RoBO cientists

Erasmus+

The Smart Light project

Project description and guidelines for teachers

Contents

General approach/considerations

RoboScientists aims at engaging secondary school students in robotic artefact construction through interdisciplinary in nature projects. The set of the projects (that are going to be carried out) offer students opportunities to explore different aspects of the field of Science, Technology, Engineering Arts and Maths. Crafting/ handcrafting is a pivotal point in all the projects. Through the crafting process (highly interwoven in the robotic artefact construction) it is likely that the students will explore a number of engineering and design concepts, confront challenges and consider multiple solutions in order to achieve the results that they want.

About the Smart Light project

This project revolves around the creation of a light that is activated when some kind of movement/ motion is detected. The following images are indicative since their main goal is to graphically illustrate the concept of the project. In details, a sensor (PIR sensor) (1a) that is able to detect motion of warm bodies (humans or animals) in a specific range, is implemented. When the sensor detects presence, the corresponding light turns on (1b, 1c). The project is related to emerging issues in regards to the environment and consequently brings up issues related to environmental friendly solutions innovation and environment as well as environmental policies, citizen engagement and smart cities. As cities grow, the challenges they pose—environmental, economic, and social—expand as well. But cities are hubs of diversity and innovation, thus they can also become the source of solutions.

When developing the designing and setting up the project, it is important to have in mind the presentations provided and discussions that took place during the Training sessions. It is recommended to the educators that for a project to be delivered it is important to: employ the makeology approach, work in teams, encourage experimentation, involves crafting and coding, apply the Engineering design process is employed, encourage sharing, employ the STEAM approach, design and develop robotics models and artefacts, use various tool, equipment and materials, involve students as makers.
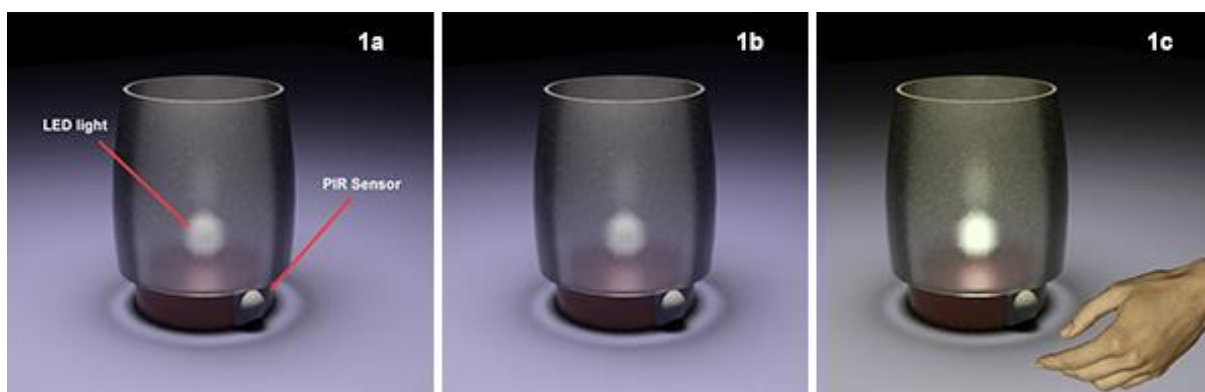
PART A: Pedagogical considerations

In this section, three categories of skills are presented and explained. The first category includes the 21st century and transversal skills, the second category are the general pedagogical skills and finally, the third category describes the learning objectives to be achieved through various subject matters when the Smart Light project is implemented.

The 1st category: 21st century and transversal skills

The 21st century and transversal skills have been outlined and described in the literature by various researchers *(e.g. Bybee & Fuchs, 2006; Ananiadou & Claro, 2009; Trilling & Fadel, 2009; Mojika, 2010; Rotherham & Willingham, 2010; Griffin & Care, 2015)* and reports from ministries of education, policies and organizations *(UNESCO 2014, 2016).* These are the following: Communication, collaboration, critical thinking, problem solving, knowledge construction, creativity, innovation, self-directed learning, global citizenship and digital literacy. In the section below, definitions, descriptions and characteristics of the main 21st century and transversal skills are given.

Learn how to learn: It is a very important skill to learn how to acquire knowledge and skills on their own and manage to construct their own knowledge and meanings.

