3.2 A representative example: "The BusRoute" project

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In this section, we will present "The BusRoute" project. It is a project developed according to the model presented in the section 3.1. The project consists of five stages: *Engagement stage, Exploration stage, Investigation stage, Creation stage, Evaluation stage*. The presentation of this project is organized in two parts:

- – Part 1: Description of the project (Teacher's guide)
- – Part 2: Students' worksheets

3.2.1 "The BusRoute": Description of the project (Teacher's guide)

During this project, students construct a bus with the use of Lego building materials and program its run along a pre-defined route with the use of appropriate software. This project mostly addresses students without previous experience in the use of educational robotics.

Goals: This project may meet learning goals in the fields of Physics, Mathematics, Technology and Informatics, while fostering, at the same time, skills and attitudes. Learners, upon completion of this project, will be able:

Knowledge:

- – to describe the basic characteristics of a robot (Technology);
- – to describe and explain the operation of simple construction (gears, axles, blocks, transfer of motion) (Technology);
- – to design and construct a moving vehicle with the use of all the appropriate materials (wheels, axles, motors) (Technology);
- – to use suitable software and programming structures in order to set in motion and control that vehicle with the use of motors and sensors (use of icon commands, control commands, repeat commands) (Informatics);
- – to calculate physical quantities affecting the design and operation of a bus, such as speed, distance, sense of direction (Physics, Mathematics).
- – to compare and evaluate proposed solutions in both, the construction and the programming of the models.

Skills:

- – to solve problems;
- – to formulate assumptions and check their soundness;
- – to express and evaluate arguments based on the data they have collected;
- – to organize their work and keep the course of their project under control

Attitudes:

– to acknowledge and appreciate the contribution of science and technology to modern man's welfare.
– to realize the value of the group work and collaboration showing respect to everybody's individuality.

Duration: The overall project may cover 12-14 teaching periods, if wholly developed. However, a teacher may choose to cover only a few of the activities and, in such a case, its duration will be shorter.

Age group and prerequisites: This project is meant for Secondary School students (12-15 years old) who have a basic knowledge on computer functions (familiarity with an operating system, with saving and retrieving files). Lastly, it is assumed that the learners concerned have very little experience or none at all in robotics.

Table 3.2.1: *The BusRoute- Duration of each stage*

Stage	Duration	Worksheets
Engagement stage	2 hours	Worksheet 1 Worksheet 2
Exploration stage	4-5 hours	Worksheet 3 Worksheet 4 Worksheet 5 Worksheet 6
Investigation stage	2-3 hours	Worksheet 7 Worksheet 8
Creation stage	1-2 hours	Worksheet 9
Evaluation stage	1-2 hours	

Inclusion in the school curriculum: The project is interdisciplinary and may, depending on the way it is introduced and the emphasis given to its development, be included in the Technology course of Secondary School, in the Informatics course or in the Physics course (topic: speed measurement) and in the Mathematics course (topic: circle perimeter, ratios) of Secondary School.

Software/Materials: Educational robotics requires both, the use of suitable building materials for the construction of robot models and the use of suitable software for their programming. For such kind of activities, the structural materials proposed is that of Lego Mindstorms NXT kit. The robot model programming may be done with Lego MINDSTRORMS Education NXT.

Proposed application in class: The following description concerns a proposed application course in class. Its goal is to display tools and methods that can be utilized within the framework of educational robotics by means of current trends about teaching and learning. Therefore, in no way are teachers prompted to faithfully follow the course, but rather to modify it with a view to serving the

requirements arising from each learner group and to meeting the teacher goals and the goals of the broader social group they belong to.

The project includes five development stages, which are not always clearly distinct, but constitute a wider developmental framework.

Engagement Stage (2 teaching periods)

The inclusion of this project in the rest of the curriculum may be done through the general issue of Public Transport. Public Transport, a subject matter of the Technology course, may become a study topic within an environmental program or an interdisciplinary activity within the frameworks of Physics, Mathematics and Technology. Upon the end of this unit, learners will be able:

- to state advantages from using Public Transport;

- to describe the characteristics of a robot structure,

- to specify desirable characteristics that a robot bus should combine in order to meet the requirements of transportation in city center

A starting point of the introduction may be a photograph or a short video with a relevant topic arising from a real story. Within the framework of the discussion, which will follow, students may refer to their own experiences and discuss questions such as:

- In which cases have they themselves or their family used a bus or a train?

