinguish the expanded cork, an insulation composed of swollen and steamed cork. Very good thermal and sound insulator, it is incompressible and shows very good resistance to humidity and temperature variations.

It is available in slabs, granules for filling or spreading in bulk or mixed with lime for concrete. Insensitive to vermin and rodents, it is practically incombustible and unalterable, and its installation is very simple. Its main drawback is its price, which is much higher than other insulators on the market.

Wood wool

Another natural insulator: **wood wool**, a product made from wood fiber and lignin. Presented in the form of rolls, panels or in bulk, wood wool is placed as a very efficient insulator adapting to all supports. Thermally efficient, permeable to the diffusion of water vapor, healthy and harmless to those who install it, recyclable, this insulation is also distinguished by its long lifespan. Only downsides: the still high cost of this type of material as well as its high density (it is therefore necessary to check that the structure can withstand the load).

Hemp

Finally, we can also mention **hemp**, a very ecological renewable raw material. It turns out to be a particularly effective thermal and sound insulator. It also shows very good resistance to humidity and is a rodent repellent. True bulwark against fire, it is a very light material and very easy to install. This insulation is available in the form of semi-rigid panels or in rolls. However, it is 4 times more expensive than glass wool or rock wool. Another disadvantage: its very rough texture which makes it difficult to cut the rolls and panels.

Ressource 2: Insulating material comparison table

Type	Name	Contioning	Lamba in W/m.K	Thickness	Average Price	Volumic Mass kg/m³	Hygroscopic Capacity	Water Vapor diffusion	Fire Class.	Shift Phase for 20cm th.	Embodied energy kWh p.e/FU	Greenhouse Effect contribution kg CO2 eq/FU
			Insulation values			Technical characteristics					Environnemental Balance	
Synthetic Insulating	EPS expanded polystyrene	Panel	0.032 à 0.038	16 to 19	5,6 €/m² (th. 6 cm)	10 to 30	No	20 to 100 000	B	4 h	81 ☹	10 ☹
	Polystyrene extruded PSX (CO2)	Panel	0.029 à 0.035	15 to 18	10,4 €/m² (th. 10 cm)	25 to 40	No	80 to 200	B	6 h	161 ☹☹	22 ☹
	Polyurethane (PUR)	Panel	0.024 à 0.030	12 to 15	5 €/m² (th. 7 cm)	20 to 40	No	30 to 200	C	6 h	115 ☹☹	16 ☹
Mineral Insulating	Glass wool	Roll	0.032 à 0.042	16 to 21	3 €/m² (th. 10 cm)	10 to 40	No	1	A	4 h	74 ☹	12 ☹
	Rockwool	Roll	0.034 à 0.044	17 to 22	6 €/m² (th. 10 cm)	15 to 200	No	1	A	6 h	168 ☹☹	43 ☹
	Cellular glass	Panel	0.037 à 0.060	18 to 30	10 à 50 €/m² varies with th.	100 to 220	No	infinite	A	7 h	118 ☹☹	25 ☹
	Expanded perlite	Bulk aggregates	0.045 à 0.060	23 to 30	15 € (100L)	70 to 240	No	1 to 5	A	6 h	65 😐	12 ☹
	Expanded vermiculite	Bulk aggregates	0.046 à 0.06	23 to 40	25 € (100L)	60 to 160	No	3 to 4	A	6 h	49 😐	10 ☹
	Mineral foam	Panel	0.045	23	29 €/m² (th. 8 cm)	115	No	3	A	7 h	34 😐	12 ☹
Natural Insulating	Wood	Fibre souple (laine)	0.038	19	11 à 13 €/m² (th. 10 cm)	45 à 55	Low	1 to 2	E	7 h	58 😐	- 4 ☺
		Fibre rigide (panneau haute densité)	0.045	23	26 à 37 €/m² (th.10 cm)	160 to 270	Low	3 to 5	E	15 h	122 ☹	- 20 ☺☺
	Expanded cork	Granules	0.034 à 0.042	17 to 21	122 €/m3	80 to120	Low	1 to 3	E	9 h	41 😐	- 26 ☺☺
		Panel	0.036 à 0.042	18 to 21	25 €/m² (th. 10 cm)	100 to 150	Low	5 to 30	E	13 h	41 😐	- 26 ☺☺
	Hemp	Roll	0.038 à 0.042	19 to 21	11 €/m² (th. 10 cm)	25	Medium	1 to 2	E	7 h	52 😐	- 1 ☺
		Roll	0.038 à 0.042	19 to 21	11 à 14 €/m² (th. 10 cm)	30 to 35	Medium	1 to 2	E	7 h	69 😐	- 1 ☺
		Bulk	0.048	24	13 € (20 kg)	90 to 115	Medium	1 to 2	E	8,5 h	16 ☺	- 49 ☺☺
	Linen wool	Roll	0.037	19	13 €/m² (th. 10 cm)	25	Medium	1 to 2	C à D	6 h	38 😐	1 ☺
		Panel	0.037 à 0.047	18 to 23	13 €/m² (th. 10 cm)	20 to 35	Medium	1 to 2	C à D	6 h	47 😐	1 ☺
	Straw	in bunch	0.045 à 0.050	20 to 25	2 € the bunch	75	Low	1 to 2	B	8 h	5 ☺	- 26 ☺
	Reed	Panel	0.055 à 0.09	28 to 45	18 à 20 €/m² (th. 10 cm)	200	No	1 to 4	B	8 h	17 ☺	- 78 ☺☺
Insulating materials from recycling	Cellulose wadding	Bulk blown under pressure	0.038 à 0.044	19 to 22	14 €/m² (200L)	23 to 45	Medium	1 to 2	B	10 h	22 ☺	- 10 ☺
		Dry projected bulk	0.037 à 0.040	18 to 20	14 €/m² (200L)	23 to 45	Medium	1 to 2	B	10 h	22 ☺	- 10 ☺
		Panel	0.039	20	16 à 20 €/m² (th. 10 cm)	70 to100	Medium	2	E	12 h	71 😐	- 5 ☺
	Recycled textile	Panel	0.039	20	11 €/m² (th. 10 cm)	25	Medium	2 to 3	E	5 h	53 😐	2 ☺
Insulators of animal origin	Sheep's wool	Roll	0.035 à 0.042	17 to 21	10 €/m² (th.10 cm)	10 to 30	High	1 to 2	C	5 h	20 ☺	0 ☺
		Panel	0.035 à 0.040	17 to 20	18 €/m² (th. 10 cm)	30	High	1 to 2	C	5 h	20 ☺	0 ☺
	Feather	Panel	0.050	25	19 €/m² (th. 11 cm)	30	Low	2	F	5 h	6 ☺	5 ☺