Investigation: Investigation can be defined quite simply as a systematic fact finding and reporting process. It is derived from the Latin word vestigere, to "track or trace," and encompasses a patient, step-by step inquiry. Investigation is finding facts; it is akin to research conducted in the academic arena. In addition, it is a multi-disciplined field of study. It encompasses law, the sciences, communications, and a host of other things. Finally, it requires an inquisitive mind coupled with an attention to detail.

Exploration: Exploration-based learning is an active learning approach. Students' abilities are dynamically balanced with difficulty level in the system to provide exhilarating and fulfilling learning experiences. The visually and intellectually compelling storylines within the environment challenge each student to leverage their own curiosity and passion to solve complex problems using data and evidence, to form arguments and reach conclusions. This approach is positioned to deliver high levels of engagement and concentration while reducing stress and boredom for all students. Through these experiences, students build their levels of confidence and creativity, resulting in improved performance and sustained motivation to learn.

Reflection: Reflecting helps you to develop your skills and review their effectiveness, rather than just carry on doing things as you have always done them. It is about questioning, in a positive way, what you do and why you do it and then deciding whether there is a better, or more efficient, way of doing it in the future.

Problem Solving: Problem-solving skills help students determine the source of a problem and find an effective solution. Although problem-solving is often identified as its own separate skill, there are other related skills that contribute to this ability.

Critical Thinking: Critical thinking is not a matter of accumulating information. A person with a good memory and who knows a lot of facts is not necessarily good at critical thinking. A critical thinker is able to deduce consequences from what he knows, and he knows how to make use of information to solve problems, and to seek relevant sources of information to inform himself.

Digital literacy: Digital literacy refers to a particular set of competencies that allow you to function and participate fully in a digital world. Students, nowadays, are generally considered to be digital natives - able to use technology effectively and easily. They must be able to resolve conflicts, source material ethically and interact with the wider world in a responsible manner.

Creativity: Creativity simply means being able to come up with something new. Therefore, creative thinking is the ability to consider something – a conflict between employees, a data set, a group project – in a new way. The term is referring to the act of turning new and imaginative ideas into reality involves two processes: thinking, then producing. Finally, creativity is characterized by the ability to perceive the world in new ways, to find hidden patterns, to make connections between seemingly unrelated phenomena, and to generate solutions.

Innovation: Innovation skills refer to the talent of exploiting new ideas for the purpose of gaining social or economic value. Innovation skills are usually a combination of one's ability to think creatively, problem-solving ability, as well as functional and/or technical abilities. Fairly speaking, innovation skills are basically one's ability to apply a blend of knowledge, skills and attributes in a specific context.

Cooperation/ Collaboration: Cooperation is a division of labour between-group members. It occurs when a task is divided up into individually manageable subparts, which are subsequently constructed into a final outcome. Although this is conceptually different to collaboration, at a fine-grained level, all collaborative tasks have a degree of cooperation (Lai & Viering, 2012).

Communication: Communication is the art of transmitting information, thoughts and attitudes from one person to a different one's. It is the route of meaningful interaction among human beings. We learn basic communication skills by observing other people and modelling our behaviours based on what we see.

Building knowledge: Knowledge building provides an alternative that more directly addresses the need to educate people for a world in which knowledge creation and innovation are pervasive. Knowledge building may be defined as the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts. Knowledge building, thus, goes on throughout a knowledge society and is not limited to education.

The 2nd category: General Pedagogical Skills / Objectives

 The second category of skills are the General pedagogical ones. These are the skills to be developed or in other words the general pedagogical objectives of the Curricula of various subject matters. They are mainly outlined within the Curricula of various subject matters and specifically from subject matters such as Mathematics, Science, Technology, Engineering, Social Sciences, Arts and Linguistics.

General skills

*Information Management Skills***:** Students make various calculations and metrics, make estimates and use graphs, tables, charts, and more optical media, to manage the various information and solve the problems which are presented. Also, students communicate with different ideas, criteria, possible solutions and outcomes. This communication takes place through sketches, graphs and representations on paper and computer, making two-dimensional and three-dimensional models and

prototypes through symbolic and verbal representations. At the same time, they recognize, organize, analyse, compile and evaluate data information and interpret different views and approaches.

Problem Solving Skills: The Design and Technology Study Program is particularly useful for developing problem solving skills. Ploblem solving is closely related to the development of critical, reflective and logical thinking mindset, the development of imagination and creativity, problem determination and analysis, the exploration, construction and control of products and constructions, the evaluation of processes and products.

