Project TERECoP: Pilot training materials

TERECoP: Training materials			
module	**subject**	**Materials for trainer (filename)**	**Materials for trainees (filename)**
1	Introduction: Trainer and trainees know each other	Guidelines 1	
2	Agreeing on a "didactic contract"	Guidelines 2	text 2
3. robotics as learning object (or getting started with robotics)			
3.1	Why robotics in education	3.1 Guidelines 3.1.a.why_robotics_in_education (ppt) 3.1.b. why legomindstorms(ppt) 3.1 Appendix - Program Blocks	Worksheet 3.1 Paper 3-1.pdf (Constructivist Learning Using Simulation and Programming Environments. MIE2002H Readings in Industrial Engineering I, *Calum Tsang*. May 5th, 2004)
3.2.a	A first approach (a): linear robots	**Guidelines 3.2.a** P1 assembling simple cars final (ppt) P1_assemblig_simple_linear_cars (ppt) P2 programming simple cars (ppt)	basic chassis (LDD software - building instructions) basic lineal car (LDD software - building instructions) lineal car 2 (LDD software - building instructions)

3.2.b	A first approach (b): turning robots	Guidelines 3.2.b P3_P4_turning_cars(3-2) Turning robots (3-2) (ppt)	**Worksheet 3.2.b** 2motors_2wheels(3-2) (LDD software - building instructions) curve(3-2) (NXT software) pivot(3-2) (NXT software)
3.2.c	A first approach (c): reactive robots	**Guidelines 3.2.c** P5_P6_P7_reactiv_ cars(3-2) Reactive robots (3-2) (ppt)	**Worksheet 3.2.c** Reactive ROBOTS
3.3	The tiny turtle robot (optional)	3.3 tinyTurtle (ppt)	3.3 TinyRobotTurtle (LDD software - building instructions)
4. **theory (Costructivism, constructionism, robotics, project-based learning)**			
4.1	How the use of technology (alternatively: robotics technology) in school class could change the traditional teacher-centred model of knowledge transmission?	Guidelines 4.1	Paper 4-1.pdf (Rethinking Learning in the Digital Age. Mitchel Resnick. The Media Laboratory Massachusetts Institute of Technology)
4.2	constructivism and constructionism in education	Guidelines 4.2 Text 4-2.doc (including text and bibliography)	Worksheet 4.2 Paper 4-2.pdf (Ackermann E., (2001) Piaget's constructivism, Papert's constructionism: What's the difference? Future of Learning Group

			Publication)
4.3	project-based learning	Guidelines 4.3 Text 4-3.doc (including text and bibliography)	Worksheet 4.3 Paper 4-3.doc (Using LEGO Robotics in a Project-Based Learning Environment. Mike Carbonaro, Marion Rex, Joan Chambers)
5. robotics as learning tool (or designing projects with robotics)			
		Guidelines	
5.1	Introduction Important features of a project Methodology for organizing a project	5_Robotics as Learning Tool (ppt) Text 5.1	Worksheet 5.1
5.2.	Working out a real project	Guidelines 5.2 Text 5.2	
	I: Work on Engagement stage		Worksheet 5.2.1
	II: Work on Exploration stage		Worksheet 5.2.2
	III: Work on Investigation stage		Worksheet 5.2.3
	IV: Work on Creation stage		Worksheet 5.2.4
	V: Work on Evaluation stage		Worksheet 5.2.5
5.3	Develop a new project based on the proposed methodology		
5.4	Presentations of new projects - Discussion		

6	**Evaluation of the course**	Evaluation methodology_for the pilot course A. Explanations and methodical recommendations for interviewees B. structured questionnaire C. Processing the results	

Module 1: introduction

Guidelines 1

Trainer and trainees know each other: “breaking the ice”

Face to face course

The trainer presents shortly him/herself and then invites each trainee to introduce him/herself in 2-3 minutes. Trainees are asked to provide personal/professional information, to express individual learning needs and goals, expectations and possible learning difficulties.

<u>Alternatively</u>: after the introduction of the trainer, the trainees in groups of two interview each other for 5 minutes and then introduce him/her shortly in 2 minutes to the whole class

e-learning

trainees are invited to post a message in the forum - topic “Class members” introducing themselves

Module 2: Agreeing on a "didactic contract"

Guidelines 2 Agreeing on a "didactic contract"

Face to face course

The trainer presents the overall aim, the specific objectives of the course, the content, the training methods and the expected training results.

The trainees are invited to express their own expectations, opinions, suggestions and ideas.

Trainer and trainees discuss and decide arrangements necessary for the smooth running of the course.

The session finishes with an agreement between trainer and trainees on the above mentioned issues (and on everything else that may emerge in the training class) leading to the formulation of a "didactic contract".

e-learning

The “didactic contract” is uploaded by the trainer in the Document area of e-class

Text 2: the overall aim, the specific objectives of the course, the training methodology and the expected training results (to be used during the module 2: Agreeing on a "didactic contract").

The overall aim of the course is to provide opportunities for teachers to examine how robotic technologies can be used to promote a constructivist-constructionist approach to learning under a co-operative and collaborative frame of work. The implementation of robotics-enhanced constructivist teaching and learning practices demands that teachers play a new role. This means that opportunities, like exposure to a number of critical examples and experience in designing computer-based robotic activities and integrating them in their classroom practice in constructivist ways, are of great priority. The goal is teachers to be convinced by their own personal experience for the potentiality of robotic technology as learning tool.

In this course we regard that technology alone cannot affect minds. Our curriculum design follows an innovative constructivist perspective with an emphasis on aligning computer and robotic technology with subject matter and learners’ needs for the purpose of constructing meaning in social learning environments. In such learning environments the focus is not on the individual but on interactive systems that include individuals interacting with each other, instructional materials, subject matter, and tools. Computer-based robotics is an innovative technology that can create a rich interactive environment encouraging constructivist learning.

Specific objectives

More specifically our objectives are

- to familiarise trainees an appropriate robotics-based learning environments (Lego Mindstorms system and a set of critical examples and activities that can support constructivist teaching and learning in science and technology subjects

- to enable trainees to use robotics technology in a way that can contribute to the realisation of

- meaningful learning based on students' own team work with teaching materials
- authentic learning using learning resources of real-life, occupational situations, or simulations of the every day phenomena,
- social learning though the use of e-learning classes
- active-reflective learning working on experiments or problem-solving and using available resources selectively according to their own interests, search and learning strategies
- project-based learning seeking solutions to real world problems, which are based on a technology-based framework

- To create a community of practice between educators and teachers for facilitating and sustaining teachers' professional development in using robotic tools to support their students' learning by active exploration and social construction of new knowledge. **,**

pedagogical and didactical approach

Constructivist-constructionist pedagogy and a learner-centered didactical approach will be applied taking into consideration learner's characteristics for an effective technology-enhanced learning design.

A collaborative e-learning environment will support the course based on the belief that the inherent dynamics of a necessary mutual process are likely to be more conducive to meaningful transformation, carrying so a sense of greater potential for development.

the expected impact on trainees is to be educated in a way that robotic technology-based learning will play an important aspect of their future work as teachers or professional educators. Trainees are expected to be able to

- develop innovative collaborative strategies in their classes supported by the development of e-learning communities
- select exploratory learning activities that can support social constructivist teaching and learning.
- use the proposed tools in real classrooms situation.
- design, build and program their own robotic models.

Module 3: robotics as learning object (or getting started with robotics)

Guidelines 3.1

robotics in education

face to face course

The trainees are separated in groups of 4-5 persons (the synthesis of the groups might be different from the previous one). The following written instructions are given to each group:

- *exploiting the paper*
  Constructivist Learning Using Simulation and Programming Environments
  MIE2002H Readings in Industrial Engineering I, *Calum Tsang*. May 5th, 2004 (available in eclass)

  talk inside your group and note three reasons you consider more important for the introduction of robotics in school education (20 min)
- *Define one representative to present to the whole class the opinions of your group (5 min)*

The trainer makes a synthesis of trainees' answers and presents his/her own additional ones (if they are different from those presented by the trainees) (15 min)

Eclass

the trainees are encouraged to write their opinion on the same topic in the forum of their eclass.

Worksheet 3.1 (50 min)

Why robotics in education

face to face course

exploiting the paper
Constructivist Learning Using Simulation and Programming Environments
MIE2002H Readings in Industrial Engineering I, *Calum Tsang*. May 5th, 2004 (available in eclass)

talk inside your group and note three reasons you consider more important for the introduction of robotics in school education (20 min)

- *Define one representative to present to the whole class the opinions of your group (5 min)*
- Write your opinion on the same topic in the forum of your eclass.

3.1 Appendix - Program Blocks

1- Blocks

In this section the list of the available commands is presented. For every command a brief description of the function and of its parameters is provided.

Common Palette

Move

It activates the outputs for a couple of motors.
Parameters: Selected port, Direction, Steering, Power, Duration, Next action
Data hub: yes

Record/Play

It records the sequence of actions of the robot and reproduces them.
Parameters: Action, Name, Recording, Time
Data hub: yes

Sound

To produce a sound file or a tone.
Parameters: Action, Control, Volume, Repeat, [File][Note, Duration], Wait for Completion
Data hub yes

Display

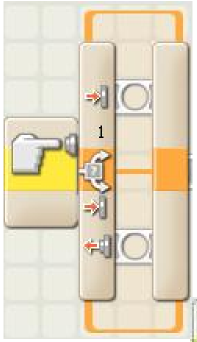
To display something on the NXT's LCD screen.
Parameters: Action, Display clear, [File, Position], [Text, Position, Line], [Type, Position]
Data hub yes

Wait for

To wait for time or sensor.
Parameters: Control, [Seconds], [Sensor, {it depends on the chosen sensor}]
Data hub no

Loop

To repeat a subsequence.
Parameters: Control, Show counter, [{it depends on the chosen element}]
Data hub no



Switch
To chose a subsequence on the basis of some condition.
Parameters: Control, [Type, Sensor], Display Flat view,
[{it depends on the chosen element}]
Data hub no

Complete Palette (apart from blocks in the common palette)

Motor
It activates the output for a single motor.
Parameters: Selected port, Direction, [Constant, Rump Up, Rump Down], Power,
Duration, Wait for completion, Next action
Data hub: yes

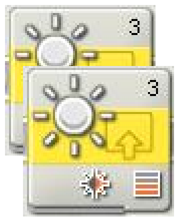
Send Message (through Bluetooth)
It sends a wireless message to another NXT.
Parameters: Connection number, [Text, Number, Logic], Destination mailbox number.
Data hub: yes

Motor*
It activates the output for a single motor of old style (RCX).
Parameters: Selected port, Direction, Power
Data hub: yes

Lamp*
It turns on or off a lamp (RCX).
Parameters: Selected port, [On, Off], Intensity
Data hub: yes

Touch sensor
It checks the sensor status at a specific point in the program, reporting a logical value.
Parameters: Port, [Pressed, Released, Bumped]
Data hub: yes

Sound sensor
It reports both a logical value (the sound is higher or lower a threshold) and
a numerical value representing the sound level.
Parameters: Port, Level of comparison, [>, <]
Data hub: yes



Light sensor
It reports both a logical value (the surrounding light is higher or lower a threshold) and
a numerical value representing the light level.
Parameters: Port, Level of comparison, [>, <], Generate light
Data hub: yes

Ultrasonic sensor

It reports both a logical value (the distance is higher or lower a threshold) and the mea sured distance in inches or centimeters.
Parameters: Port, Level of comparison, [>, <], [Inches, Centimeters]
Data hub: yes

NXT buttons

It checks the status of one of the NXT buttons.
Parameters: [Enter, Left, Right], [Pressed, Released, Bumped]
Data hub: yes

Rotation sensor

It counts the number of degrees/full rotations of one motor e reports both a logical value (the counted number is higher or lower a threshold) and the counter value.
Parameters: Port, [Read, Reset], Direction, [>, <], Level of comparison, [Degrees, Rotations]
Data hub: yes

Timer

It reads one of the three built-in timer or resets it. If reading, it reports both a logical value (the timer value is higher or lower a threshold) and the timer value.
Parameters: [1,2,3], [Read, Reset], [>, <], Level of comparison
Data hub: yes

Receive message (through Bluetooth)

To receive a wireless message reporting both a logical value (the message contents is equal or not to a given value) and the message.
Parameters: [Text, Number, Logic], Compared value, [1..10]
Data hub: yes

Touch* sensor

It checks the sensor status at a specific point in the program, reporting a logical value (RCX).
Parameters: Port, [Pressed, Released, Bumped]
Data hub: yes

Rotation* sensor

It counts the number of ticks (16 ticks/rotation) e reports both a logical value (the counted number of ticks is higher or lower a threshold) and the counter value.
Parameters: Port, [Read, Reset], Direction, [>, <], Level of comparison
Data hub: yes

Light* sensor

It reports both a logical value (the surrounding light is higher or lower a threshold) and a numerical value representing the light level (RCX).
Parameters: Port, Level of comparison, [>, <]
Data hub: yes

Temperature* sensor
It reports both a logical value (the measured temperature is higher or lower a threshold) and a numerical value representing the temperature (RCX).
Parameters: Port, Level of comparison, [>, <], [Celsius, Fahrenheit]
Data hub: yes

Stop
It stops the program, motors and lamps.
Data hub: yes

Logic
It performs a logic function on its inputs or data wire inputs and gives out the result on an output data wire.
Parameters: [And, Or, Xor, Not], [Input, Data wired input]
Data hub: yes

Math
It performs a math function on its inputs or data wire inputs and gives out the result on an output data wire.
Parameters: [+, -, *, /], [Input, Data wired input]
Data hub: yes

Compare
For numerical comparison.
Parameters: [≤, =, ≥], [Input, Data wired input]
Data hub: yes

Range
It checks if a number is or not is within a range of numerical values.
Parameters: [Inside, Outside], [Input, Data wired input]
Data hub: yes

Random
Random number generator.
Parameters: Minimum, Maximum
Data hub: yes

Variable
It reads/writes a variable.
Parameters: [Logic, Number, Text], [Read, Write], [Value]
Data hub: yes

Text
Text concatenation.
Parameters: [Strings A/B/C, Data wired input]
Data hub: yes

Number to Text
Number to text conversion.
Parameters: [Number, Data wired input]
Data hub: yes

Keep alive
It will keep the NXT from entering sleep mode.