The **lambda (λ), coefficient of thermal conductivity (in W/m.K),** provides information on the insulation performance of a material. The lower λ, the more insulating the material. Most insulators have a λ around 0.040 W / m.K. However, insulation manufacturers rarely calculate their λ in the same way. Better to take the Thermal Resistance R to compare.

The **Thermal Resistance R (in m².K/W)** is obtained as :

$$\frac{\text{thickness of a material in meters}}{\lambda \text{ of the material}}$$

The larger R, the more insulating the material.

Recommandations (France) **RT 2005** : **Roof R=5** **Wall R=2,8** **Floor R = 3,7**

Recommandations (France) **RT 2012** : **Roof =7** **Wall R=5** **Floor R = 3,7**

The **Hygroscopic Capacity** is the ability of a material to absorb excess water vapor when the air is too humid and release it when it dries up.

The **Coefficient of resistance to Water Vapor Diffusion (μ [mu])** indicates the ability of a material to diffuse water vapor. The higher μ, the less water vapor can pass through the wall. A small value of μ therefore corresponds to a very breathable wall.

The **fire classification** is governed by Euroclasses. Class A groups together products that contribute little or nothing to the development of fire. On the other hand, in class F, there are materials which have not demonstrated any performance against the spread of fire.

The **Phase shift** of a material plays a big role in the summer thermal comfort of the home. It represents the time between when the temperature is highest outside and when it is highest inside. In regions affected by summer overheating, preference will be given to a roof insulation having a phase shift of at least 10 hours so that the external heat wave of the middle of the day reaches the interior of the house during the night.

The **embodied energy** refers to all the energy consumed for all manufacturing, transport and transformation processes, from the degradation of the raw material to the finished product. It is expressed here in kWh p.e/FU[b].

The **green house effect contribution**, also called carbon balance, is the greenhouse gas production / storage balance of the element. It is expressed here in kg CO2 equivalent per UF[b] of material (kg CO2 eq/FU).

[b] Functional unit: 1 UF = 1 m² of insulation which provides thermal resistance of 5 m².K / W

Update May 17, 2011

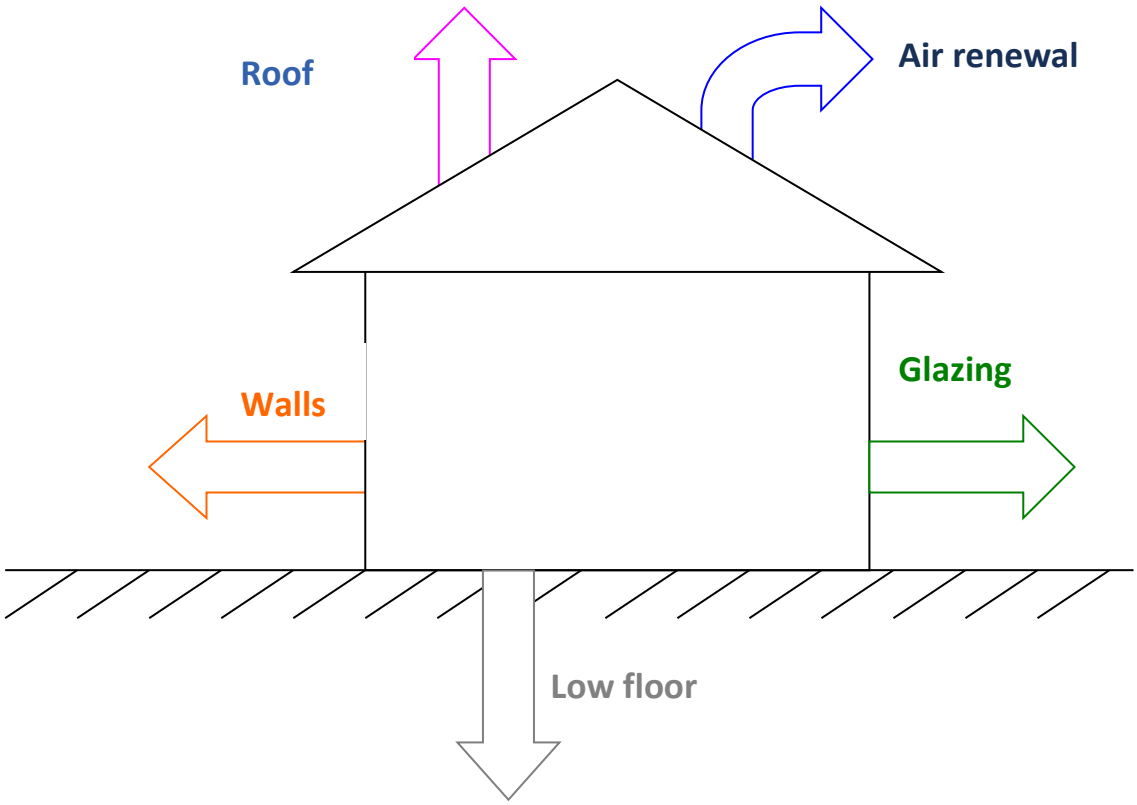
Data taken from La Maison Ecologique n ° 49; Natural Habitat HS n ° 10; The Ecological Thermal Insulation by JP Oliva and S Courgey; insulation manufacturers