Project Management Skills: Through cross-thematic activities proposed and implemented through teamwork, pupils can develop skills in targeting, managing time and the available resources, computation, risk-taking and dispute resolution.

Social and Interpersonal Skills: The proposed activities as well as the respective framework offer a rich and authentic communication environment between pupils and teachers, working in groups, respect and cooperation, etc.

Skill Category: Design

Middle School

1. Ask appropriate questions and through ideas of stature propose ideas for various constructions and procedures.

2. They discuss ready-made technology products, referring to their form, function and safety.

3. Analyse the factors that affect a problem, through the collection and utilization of various information.

4. Report and develop problem-solving ideas, taking into account security, ergonomics, aesthetics, economy, applying the design process.

5. Carry out research and evaluate sources and information about a particular product or process.

6. Evaluate products and processes based on criteria that have been set.

7. Apply the stages of the design process.

8. Recognize and use symbols in diagrams, circuits and drawings, in applications on paper and on PC.

High School

1. Investigate and evaluate industrial products and processes based on specifications.

2. Implement a manufacturing process according to the product they are going to manufacture.

3. Draw up an action plan and implement the planning process stages.

4. Evaluate products based on specifications and needs that have been put forward and propose modifications.

5. Report and document modifications and variations made during the design and construction phases and explain the necessity of these differentiations.

Skill Category: Communication

Middle School

1. Describe verbatim and / or design the design process for ideas to be implemented.

2. Use lines, shapes, and simple design methods to present their ideas.

3. Recognize and use symbols that recognize within diagrams, circuits and patterns.

4. Communicate using sketches and 3D drawings and spelling projections.

5. Communicate using recognized symbols.

High School

1. Enhance their designs by adding information through detailed three-dimensional drawings and magnifications.

2. They present ideas and ways of construction through three-dimensional drawings and spelling projections.

Skill Category: Construction

Middle School

1. Collect and categorize materials from simple constructions.

2. Prepare simple constructions with various materials, using different skills and manufacturing methods.

3. Cut, bind and shape materials to use in simple constructions.

4. Mark, cut and assemble with precision various materials.

5. Safely use a range of tools and machines to manufacture products made up of more than one kind of materials.

High School

1. Use manufacturing techniques, materials, tools and machinery in a way that appears to be familiar with manufacturing processes, taking into account safety during manufacture and quality assurance of the final product.

2. Propose and apply alternatives to implement their ideas.

Additionally, exploratory skills are promoted through the Curricula (Programs of Study) of Secondary Education. The exploratory skills are summarized below:

- Writing hypotheses that can be checked.
- Designing and conducting research, determining which variables will change, what will remain stable and what will be measured.
- Selecting appropriate tools, technological equipment and suitable materials for a construction.

- Presenting and interpreting the results using a range of representations and dynamic images, simulations and models.
- Communicating results and explaining structures to classmates and other audiences / users, using appropriate vocabulary.
- Evaluating ready-made technology products and suggesting improvements.
- Presenting a design and explaining the use of the finished product.

The 3rd category: The Learning Objectives

The third category includes the Learning Objectives to be achieved within various subject matters, or in other words across various disciplines. The particular project, the Smart Light, aims to achieve learning objectives from the disciplines/subject matters of Environmental Education & Sustainable Education, Language and Literature, ICT, Physics, Maths and Arts:

- Environmental Education & Sustainable Education (environmental policies, environmental friendly actions and decisions, innovative solutions, citizenship and active engagement)
- Language and Literature (brainstorm, discuss and answer various questions develop reports, present, i.e. how can we protect the environment? How can we become active citizens? What do we mean by active citizenship and engagement?)
- ICT (programming, connecting physical and digital world through the use and synchronization of multiple sensors)
- Physics (movement, sensors, electrical circuit making, understanding what a motor is and how it works, controlling motion)
- Maths (variables, interpreting statistical data/ street mathematics)
- Arts: design a light which is enviromentallly and aesthetically sensitive