Data hub: yes

File access
File operations.
Parameters: [Read, Write, Close, Delete], Name, [Text, Number], Text
Data hub: yes

Calibrate
Sensor calibration.
Parameters: Port, [Light, Sound, Light*], [Calibrate, Delete], [Maximum, Minimum]
Data hub: yes

Reset motor
It resets the automatic error correction mechanism of the motors.
Parameters: Ports
Data hub: yes

Custom Palette

Myblock
It lists the customized blocks (selected blocks already put on the work area can be grouped into one new block).
Data hub: no

Module 3.2.a A first approach (a): linear robots

Guidelines 3.2.a

<table>
<tr><td>CURRICULUM'S CONTEXT:</td><td>NTX robot as a learning object. First approach to the robot</td></tr>
<tr><td>THEME:

breafing</td><td>Building up "lineal" robots

After opening the LEGO Mindstorms box and looking around it with a first demonstration of its elements, the students start building and programming their first LEGO robot-cars.</td></tr>
<tr><td>PROBLEM:</td><td>P1: "How to assembly very simple cars with only one motor"</td></tr>
<tr><td>OBJECTIVES:</td><td>Knowledge of the basic assembling techniques of LEGO NXT pieces:
Parallel assembling of beams with connector pegs (with/without friction)
Transversal assembling of beams with cross elements
Axes, bushes and wheels
Motor; NXT brick
Knowledge of basic mechanical technics to improve:
Simplicity and aesthetic (number of pieces of the robotic construction, symmetry,…)
Rigidity (as a solid body)
Stability (of the center of mass)</td></tr>
<tr><td>COMPETENCES:</td><td>At the end of this unit, the pupils will be able of:
Constructing a simple but well designed robot-car with only lineal motion, including one motor and the NXT brick</td></tr>
</table>

	• Comparing several robot-cars (already made or only designed [1]) evaluating and classifying them from their simplicity, rigidity and stability

THE SEQUENCING OF THE UNIT:

A.- ENGAGEMENT STAGE

media	***student's activities***	***teacher's activities***	***linguistic output***
The exhibition robot The LEGO Mindstorms boxes (one per group). We can consider not bringing to each group all the box pieces, but a subset good enough to assembly simple robots…	Listening and engaging dialog with the teacher	He remembers the wonderful behaviour of the exhibition robot seen before, and encourages them to make something like it but a very simple piece…	Did you like this robot behaviour…? What did you like the most… (asking to several students)…? Do you think is it difficult to make a robot like this one…? (yes, but we could start making simpler robots equally interesting…) I'll help you, but it's up to you to try to work carefully and build up a simple but nice robot…. Let's start!

B.- EXPLORATION STAGE

media	***student's activities***	***teacher's activities***	***linguistic output***

[1] With the LEGO Digital Designer

The LEGO Mindstorms boxes (one per group), or a subset of it The LEGO Digital Designer file: "first LEGO most usual pieces assembling" The LEGO Digital Designer file: "first simple car examples"	Hearing the remarks of the teacher, asking if necessary Looking and tying to replicate the demonstrations of the teacher.	a) He shows (demonstrates) the basic rules of the assembly of the LEGO pieces (parallel and transversal assembling, axes and wheels, …), making directly the assembling or using LEGO Designer shows (See the file provided) b) He shows, with the LEGO Designer, several simple LEGO cars already made, to add an insight of the final work to be done (See the file provided) c) He states the general rules of the pupils work in the next exploration stage (about the care of the LEGO pieces, the safety rules, the cooperation inside each group, …)	"Let me show to you how to assembly this LEGO beams… look at me (or look at the screen, in case Designer is used) and try to make it by yourselves…" "Look how to add an cross axle through the motor rotor…, be careful when you inserting it: you have to make some force, pushing and at the same time rotating a little bit…" "Look this wonderful cars… you could assembly something like this… any questions about them…?"
C.- INVESTIGATION STAGE			
media	***student's activities***	***teacher's activities***	***linguistic output (examples)***
The LEGO Mindstorms boxes (one per group), or a subset of it The LEGO Digital Designer file:	Building by exploration steps (by trial and error, by asking the teacher,…) its robot Writing a simple report of the	Helping (in a Vygotsky approach) to the working groups, providing them small "solutions" to permit their constructivist progress, for	"Any problem with your car construction…, yes, tell me…?" "Look to the connexion you had made between this beams…

“first assembling”	follow up of its construction. Everybody in the team discuss how to express the actions they make and one of them, “the writer”, writes down a briefing	instance: Adding some meaningful hints and suggestions (the good piece, the good way to link it,…) to the pupils questions and work Showing again the Designer files to some groups (pupils) to solve some assembling strategies	instead of using this simple double connector peg you should consider to use this big one triple connector peg…” “Look again the Designer Player to see how to fix the bushes on this axle… Do you remember how to use the “Building Instructions Player “ to see forward and backward the building stages… Let me to show you again…” “Teacher, we’d like to put this beam upside this one… how can we get it…?” “Are you writing a brief of the stages in your construction..? Who is the writer…? Let me see. It is important that all of you discuss and agree with the steps that Paul is writing …, for instance, what does it mean this sentence…?”
D.- PRODUCTION AND EVALUATION STAGES			
media	***student’s activities***	***teacher’s activities***	***linguistic output***

The car robots built by the teams of pupils at the previous stage	Discussion in the whole class to answer collectively to the questions written in the blackboard by the teacher Achieve agreements, giving empirical reasons to evaluate (accept or reject) those answers	Precise the initial problem (in this case: "How to assembly very simple cars with only one motor") splitting it in more precise sub-problems to be answered at this stage. Writing them at the blackboard (leaving place for the pupils answers…) (Note that this "sub-problems" have to be "class sub-problems", to be answered generalising the common characteristics of the different robots built by the pupils)	a) The teacher introduces: "A "very simple car" must be: • Simple • Rigid • Stable From our experience assembling cars, we are going to agree and write rules for these characteristics and then we'll classify our robots according them…" b) The *initial writings* at the blackboard: "Rules to evaluate the "simplicity" of the cars (space to write down answers) Rules to evaluate the "rigidity" of the cars (space to write down answers) Rules to evaluate the "stability" of the cars (space to write down answers)" c) The ***final writings*** at the blackboard (one example). See the next page

Linguistic output

c) The ***final writings*** at the blackboard (one example)

Rules to evaluate the "simplicity" of the cars:

- The less pieces has a car, the simpler it is
- The less pigs has a car, the simpler it is
- The more symmetric is a car, the simpler it is

Rules to evaluate the "rigidity" of the cars:

- The less is the bending of a car (with a small external force made by hand) the more rigid a car is
- The longer the distance between the connector pegs, the stronger the compound beam is
- The better a strong attach of the transversal beams (using the cross blocks) is, the more rigid a car is

Rules to evaluate the "stability" of the cars:

- The lower is the mass centre (the lower the weight parts of the car are), the better the stability is
  (It should be better begin the construction with the brick, no with the motor…)
- The more separate are the wheels, the better the stability is
  (It is better four wheels than three,…)

Additional rules:

- The more weight is upon the driving wheels (the more heavy is the car,…) , the more threat the wheels have
  (The brick should be placed over the driving wheels…)

APLICATION STAGE	

media	*student's activities*	*teacher's activities*	*linguistic output (examples)*
The car robots built by the teams of pupils at the previous stage The LEGO Mindstorm box (to modify the cars)	Pupils apply the above rules to classify the cars of the teams. They explicit the way they apply the rules in each case Each group modifies eventually its car according to the rules to improve it (it is permitted to "copy" the best assembling solutions between groups) At the end of this stage, all the groups have simple but efficient cars to start with the next problem	Helps the pupils process of *applying* the rules to improve the cars: a) asking to them to explicit the general statement of one rule b) asking to them to show the actual concrete state of their car (by reference to this rule) c) asking to them to think of one better state according to the rule d) asking to them to modifying their car to get this improved "new state"	(a pupil) " I think this car (takes a car) is less stable than this one (shows another car), because this (shows the first one) has the brick too high and has the centre of mass high (looks for the teacher approval…)… and it's easier to overturn it…" (the teacher to a group) " Do you think that could be improve the stability of your car…? Look at it…, what about the width between wheels of the car…? Could we to make any change to improve the stability of the car…? Any suggestion…?

CURRICULUM CONTEXT:	**robot as a learning object. First approach to the robot**
THEME: **breafing**	**Building up "lineal" robots** After opening the LEGO Mindstorms box and looking around it with a first demonstration of its elements, the students start building and programming their first LEGO robot-cars.
PROBLEM:	**P2: "How to *program* very simple cars with only one motor"**

<table>
<tr>
<td>OBJECTIVES:</td>
<td>

Knowledge of the meaning of each parameter in the MOTOR procedure (from the NTX-G language):

The basic parameters, directly involved in the motion of the car: direction, power, duration (degrees), duration (rotations), duration (seconds)
The parameters that add some conditions to that basic motion: Port, action (constant, ramp out, ramp down), motor power, wait for completion, Next action (brake, coast)

Knowledge that the MOTION procedure express actually the class of “uniform motions” of the car [2] :

the “power” parameter being related with the speed (v) of the motion (accompanied by the “direction” parameter, that specifies the directional sense of the move, that’s it: the “+” or “-“ sign of the velocity)
the “duration” parameter being:

related with the distance (x) of the motion, if we put in a value in rotations or degrees units (knowing how to relate lineal and angular variables)
being the time (t) of the motion, if we put in a value in seconds unit

</td>
</tr>
<tr>
<td>COMPETENCES:</td>
<td>
At the end of this unit, the pupils will be able of:

program MOTOR instructions to “solve” any particular (uniform) motion problem of the car:

for a specified velocity and distance (predicting how time this motion will take)
for a specified velocity and time (predicting how long this motion will take)

solve problems involving two cars motion

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

[2] We suppose that the trainees already known the “uniform motion” model, where the position x and the time t of the car are related by a constant v of proportionality: $x = v \cdot t$

THE SEQUENCING OF THE UNIT:

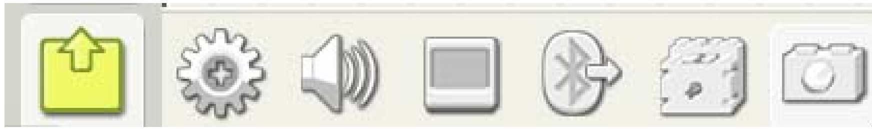
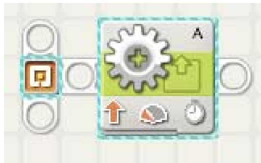
A.- ENGAGEMENT STAGE

media	*student's activities*	*teacher's activities*	*linguistic output*
The exhibition robot	Listening and engaging dialog with the teacher	He remembers again (He did it at the beginning of P1) the wonderful behaviour of the exhibition robot seen before, and encourages them to make something like it but a very simple piece… as a mechanical construction and as a "intelligent" device… Now, that the simple car has been already built, it's time to give it some kind of "intelligence"… and the basic level of "intelligence" could be the *self behaviour*. And this is achieved by programming the robot.	"Did you like this robot behaviour…(he shows it)…?" "As important as assembling a good robot is to make it "*intelligent*" enough to make some tasks… but the basic level of this intelligence could be, at least, to be autonomous… We should be able to tell the robot how to do some task and the robot to make it by itself. And this is possible by programming the robot… Do you like to know how to program it?... I'll help you, I'm showing how to start to program…but it's up to you to try to write up very simple programs, at least to make move the robot by itself…. Let's start!