Resource 4: Insulations and heat losses explanation

1. HEAT LOSSES

Heat losses corresponds to the loss of heat that a building undergoes through its walls and its fluid exchanges with the outside (air renewal).

It is even more significant when the thermal insulation is low and **the temperature difference between the inside and the outside is large.** Estimating losses consists in calculating the power that leaves a room or a building. This will make it possible to size the thermal installation (Ex: Boiler, radiators ...) according to the losses



The loss areas are:

- Surface losses (Through the walls: walls, windows, floor, roof...).
- Linear losses (wall/wall, window/wall connections, etc.).
- Losses by infiltration and air renewal.

The heat inputs are:

- The sun.
- The occupants.
- Lighting, engines...

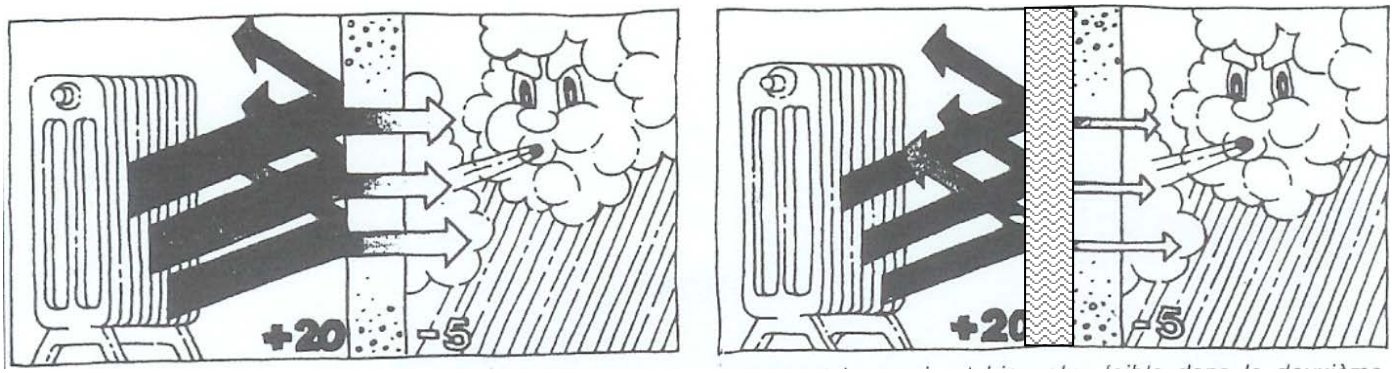
Heat leaks

This phenomenon is caused by the temperature difference between the inside and outside of a home. If there is no temperature difference, there is no loss.
Conversely, the greater the temperature difference, the more heat leakage increases.

SO: HEAT LEAKAGE (effect) proportional to THE **TEMPERATURE DIFFERENCE (cause)**

Solution to bring:

The use of specific materials called insulation makes it possible to oppose to the heat transfer through the walls and therefore to reduce losses, so the heat power to be installed will be less important.



Thus, in the two situations schematized above, although the temperature difference (the cause) is identical, the heat leakage (the effect) symbolized by the arrows crossing the wall is much smaller in the second case. This is due to the addition of insulation that increases the thermal resistance of the wall.

Indeed, the size or sizing of the emitters is a function of the power that is calculated in relation to the heat losses.

COEFFICIENT OF THERMAL CONDUCTIVITY: λ (lambda)

Definition:

The coefficient λ (lambda), is defined as the heat flow through 1 [m²] of a material of thickness 1 m when there is a temperature difference of 1° C between its two faces. The coefficient λ characterizes the ability of a material to conduct heat. The more insulating a material is, the less heat it conducts. Therefore, its λ coefficient will be low. Conversely, if the material is not very insulating, its λ coefficient will be high.