The process

The process to be followed from the students is the Engineering Design Process as presented in the following two diagrams.
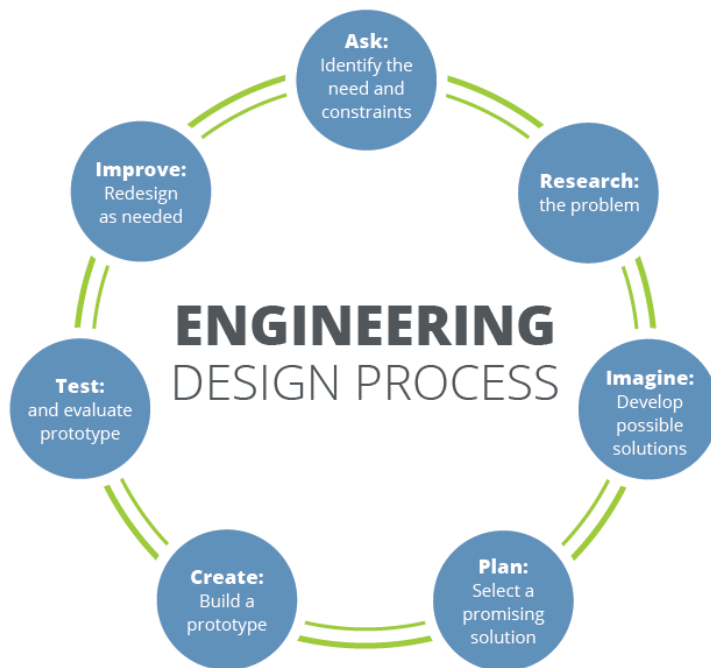
Diagram 1: The Engineering Design Process

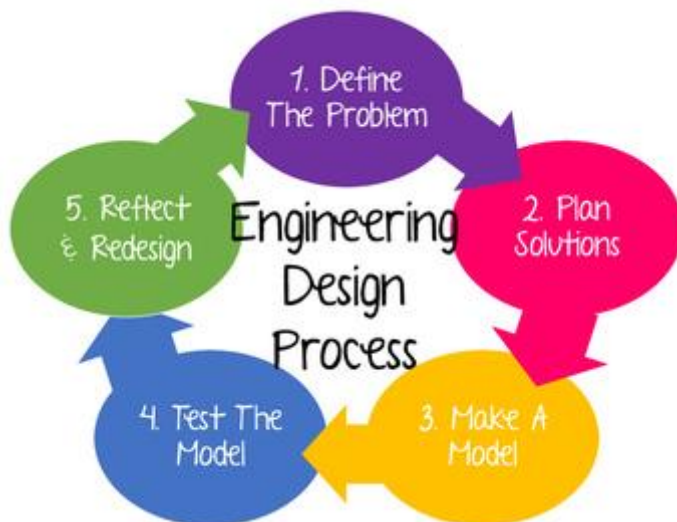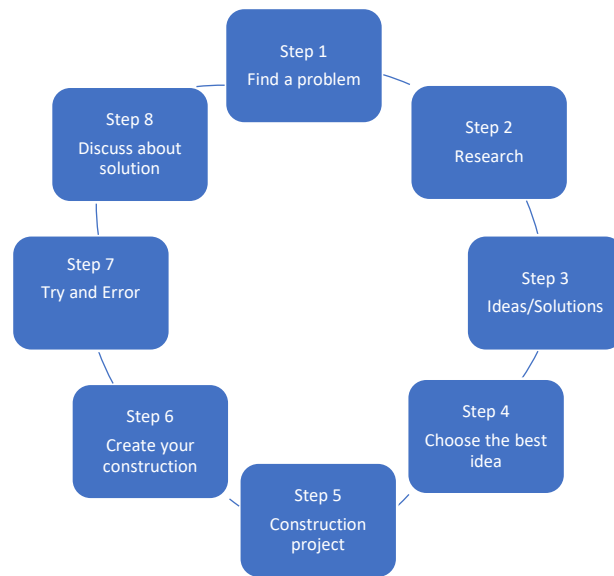Diagram 2: The Engineering Design Process

Diagram3: The Design process according the Design and Technology Curriculum (Cyprus Ministry of Education and Culture)