B.- EXPLORATION STAGE:

B.1.- MAKING MOVE THE ROBOT BY THE FIRST TIME. A RACE CAR

media	*student's activities*	*teacher's activities*	*linguistic output*
(each team)	Hearing the	He makes move by the first	"Look at this process: (he shows at the screen the LEGO Mindstorms NXT

The car robots built by the teams at the previous problem P1. One computer with the LEGO Mindstorms NXT software installed and a USB connection.	remarks of the teacher, asking if necessary Tying to replicate the demonstration of the MOTOR program made by the teacher and trying to explore some simple changes to it. To compare the different programming options, the teams *make races* among their robots: A first race with the teacher's replicated robots; a second and a third races with the different MOTOR instructions downloaded by each team.	time one of the pupils cars, in front of the whole class with a *demonstration* of the whole process: a) selecting a MOTOR procedure for the program b) showing and speaking out the parameter inputs he makes in the procedure (to specify an instruction) c) downloading the program to the NXT brick (either by USB or Bluetooth connexion) d) running the program on the NXT bridge Finally, the teacher organise the "car races" between teams. It is important to tell to the pupils that the race's objective is not to win, but to compare the different car's behaviour and compare, as a result, the different programmed MOTOR's instructions, to start a first understanding of the MOTOR procedure parameters.	windows)… I choose from the "complete palette" (shows it)… in the "action" folder (shows it)… the motor icon here… and I drag it here… after the starting point of the program… "    "I'm going to convert this procedure to one instruction by giving values to the parameters…for instance, we can click on "A" to make to show to the NXT brick that the motor is connected to the A port… we can put initially "30" as the value of power (we'll see later on the meaning of this value…); we can put 4 seconds of duration…(the teacher enters this values into the program as he speaks…) "With this inputs I have made the simplest NXT program with only one instruction… Now, I am going to saving and naming the program…" "Now I'm going to download it to the NXT brick memory and make it run… to make this I click here (download and run option)… We have to wait for a while… and look, the car moves!!... "

	At each race the whole group discuss the results, looking for the speed, distance and time of the different cars and relating them with the different values assigned to the parameters of the MOTOR instruction in each case	All this should be made in a exploratory and not in a systematic way… The most important conclusion is to realize that in all cases the cars seem (intuitively) to have a "uniform" motion, with more or less velocity, which is related with the "power" parameter. And that they take more or less time and walk more or less distnce, depending of the time and degrees/turns programmed. It is good enough if the pupils realize qualitatively the independent effect of each parameter on the speed, the distance or the time of the car's motion. It is not necessary, at this stage, that the pupils realize the relation between v, x, t variables in the uniform motion.	"This is tour time…, try to repeat this steps and make move your car…, ask me if you are in trouble…" (at the races) " Every team bring their car and put it at the start line… When I say "go" you press the run buttons of the bricks, and you push the start buttons of the clocks that measure the running time of each car…" "Well, we are making this race just to look for the speed of the cars… watch attentively the speed of the cars, not the final distance or the time… One, two, three, go!...(at the end of this race) which car has been the quickest?... (answers) …, yes, it seems the second car had the biggest velocity… and which was its power value?...(pupils compare the parameter's values of the cars for this race, that are written at the black board)…the highest!!... any hypothesis…? (discussion starts…)…" 

B.- EXPLORATION STAGE:

B.2.- DISTINGUISHING BETWEEN "BASIC" AND "COMPLEMENTARY" PARAMETERS OF THE MOTOR PROCEDURE

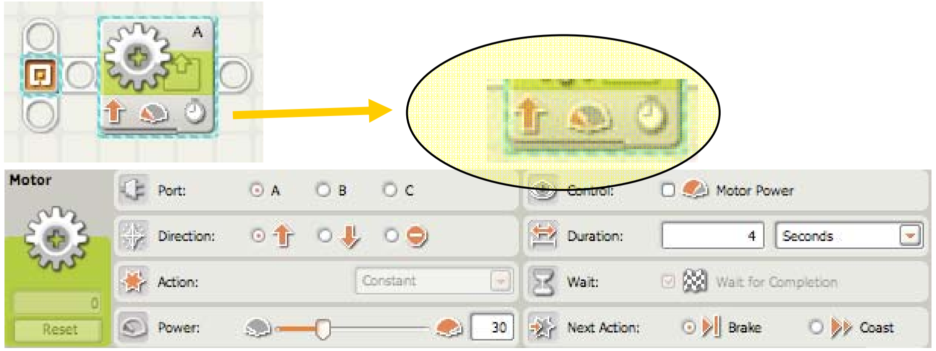
<table>
<tr><th>media</th><th>student's activities</th><th>teacher's activities</th><th>linguistic output (examples)</th></tr>
<tr>
<td>The teacher's computer with the LEGO Mindstorms NXT software installed (and a screen projector)</td>
<td>After finishing the race

Hearing the remarks of the teacher, asking if necessary</td>
<td>After the first experience gained with the car race, the teacher invites to the pupils to get a deeper look at the MOTOR procedure…

He states that, to simplify the initial use of the MOTOR procedure, it is useful to select the "main" or "basic" parameters, that control the basic kinematical aspects of the motion (a uniform motion, as we'll see), and the "complementary" or "conditional" parameters, that control the environment conditions of the move.

He pay attention:

a) to the fact that, the direction sign apart, we can choose only two basic parameters to configure one MOTOR instruction, that's it, to specify one concrete move task.

b) that the above is consequent</td>
<td>


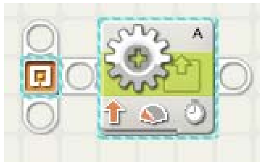
"Look at the downside of the graphic MOTOR instruction… (he shows this part at the screen with the mouse…) we can see three small icons that show us the basic state of this instruction, that is, the specific motion the instruction is controlling:

- the upside arrow ; it means that the robot will move upward. We can change that upward arrow by clicking on the other direction sense button in the motor parameters window (he clicks on this button an the arrow changes…)

- the power measure icon ; it shows how much "power" is applied to the robot (we'll investigate that later on…). If I change the value of the power sliding its button… (he makes it) you'll see that the needle in the icon changes…

- the clock ; it means that we have specified some time as the duration of the motion.

Attention, please! Look that instead of time we could select a very different kind of duration, specifying the amount of angular rotation of the wheels,</td>
</tr>
</table>

		with the “rule of the uniform motion” , where the variables are v, x, t and the relation between them is x = v . t, which means that they are only two independent variables. He arrives at the conclusion that they are two MOTOR procedures: a) MOTOR driven by time (when you input power and time, and the distance is d = v . t), and b) MOTOR driven by distance (when you input power and distance, and the time is t = d / v) This exposure tries to link the experience of the pupils about the basic parameters of the MOTOR procedure, where they find *several* parameters, with the rational “model” of the uniform motion which states that only two of these parameters are independent (state parameters of the system). This structured view of the	(he makes the change and the icon changes), or choosing the amount of *turns* the wheels have to do…(he makes the change)… I insist that these are distance durations (not time durations) and are expressed by the amount of rotation of the wheels, which is related with the distance the car moves…(take a car and makes a demonstration…). It’s not difficult to calculate the linear distance d from the degrees or turns the wheel makes… but we investigate this later… “Well, all this icons show us the *basic* parameters whose values we have to choose to specify the move of the robot…the others are *complementary* parameters, that we can study later on…”  “Look again at the MOTOR procedure icon, if we take apart the direction arrow parameter, we have *only two* basic parameters to command the cars move… Which are…? (answers)…, Yes, power and time or power and distance (we call “d”), depending if we choose time or degrees(turns in the duration box…) If the power is related with the speed of the car (we call “v”),and if I speak in physical motion terms of the car, we can choose alternatively two parameters: { v , t } or { v , d } …(he writes on the black board…) Remember that as the cars have a uniform motion, they obeys to the well known relation: d = v . t (writes), and this means that only two of this three variables can take independent values (which we choose freely) b’cause the third variable can only take the value predicted (deduced) by this relation. Then, summarizing all this, we have…in fact… (he writes):

		MOTOR procedure should guide the pupils to enter in the next stage of more systematic explorations about the car motion controlled by the two MOTOR procedures.	Two MOTOR procedures: a) “MOTOR driven by time”, we choose { v , t } and we can deduce d by calculating d = v . t b) “MOTOR driven by distance”, we choose { v , d } and we can deduce t by calculating t = d / v “Now, we could go deeper in this two procedures, investigating more systematically how they work…, and looking specially for the behaviour of the power parameter… I propose three investigations…”

1.- INVESTIGATING THE *"MOTOR DRIVEN BY TIME"* PROCEDURE

(This research can be developed at the same time as the other two, dividing the working teams)

C.1.- INVESTIGATION STAGE

media	*student's activities*	*teacher's activities*	*linguistic output (examples)*
(each team) The car robots built by the teams at the previous problem P1. One computer with the LEGO Mindstorms NXT software installed and a USB connexion. Graphics paper or EXCEL sheet	They try to answer the problem by a inquiry approach, that is by getting experience on the effect that the different values of the time parameter produce on the robot, obviously on the length of time the robot is moving. a)They discuss the representation spaces to record the observations (data table and graphical representation) b) they observe systematically the length of time the robot is moving (ROBOT-TIME) as they inputs different values of the time	It is a very simple investigation, just to be proposed to the trainee's team less "competent"… The problem is: "*What is the physical effect on the car of the time parameter in the MOTOR procedure*" To answer to this problem by inquiry, the pupils at this stage have to get experience with the effect that the different values of the time parameter produce on the robot, obviously on the length of time the robot is moving. The teacher encourages	"…*What is the physical effect on the car of the time parameter in the MOTOR procedure?* … (he speaks out as he writes it on the black board) This is the question the team one is going to answer…What are you doing to investigate this very simple question…? everybody can make suggestions… What is in this problem the independent variable…? (discussion)…good, the time parameter of the MOTOR procedure. How are we going to call this variable…? (discussion)…, good, we'll call NXT-TIME to express it's the time input on the NXT program… (he writes it on the black box…) What is the "dependent" variable…? (discussion)…, good, the length of time the robot is moving each time…. And we call it…?..., good, ROBOT-TIME… Then getting experience means… (discussion) observing the ROBOT-TIME values for different NXT-TIME values… Which are going to be this NXT-TIME values…? (discussion).. Well, let's be: 2, 4, 6,8 ,10 second…

parameter (NXT-TIME) on the MOTOR procedure.

c) They record all these observations on the above representational spaces

the team to design in advance a suitable data table and a graphics chart to collect the observations, and to make carefully these measures with a stopwatch.

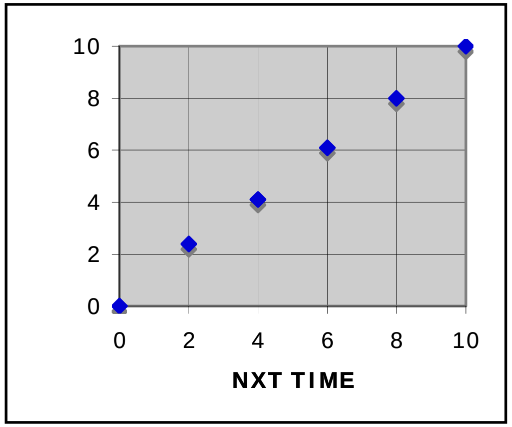
(look for possible answers on the “linguistic output” on the right column)

Remember that you have to get fixed the other basic variable of the MOTOR procedure… that means…? (discussion) Yes, that the power value has to be fixed, … which value for instance…? (discussion) Yes, it could be 20; power = 20 % (he writes it)… Then… at work .. and bring us back yours answers…!

(The team) Here’s our results! , it was very easy : (they shows it..)

ROBOT TIME as a function of NXT TIME
(power = 20%, direction = forward)

NXT-TIME	**ROBOT-TIME**
0	0
2	2,4
4	4,1
6	6,1
8	8
10	10



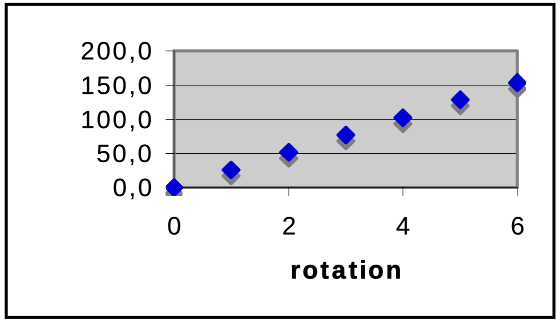
D.1.- PRODUCTION AND EVALUATION STAGES			
media	***student's activities***	***teacher's activities***	***linguistic output***
The above experiment results.	They generalize the above results. The simple lineal hypothesis: ROBOT-TIME = NTX-TIM is evident and it's corroborated…	He discuss with all the pupils about the most simple and effective hypothesis, which in this case is obvious…: both variables take the same values with good enough experimental accuracy. They discuss the difficulty to measure small lengths of time…	"Well, what can we generalize from all this data…(the data are shown on the screen in a EXCEL sheet … discussion) Yes, tat both variables take the same values…, we write that saying (hw writes) ROBOT-TIME = NTX-TIM Then, we can conclude that , within the experimental accuracy, the time programmed on the NXT is just the time the robot is moving…(he writes)…"

2.- INVESTIGATING THE *"MOTOR DRIVEN BY DISTANCE"* PROCEDURE

(This research can be developed at the same time as the other two, dividing the working teams)

C.2.- INVESTIGATION STAGE

media	***student's activities***	***teacher's activities***	***linguistic output (examples)***
(each team) The car robots built by the teams at the previous problem P1. One computer with the LEGO Mindstorms NXT software installed and a USB connexion. Graphics paper or EXCEL sheet	They try to answer the problem by a inquiry approach, that is, by getting experience on the effect that the different values of the degrees/turns parameter produce on the move of the robot, obviously on the lineal length (they call DISTANCE) travelled by the robot. a)They discuss	The problem has a first formulation: "*What is the physical effect on the car of the degrees/turns parameters in the MOTOR procedure*" To answer to this problem the previous question is to discuss if the two degrees/turns parameters are different ones… The conclusion is not. Both are the same parameter: the angular rotation of the wheel (the pupil call it as ROTATION), and only changes the unit of its value, degrees or turns… The teacher ask the pupils program two robots, one with 720 degrees, the other with 2 turns to see if they travel the	"…"*What is the physical effect on the car of the degrees/turns parameters in the MOTOR procedure*" … (he speaks out as he writes it on the black board) This is the question the team two is going to answer…What are you doing to investigate this question…? everybody can make suggestions… What is in this problem the independent variable…? (discussion)…good, it isn't so clear… really are they degrees and turns a different kind of parameters?... What is it supposed to "1 turn" to make..?... and 360 degrees to make?..., or 2 turns and 720 degrees…? (discussion) Could verify this…? (pupils programme two robots to make this comparison …) Well, turns and degrees are simply different units of one magnitude… how could we call it…? (discussion) Yes, the ROTATION of the wheels of the car… This is our independent variable in this investigation! What the rotation of the wheels makes on the robot…? Yes, the move of the car, measured by…? (answers) .. by the DISTANCE that the car runs… This is our dependent variable!