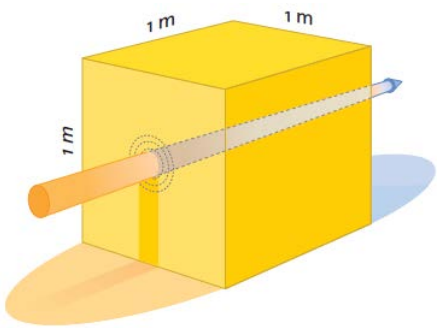


Figure 1 - Lambda representation

This λ coefficient is expressed in watts per meter per degree Celsius [W/m.°C]

Table of values:

Construction product	*Lambda (λ)*	*Insulation product*	*Lambda (λ)*
Honeycomb cinder block	λ = 0.95	**Glass wool**	λ = 0.030 to 0.040
Terracotta monowall brick	λ = 0,120	**Rock wool**	λ = 0.034 to 0.040
Aerated concrete 350kg/m3	λ = 0,090	**Hemp wool**	λ = 0.041 to 0.044
Aerated concrete 400kg/m3	λ = 0,1	**Expanded polystyrene (EPS)**	λ = 0.030 to 0.038
Solid concrete	λ = 1,75	**Extruded polystyrene (PSX)**	λ = 0.028 to 0.035
Solid bricks (baked)	λ = 1,15	**Polyurethane**	λ = 0.021 to 0.028
Raw light wood	λ = 0.14	**Wood fiber**	λ = 0.038 to 0.060
Plasterboard Standard plasterboard	λ = 0.35	**Sheep's wool**	λ = 0.039 to 0.042
Steel	λ = 52	**Linen wool**	λ = 0.037 to 0.041
Aluminium	λ = 230	**Cellulose wadding**	λ = 0.038 to 0.040
Copper	λ = 380	**Cotton wool**	λ = 0.039 to 0.042
Iron, cast iron	λ = 56	**Straw**	λ = 0.045 to 0.050

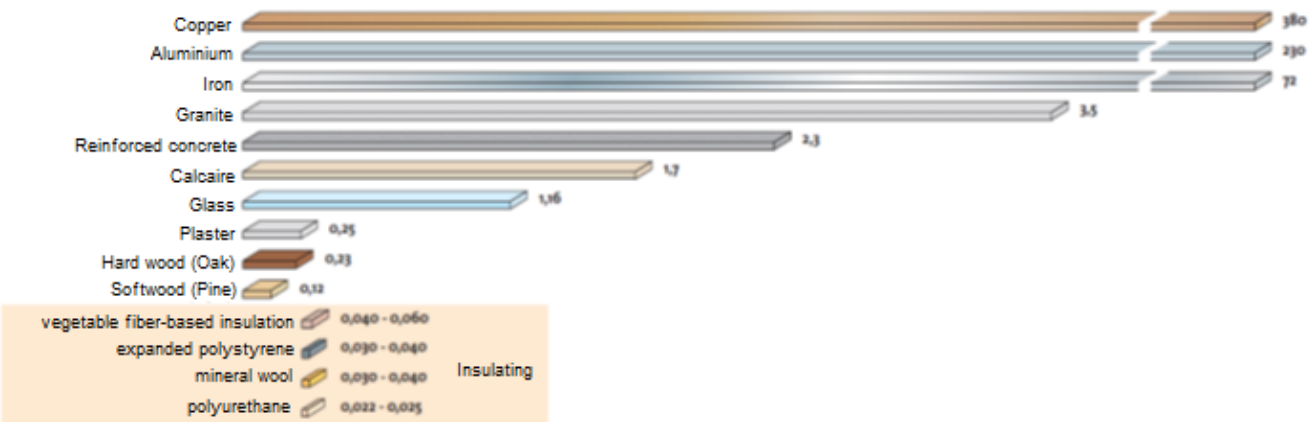


Figure 2 - Illustration of the difference in thermal conductivity of some common materials in [W/m.°C]

THERMAL RESISTANCE: R

Definition:

The thermal resistance of a material expresses its ability to impede the passage of heat flow. The greaterthe thermal resistance of amaterial, the more insulating it is and the less heat it conducts. Resistance R is expressed in square meters degree Celsius per watt [m².°C/W].

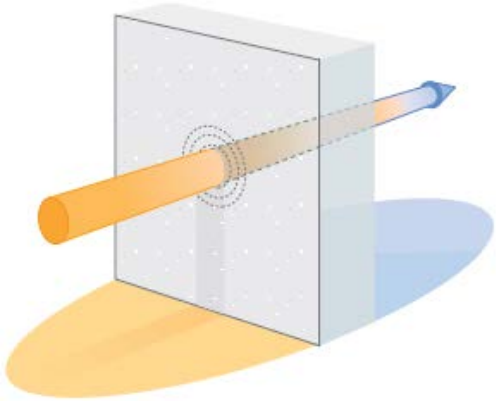


Figure 3 - Representation of thermal resistance

An important advantage of R is that to calculate the thermal resistance of a wall composed of several layers, it is enough to add the resistances of the materials that compose it. Thus, resistance total of a wall **R** composed of 3 materials would give:

R = (R of material 1) + (R of material 2) + (R of material 3) ➡ **$R = R_1 + R_2 + R_3$**