- Who normally use Public Transport on a daily basis?

- In what respect does Public Transport have advantages as compared with a private means of transport?

- In what respect does Public Transport have disadvantages as compared with a private means of transport?

- What is the action taken by the State or local authorities in order to encourage the use of Public Transport?

- Is Public Transport friendlier to the environment?

First Teaching period

In **Worksheet 1** (presented in Part 2 of this section), 5 pictures are given, each one of which can give rise to discussion on various issues.

Picture 1: Morning traffic in Washington. 98% of the Americans think that Public Transport must be used. (http://www.theonion.com/content/node/38644). This may well give rise to a discussion about the traffic problem, pollution, over-consumption of fuel, waste of time in traveling from place to place.

Picture 2: Modern electric trains in the USA. These trains serve commuters (living 20-30 km away from town), thus mitigating traffic problems on motorways and shortening the time needed to get to a town. These trains have amenities serving people with special needs. It may give rise to a discussion on issues concerning the convenience of passengers (air-conditioning, special groups, children, mothers, elderly people) (http://www.movingtoportland.net/public_transportation.htm)

Picture 3: Tramway in Budapest. Budapest has a good Public Transport system, operating from 4:30 to 23:00. Selectively, certain lines provide night services. This may give rise to a discussion on transport service frequency. (www.budapesthotels.com/touristguide/bkv.asp)

Picture 4: Line buses in Guatemala. They are regional buses manufactured as school vehicles. Now, in the seat that was meant for two children, two to three adults are squeezed in, together with their luggage. Of course, failures and accidents are expected (antiguadailyphoto.com/2006/08/01/).

Picture 5: Map of the London Underground railway system. The London Underground system has 12 lines, which, in combination with the bus services and the surface trains, serve a very large area. The London underground system became target of terrorists in 2005. This last item may give rise to discussion on safety matters(http://www.propertyinvesting.net/cgi-script/csNews/image_upload/specialreports_2edb.London%20 Tube%20Map.gif).

At the end of this initial teaching period, students may draw up a list of arguments supporting the use of Public Transport (section 3.2.2, Worksheet 1).

Second Teaching period

In the second teaching period, students are introduced into the scenario of the following project: the construction of a robot bus moving along a specified route. This route may be proposed by the teacher or may be planned in cooperation with the students. This task may be related to the stories studied already by the students in the previous teaching period, as well as to the students' own experiences. In the case of the urban centers, a good proposal is a robot bus serving a neighborhood and linked with different means of transport, such as a train. Alternative proposal is a robot train running within a park. In any case, the route covered should provide the students with opportunities and challenges for research and exploration (experimentation). At the end of this teaching period, the functions that we want the robot bus to perform and the route we want it to cover are expected to have been clearly described.

As an example, Worksheet 2 (Part 2) presents a scenario, where the learners are asked to design a robot bus to serve a downtown area restricted to pedestrians. Positive points, as well as concerns arising from the use of such a solution are:

Positive Points	Concerns
Easy downtown access within a short time (traffic problem avoided)	Difficult access of all the residents to the bus terminus and stops. Need for development of intermediate private car parking areas.
Reduced need for downtown car parking areas and, as a result, increased areas of green.	Delays caused to timetables and problems referring to transfers to and from other means of transport (train).
Less downtown air and noise pollution.	Difficult access by special groups of people (elderly people, mothers with young children, disabled).
More consumers and increased downtown commercial growth.	

At this point, we propose a discussion on the basic characteristics of a robot structure. A robot is a structure which has a physical entity, can carry out actions, i.e. has a behavior, but what makes it different from any ordinary mechanical structure is that it contains within it the 'control' element. In other words, a robot structure may collect data from the environment, decides, depending on those data, upon the actions to be taken and performs those actions (data as input, instructions-program, action-behavior as output).

At this point, we can continue with the description of the route. The bus can have a terminus and bus stops in an area easily accessible to residents, e.g. near a public car park, near the inter-city bus station, near the train station. Along its route, it will have to stop at bus stops, where there are passengers and wait while passengers get on and off the bus. For the convenience of blind people, it would be advisable to provide sound signals during the time passengers get on and off the bus. It is expected to develop a different speed at points where the road is not particularly safe, as well as to spot any obstacles and get immobilized. It is, finally, expected to be in a position to follow a pre-set route and park in a specific place.