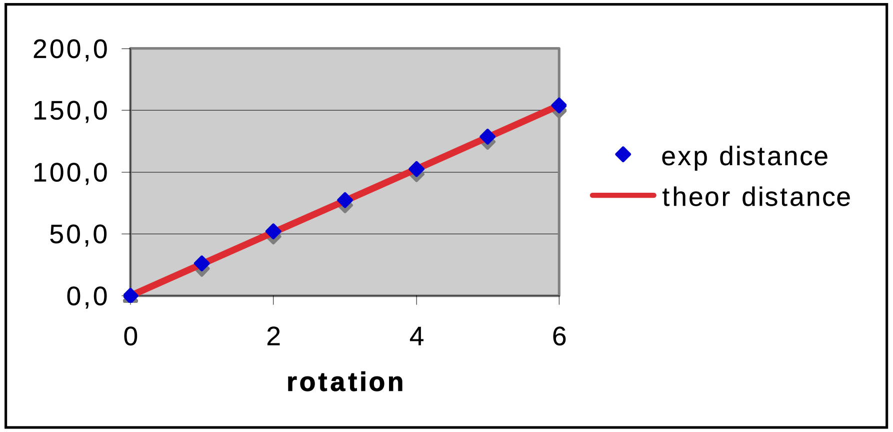
	the representation spaces to record the observations (data table and graphical representation) b) they compare the effect of both degrees/turns parameters, to conclude that both are the same parameter: the angular rotation of the wheel (they call ROTATION), and only changes the unit of its value, degrees or turns… b) they observe systematically the DISTANCE the robot travel as they input different values of ROTATION	same distance… Stated the x and y variables (in this case: ROTATION and DISTANCE) the teacher ask the pupils reformulate the problem of this investigation… The problem is reformulated as: *“What is the effect of the ROTATION parameter on the DISTANCE the robot travels”* To solve this question by inquiry, the pupils at this stage have to get experience, observing the DISTANCE travelled by moves of different ROTATION values The teacher encourages the team to design in advance a suitable data table and a graphics chart to collect the observations, and to make carefully these measures, putting a metric tape below the path of the robot (look for possible answers to the problem on the “linguistic output” on the right column)	Then, how do we reformulate our problem? (discussion).., Yes, more or less like that: (writes) *“What is the effect of the ROTATION parameter on the DISTANCE the robot run?*  Then, getting experience to solve this problem means… (discussion) observing the DISTANCE values for different ROTATION values… Which are going to be this values…? (discussion).. Well, which rotation units are we going to choose? (discussion) … rotations, well,… then which values of rotations? (discussion) : 1, 2, 3, 4, 5, 6 rotations Remember that you have to get fixed the other basic variable of the MOTOR procedure… that means…? (discussion) Yes, that the power value has to be fixed, … which value for instance…? (discussion) Yes, it could be 20; power = 20 % (he writes it)… Then… at work .. and bring us back yours answers…! (The team) Here’s our results! , it was very easy : (they shows it..)

	on the MOTOR procedure. c) They record all these observations on the above representational spaces		

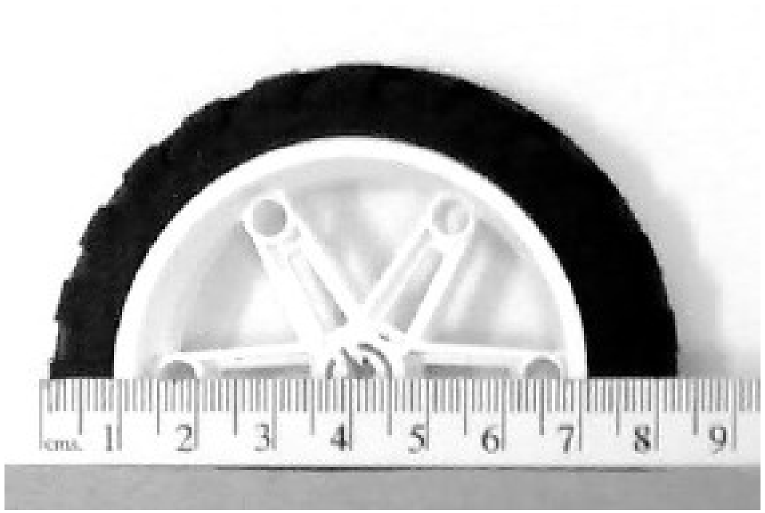
rotation (turns)	exp distance (cm)
0	0,0
1	26,0
2	52,0
3	77,3
4	102,5
5	128,7
6	153,8

D.2.- PRODUCTION AND EVALUATION STAGES

media	***student's activities***	***teacher's activities***	***linguistic output***
The above experiment results.	They generalize the above results. They discuss the conversion of the wheel's rotational motion to the car's longitudinal distance travel.	He discuss with all the pupils about the most simple and effective hypothesis. He proposes to study the relation between the wheel's rotational motion and the	"Well, what can we generalize from all this data…(the below experimental distances are shown on the screen in a EXCEL sheet … discussion) We should discuss the relation between the wheel's rotational motion and the d longitudinal distance travelled by the car… Look (he demonstrates…) here I am the car and I put a mark on the wheel.. I push the car just to make one wheel turn… do you see the distance travelled by the car… How far has gone the car?... (discussion) The length of the circumference, good!... Then, what is the hypothesis we can do?... (discussions)… good! (he writes) DISTANCE = 2 ∏ R ROTATION (in turns) Being R the radius of the wheel… You are going to test this hypothesis…! Go, please!..."

<table>
<tr>
<td></td>
<td>They choose as hypothesis:
DIST = 2 ∏ R ROT (turns)
They corroborate this hypothesis on an EXCEL sheet, finding out that the R value obtained from the hypothesis is just the radius of the wheels of the car very accurately</td>
<td>c longitudinal distance travelled by the car
He make some demonstrations, making a car giving one turn…
He, finally, from the discussion with the pupils propose to them to test the DISTANCE = 2 ∏ R ROTATION (turns) hypothesis
He help to the pupils with the modelling work, eventually making himself collaboratively this work with</td>
<td>“I’m going to testing with you…
Look at the EXCEL worksheet of the screen…
<table>
<tr><td>rotation</td><td>exp distance</td><td>theoretical distance (2*pi*R*rotation)</td><td>R= 4,08</td></tr>
<tr><td>0</td><td>0,0</td><td>0,0</td><td></td></tr>
<tr><td>1</td><td>26,0</td><td>25,6</td><td></td></tr>
<tr><td>2</td><td>52,0</td><td>51,3</td><td></td></tr>
<tr><td>3</td><td>77,3</td><td>76,9</td><td></td></tr>
<tr><td>4</td><td>102,5</td><td>102,5</td><td></td></tr>
<tr><td>5</td><td>128,7</td><td>128,2</td><td></td></tr>
<tr><td>6</td><td>153,8</td><td>153,8</td><td></td></tr>
</table>
We are going to write in it another column with the values of our hypothesis, we’ll call it theoretical distance (he writes)…. And now we are to express the hypothesis on each cell… we put any value on the R cell, just to begin… (he starts to make a modelling process, helped by the pupils)


We are going to obtain a graphical view of these data… And trying to adjust the R value in the worksheet to match the</td>
</tr>
</table>

		an EXCEL worksheet (with a output screen projector) Finally he encourages to modify the program to introduce directly the distance in centimetres we want the car to travel.	experimental data…“ “Finally we have this good agreement between our hypothesis and the data for an R value of 4,08.. well, 4,1 cm.. Our model proposes that the car wheels must to have this value for the radius… Is it true?... Let’s go to verify it… (the pupils measure the radius of the wheels of the car … that results to be 4,1 cm!!  We have discovered that: (he writes) DISTANCE (in cm) = 2 ∏ 4,1 ROTATION (in turns) or DISTANCE (in cm) = 25,8 ROTATION (in turns) , with these wheels… Now we can modify the program to input directly the distance we want the car runs… How? Any suggestion? (discussion)…”

3.- INVESTIGATING THE *POWER* PARAMETER IN THE MOTOR PROCEDURES

(This research can be developed at the same time as the other two, dividing the working teams)

C.3.- INVESTIGATION STAGE

media	***student's activities***	***teacher's activities***	***linguistic output (examples)***
(each team) The car robots built by the teams at the previous problem P1. One computer with the LEGO Mindstorms NXT software installed and a USB connexion. Graphics paper or	They try to answer the problem by a inquiry approach, that is, by getting experience on the effect that the different values of the power parameter produce on the move of the robot, obviously on the lineal speed of the robot motion a)They discuss the representation spaces to record the observations (data table and graphical representation) b) they observe systematically the robot's SPEED values as they input different values of POWER on the MOTOR procedure. They discuss with the	On the exploration stage we have worked up that the robots travel (intuitively) with a constant speed. We'll take this for granted in this investigation (although we propose in this unit an additional and optional investigation to verify this assumption: the uniform motion of the robots. See later on) So, the problem is formulated as: *"What is the effect of the POWER parameter on the SPEED the robot motion has?"* To solve this question by inquiry, the pupils at this stage have to get experience, observing the SPEED of different motions corresponding to different ROTATION programmed values The teacher remembers that to	The problem to investigate is (he writes on the black board… : *"What is the effect of the POWER parameter on the SPEED the robot motion has?"* Then, getting experience to solve this problem means… (discussion) observing the speed values of the car for different power values of the MOTOR procedure… Which are going to be this values…? (discussion).. The possible power values vary from 0 to 100%... then we could choose (discussion)…: 10, 20, 30, 40, 50 … (this is not well represented all the rang of power values…, but the teacher accepts) Remember that you have to get fixed the other basic variable of the MOTOR procedure… that means…? (discussion) Yes, that the time or distance value has to be fixed, … which value for instance…? (discussion) Yes, we can choose the time, for instance? (discussion) well, time = 10 seconds (he writes) Common, let's go to observe… ! …(after some time)… (The team) Here's our results! : (they shows it..). We have got 10 seconds as the time value, and to calculate the speed value we

<table>
<tr>
<td>EXCEL sheet</td>
<td>teacher that SPEED is not a “direct” measure, and it has to be calculated from the uniform motion equation: SPEED=DISTANCE/TIME dividing the distance travelled by the robot in each case by the corresponding value of the time parameter (that we’d seen in the Investigation A that it is the actual time the robot is moving).
After discussion with the teacher, they choose a specific time parameter value.

c) They record all these observations on the above representational spaces</td>
<td>program any robot motion, besides the power parameter we have to fix another basic parameter (time or distance, see “linguistic output” at exploratory stage), and the easiest way is to fix a specific time length (not distance) for all power values. After discussion, a time value around 10 seconds should be considered as most suitable for this investigation.

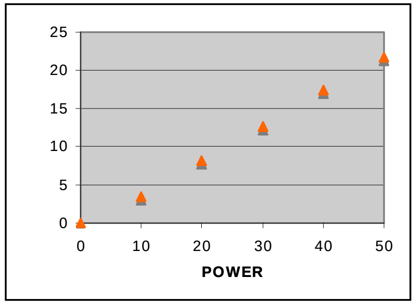
The teacher encourages the team to design in advance an appropriate data table and a graphics chart to collect the observations, and to make carefully these measures:

- putting a metric tape below the path of the robot and measuring the distance of each motion,

- and calculating the corresponding speed of the motion by dividing distance by time:
SPEED=DISTANCE/TIME

(look for possible answers to the problem on the “linguistic output”</td>
<td>have divided ….”

<table>
<tr><th>POWER (%)</th><th>DISTANCE (cm)</th><th>TIME (S)</th><th>SPEED (m/sec)</th></tr>
<tr><td>0</td><td>0</td><td>10</td><td>0</td></tr>
<tr><td>10</td><td>35</td><td>10</td><td>3,5</td></tr>
<tr><td>20</td><td>82</td><td>10</td><td>8,2</td></tr>
<tr><td>30</td><td>126</td><td>10</td><td>12,6</td></tr>
<tr><td>40</td><td>174</td><td>10</td><td>17,4</td></tr>
<tr><td>50</td><td>217</td><td>10</td><td>21,7</td></tr>
</table>



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

		on the right column)	

D.3.- PRODUCTION AND EVALUATION STAGES

<table>
<tr><th>media</th><th>student's activities</th><th>teacher's activities</th><th>linguistic output</th></tr>
<tr>
<td>The above experiment results.</td>
<td>They generalize the above results. They realize that the more the power is, the more is the speed…, and that seems to be a linear proportion…
They choose as hypothesis for the “theoretical” or rational speed:
THEORETICAL SPEED = k * POWER
They try and corroborate this hypothesis on an EXCEL sheet, finding out that
k = 0,42 makes the most accurate fitting.
They find out that the power parameter express the speed of the car, by a factor of 0,42…</td>
<td>He discuss with all the pupils about the most simple and effective hypothesis.
From the discussion with the pupils (see “student's activities”) they propose to test:
THEORETICAL SPEED = k * POWER
as the working hypothesis

He help to the pupils with the modelling work, eventually making himself collaboratively this work with an EXCEL worksheet (with a output screen projector)
Finally he encourages to modify theNXT program to introduce directly the</td>
<td>“Well, what can we generalize from all this data…(the below experimental data are shown on the screen in a EXCEL worksheet … discussion)
We should discuss the relation between the power parameter and the speed of the car… Look the graphical data… What do we find in there?... What happens as the power parameter increases…? (discussion) Do you think there's a proportion between the values of the two variables, POWER and SPEED…? Yes?... What relation could express between them as a hypothesis…? (discussion)… (he writes) Yes we could test… that:
THEORETICAL SPEED = k * POWER

You are going to test this hypothesis…! Go, please!...”
Do you remember how to do this…? You have to choose a cell named k… and to make a new column… named? (discussion) well, theoretical speed…, and which expression have we to write on it?.... “
…(after some time)… (The team and the teacher) Here's our results! :
<table>
<tr><th>POWER (%)</th><th>DISTANCE (cm)</th><th>TIME (S)</th><th>SPEED (m/sec)</th><th>THEORETICAL SPEED (=k * power)</th></tr>
<tr><td>0</td><td>0</td><td>10</td><td>0</td><td>0</td></tr>
</table>
</td>
</tr>
</table>