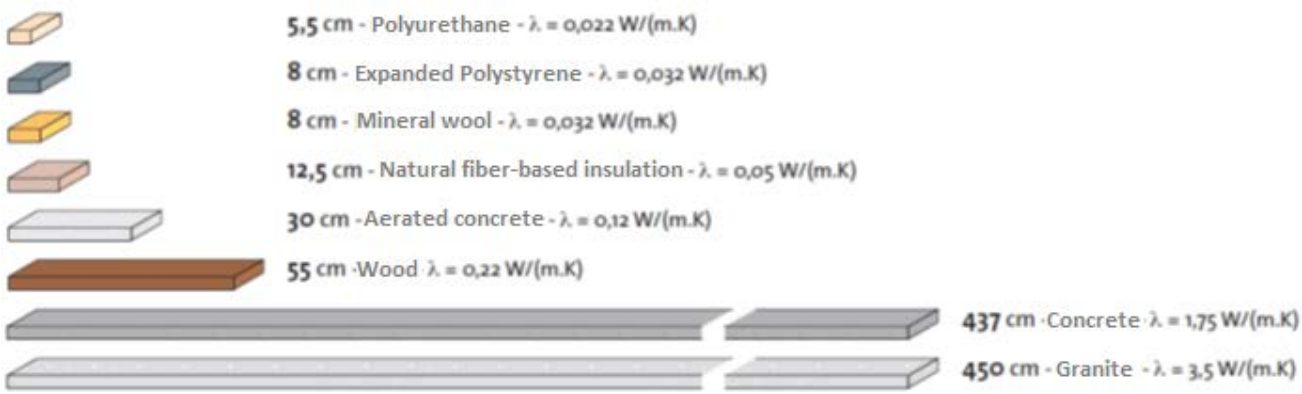


Figure 4 - Equivalent thickness of different materials to obtain a thermal resistance of R = 2.5 m².°C/W

<u>Calculation of thermal</u> resistance:

The thermal resistance of a material is calculated using the following formula:

$$\mathbf{R} = \frac{\mathbf{e}}{\boldsymbol{\lambda}}$$

R: Thermal resistance in [m².°C/W]
e: Material thickness in meters [m]
λ: Coefficient of thermal conductivity [W/m.°C]

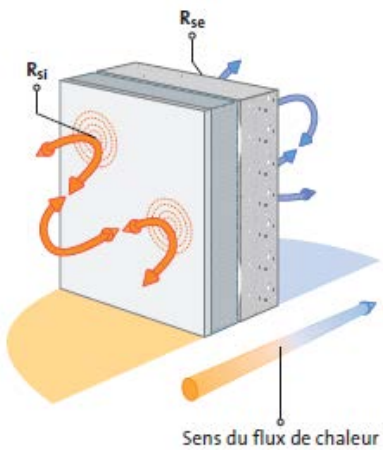
The resistance of a wall of several layers is calculated as follows:

$$\mathbf{R = \sum R = R_1 + R_2 + R_3 + Rn = \frac{e_1}{\lambda_1} + \frac{e_2}{\lambda_2} + \frac{e_3}{\lambda_3} + \frac{e_n}{\lambda_n}}$$

Inside and outside air film: Rsi and Rse

The surface resistance of a wall characterizes the part of the heat exchanges that occurs on the surface of the walls by convection and radiation. It depends on the direction of heat flow and the orientation of the wall.

Rsi (Inside air film) for exchanges on the inner wall surface and **Rse** (Outside air film) for exchanges on the outer wall surface. It is expressed in [m². °C/W].

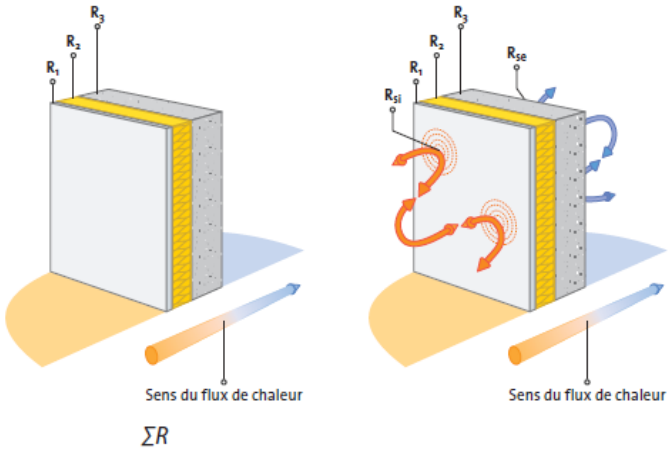


Walls	Rsi	Rse	ΣRs
Horizontal (e.g flat ceiling)	**0.13**	**0.04**	**0.17**
Vertical (e.g a wall) Direction of heat transfer upward (winter)	**0.10**	**0.04**	**0.14**
Horizontal (e.g a wall) Direction of heat transfer downward (summer)	**0.17**	**0.04**	**0.21**

Glazing	Rsi	Rse	ΣRs
Vertical	**0.13**	**0.04**	**0.17**
Horizontal	**0.10**	**0.04**	**0.14**

TOTAL THERMAL RESISTANCE OF A WALL: Rt

The total thermal resistance of a homogeneous wall characterizes the sum of heat transfers carried out by conduction within the materials and superficial heat exchanges made by convection and radiation (Rsi and Rse). It is calculated by adding the thermal resistances of the constituents of the wall and the inside and outside air films and is expressed in [m².°C/W].