Exploration Stage (3-4 teaching periods)

At the exploration stage, students become familiar with the materials that they are going to use (construction materials and software). Through their actions at this stage, they acquire the necessary experience which will enable them, at the subsequent stages, to develop independently their ideas. The activities at this stage are structured in such a way as to display the aspects that can be utilized in the solution of the problem they are asked to address. At the end of this unit, learners will be able:

–   to recognize and name the basic categories of building materials;

- to combine materials in simple working structures;

- to observe and explain the operation of simple machines;

- to state characteristics of simple machines (e.g. relationships between motor rotations and vehicle displacement);

- to make use of the basic icon-commands in order to program their models;

- to investigate and compare;

- to draw conclusions.

Third Teaching period

Learners recognize and name the given materials and relate them to the functions of a robot. The materials that can be utilized are gears, pulleys, beams, blocks and different kinds of sensors. The Try Me menu of the NXT brick can be tested in order to illustrate the function of sensors within NXT programs. The activities of Worksheet 3 may be carried out in small groups.

Fourth Teaching period

The students continue their exploration activity with simple structures aimed at the construction of a small bus capable of moving forward and backward (Worksheet 4). Typical car structures can be found in Lego Mindstorms Edu software: Lego Manual (pages 8-14) or Lego Mindstorms Edu NXT Software (Common palette/ 03 Drive Forward/ Building Guide)

The buses that are to be constructed will be able to move if:

- the motors are connected by a cable to Port A, B or C,

- the micro-processors NXT is switched on by pressing the orange button,

- My files/software files/Demo is selected by pressing the orange button.

The learners will have already been familiar with the construction of the model. It is very possible that they will have already begun to compare the bus models they have constructed, drawing conclusions in respect of speed, stability and functional capacity of each model.

Fifth Teaching period

During the fifth teaching period, learners can deal with their programming part. A brief introduction regarding the micro-processor operation may take place and, once the right connections of touch and light sensors and those of the motor have been made, learners can proceed with the programming environment (Worksheet 5).

Once the construction of the model is complete, the learners can proceed with programming. In Worksheet 5 the students are asked to develop two programs,

which drive and stop the bus with the use of clock and touch sensors. Learners are also asked to compare those two programs, which solve the same "problem", so that the advantages and disadvantages of each solution may be discussed.

Sixth Teaching period

During the sixth teaching period, the students will be exploring the light sensor (Worksheet 6). This activity aims at the learners' understanding of the sensor operation enabling them to utilize it when carrying out their programming work at the subsequent steps. They connect the light sensor to the microprocessor and move with the sensor in space. They record the readings given by the sensor in the room's various areas: in front of the open window, on the floor, on the table, in the black color area near the window, in the black color area at a darker point of the room.

Investigation Stage (3-4 teaching periods)

At this stage, the learners are asked to determine anew the problem which they worked on during the second teaching period in the light of the experience they gained with the materials and the software and to formulate a solution. After the end of this unit, the students will be able:

– to express questions and direct their research independently;

– to design, realize and evaluate a structural work;

– to design, realize and evaluate a programming solution.

Seventh Teaching period

In the seventh teaching period learners will be re-examining their original problem on the basis of the scenario presented during the second teaching period (Worksheet 7).

They will have to determine the structural characteristics which the bus model they will construct must have, as well as the functions it must fulfil. A route upon which testing by the teams will be performed is essential to be constructed in the area where the students will be working.

The teacher may discuss with the learners the criteria whereupon they will evaluate their structural work. These may be:

Criterion	4	3	2	1
Does it work as I originally planned?				
Does it always work?				
Can it be reused many times?				
Is it easy to use?				
Is it easy to construct?				
Is it safe to use?				

(1= low, 2= moderate, 3= very good, 4 exceptional)

The list will be completed by the class. This list must stay within the class on a notice board so that everyone can consult it.

Eighth – Tenth Teaching periods

Each group of students selects a question/subject from the list of bus' functions the have already create during the previous teaching period. They will research this question and they will propose an appropriate solution to the rest of the class

Examples of questions/ subjects for research can be:

– A study on the way in which the bus can turn.

– A study on stopping and waiting for passengers, as well as on selective stopping, depending on whether there are waiting passengers at a stop.

– Means by which it can serve disabled people while in the process of stopping etc. (e.g. sound signal)

– How it parks and how it starts off at the terminus.

– How it will be moving on a pre-defined track.

– How will it deal with situations of danger/obstruction?