Step 1
Find a problem

Step 2
Research

Step 3
Ideas/Solutions

Step 4
Choose the best idea

Step 5
Construction project

Step 6
Create your construction

Step 7
Try and Error

Step 8
Discuss about solution

PART B: Practice

Level 1: The smart light that turns on only when movement is detected

Creating the circuit

For the circuit of this activity, students will need – apart from the breadboard and some jumpers - a LED and a 220 ohm resistor, as well as a PIR sensor. The following diagram indicates how the aforementioned components should be connected to the Arduino.
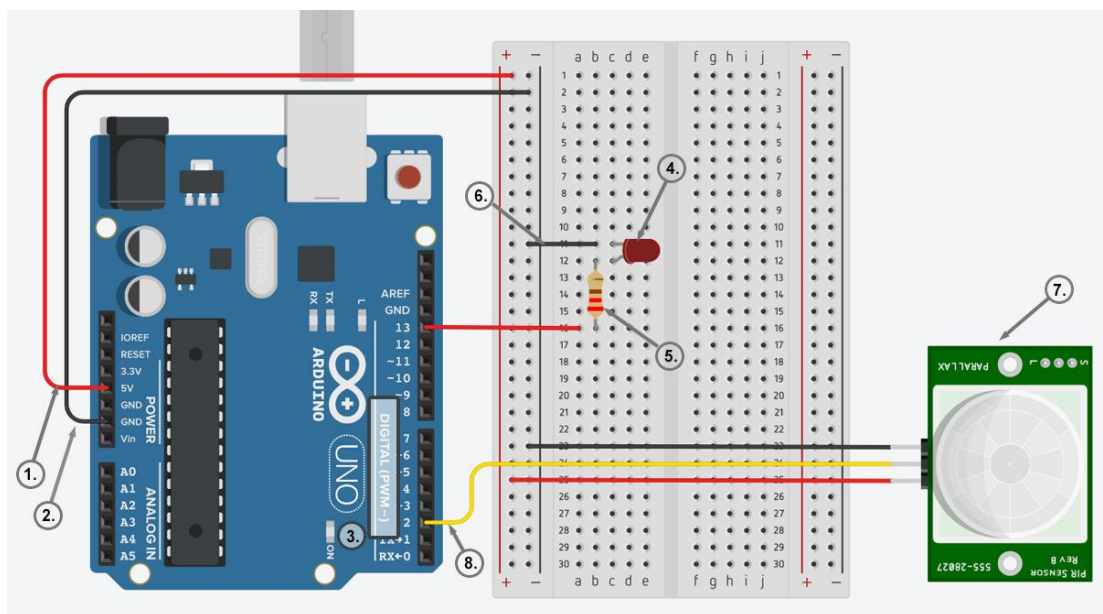
- Use 5V (**1**) and Ground/ GND (**2**) pins to respectively provide 5V power and ground to your breadboard
- Use one of the digital pins (**3**) (pin 13 in the example) to connect the anode of your LED (**4**) through the resistor (**5**)
- Connect the cathode of your LED to ground (**6**) in order to create a closed circuit
- Use, again, one of the digital pins (**3**) (pin 2 in the example) to connect the signal pin (**8**) of your PIR sensor (**7**). Use the remaining two pins to provide 5V power and ground to your sensor.
- Keep in mind that some PIR sensors have the signal pin on the left. Therefore, before connecting the sensor to your breadboard, please check the label on each pin.

Questions that can be raised/discussed:

- Why a resistor is needed? What does the PIR sensor do?
- Why are we using digital instead of analog pins?
- Why the PIR sensor does not need a resistor?

The PIR Sensor and the 'delay' time

Take a moment and check your PIR Sensor. The potentiometer highlighted in yellow box can be used to control the 'ON' delay time for the sensor. If your PIR Sensor does not have this potentiometer (back view) then consider introducing later on in your code the Wait block.

Towards a block-based programming solution

At this level, the students should be encouraged to implement the functionality of the "smart light". The "smart light" is turn on when movement is detected, otherwise is off. The blocks that appear below will be needed: The gold blocks are from the Control palette. The turquoise blocks are from the Arduino palette and achieve the communication with the Arduino board. A script in Snap4Arduino (and in most of the block-based programming environments) is assembled by dragging blocks from a palette into the scripting area in the middle part of the window in Snap4Arduino. Blocks snap together when you drag a block so that its indentation is near the tab of the one above it.

This is a *hat* block that indicates that the script should be carried out when the green flag will be clicked.

This is a *C*-block. The slot inside the *C* shape is a special kind of input slot that accepts a *script* as the input. Any script placed in there will be carried out forever in a circle.

This block sets the selected digital pin (in this case 13) to the logical true value. You can toggle between the true and false values directly in the block. Normally a LED is connected to pin 13.