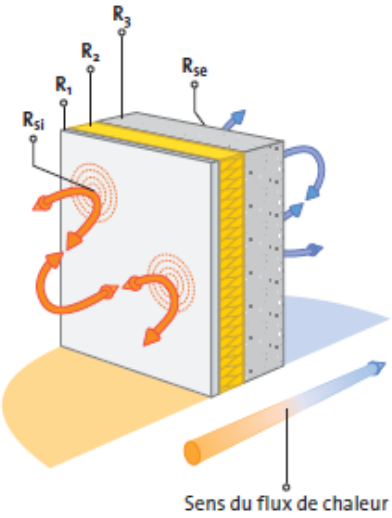


$$Rt = Rsi + \sum R + Rse = Rsi + R_1 + R_2 + R_3 + Rse$$

Rt: Total thermal resistance in [m².°C/W]
Rsi : Inside air film in [m².°C/W]
Rse: Outside air film in [m².°C/W]

WALL THERMAL TRANSMISSION COEFFICIENT: U

Definition:



The coefficient of thermal transfer of a wall, denoted U (formerly k) reflects the amount of heat passing through a wall. The U coefficient is expressed in watts per square meter per degree Celsius [W/m². °C]. It is used to characterize the heat losses of a wall composed of a single material or several materials. Thus, the greater the insulation of a wall, the lower its U coefficient, and the less loss it has to the outside.

Calculation:

The thermal resistance of a single wall is calculated using the following formula:

$$\mathbf{U} = \frac{\mathbf{1}}{\mathbf{Rsi + R + Rse}} = \frac{\mathbf{1}}{\mathbf{Rsi} + \left(\frac{\mathbf{e}}{\boldsymbol{\lambda}}\right) + \mathbf{Rse}}$$

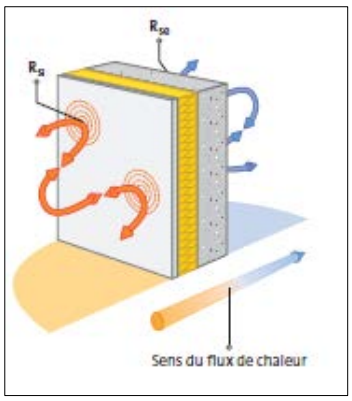
U: Thermal transmitting coefficient [W/m².°C]
R: Thermal resistance in [m².°C/W]
e: Material thickness in meters [m]
λ: Coefficient of thermal conductivity [W/m.°C]
Rsi: Inside air film in [m².°C/W]
Rse: Outside air film in [m².°C/W]

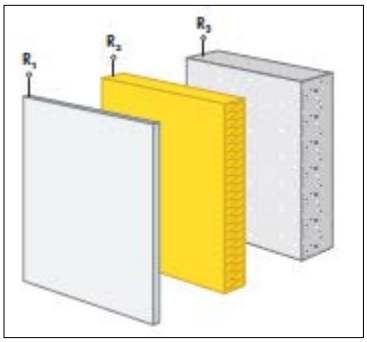
The thermal resistance of a wall composed of 3 materials would be calculated as follows:

$$\mathbf{U} = \frac{\mathbf{1}}{\mathbf{Rsi} + \Sigma\mathbf{R} + \mathbf{Rse}} = \frac{\mathbf{1}}{\mathbf{Rsi} + \mathbf{R_1} + \mathbf{R_2} + \mathbf{R_3} + \mathbf{Rse}}$$

<u>Pictorial representation</u>

$$\mathbf{U} = \frac{\mathbf{1}}{(\mathbf{Rsi + Rse +}\ \ \mathbf{R_1 + R_2 + R_3})}$$





HEAT FLUX: ϕ or ϕ (phi)

The heat flux ϕ (phi) is the amount of energy or heat passing through a wall when there is a temperature difference between its 2 faces. It is expressed in Watt.

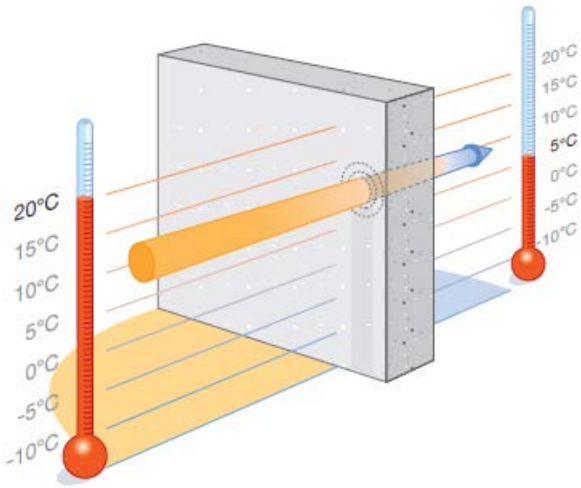


Figure 5 - Heat flow or heat leakage

Calculation:

The heat flux of a wall is calculated using the following formula:

$$\phi = U \times S \times (t^\circ ins - t^\circ out) = \frac{1}{Rsi + \Sigma R + Rse} \times S \times (t^\circ ins - t^\circ out)$$

ϕ: Heat flow in Watt [W]
U: Thermal transmitting coefficient [W/m².°C]
S: Wall area in [m²]
t° ins: Inside room temperature [°C]
t° out: Exterior temperature [°C]
Rsi : Inside air film in [m².°C/W]
Rse: Outside air film in [m².°C/W]

AIR RENEWAL

Ventilation in a room allows the renewal of polluted indoor air (or stale air) by new air.
This air renewal is mandatory because it allows:

- Improve the health and well-being of occupants
- The durability of the building (mold, humidity)
- Safety in the face of combustion appliances

This air renewal depends on:

- The number of people present in the premises
- The activity carried out by the occupants
- The type of room (Classroom, living room, office, gymnasium...)