The learners are guided in their exploration work through Worksheet 8. At the end of each teaching period, the learners are asked to record, for five to seven minutes, important events that occurred during the course of their lesson. They are asked to record the individual problems which they faced, what they tried, how they evaluate the results. The learners, at the end of this teaching period, are asked to present the results of their work, in other words, their suggested solutions to their peers. Their programs can be printed out alongside interpretative comments and be mounted on the notice board of the classroom.

Creation Stage (1-2 teaching periods)

At this stage, the students will be asked to put together in a creative manner all the parts they have constructed so far. The purposes served by those activities are:

– Formulation of questions and exploration (experimentation);

– Testing and evaluating the results of exploration;

– Combine software programs in a coherent final solution;

– Justification of their choices.

The students will be recording useful ideas, which were suggested by their peers during the exploration at both, the construction and the programming stages. Afterwards, they will be asked to put together a complete suggestion for the robot bus which will be moving on a specific route. The course of their project is recorded in the diary just as it was at the previous stage. When their project is complete, they must draft a report in which they will:

– Describe the structural characteristics of the robot bus.

– Describe the functions which it can fulfil.

– Support their choices with arguments.

– Record the advantages and disadvantages of their proposal.

Evaluation Stage (1-2 teaching periods)

At the evaluation stage the learners are asked:

– to present the results of their project;

– to justify their choices to the rest of the class;

– to utilize evaluation criteria.

Each team is asked to present its project and participate in the discussion which will be developed within the class. Suggested topics/questions which can be discussed in the class are:

Regarding the suggested solution:

– Effectiveness of the solution

– Stability during testing

– Originality

– Simplicity

– Safety

Regarding the procedure followed:

- Did you ask questions?

- Did you try more than one solution?

- Did you support your solutions with arguments?

- Did you make good use of the new information which was given to you?

Regarding cooperation (team work):

- Did you express your ideas, opinions to the team?

- Did the contribution of the rest of the team help in the completion of the project?

- Were there situations where your opinion differed?

In a similar way we can give feedback to the learners that took part in the activity. An evaluation worksheet can first be completed by the learners and, subsequently, by the teacher in a different color.

3.2.2 Part 2: Students' Worksheets

The Bus Route Project

Name…………………………………………………….

Date……………………………………….

Worksheet 1: Public Transport

1. In your team, study the following pictures. Give a title to each one of them and write it down in the following table.

Picture 1

Picture 2

Picture 3

Picture 4

Picture 5

	Title
Picture 1	
Picture 2	
Picture 3	
Picture 4	
Picture 5	

2. Write two reasons for which you would use the bus rather than the train. Share them with the rest of your team and complete your list.

I will use the bus/ train because…

The Bus Route project

Name…………………………………………………….

Date……………………………………….

Worksheet 2:A robot bus

1. Scenario: You work for your municipality in the transport sector. The downtown area is facing very serious traffic problems, especially when the shops are open. There is a proposal to pedestrianize the downtown area and to ban private cars in it during shopping hours. In this case, the development of a reliable transport system to and from the downtown for the residents is necessary.

Write down at least three positive points and three concerns that you see in this decision.

Positive points	Concerns

2. The Municipality proposes to get a supply of buses which will be programmed by means of computer systems and will run without a driver. How would you describe such a robot bus? Which is the particular characteristic that distinguishes a robot from other machines?

………………………………………………………………………………

3. Describe clearly the route that the above robot bus will be following and the functions expected to perform.

………………………………………………………………………………...

The Bus Route project

Name……………………………………………………….

Date……………………………………….

Worksheet 3: Getting to know the structural materials

1. Match the names found in the list on your right hand side with the respective items on the left hand side.
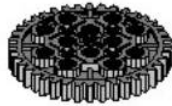
gear

pulley

tire

axle

beam

block

connector

2. Name the sensors, NXT brick and motors in the following picture. Please notice in which port each of these objects is connected.

3. Connect the light sensor, the touch sensor, the ultrasonic sensor, the sound sensor and a motor to the NXT brick Open the NXT brick and use the *TRY MENU*. Test the *Try-Light*, *Try-Touch*, *Try-Sound*, *Try –Ultrasonic, Try-Motor* functions. Observe the behavior of the robot in each case.