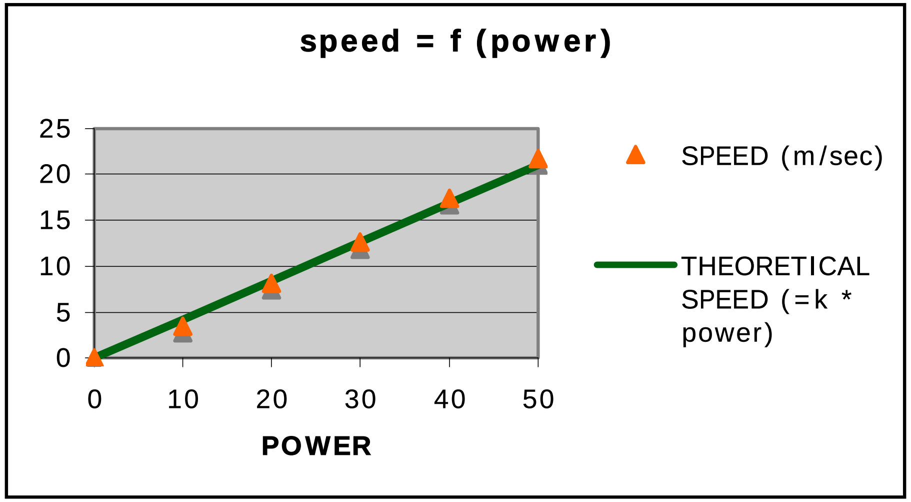
speed of the motion in centimetres/s

10	35	10	3,5	4,2
20	82	10	8,2	8,4
30	126	10	12,6	12,6
40	174	10	17,4	16,8
50	217	10	21,7	21
k=	0,42			

We can conclude… (he writes): SPEED (in cm/s) = 0,42 * POWER (in %)

¿Could you change the NXT program to input directly the speed of the car in cm/s…? How can we make that… (discussion)…”

¿Could change this k value…, depending of which factor…? (discussion)



<table>
<tr><th colspan="4">APPLICATION STAGE (ALL THE INVESTIGATIONS)</th></tr>
<tr><th>media</th><th>student’s activities</th><th>teacher’s activities</th><th>linguistic output</th></tr>
<tr><td>The car, the NXT program</td><td>They help to formulate concrete problems that can be solved as application of the general knowledge got by the above investigations…</td><td>The teacher formulate some concrete problems that can be solved as application of the general knowledge got at the investigation stage …</td><td>“Now, we are to test if we are understood the knowledge outputs of the previous investigations…. For instance, here are some simple problems to be solved by programming one or two robots… (he distributes some worksheets with the problems that he shows at the same time at the screen…):

Problem 1: We program a car motion with the next parameters values (in the “MOTOR driven by time” way of program writing):
Power = 20 ; Duration (time) =6
Calculate the distance the car is going to drive, and run this program to test your answer”

Problem 2: We program a car motion with the next parameters values (in the “MOTOR driven by distance” way of program writing):
Power = 20 ; Duration (degrees) =1620
Calculate the distance the car is going to drive and the time it lengths, and run this program to test your answer”

Problem 3: Two cars A and B make a race for a distance of 2 m. They start and the car B wins. It takes 8 s to cross the “end” banner of the race, and at this moment the car A is at 1,5 m.
Can you program two robots A and B to produce the behaviour of this race?</td></tr>
</table>

			Run and test. Problem 4: Two cars X and Y, start running at the same time from two points A and B separated a distance of 3 m. The cars are going to encounter each other, and they stops just when they are to crash, at the point P at 2 m from A (and consequently 1 m from B). They were running for 6 s. Can you program two robots A and B to produce the behaviour of this race? Run and test.

Guidelines 3.2.b turning robots

CURRICULUM'S CONTEXT:	**NTX robot as a learning object. First approach to the robot**
THEME: **breafing**	**Building up "turning" robots** After the first experience with linear robots (problems P1 and P2) in this unit the students try to add a new motor and to turn with the new car. Most of the purposes of the previous units are again present within this unit.
PROBLEM:	**P3: "How transform a one motor robot into a two motor robot, able to turn"** **P4: "How to program simple robots with two motors"**

OBJECTIVES:	• Knowledge of the ***basic assembling techniques*** of LEGO NXT pieces:
	    o Improving building skills in order to modify the previous car adding another motor
	• Knowledge of basic mechanical ***techniques*** to improve:
	    o Simplicity and aesthetic (number of pieces of the robotic construction, symmetry,…)
	    o Rigidity (as a solid body)
	    o Stability (of the centre of mass)
	• Knowledge of basic programming skills with NXT-G:
	    o Creating, saving, editing/writing, compiling and downloading programs
	    o Motor and Move blocks
	• To design a circuit with turnings (white floor with black lines, for example) and to program the robot in order to be able to follow a path with turnings within the circuit

COMPETENCES:	At the end of this unit, the pupils will be able of: • Constructing a simple 2 motor NXT LEGO robot, able to move straight on and to turn • Comparing several robot-cars (already made or only designed [3]) evaluating and classifying them from their simplicity, rigidity and stability • Making simple programs with NXT, to open them, to re-use them, to use them, etc…. • Comparing several programs NXT, observing their behaviour

THE SEQUENCING OF THE UNIT:

A.- ENGAGEMENT STAGE

media	***student's activities***	***teacher's activities***	***linguistic output***
The linear robots of previous units	Listening and engaging dialog with the teacher	He says that the previous robots were interesting but with lack of different features….like what? Linear moving limitation? What to do? Encouraging to try to solve this problem….with another motor….	Did you like this robot behaviour…? What did you like the most…What would you like to improve on this robot (asking to several students)…? Do you think is it difficult to add another motor to this robot…? (maybe yes, but we can try it …) I'll help you, but it's up to you to try to work carefully and build up a 2 motor simple but nice and "turning" robot…. Let's start!

[3] With the LEGO Digital Designer

B.- EXPLORATION STAGE

media	*student's activities*	*teacher's activities*	*linguistic output*
The LEGO Mindstorms boxes (one per group), or a subset of it The LEGO Digital Designer file: "first LEGO most usual pieces to assembly 2 motors" The LEGO Digital Designer file: "first 2 motor car examples" The LEGO NXT-G software development environment	Hearing the remarks of the teacher, asking if necessary Looking and tying to replicate the demonstrations of the teacher. Building by exploration steps (by trial and error, by asking the teacher,…) its robot	a) he shows to the pupils several 2 motor vehicles (INTERNET, LDD, pictures). b) He shows techniques to transform 1-motor car into a 2-motor car. c) He shows to the student how the command MOVE works on NXT-G. At this step a reflection about left & right directions and this command can be made. d) He states the general rules of the pupils work in the next exploration stage (about the care of the LEGO pieces, the safety rules, the cooperation inside each group, …)	"Let me show to you how to add another motor… look at me (or look at the screen, in case Designer is used) and try to make it by yourselves…" " Let think about left & right, how do you can control the direction…the command MOVE, yes…but how?...." "Look these wonderful cars… you could assembly something like this… any questions about them…?" "…what if with the car we design a circuit and we try to program the robot to achieve it…."

C.- INVESTIGATION STAGE

media	***student's activities***	***teacher's activities***	***linguistic output (examples)***
The LEGO NXT-G software development environment	Designing a circuit with turnings (for example an "S") and deciding what the car should do. Designing the program to accomplish this task. Observing the behaviour: Testing the robot with the program in the circuit. Writing a simple report of the follow up of its construction. Everybody in the team discuss how to express the actions they make and one of them, "the writer", writes down a briefing	Helping (in a Vygotsky approach) to the working groups, providing them small "solutions" to permit their constructivist progress, for instance: Adding some meaningful hints and suggestions (the good piece, the good way to link it,…) to the pupils questions and work Showing again the Designer files to some groups (pupils) to solve some assembling strategies Helping in designing circuits, programming, using the NXT-G environment, making tests, etc…	"Any problem with your car construction…, yes, tell me…?" "Any problem with the command MOVE" "How to go to the left?" "…and to the right?" "Is it a correct program?" "Has the program has been downloaded?"
D.- PRODUCTION AND EVALUATION STAGES			

media	***student's activities***	***teacher's activities***	***linguistic output***
The testing of the 2-motor cars within the circuit: building, programs, observations, reports.	Discussion in the whole class to answer collectively to the questions written in the blackboard by the teacher Achieve agreements, giving empirical reasons to evaluate (accept or reject) those answers	Precise the initial problem (in this case: "How to assembly and use by programming simple cars with 2 motors") splitting it in more precise sub-problems to be answered at this stage. Writing them at the blackboard (leaving place for the pupils answers…) (Note that this "sub-problems" have to be "class sub-problems", to be answered generalising the common characteristics of the different robots built by the pupils)	a) The teacher introduces: A "2 motor simple car" must be: • Simple, Rigid and Stable (as before) • Able to turn A good program must be: • As simple as possible (less elements, simple ones, etc….) • The generated code (for downloading) has to be as small as possible From our experience assembling cars, we are going to agree and write rules for these characteristics and then we'll classify our robots according them…" We use again the blackboard

Linguistic output

b) The ***final writings*** at the blackboard (one example)

<u>Rules to evaluate the cars:</u>

- Able to turn to left & right
- Able to turn in most of the situations
- Follows OK the circuit
- Follows the best and short tour

<u>Rules to evaluate the programs:</u>

• Number of the instructions • Size of the downloaded code • Etc…			
APPLICATION STAGE			
media	***student's activities***	***teacher's activities***	***linguistic output (examples)***
The car robots built by the teams of pupils at the previous stage	Pupils apply the above rules to classify the cars of the teams. They explicit the way they apply the rules in each case Each group modifies eventually its car according to the rules to improve it (it is permitted to "copy" the best assembling solutions between groups) At the end of this stage, all the groups have simple but efficient cars to start with the next problem	Helps the pupils process of *applying* the rules to improve the cars: a) asking to them to explicit the general statement of one rule b) asking to them to show the actual concrete state of their car (by reference to this rule) c) asking to them to think of one better state according to the rule d) asking to them to modifying their car to get this improved "new state"	"What is a good turning car?" "What is a good program?" "How we can know if the combination of robot & program do well what we want it to do?"

Worksheet 3.2.b: Turning ROBOTS

1.- What are you going to do in this activity? Explain it, please.

2.- Building the robot. Explain here the main features of your "turning robot". Take some pictures.

3.- Programming the robot. Explain here main features of your program. Take some snapshots.

4.- Analysing your car & program with the rules. Write the main features of the observed behaviour of your car (according to the classifying rules).

5.- What would you like to do better, to improve on your car? On your program?

Guidelines 3.2.c: reactive robots

CURRICULUM CONTEXT:	**NTX robot as a learning object. First approach to the robot**
THEME: **briefing**	**Building up "reactive" robots** We introduce sensors as the way to perceive and react from the point of view of the robot. This will give us to improve our programming skills (switch statements and loops).
PROBLEM:	**P5: "Approaching a wall": cars with touch sensors** **P6: "Approaching a lighting object": reacting to the light** **P7: "The 2-ear robot": reacting to the nearest sound**

OBJECTIVES:	• Knowledge of the ***basic sensors*** of LEGO NXT:
	  o Type of sensors: sound, light, touch, distance, etc…
	  o Use of the sensors with the NXT brick
	• Knowledge of basic mechanical technics to add sensors to our robots:
	  o Which sensor we need?
	  o Where we put it, how, etc…?
	• Knowledge of programming skills with NXT-G:
	  o Using sensors in NXT G programs
	  o Switch statements and loops

COMPETENCES:	At the end of this unit, the pupils will be able of: • Constructing a simple 2 motor NXT LEGO robot, able to move straight and to turn, and to react with 2 sound

	sensors • Making programs with NXT able to control sound sensors, and using control structures….

THE SEQUENCING OF THE UNIT:

A.- ENGAGEMENT STAGE

media	***student's activities***	***teacher's activities***	***linguistic output***
The turning robots of previous units	Listening and engaging dialog with the teacher	He says that the previous robots were interesting but with lack of different features….like what? Perception….sensing and reacting….	Did you like this robot behaviour…? What did you like the most…What would you like to improve on this robot (asking to several students)…? What about perception????? do they perceive and react? Shall we make a robot that senses & react?

B.- EXPLORATION STAGE

media	***student's activities***	***teacher's activities***	***linguistic output***
Sensors & bricks	Hearing the remarks of the teacher, asking if necessary Looking and tying to replicate the demonstrations of the teacher.	a) he show to the students how to check values of sensors with the brick b) He shows how to connect sensors to their cars c) He shows different commands to control and use sensors in NXT-G programming d) He presents the control structures, loop & switch	

C.- INVESTIGATION STAGE

media	*student's activities*	*teacher's activities*	*linguistic output (examples)*
The previous robots with sensors	They have to choose one class of reactive robot (with sound, touch or light sensor)	Helps in deciding 3 different problems with the 3 type of sensors. a) with touch sensor, to escape from walls b) with sound sensor, the 2-ear dog. c) With light sensor…..	