The if-else block runs its if-input script if (and only if) the expression in its hexagonal input reports true.

If it reports false, the else-input is executed.

The hexagonal block is a predicate/condition, but the value it reports is a Boolean.

Click on the Variables Palette and then here to make a variable

Observing the digital readings from the PIR sensor:

This block reports the value of the digital reading retrieved by the PIR sensor and can run in parallel with the scripts below. It gives you a visual feedback of the movement detection and you can check whether your script works well.

Tip: You can introduce the project by starting with this script and encouraging the students to observe the digital readings retrieved by the PIR sensor.

Solution 1 for Level 1

A continuous loop will turn the LED on as long as the digital reading from the PIR sensor is true; in other words, if movement is detected the digital reading from PIR sensor is set to 1, thereby to true…so the if-part is executed and the led is turn on (led is connected to digital pin 13)

Solution 2 for Level 1

The script follows the same idea as above (solution 1) but it is enriched with the use of a variable. The digital reading from the PIR sensor is stored in a variable called *PIR_status*. Each time the value of the *PIR_status* variable is checked. The Boolean value (true or false) determines whether the light will be turn on.

The scripts above can be also replaced with these ones (without the use of the equality operator). They perform the same as the scripts above.

```
when [flag] clicked
forever
  if < digital reading (2▼) >
    set digital pin (13▼) to < true >
  else
    set digital pin (13▼) to < false >
```

```
when [flag] clicked
set PIR_status ▼ to < false >
forever
  set PIR_status ▼ to < digital reading (2▼) >
  if < PIR_status >
    set digital pin (13▼) to < true >
  else
    set digital pin (13▼) to < false >
```

Questions to raise in the class:
- *Why the forever loop is needed? What will happen if we remove it?*
- *What values does the PIR sensor return when you place your hand in front of it? Does it give the same value when you remove your hand?*
- *If your PIR sensor does not have the potentiometer that controls the delay time, encourage your students to experiment with the use of the wait block.*

```
if < >
  set digital pin (13▼) to < ✓ >
  wait (3) secs
else
  set digital pin (13▼) to < ✗ >
```

Arduino IDE (solution)

```
/*
    Arduino with PIR motion sensor
*/

int led = 13;                  // the pin that the LED is atteched to
int sensor = 2;                // the pin that the sensor is atteched to
int PIR_status = 0;                // variable to store the sensor status (value)

void setup() {
  pinMode(led, OUTPUT);        // initalize LED as an output
  pinMode(sensor, INPUT);      // initialize sensor as an input
  Serial.begin(9600);          // initialize serial
}

void loop()
{
  PIR_status = digitalRead(sensor);    // read sensor value
  if (PIR_status == 1)
  {               // check if the sensor is HIGH
    digitalWrite(led, 1);      // turn LED ON
    Serial.println("Motion detected!");
    delay(100);                     // delay 100 milliseconds
  }
  else
  {
      digitalWrite(led, 0); // turn LED OFF
      Serial.println("Motion stopped!");
      delay(200);               // delay 200 milliseconds

  }
}
```
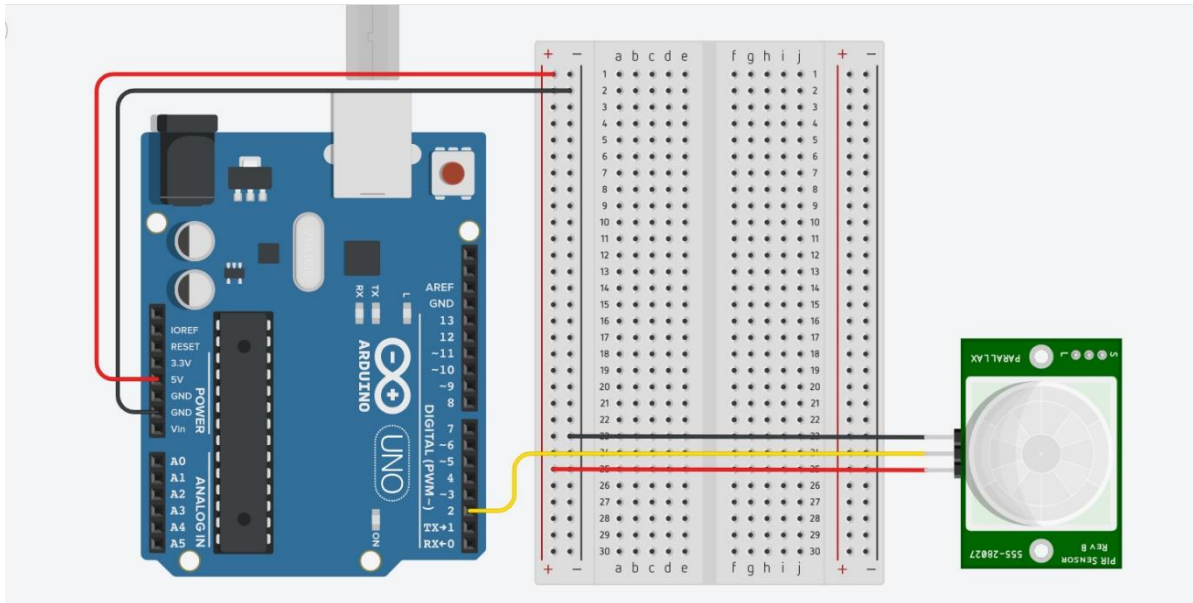
Level 2: The smart light detects movement in the dark