This fresh air is at the outside temperature, so it is cold.

Temperature difference between inside and outside in [°C]

Basic losses by ventilation in [W]

$$AR = 0.34 \times QvV \times (\theta i - \theta e)$$

Heat volume of air in [Wh/m³.°C]

Ventilation flow [m³/h]

Total losses = Losses by the walls + losses by air renewal + leaks

LESSON: SCIENCE

Occupants perception survey

Purpose/ Learning objective

- Set up a numerical survey (ex: Google form)
- Collecting data and making analysis

Intersecting objectives

- Temperature, humidity, ventilation
- Comfort
- Public space regulation

Facilitation

- Occupants survey questionnaire model (resource 1)

Ideas for follow-up

Develop other specifics questionnaires for special purposes

While visiting classes to present the survey, some of the students of the group can conduct a quick audit of the room (temperature, luminosity) at the same time

From the analysis:

- communicate the results to all stakeholders

- establish an enhancement strategy

Resources required

- Resource 1: Occupants survey questionnaire

Source/The day of the lesson: Materials & Class prep.

https://thehtrc.com/

Implementation

Timing	Instructions step by step
	Preparation before the lesson: - Discuss with the students about the relevant questions that the questionnaire should contain. - Results of the survey may guide energy audit and enhancement recommendations. - This survey will need interactions with other students/teachers during their class. Some rules will have to be reviewed to avoid any disturbances. Inform the teacher before, ask for 5 to 10 min to present and fill the survey.
60 min	With the questionnaire - Create group of students. Ideally, they will be accompanied by an adult. - Visit different class to present the questionnaire and the project purposes The other solution would be to create an online questionnaire form to gain time in the treatment of the data. It will be promoted through online network of the high school - School website - Internal messaging - Social networks etc…
60 min	Analyze with the students all the results of the survey to establish energy audit and enhancement recommendations.

ECOSMART SCHOOLS OCCUPANT'S SURVEY

This survey will help us to understand the occupant's feelings and guide us directly to some improvement measure that could enhance the situation. Il will give us a good view of the situation and it will help us to measure the improvements from year to year.

Part 1: Environment and social knowledge and climate change

Part 2: Building energy, water, waste, and comfort analysis

Part 3: Behavior analysis (related to part 2)

Name:

Gender: Male Female

Age: □ 15-20 □ +20

Status: □ Student □ Teacher □ Administrative □ Staff

Part 1: Environment and social knowledge and climate change

Q1: Are you aware of the concept of climate change and global warming?

□ Yes □ No

Q2: How would you rate your knowledge about climate change and all concepts related to it?

□ Poor: I do not know what this is about

□ Medium: I have heard some things about it

□ Good: I have a good understanding of the concept

□ Excellent: I am fully aware about the principles and what is at stake

Q3: Do you think that the heating/cooling and energy consumption of the school have an impact on the environment?

□ Yes □ No

Q4: Are you aware of the concept of the carbon footprint?

□ Yes □ No

Q5: Are you aware of environmental issues related to air pollution, food safety, and habitat destruction?

□ Poor: I do not know what this is about

□ Medium: I have heard some things about it

□ Good: I have a good understanding of the concept

□ Excellent: I am fully aware about the principles and what is at stake

Q6: Do you care about environmental problems caused by climate change?

□ Poor: I do not know what this is about

□ Medium: I have heard some things about it

□ Good: I have a good understanding of the concept

□ Excellent: I am fully aware about the principles and what is at stake

Q7: Doo you believe that toxic emissions from anthropogenic waste (i.e., motor vehicles, factories, etc.) can cause a negative environmental impact?

□ Strongly agree □ Agree □ Disagree □ I don't know what this is about

Q8: Do you think human lives are critically dependent on the supply of the earth's natural resources?

□ Strongly agree □ Agree □ Disagree □ I don't know what this is about

Q9: Do you think that the practice of environmentally friendly behavior can solve many environmental problems in life?

□ Strongly agree □ Agree □ Disagree □ I don't know what this is about

Q10: Would you be interested to learn environmental knowledge (i.e., interactions between people and the environment), to enhance your understanding of the natural world?

□ Very interested □ Fairly interested □ Somewhat interested □ Not at all interested

Q11: Which actions do you take in your Daily routine/life to reduce the threat of global warming? (You may choose more than one)

□ Recycling □ Composting □ Reducing energy consumption

□ Planting a tree □ Reducing food waste

Part 2: Building energy, water, waste and comfort analysis

According to the location in the school map (Divide the school map into several areas. Occupants will have to answer the questions regarding this precise area where they stay the most. A picture of the school map will be inserted right here)

For which area (A-B-C-D-E-F etc…) are you going to answer? _____

Floor:_____

Classroom: _____

Q12: What is your feeling regarding the room temperature?

□ Too hot □ Good □ Too cold

Q13: What is your feeling regarding the room ventilation?

□ Draughty □ Good □ Dry □ Non-existent

Q14: What is your feeling regarding the room lighting?

□ Too dark □ Good □ Too bright

Q15: Do you regularly experience any of the following feelings when using this room? You can select multiple feelings.