D.- PRODUCTION AND EVALUATION STAGES

media	*student's activities*	*teacher's activities*	*linguistic output*
The previous robots with sensors	Let us test the cars	What happens	

Linguistic output

c) The ***final writings*** at the blackboard (one example)

<table>
<tr><td colspan="4">

- **Does the robot & program solve the problem**
- **Slowly or quickly**
- **Is complicate the program or no**
- **Etc…..**

</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>APPLICATION STAGE</td><td colspan="3"></td></tr>
<tr><td>media</td><td>student's activities</td><td>teacher's activities</td><td>linguistic output (examples)</td></tr>
<tr><td>The previous robots with sensors</td><td>Pupils apply the above rules to classify the cars of the teams. They explicit the way they apply the rules in each case
Each group modifies eventually its car according to the rules to improve it (it is permitted to "copy" the best assembling solutions between groups)
At the end of this stage, all the groups have simple but efficient cars to start with the next problem</td><td>Helps the pupils process of applying the rules to improve the cars:
a) asking to them to explicit the general statement of one rule
b) asking to them to show the actual concrete state of their car (by reference to this rule)
c) asking to them to think of one better state according to the rule
d) asking to them to modifying their car to get this improved "new state"</td><td></td></tr>
</table>

Reactive ROBOTS

Worksheet 3.2.c

1.- What are you going to do in this activity? Explain it, please.

2.- What application did you choose and why: escaping from walls, our 2-ears dog or leaving the dark side of the moon.

3.- Building the robot. Explain here min features of your “reactive robot”. Take some pictures.

4.- Programming the robot. Explain here main features of your program. Take some snapshots.

4.- Analysing your car & program with the rules. Write the main features of the observed behaviour of your car (according to the classifying rules).

5.- What would you like to do better, to improve on your car? On your program?

Module 4

Guidelines 4.1

Face to face course

Brainstorming:

The Trainer defines the problem:

How the use of technology (alternative: robotics tecnnology) in school class could change the traditional teacher-centred model of knowledge transmission?

- Encourages an enthusiastic, uncritical attitude among trainees
- Tries to get everyone to contribute and develop ideas (orally)
- Notes down on a blakboard ideas that come out of the session
- Doesn’t criticise trainees’ ideas at this stage!
- Makes a synthesis summarizing trainees' ideas as they emerge from brainstorming.

E-learning

The trainees are encouraged to find, share and present on qualitative resources / papers (one or two) about the role of technology in education through the forum of their eclass and Dropbox utility.

Guidelines 4.2

constructivism and constructionism in education

face to face course

The trainees are separated in groups of 4-5 persons. The following written instructions are given to each group:

- *exploiting the paper*
    - *Ackermann E., (2001) Piaget's constructivism, Papert's constructionism: What's the difference? Future of Learning Group Publication* (trainees have already read the paper through eclass)

    Talk inside your group and note the main similarities and differences between constructivism and constructionism (20 min)
- *Define one representative to present to the whole class the opinions of your group (5 min)*

The trainer makes a synthesis of trainees' answers and presents his/her own ones (if they are different from those presented by the trainees) focusing on principles such as (15 min):

- the cognitive background and culture of the learner plays an important role for learning
- learners construct their own understanding and they do not simply mirror and reflect what they read
- learning is an active, social process
- stress the need for collaboration among learners, in direct contradiction to traditional competitive approaches.
- learning is most effective when part of an activity the learner experiences as constructing a meaningful product
- Constructionist learning involves students drawing their own conclusions through creative experimentation and the making of social objects.
- Instructors have to adapt to the role of facilitators and not transmitters of subject matter. The constructionist teacher takes on a mediational role rather than adopting an instructionist position. Teaching "at" students is replaced by assisting them to understand problems in a hands-on way.

Eclass

The paper *Ackermann E., (2001) Piaget's constructivism, Papert's constructionism: What's the difference? Future of Learning Group Publication* becomes available for trainees through eclass from the beginning of the course and is recommended for reading.

The trainees are encouraged to write their opinion on the same topic in the forum of their eclass.

Text 4-2.doc (including text and bibliography)

Constructivism and Constructionism in Education

1.1. Constructivism

Constructivism is a theory about learning, one where the learner has a "a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse and reflection" (Brooks and Brooks 1993). Simply put, when someone doesn't understand something, it bothers them internally. This nagging is resolved when one has the chance to experiment by doing, share the experience with others, and have time to think about the confusion.

Constructivism has roots in philosophy, psychology, sociology, and education. But while it is important for educators to understand constructivism, it is equally important to understand the implications this view of learning has for teaching and teacher professional development.

Constructivism's central idea is that human learning is *constructed*, that learners build new knowledge upon the foundation of previous learning. This view of learning sharply contrasts with one in which learning is the passive transmission of information from one individual to another, a view in which reception, not construction, is key.

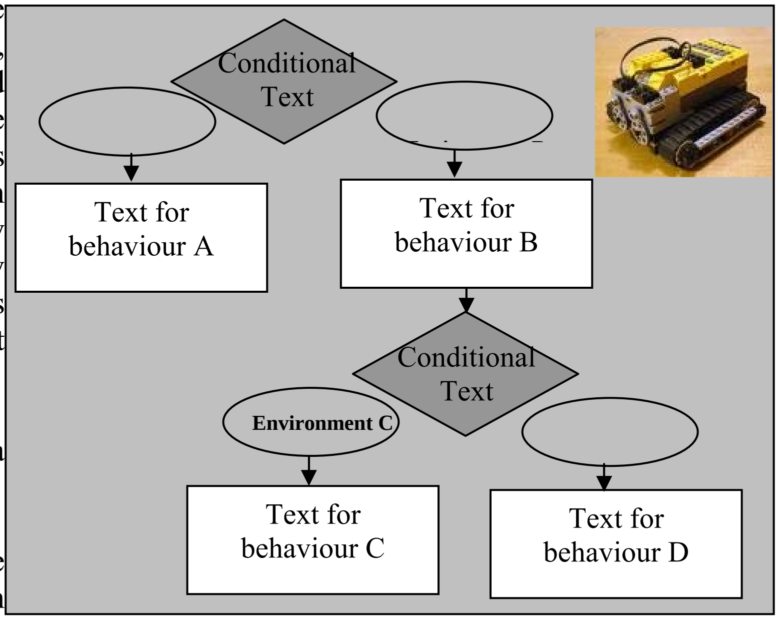
Two important notions orbit around the simple idea of constructed knowledge (Hoover, 1996). The first is that learners construct new understandings using what they already know. Learners come to learning situations with knowledge gained from previous experience, and prior knowledge influences what new or modified knowledge they will construct from new learning experiences. The second notion is that learning is active rather than passive. Learners confront their understanding in light of what they encounter in the new learning situation. If what learners encounter is inconsistent with their current understanding, their understanding can change to accommodate new experience. Learners remain active throughout this process: they apply current understandings, note relevant elements in new learning experiences, judge the consistency of prior and emerging knowledge, and based on that judgment, they can modify knowledge.

Key assumptions of the constructivist perspective are summarised below (Driver and Bell, 1985):

- What the students currently believes, whether is correct or incorrect, is important
- Despite having the same learning experience, each individual construct on individual meaning
- Understanding or constructing a meaning is an active and continuous process
- Learning may well involve some conceptual changes
- When students construct a new meaning, they may not believe it but may give it provisional acceptance or rejection
- Learning is not a passive process, but active, and depends upon the students taking responsibility to learn.

Constructivism has important implications for teaching that should be carefully considered when designing instruction (Hoover, 1996):

- teaching cannot be viewed as the transmission of knowledge from enlightened to unenlightened; constructivist teachers do not take the role of the "sage on the stage." Rather, teachers act as "guides on the side" who provide students with opportunities to test the adequacy of their current understandings.
- if learning is based on prior knowledge, then teachers must note that knowledge and provide learning environments that exploit inconsistencies between learners' current understandings and the new experiences before them. This challenges teachers, for they cannot assume that all children understand something in the same way. Further, children may need different experiences to advance to different levels of understanding.
- if students must apply their current understandings in new situations in order to build new knowledge, then teachers must engage students in learning, bringing students' current understandings to the forefront. Teachers can ensure that learning experiences incorporate problems that are important to students, not those that are primarily important to teachers and the educational system. Teachers can also encourage group interaction, where the interplay among participants helps individual students become explicit about their own understanding by comparing it to that of their peers.
- if new knowledge is actively built, then time is needed to build it. Ample time facilitates student reflection about new experiences, how those experiences line up against current understandings, and how a different understanding might provide students with an improved (not "correct") view of the world.



This constructivist view of learning also influences the role of teachers. The main task that teachers are assumed to perform, according to constructivists, is no longer the transmission of knowledge, but the facilitation and coaching of learning (Korthagen, Klaassen, & Russell, 2000).

The *constructivism* as an educational - learning process. The expertise in "commanding tasks to robots so that they have certain behaviours (with a goal in mind)" can be the object of constructivist education (on the teacher's side) and learning (on the student's side).

For this we have to select and adapt to our objective the most pertinent characteristics of the theories of Piaget and Vygotsky, known as cognitive reconstruction theories assuming a constructivist education-learning.

The adaptation process according to Piaget

The Piaget theory is a theory of the *dynamic construction* of knowledge. Piaget bases this construction on the process of “majorant” (increasing) adaptation, that formulates as the tendency to a balance (equilibrium) every time bigger between the processes of *assimilation* and *accommodation*.

Assimilation	⟺	**Accommodation**
We intend “the process by which the subject interprets the information that come from media, on the basis of his/her schemes or the available conceptual structures		We intend “the process of modification of schemes or conceptual structures by the subject, when trying to assimilate new characteristics of the media”

The assimilation suggests that “we see” all things not as they are, but as we (ourselves) are, according to our available schemes of understanding. Of the reality we incorporate only those (inclusive) elements that correspond to ours previous schemes[4].

If only the assimilation exists, great part of our knowledge would be fantastic and it leads to continuous mistakes.

The accommodation explains the tendency of our schemes of assimilation to adapt themselves to reality, and to transform themselves into “agreed” (or more *balanced*) schemes. If my schemes are insufficient to assimilate a determined situation, I will probably modify some of my schemes adapting it to interpret additional characteristics of the situation.

But the accommodation supposes not only a modification of the previous schemes based on the assimilated information, but also a new assimilation or reinterpretation of the data or the previous knowledge based on the new constructed schemes. It is what we call “reconstruction” and is the most important effect of the adaptation and the personal constructivist process.

Education - learning like a process of successive reequilibration. When a student has a first contact with a new “knowing work”[5] generally s/he is unbalanced in front of it. S/he applies her/his previous cognitive schemes to it (his/her context) and generally s/he assimilates only part of the aspects of the subject. A double work: a *direct empirical interaction* with the object and *a linguistic interaction* with a teacher (in reference to the object). This will facilitate the student to have a progressive adaptation both to the understanding of the actions of this object and to the understanding of the terms of the language with which we described these actions.

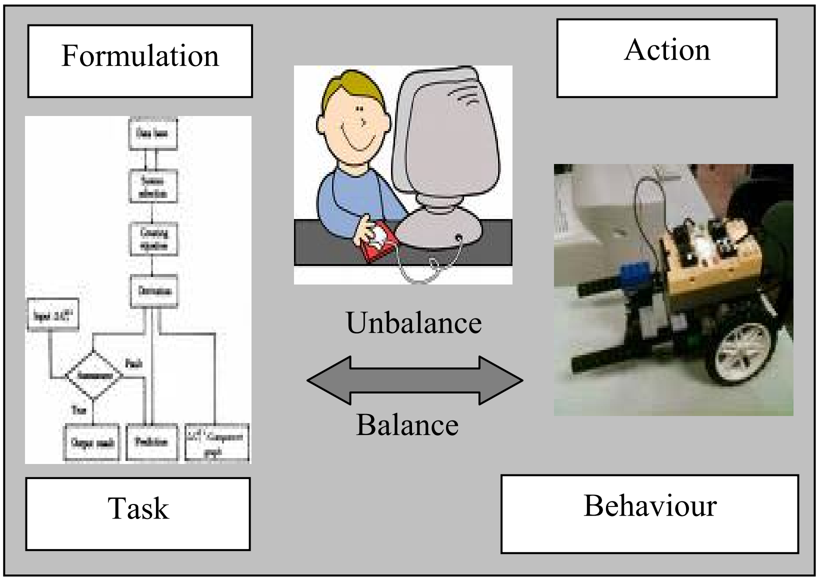
S/he will reach a one first reequilibration, but a new interaction with the object and/or a new problematic question of the teacher regarding the object will lead the student to

[4] see the (constructivist) theory of AUSUBEL about the significant verbal learning

[5] this term designates any element, more or less complex, of our environment whose structure and/or function must later be explained by the student

a new situation of disequilibrium that s/he will have to overcome through the same procedure (of do-with and of speak-on the object) to reach a new state of equilibrium. And so on…

The main task of the teacher is to cause successive “controlled” unbalances (in order to not introduce too many new aspects in the same problematic question) and, to guide (lead) with “demos”[6] towards the reequilibrium of the student (showing “well realized” actions contingent with the object, and linguistic expressions referring to the object and “well formulated”).
The aim of the student is essentially to follow the process in an “active intellectually” manner, making an effort in identifying and incorporating the new inclusive elements in the previous schemes and trying to add meanings to the teacher’s demos[7].
“greater” than the previous one, in the sense that permits a greater understanding of the social-natural characteristics of the object. For that reason Piaget speaks of as a “ *majorant* adaptation.
Let us say, eventually, that in front of “knowing works, where the student must be able to talk about verbally to them or on them, the individual constructivism of the student does not fit; one is necessarily “a guided” constructivism of the student: interacting with the object and, concurrently, engaging in a dialog with the teacher.



Levels of complexity of the reequilibration
Following J.I. Pozo[8], Piaget elaborated, throughout all its work, several models of the equilibrium process. In the last of them he says that the equilibrium between assimilation and accomodation takes place (and breaks) in three levels of increasing complexity:

1 At a first level: *equilibrium with the facts*: the individual schemes must reach the balance with the new objects that s/he assimilates

2 At a second level: *equilibrium with the schemes*: s/he must reach a balance between the old and new individual schemes, that must be assimilated and comply reciprocally.