Creating the circuit

Apart from the components used for the aforementioned activity (*The smart light detects movement*)
students will also need a photoresistor and a 10 KΩ resistor. The following diagram indicates how the
components should be connected to the Arduino.

- Use 5V (**1**) and Ground/ GND (**2**) pins to respectively provide 5V power and ground to your breadboard
- Use one of the digital pins (**3**) (pin 13 in the example) to connect the anode of your LED (**4**) through the resistor (**5**)
- Connect the cathode of your LED to ground (**6**) in order to create a closed circuit
- Use, again, one of the digital pins (**3**) (pin 2 in the example) to connect the signal pin (**8**) of your PIR sensor (**7**). Use the remaining two pins to provide 5V power and ground to your sensor.
- Connect one of photoresistor's (**9**) legs to power (5V), and the other to one of the analog pins (**10**) (pin A0 in the example), as well as to ground through the 10KΩ resistor (**5**).

Questions that can be raised/discussed:

- Why resistors are needed?
- Why do we use analog instead of digital pins to connect the photoresistor?
- Why the PIR sensor does not need a resistor?

Towards a block-based programming solution

At this level, the students should be encouraged to implement the functionality of the "smart light". The "smart light" is turn on when movement is detected, otherwise is off. The blocks that appear below will be needed: The gold blocks are from the Control palette. The turquoise blocks are from the Arduino palette and achieve the communication with the Arduino board. A script in Snap4Arduino (and in most of the block-based programming environments) is assembled by dragging blocks from a palette into the scripting area in the middle part of the window in Snap4Arduino. Blocks snap together when you drag a block so that its indentation is near the tab of the one above it.

This is a *hat* block that indicates that the script should be carried out when the green flag will be clicked.

This is a *C*-block. The slot inside the *C* shape is a special kind of input slot that accepts a *script* as the input. Any script placed in there will be carried out forever in a circle.

This block sets the selected digital pin (in this case 13) to the logical true value. You can toggle between the true and false values directly in the block. Normally a LED is connected to pin 13.

The if-else block runs its if-input script if (and only if) the expression in its hexagonal input reports true.

If it reports false, the else-input is executed.

The hexagonal block is a predicate/condition, but the value it reports is a Boolean.

Click on the Variables Palette and then here to make a variable

Observe the digital readings from PIR sensor:

This block reports the value of the digital reading retrieved by the PIR sensor and can run in parallel with the scripts below. It gives you a visual feedback of the movement detection and you can check whether your script works well.

Tip: You can introduce the project by starting with this script and encouraging the students to observe the digital readings retrieved by the PIR sensor.