Program	States of sensor	Actions
Try-Touch	Press of touch sensor	Display of a smiling face
Try-Light		
Try-Sound		
Try–Ultrasonic		
Try-Motor		

4. A "robot" is a structure that can:

Collect data from the environment **INPUT**	→	Process those data and make decisions **PROCESSING**	→	Execute those decisions having a behaviour **OUTPUT**
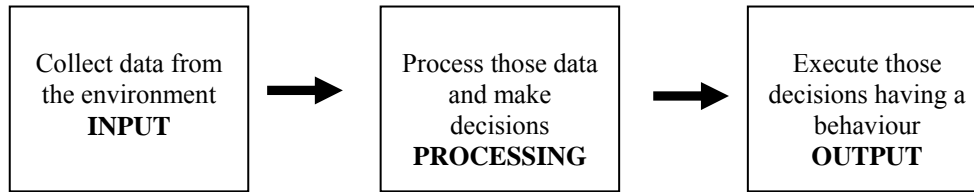
According to the above definition, match the following items with the functions they serve.

INPUT   OUTPUT   PROCESSING

The Bus Route project

Name……………………………………………………….

Date…………………………………………….

Worksheet 4: Construction of a robot bus

1. In order to construct a robot bus it is necessary to use a NXT brick, motors and sensors, together with other structural materials. You may try to construct a small bus model like the following.

2. How many motors will be needed to make your bus?

to move forward:
backward:
to turn left and right:

3. Use additional materials to construct a small bus capable to move freely to all directions. How will you transfer motion from the motor to the wheels? Draft a sketch.

The Bus Route project

Name……………………………………………………….
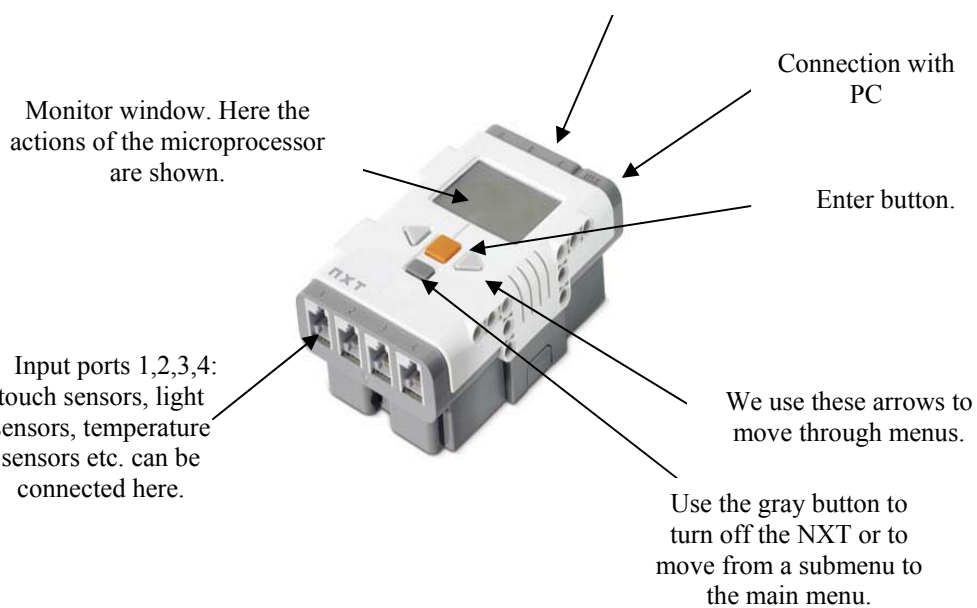
Date……………………………………….

Worksheet 5: Programming a robot

1. The NXT brick can communicate with the computer through a USB cable or a Bluetooth connection.

2. On the NXT brick, sensors, motors, lights are connected with cables. Study the following picture.

Output ports A, B, C: Motors and lights can be connected here.

Connection with PC

Monitor window. Here the actions of the microprocessor are shown.

Enter button.

Input ports 1,2,3,4: touch sensors, light sensors, temperature sensors etc. can be connected here.

We use these arrows to move through menus.

Use the gray button to turn off the NXT or to move from a submenu to the main menu.

Connect a motor, a light sensor and a touch sensor to the appropriate ports.

3. Open the LEGO MINDSTRORMS Education NXT software. In this program, the commands are symbolized by icons. What follows is a series of commands. What do you think is going to happen if NXT executes this program?

4. Create this program with the LEGO MINDSTRORMS Education NXT software. You will find all the icons in the Common Palette.

– Open the NXT brick.
– Connect the NXT with the PC through USB cable and download the program.
– Run the program by pressing the Enter button (orange button) 4 times.