[6] We will see better this issue when we consider the Vygotsky theory

[7] to construct with it the elaboration of shared meanings

[8] POZO, J.I., Teorías cognitivas del aprendizaje, Ed. Morata, Madrid, 1989

In a third level: *equilibrium with the hierarchic structure of schemes*: s/he must reach a balance between the old and new hierarchies of schemes.

1.2. Constructionism

What is the difference between Piaget's constructivism and Papert’s “constructionism”? As Ackerman (2001) suggests “Beyond the mere play on the words, I think the distinction holds, and that integrating both views can enrich our understanding of how people learn and grow. Piaget’s constructivism offers a window into what children are interested in, and able to achieve, at different stages of their development.

The theory describes how children’s ways of doing and thinking evolve over time, and under which circumstance children are more likely to let go of—or hold onto— their currently held views. Piaget suggests that children have very good reasons not to abandon their worldviews just because someone else, be it an expert, tells them they’re wrong. Papert’s constructionism, in contrast, focuses more on the art of learning, or ‘learning to learn’, and on the significance of making things in learning. Papert is interested in how learners engage in a conversation with [their own or other people’s] artifacts, and how these conversations boost self-directed learning, and ultimately facilitate the construction of new knowledge. He stresses the importance of tools, media, and context in human development. Integrating both perspectives illuminates the processes by which individuals come to make sense of their experience, gradually optimizing their interactions with the world.”

Moreover, Papert also approaches the issue of relevance and emotional attachment with an observation that by adding new objects such as “cybernetic construction kits” for LEGO/Logo, children might “want to learn it because they would use it in building” (Harel and Papert ,1991).

Papert (1980) and later Resnick (1994) lay out a vision for learning-by-design which enables students to learn by participating in the design of digital environments such as Digital Manipulatives (Resnick, 1994) and Logo (Papert, 1980). Within the constructionist frame, the learner is not a passive recipient of information; rather s/he is an active participant in the learning process, working to construct knowledge through experience, thusly shifting the control of digital learning into the hands of learners. Papert (1980) describes four learning-by-design principles.

Individuals are active learners and control their own learning process. Individuals create concrete, tangible evidence (artifacts) that reflect their understanding. Artifacts are shared collectively as well as reflected upon individually to extend one’s understanding. The learning problems and contexts are authentic, that is, they focus on solving a practical problem.

Papert explained constructionism as including, but going beyond what Piaget would call constructivism (Papert, 1991, p. 518). As an extension of constructivism, the constructionist approach involves learners building knowledge and meaning through the construction of something external or shareable (Papert, 1991). Furthermore, such a process also provides a motivating context for students to learn the subject matter and content and test their knowledge. Just as maintained by Puntambakar and Kolodner (2005) that when students are engaged bin cycles of designing, evaluating, and redesigning, they also have the opportunity to confront their understanding and misunderstandings of . . . concepts (p. 185). This means that the learner is a designer, rather than just the receiver of designed materials. The (instructional) designer is thus charged with creating a learning environment within which the learner can explore and create. Facilitators later serve as advisors to learners who are dealing with their own needs within the environment (Hannafin & Hill, 2002).

Resnick (1994) described the value of construction as actively engaging participants in creating something that is meaningful to themselves or to others around them. Constructionism urges learners to build a context for learning through community-supported collaborative construction (Bruckman, 1998, p. 50). This way, a constructionist learning environment can provide learners a self-motivated and peer-supported environment (Bruckman, 1998).

In the robotic context, the phase of the physical building of the robot should be distinguished from the phase of programming it (or, saying better, of instructing it). The Lego Robotic system leads to a bottom-up oriented developing of the first phase: starting from the basic brick, which defines the fundamental standard for all the other elements of the Lego kits, you can build more and more complex architectures combining simpler, already realized parts. The reusability of these components is not so obvious and it depends on the detailed process of construction of the robot. For example, a large bumper mechanically connected to one or two touch sensors is a more o less replicable part of a robot able to react to obstacles found during its movement, but very often changing robot requires minor modifications to an accessory like a bumper. These limitations in reusability are apparently made even worst in the NXT system whose kit contains much less traditional pieces in favour of more technical elements (this aspect is referred by the student who is presently working with the kit and it must be more deeply investigated). Actually, kids and adults using Lego Mindstorms experience an increasing ability to build robots: they start from proposals given in the documentation which comes with the kit, in other books and in specialized web sites on the Internet; later the can try to design new architectures by themselves applying general rules they applied during this progressive learning process. But this kind of layered knowledge seems not to be so clearly formalized (and so easily formalizable) as in the Logo environment.

Especially, *Learning by Design* emerges from the constructionist theory that emphasizes the value of learning through creating, programming, or participating in other forms of designing. The design process creates a rich context for learning. Learning by Design values both the process of learning and its outcomes or products. The essence of Learning by Design is in the construction of meaning. Designers (learners) create objects or artifacts representing a learning outcome that is meaningful to them.

Specific guidelines for effective Learning-by-designing provided by Resnick (http://llk.media.mit.edu) are:

- Design projects that engage kids as active participants, giving them a greater sense of control and responsibility for the learning process.
- Design projects that encourage creative problem-solving.
- Design projects are often interdisciplinary, bringing together ideas from art, technology, math, and sciences.
- Design projects help kids learn to put themselves in the minds of others, since they need to consider how others will use the things they create.
- Design projects provide opportunities for reflection and collaboration.

- Design projects set up a positive-feedback loop of learning: when kids design things, they get new ideas, leading them to design new things, from which they get even more ideas, leading them to design yet more things, and so on.

Learning by Design strongly suggests that tasks should be based on hands-on experience in real-world contexts. The designers/participants should be given the option of multiple contexts so that they can devise multiple strategies when they use the problem-solving process. Because the learning process is open and varied according to the student learning preferences, skills, and knowledge, it is important that there be a balance among guided tasks, challenges, discussions and reflections that follow. Collaborative work allows the learners to obtain feedback from both peers and the instructor, who primarily plays the role of facilitator (Han and Bhattacharya, 2001).

In summary, the essence of Learning by Design lies in the experience of the learner as a designer and creator of an external, shareable artifact. Learners become more accountable for their learning through designing, sharing, piloting, evaluating, modifying their work, and reflecting on the process. The instructor acts as a facilitator and motivator by creating an open-ended learning environment and by challenging and scaffolding the learners in a balanced manner while providing options with rich and varied feedback. Through this experience, learners construct meaning and internalize the learning process (Han and Bhattacharya, 2001).

What does it mean *constructionism* in (elementary) robotics? Following Papert's words, " … [constructionism] adds [to constructivism {learning as "building knowledge structures"}] the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe", we must define more and more clearly what this means in the robotic context.

A progressive knowledge means using the past experience in order to synthesize new experiences and a new knowledge. In case of Logo it is realized in two aspects. First, through the recursive procedural paradigm which permits, starting from the language primitives, to create substantially homogeneous building blocks (i.e. they can be used just like new primitives, one command and possible parameters). Second, through the drawing turtle paradigm, which operates on a 2D simple environment: complex figures can be built juxtaposing simpler, already programmed, parts.

When you consider the robotic context, you must distinguish the phase of the physical building of the robot from the phase of programming it (or, saying better, of instructing it). The Lego Robotic system leads to a bottom-up oriented developing of the first phase: starting from the basic brick, which defines the fundamental standard for all the other elements of the Lego kits, you can build more and more complex architectures combining simpler, already realized parts. The reusability of these components is not so obvious and it depends on the detailed process of construction of the robot. For example, a large bumper mechanically connected to one or two touch sensors is a more o less replicable part of a robot able to react to obstacles found during its movement, but very often changing robot requires minor modifications to an accessory like a bumper. These limitations in reusability are apparently made even worst in the NXT system whose kit contains much less traditional pieces in favour of more technical elements (this aspect is referred by the student who is presently working with the kit and it must be more deeply investigated). Actually, kids and adults using Lego Mindstorms experience an increasing ability to build robots: they start from proposals given in the documentation which comes with the kit, in other

books and in specialized web sites on the Internet; later the can try to design new architectures by themselves applying general rules they applied during this progressive learning process. But this kind of layered knowledge seems not to be so clearly formalized (and so easily formalizable) as in the Logo environment.
Considering now the programming phase, things appear even more problematic. If we build a simple robotic version of the Logo turtle, we do not add any special improvement to the learning qualities of the Logo environment. But a robot is generally characterized by some important properties:

- Autonomy: the robot acts without being in continuous connection with a 'master' computer
- Proactivity: in its knowledge it is included the possibility to take more or less autonomous decisions in presence of not completely foreseen stimula
- Knowledge of its environment: the robot could have a model, more or less precise, of the world in which it is moving and its behaviour could depend on this knowledge

The programming of a robot seems to be much more based on a 'per objectives' approach than representing the application of a layered sequence of applied abstractions like in a general purpose procedural or object oriented language. For example, following the semantic of the Lego Robotic Invention System, if you have a robot with a couple of motors controlling separately wheels or tracks, plus a proximity sensor and a light sensor, you can define separately: a general moving action (for example, starting both motors at the same power), a reaction to the reaching of an obstacle revealed by the proximity sensor, a reaction to the deviation from a drawn path revealed by the light sensor. The actions can be programmed with some simple sequences of very elementary commands and, though a 'my command' option is provided to allow the user to define his/her own macrocommands, this option seems to be very rarely compulsory or at least suggested by the complexity of the required programme.
Thus, the question is: what does it remain of the layered and structured knowledge of Logo when programming a Lego robot? What did Papert have in mind when inspiring the Lego advisory board during the designing phase of their robotic system?
We should remember that the RCX and NXT are actually the descendants of previous experiences: the Lego DACTA division, the Lego Logo and Cricket projects at MIT. There is also another descendant of these old experience, PicoCricket (http://www.picocricket.com/). Some other references:
http://llk.media.mit.edu/projects.php?id=1942
http://mres.www.media.mit.edu/people/mres/
http://uchcom.botik.ru/educ/history/1995/lego/lego.html
http://eurologo.web.elte.hu/lectures/hecht.htm
http://scholar.lib.vt.edu/ejournals/JTE/v9n2/jrvinen.html
http://www.ucls.uchicago.edu/students/projects/1994-95/Lego-Logo/newsletter.html
http://el.media.mit.edu/projects/ybl/
http://www.blakeschool.org/academics/lower/projects/lego/0506gears/page1a.html
By the way, some current projects in the Resnik's laboratory at MIT are of interest:
Learning About Motion (http://llk.media.mit.edu/projects.php?id=212)
Logo blocks (http://llk.media.mit.edu/projects.php?id=141)
Tangible Programming with LEGO Bricks
http://llk.media.mit.edu/projects.php?id=138)

Robotic Art Studio (http://llk.media.mit.edu/projects.php?id=611)
Learning Engineering by Designing Robots
http://llk.media.mit.edu/projects.php?id=345)
Flogo: Robotics Programming for Children
(http://llk.media.mit.edu/projects.php?id=535)

What is LOGO? Who needs it? Some reflections from: S. Papert, "Introduction: What is Logo? And Who Needs It?", in *Logo Philosophy and Implementation*, Montreal, Canada, LCSI, 1999. Available at http://www.microworlds.com/company/philosophy.pdf

- Why then does it need an introduction? . . . The point is the same as the first of two extensions to the principle of learning by doing: *we learn better by doing … but we learn better still if we combine our doing with talking and thinking about what we have done*.
- What makes (them) all Logo projects? An easy answer might seem to be that they all use a programming language called "Logo." They do, but this is not enough to qualify, for when you read the chapters you will see that what is important to the writers is not the programming language as such but a certain spirit of doing things: I (and again I guess all the authors) would see many projects that use Logo as thoroughly counter to the "Logo spirit."
- "Logo is a programming language plus a philosophy of education" and this latter is most often categorized as "constructivism" or "discovery learning."
- I want you to consider the idea that the right answer to "what is Logo" cannot be "An X plus a Y." It is something more holistic and the only kind of entity that has the right kind of integrity is a culture and the only way to get to know a culture is by delving into its multiple corners.
- This acceptance of "negatives" is very characteristic of the Logo spirit: what others might describe as "going wrong" Logoists treat as an opportunity to gain better understanding of what one is trying to do. Logoists reject School's preoccupation with getting right or wrong answers as nothing short of educational malpractice. Of course rejecting "right" vs. "wrong" does not mean that "anything goes."
- The frame of mind behind the Logo culture's attitude to "getting it to happen" is much more than an "educational" or "pedagogic" principle. It is better described as reflecting a "philosophy of life" than a "philosophy of education." But insofar as it can be seen as an aspect of education, it is about something far more specific than constructivism in the usual sense of the word.
- I have adapted the word constructionism to refer to everything that has to do with making things and especially to do with learning by *making*, an idea that includes but goes far beyond the idea of learning by *doing*.
- But the constructionist content area is a different matter. *This is not a decision about pedagogic theory but a decision about what citizens of the future need to know*.
- So this is the choice we must make for ourselves, for our children, for our countries and for our planet: acquire the skills needed to participate with understanding in the construction of what is new OR be resigned to a life of dependency.
- A crucial aspect of the Logo spirit is fostering situations which the teacher has never seen before and so has to join the students as an authentic co-learner. This is

the common constructivist practice of setting up situations in which students are expected to make their own discoveries, but where what they "discover" is something that the teacher already knows and either pretends not to know or exercises self-restraint in not sharing with the students. Neither deception nor restraint is necessary when teacher and student are faced with a real problem that arises naturally in the course of a project. The problem challenges both. Both can give their all.