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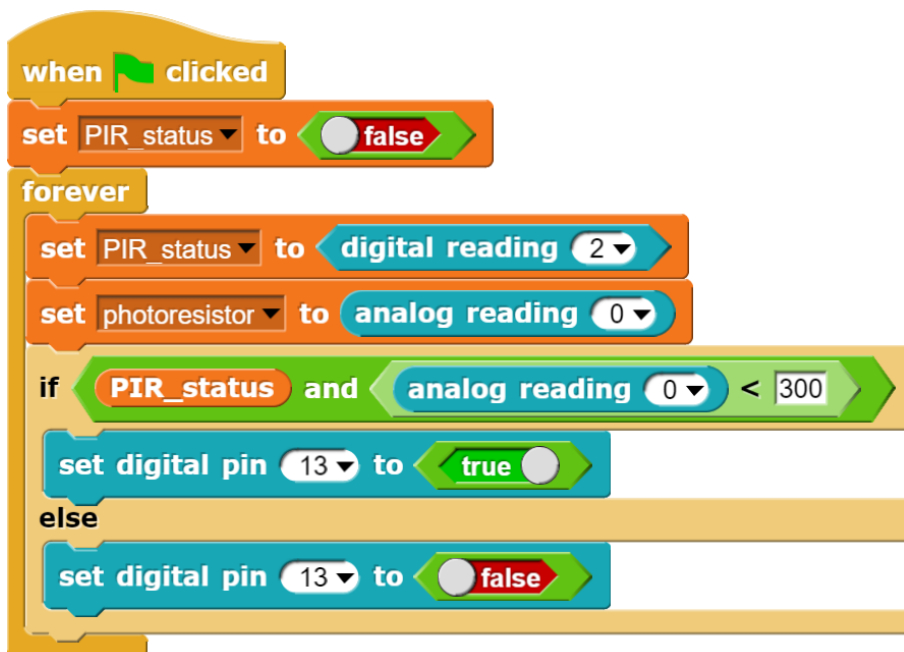
Solution 1:

```
when 🚩 clicked
set PIR_status ▾ to ( false )
forever
    set PIR_status ▾ to < digital reading (2 ▾) >
    set photoresistor ▾ to ( analog reading (0 ▾) )
    if < (PIR_status) = < true > > and < (analog reading (0 ▾)) < 300 >
        set digital pin (13 ▾) to < true >
    else
        set digital pin (13 ▾) to ( false )
```

Solution 2 (without the equality operator):

```
when 🚩 clicked
set PIR_status ▾ to ( false )
forever
    set PIR_status ▾ to < digital reading (2 ▾) >
    set photoresistor ▾ to ( analog reading (0 ▾) )
    if < (PIR_status) and < (analog reading (0 ▾)) < 300 > >
        set digital pin (13 ▾) to < true >
    else
        set digital pin (13 ▾) to ( false )
```

Questions to be discussed in the class:

- *Can you implement a traffic road with multiple smart lights?*
- *Can you think of multiple scenarios into which the smart light functionality can be used?*
- *If your PIR sensor does not have the potentiometer that controls the delay time (see page 12), encourage your students to experiment with the wait block:*

```
when [flag] clicked
set PIR_status to (false)
forever
    set PIR_status to (digital reading (2))
    set photoresistor to (analog reading (0))
    if < (PIR_status = (true)) and (photoresistor) < 300 >
        set digital pin (13) to ✓
        wait (3) secs
    else
        set digital pin (13) to ✗
```

For further experimentation (optional)

An additional experimentation that can take place in the class is the gradual turning on of the light. For achieving this, the PWM (~) pins should be used.
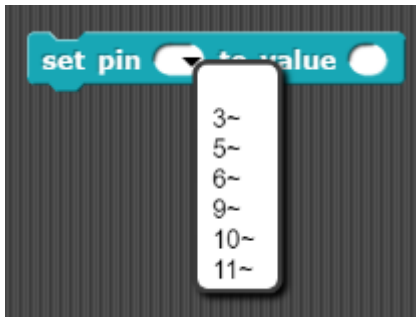
The block command "set pin (number) to value (value)" from Snap4Arduino. The numbers that can be used range from ~3,5,6,9,10,11.

The final code/solution appears bellow. Based on the code, the LED (attached in pin 11) gradually turns on when movement is detected. When there is no movement it turns off.

Setting the initial values

(PIR_status and photoresistor are initiated based on the corresponding readings)

If movement is detected the LED turns on gradually until it gets its brightest value (255).

If there is no movement the LED turns off.

Tips: You can encourage your students to experiment with different parameters and different levels of brightness (depending on the use of the smart light *i.e street lights, desk lamp, garden lights, bicycle lights and more…*)

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ROBOSCIENTISTS PROJECT

Motivating secondary school students towards STEM careers through robotic artefact making

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Declaration

This report has been prepared in the context of the ROBOSCIENTISTS project. Where other published and unpublished source materials have been used, these have been acknowledged.

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