5. Create on your computer a program which can stop the bus by means of a touch sensor. Run it.

6. Compare the use of the block *wait for time* (question 3) with the block *wait for touch sensor* (question 4) in the control of the bus's running interruption.

Interruption by clock	Interruption by touch sensor

The Bus Route project

Name……………………………………………………….

Date…………………………………………….

Worksheet 6: Use of light sensor

1. The Light Sensor enables your robot to distinguish between light and dark. It can read the light intensity in a room and measure the light intensity of coloured surfaces. Which port should the light sensor be connected with?

2. Connect a light sensor with the Port 3 of the NXT brick. Open Lego Mindstrorms Education NXT software and create a program with a light sensor only. Download and run the program.

The value shown here is the reading of the sensor

3. Move the sensor in space and observe its reading changes taking place. Complete the following table:

Position	Value of Sensor
In front of the window	
Towards a lit lamp	
On black color	

4. Construct and test a program which can stop the bus by means of a light sensor. Run it.

The Bus Route project

Name……………………………………………………….

Date……………………………………….

Worksheet 7:Reconstruction of the bus

In the light of the experience acquired, study again the scenario:

You work for your Municipality in the transport sector. The downtown area is facing very serious traffic problems, especially when the shops are open. The downtown area is going to be pedestrianized and private cars are to be banned during shopping hours. The transportation of the residents will be effected by programmed buses which will be run without a driver.

As a team, you are asked to write down in the following list the structural features that such a bus should have or the functions that it should perform in order to be in a position to serve the needs of the residents. Bear in mind that your town is to become famous by this original means of transport!

Subsequently, share your thoughts with the rest of the class and complete your list if necessary.

Structural features	Behaviour

Which are the criteria whereby you would evaluate a structure? Write down your criteria in the table given below. Then, configure a criteria list working jointly with the rest of the class.

Criteria

Based on the structural features that you have defined above, construct a bus in the light of what you have so far learned.

Describe the bus that you have constructed.

……………………………………………………………………………………

Which are the difficulties you encountered?

……………………………………………………………………………………

What experiments have you carried out?

……………………………………………………………………………………

How do you evaluate your bus using the criteria you have defined above?

……………………………………………………………………………………

The Bus Route project

Name……………………………………………………….

Date…………………………………………..

Worksheet 8: Suggest a solution

1. State clearly the problem which you will be trying to solve.

……………………………………………………………………………………

2. Write down ideas that can be utilized in its solution.

……………………………………………………………………………………

3. Use your personal computer in keeping a diary of your project. Indicate :

Date:

Which problem you have tried to address?

……………………………………………………………………………………

What did you try?

……………………………………………………………………………………

How did it go?

……………………………………………………………………………………

Have you accepted or not that solution and why?

……………………………………………………………………………………

4. For the presentation of your work in class, prepare four slides. The first will present the problem/question that you researched, the second one will present the structural and functional requirements that your model had. The third slide will present the program you have created and the fourth slide will present your reflections. All the best to your presentation!!

The Bus Route project

Name……………………………………………………….

Date……………………………………….

Worksheet 9: Synthesize and create

1. Create and program a robot bus which will be serving your municipality residents in accordance with the features and functions that you have written down (consult your class notice board).

2. Write down questions and ideas regarding their solutions, utilizing, probably, the proposals put forward by the other teams as well. You may also consult the class notice board.

Questions	Proposed Solutions

3. Use your computer in order to continue your project diary. Indicate:

- Date:

- Which problem you tried to solve?

- What did you try?

- How did it go?

- Have you accepted or not that solution and why?

4. Draft a text supporting the solution you have proposed.

- Describe the construction work.

- Describe the functional capabilities that it has.

- Support with arguments your choices.

- Write down the advantages and disadvantages of your proposal, as well as your proposals for future improvement.

5. Prepare the presentation of your project.

In order to organize effectively your research work being with:

- Define the problem

- Search for information and give ideas that will lead to the solution

- Evaluate the ideas and select the most suitable

- Plan the solution on paper

- Implement, test and correct

- Evaluate based on specific criteria

- Describe the solution, argue for your choices

- Presentation

Keep in mind:

- When we do not know how to go on, we state clearly the question/problem that we are faced with.

- When something works then we deserve acknowledgement.

- We get to learn something new when something does not work.

- It is worth choosing the simplest way in doing something.

- If something makes sense to us, then it may make sense to other people as well.