□ Headache □ Eye soreness □ Sleepiness

□ Dry Throat □ Runny Nose □ Runny eyes

□ Respiratory difficulties □ Cough

Q16: Do you regularly experience any of the following problems when using this room? You can select multiple causes.

□ Poor lighting □ Excessive lighting □ Sun glare

□ Excessive hot □ Excessive cold □ Excessive humidity

□ Excessive drought

Q17: Which of the following school items do you believe to have a carbon footprint that could be reduced? Check anything that applies. Take into account the whole life of the product (production-usage-disposal).

□ Light bulbs □ Lunch menu □ Plastic markers □ Clothing

□Plastic pens □ School buses □ Boilers □ Boilers □ All of the above

Q18: Were you aware of the amount of waste we generate every day?

□ Yes □ No □ I don't know

Q19: How would you rate the level of knowledge about waste disposal?

□ Poor: I do not know what this is about

□ Medium: I have heard some things about it

□ Good: I have a good understanding of it

□ Excellent: I am fully aware about it

Q20: How conscious are you about the waste problem?

□ Poor

□ Medium

□ Good

□ Excellent

Q21: How would you rate your recycling skills?

□ Poor: I do not know what this is about

□ Medium: I have heard some things about it

□ Good: I have a good understanding of it

□ Excellent: I am fully aware about it

Q22: Would you transfer your waste management knowledge to your peers, community, etc?

□ Yes □ No □ I don't know

Part 3: Behavior analysis

Q23: How would you rate your energy saving behavior?

□ Poor: I do not make effort to save energy

□ Medium: I sometimes make effort to save energy

□ Good: I often make effort to save energy

□ Excellent: I always make effort to save energy

Q24: How would you describe your involvement and the following actions?

Switch off lights if you are the last person to leave a room?

□ Very proactive □ Proactive □ Sometimes □ Never

Switch off lights when there is plenty of natural daylight?

□ Very proactive □ Proactive □ Sometimes □ Never

Shut down computers once you have finished using them?

□ Very proactive □ Proactive □ Sometimes □ Never

Turning off power points for items not in use?

□ Very proactive □ Proactive □ Sometimes □ Never

Set your computer to sleep or hibernate if not using it for a short period of time?

□ Very proactive □ Proactive □ Sometimes □ Never

Turn off your computer screen when you have finished using it or when not in use?

□ Very proactive □ Proactive □ Sometimes □ Never

Turn the heating down when it is too hot rather than opening windows?

□ Very proactive □ Proactive □ Sometimes □ Never

Commuting to school via bicycle, public transport or a group of friends (full car)?

□ Very proactive □ Proactive □ Sometimes □ Never

Q25: How would you rate your satisfaction level with the high school well-being?

□Very satisfied □Satisfied □Neither satisfied nor dissatisfied

□Dissatisfied □Very dissatisfied

Q26: Which climate-friendly actions do you take at school to reduce the threat of global warming? (you may choose more than one)

□ litterless lunches □ create an eco-group □ eliminating bottled water

□ becoming paper free □ making sustainable transportation decisions

□ use non-throw away plates, cups, utensils and napkins □ Mostly rely on natural light

□ Planning and leading climate action projects, in class or as part of a club

Q27: If you spot something in your school that is not eco-friendly but could easily be, do you speakup and propose solutions?

□ Always □ Sometimes □ Never

Q28: How confident are you that you could use less energy than you do now? (10=Very confident)

□01 □ 02 □ 03 □ 04 □ 05 □ 06 □ 07 □ 08 □ 09 □ 10

LESSON: SCIENCE/TECHNOLOGY/MATHEMATIC/ENGINEERING

Energy audit (hvac, electricity, water…)

Purpose/ Learning objective

- Discover auditing techniques
- Identify energy production and distribution in buildings
- Process the data and group them in an understandable way

Intersecting objectives

- Energy production and distribution
- Technical equipment's

Facilitation

- Ask for maintenance or administration staff:

- Access to the meters and technical equipment premises

- Ask for the possibility of being accompanied by a maintenance staff member

- Blueprint of the building

Ideas for follow-up

- The results of the surveys will be compared from year to year to visualize the evolution of the feelings of the occupants
- Data processing skills and enhancement strategy can be reused in many fields

Resources required

All resources listed below will be available in IO3 folder

- Resource 1: Energy audit guide
- Resource 2: Energy audit tables
- Resource 3: Meters and devices to measure energy consumption

Source/The day of the lesson: Materials & Class prep.

- Guide technique d'audit énergétique (Marchio D., Krarti M.)
- https://thehtrc.com/

Implementation

Timing	Instructions step by step
	Preparation before the lesson: • Students should have worked on the previous modules to be aware of all the problematics and be able to analyze and calculate the energy use, carbon emission and all the consumptions • Students will work in groups • Organize access to technical premises with the maintenance staff • According to the facilities, check if security equipment such as helmet or security shoes are suitable • Build a walk-through audit routine to optimize space and time • Ideally, group of students should be accompanied by an adult.
60 min	Activity: Energy audit - Each team walk through the school to measure and pick up the data (Meter, on field measurement, visual analysis) - It should be performed each month to have a clear view of the energy trends - All the data are logged into tables and charts in the IO3 audit worksheet - An analysis between the simulation/theoretical model and the measure on site will be made