- The best way to become a good carpenter is by participating with a good carpenter in the act of carpentering. By analogy the way to become a good learner is by participating with a good learner in an act of learning. In other words, the student should encounter the teacher-as-learner and share the act of learning.
- Logo, both in the sense of its computer system and of its culture of activities, has been shaped by striving for richness in giving rise to new and unexpected situations that will challenge teachers as much as students.
- In short I like to recognize – only slightly simplifying a complex issue—two wings of digital technology: the technology as an informational medium and the technology as a constructional medium . . . Of course the two wings are equally important; but popular perception is dominated by the informational wing because that is what people see . . .
- However here too there is an imbalance: in large part because of the absence of suitable technologies, the constructional side of learning has lagged in schools, taking a poor second place to the dominant informational side.
- The primary way that digital technology will help is to provide more opportunity for wonderful teachers to work with wonderful students on projects where they will jointly exercise wonderfully powerful ideas.
- The true power of both sides – the constructional and the informational sides — of the digital technology comes out when the two are put together.
- Yes doing is a good way to learn. And it is made better by talking and thinking. But we learn best of all by the special kind of doing that consists of constructing something outside of ourselves. . .
- They [several types of activities including robotic constructions] are subject to the test of reality; if they don't work they are a challenge to understand why and to overcome the obstacles. They can be shown, shared and discussed with other people. But what causes some of them to be specially valued in the Logo culture is their contact with powerful ideas that enables them to serve as transitional objects for the personal appropriation of the ideas.
- But here is a paradox of our educational system: we want children to learn at least some of Euclid but deny them the opportunity to develop the wings of the mind that led geometry to its power. Why would anyone do such a foolish thing? I think that the answer is really quite obvious: The culprit is the influence of technology.
- It was that old technology that pulled geometry down to earth, for it is essentially a technology for drawing static figures on flat surfaces.
- Much of my own current work consists of extending earlier ideas about using turtles to re-empower geometric ideas by breaking the static barrier.
- The Logo programming language is far from all there is to it and in principle we could imagine using a different language, but programming itself is a key element of this culture.
- So is the assumption that children can program at very young ages.

- And the assumption that children can program implies something much larger: in this culture we believe (correction: we know) that children of all ages and from all social backgrounds can do much more than they are believed capable of doing. Just give them the tools and the opportunity.
- Opportunity means more than just “access” to computers. It means an intellectual culture in which individual projects are encouraged and contact with powerful ideas is facilitated.
- Doing that means teachers have a harder job. But we believe that it is a far more interesting and creative job and we have confidence that most teachers will prefer “creative” to “easy.”
- But for teachers to do this job they need the opportunity to learn. This requires time and intellectual support.
- Just as we have confidence that children can do more than people expect from them we have equal confidence in teachers.
- We believe in a constructivist approach to learning.
- But more than that, we have an elaborated constructionist approach not only to learning but to life.
- We believe that there is such a thing as becoming a good learner and therefore that teachers should do a lot of learning in the presence of the children and in collaboration with them.
- We believe in making learning worth while for use now and not only for banking to use later.
- This requires a lot of hard work (we’ve been at it for thirty years) to develop a rich collection of projects in which the interests of the individual child can meet the powerful ideas needed to prepare for a life in the twenty-first century.
- It is based on the belief that the Logo philosophy was not invented at all, but is the expression of the liberation of learning from the artificial constraints of pre-digital knowledge technologies.

Some reflections from: G. Marcianò, S. Siega, , “Papert, Feuerstein, didattica innovativa e formazione dei docenti”, Proceedings of the e-learning Expo 2005, Ferrara, Italy, 2005.
http://robotica.irrepiemonte.it/robotica/biblografia/doc/Papert_Feuerstein_x.pdf

- The [Fauerstein] convintion starts from the assumption that any individual intellectually evolves all along his/her life without any environmental or genetic limitation.
- [The Fauerstein’s method] is fundamental for developing the individual learning process, a challenge to fight the social marginalization; for learning to learn, for knowing how to adapt oneself to innovations; for making self-efficiency and self-regard to grow.
- The figure of a mediator plays the role of exciting and supporting individual paths towards a cognitive improvement.
- The mediator creates the conditions so that learners may gradually take direct responsibility of their learning and start to self-evaluate.
- When Fauerstein talks about intelligence he consider a subject that can be taught, guiding the learner to observe and to put questions, stimulating to compare objects and events and to look for links between facts, convincing to use a correct and appropriate vocabulary.

- In the Fauerstein's method there is a continuous exchange of information on different levels (logic, emotive, cultural, affective, etc.) between mediator and mediated. Teachers enrich professionally themselves both under the methodological-educational and relational point of view. This enrichment is not based on notionistic but logic strategies: anybody can have the answer to a problem provided he/she can give a logical demonstration.
- The Mediator acts so that every information becomes knowledge: it means that he/she offer to the learners the possibility to learn and to interpret, to organize and to structure all the information received from the environment and, consequently, this stimulates the possibility to become autonomous in learning and adapting themselves with flexibility to new situations.

The teacher role in Papert approach. The focusing comments by Papert and the real experience of synthesize constructionism and the Fauerstein's method may help to have a clearer idea of how constructionism may be applied to educational robotics. Some general principles may be derived from the sentences aforementioned.

- Educational Robotics is not taught to add new competences to traditional curricula, it is not taught at all. It acts as a problematic challenge both to teachers and students to face practical problems where other competences can be exploited to find effective solutions that are hereafter used as argument of discussions and as source of new problems.
- Guidelines on using educational robotics can refer to specific (programming) languages and robotic architectures (kits) but they should not strictly depend on them. The goal should be how to instill a 'Logo spirit' when constructing, programming and moving robots: experimentations with different languages and robots could result much more methodological validated. Moreover suggestions (and not compulsory recipes) on how conducting discussions and on possible improving the given solutions must be supplied together with basic materials like constructing instructions, programme skeletons etc. This does not mean the programming phase is not important.
- Even in robotics there is no "right/wrong" dilemma: the learning activity proceeds step by step refining the problem specs and improving the more or less acceptable found solutions. It will be very common that the teacher has to afford unpredictable or at least unknown situations during which he/she is co-learner with his/her students. These situations will spontaneously arise during the lab activities because of the nature of robotics itself. And they give new opportunity to teachers and students to try out their skills and eventually their 'believed' limits.
- If we want to emphasize the "constructional side" of digital technology in spite of its "informational side", educational robotics is a perfectly balanced synthesis of "material" (the robot) and "immaterial" (the programme) construction. In this sense, other activities like exchange of experiences and guidelines through the Internet can be allowed without the risk to be prevailing on the mainstream activity.

Self-awareness, self-efficiency, self-regard, self-rewarding, that seem to be so relevant in the Fauerstein's approach, are easily stimulated with experiences of educational robotics. The role of the mediator is important as a co-learner during the developing and problem-solving phases.

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Internet resources

1. Lifelong Kindergarten at http://llk.media.mit.edu/mission.php
   The Lifelong Kindergarten group is fortunate to be located within the MIT Media Lab, a hotbed of creative activity. In one corner of the Media Lab, students are designing new musical instruments. In another corner, students are designing new social-networking software. This type of activity makes the Media Lab not just a good research lab, but a good place for learning, since people learn a great deal when they are actively engaged in designing, creating, and inventing things.
2. LEGO Engineering – Mindstorms education at http://www.legoengineering.com
   dedicated to providing educators with resources for teaching through engineering with LEGO materials.
3. Educational Robotics Repository at http://www.sci.brooklyn.cuny.edu/~sklar/er/er.html
   a shared space for collecting curricular materials on the use of educational robotics, currently in undergraduate classes
4. LEGO Mindstorms at http://mindstorms.lego.com
   the official site of Lego Mindstorms
5. Homepage of Seymour Papert at http://www.papert.org/
6. Homepage of Mitchel Resnick http://web.media.mit.edu/~mres/

Worksheet 4.2 (time 50 min)

(The trainees are separated in groups of 4-5 persons. The following written instructions are given to each group)

- exploiting the paper (already uploaded in your eclass)
  - *Ackermann E., (2001) Piaget's constructivism, Papert's constructionism: What's the difference? Future of Learning Group Publication* (trainees have already read the paper through eclass)

  Talk inside your group and note the main similarities and differences between constructivism and constructionism (20 min)
- *Define one representative to present to the whole class the opinions of your group (5 min)*
- Define one representative to present to the whole class the opinions of your group (5 min)

Guidelines 4.3

project-based learning

face to face course

The trainees are separated in groups of 4-5 persons (the synthesis of the groups might be different from the previous ones). The following written instructions are given to each group:

- exploiting the paper

Using LEGO Robotics in a Project-Based Learning Environment
Mike Carbonaro, Marion Rex, Joan Chambers, The Interactive Multimedia Electronic Journal of Computer-Enhanced Learning 6 (1) 2004

talk inside your group and note three main advantages of the project-based learning against the traditional teacher-centered teaching model of the transmission of knowledge (20 min)

- Define one representative to present to the whole class the opinions of your group (5 min)

The trainer makes a synthesis of trainees' answers and presents his/her own ones (if they are different from those presented by the trainees) (15 min) focusing on helping trainees to recognise the educational advantages of project-based learning as a model for classroom activities that shifts away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices.

eclass

The paper *Using LEGO Robotics in a Project-Based Learning Environment Mike Carbonaro, Marion Rex, Joan Chambers,* The Interactive Multimedia Electronic Journal of Computer-Enhanced Learning *6 (1) 2004* becomes available for trainees through eclass and is recommended for reading.

The trainees are encouraged to publish and exchange opinions on the same topic in the forum of their eclass and to evaluate the particular learning experience described in the paper (based on specific criteria, etc.) through the forum of e-class

Text 4.3 (including text and bibliography)

Project-based learning

Project-Based Learning is a comprehensive instructional approach to engage learners in sustained, cooperative investigation (Bransford & Stein, 1993). Project-Based Learning is a teaching and learning strategy that engages learners in complex activities. Projects focus on the creation of a product or performance, and generally call upon learners to choose and organize their activities, conduct research, and synthesize information. According to current research (Thomas, Mergendoller, & Michaelson, 1999; Brown & Campione, 1994), projects are complex tasks, based on challenging questions, that serve to organize and drive activities, which taken as a whole amount to a meaningful project. They give learners the opportunity to work relatively autonomously over extended periods of time and culminate in realistic products or presentations as a series of artifacts, personal communication, or consequential tasks that meaningfully address the driving question. PBL environments include authentic content, authentic assessment, teacher facilitation but not direction, explicit educational goals, collaborative learning, and reflection (Han and Bhattacharya, 2001) http://www.coe.uga.edu/epltt/LearningbyDesign.htm.

Project-based learning as a method of teaching and learning is mainly based on contemporary learning theories which argument that knowledge, thinking, doing and the contexts for learning are inextricably tied. We know now that learning is partly a social activity; taking place within the context of culture, community, and real life experiences (BIE, 2003). Knowledge construction has become a key term in describing a more active student role in developing and creating their own knowledge (see for example McCormick & Paechter, 1999). It is central in describing the process of learning within problem-based and project-based learning. It is based on pedagogical ideas from Dewey and certain constructivist perspectives (Steffe & Gale 1995).

Knowledge construction implies an active and reflective information-seeking process among the students where the teacher is not the primary or sole provider of information. Within these case studies it also implies a social process where the students have to relate to each other in order to complete their tasks. What is lacking in many studies, however, is how the use of information and communication technology influences the process of knowledge construction in different subject areas. One objective of the cases has been to provide better insight on how students work on knowledge management and construction in different activities and learning environments.

Project-based learning (PBL) is a model for classroom activity that shifts away from the classroom practices of short, isolated, teacher-centered lessons and instead emphasizes learning activities that are long-term, interdisciplinary, student-centered, and integrated with real world issues and practices.

PBL helps make learning relevant and useful to students by establishing connections to life outside the classroom, addressing real world concerns, and developing real world skills. PBL supports learners to develop a variety of skills including the ability to work well with others, make thoughtful decisions, take initiative, and solve complex problems.

In the classroom, PBL provides many unique opportunities for teachers to build relationships with students. Teachers may fill the varied roles of coach, facilitator, and co-learner. Finished products, plans, drafts, and prototypes all make excellent "conversation pieces" around which teachers and students can discuss the learning that is taking place.

Components of Project-Based Learning. Key components of Project-Based Learning that should be considered in describing, assessing, and planning for projects, are (Han and Bhattacharya, 2001):

1. Learner-centered environment
2. Collaboration
3. Curricular content
4. Authentic tasks
5. Multiple expression modes
6. Emphasis on time management
7. Innovative assessment

Learner-centered environment*:* PBL should be designed to maximize student decision-making and initiative throughout the course of the project involving learners in topic selection, and throughout the course of the project providing them control over the production, and presentation of artifacts. Additionally, projects should include adequate structure and feedback to help learners make thoughtful decisions and revisions. Learners should document their decisions, revisions, and initiative, with the am to enhance reflections on their learning process and capture valuable material for assessing their work and growth.

Collaboration: PBL aims to the development of communication and collaborative skills, enhancing group decision-making, interdependence, integration of peer and mentor feedback, providing thoughtful feedback to peers, and working with others as learners researchers.

Authentic tasks*:* PBL should connect to the real world stimulating learners to address real world issues that are relevant to their lives or communities.

Multiple presentation modes: It is important to support and prompt learners, in the course of the project, to effectively use various technologies as tools in the planning, development, or presentation of their projects.

Time management*:* Learners should have control of their learning through the course of the project, planning, revising and reflecting on their learning. Given the time frame and scope of a project, all projects should provide adequate time and materials to support meaningful doing and learning.

Innovative assessment: Assessment should be an ongoing process of documenting learning through the course of the project. PBL requires varied and frequent assessment, including teacher assessment, peer assessment, self-assessment, and reflection. Assessment practices should involve learners through consistent documentation of the process and results of their work enhancing reflection and self-assessment throughout the project.

Designing Projects based on Robotics. Constructionism is reflected in PBL by (Han and Bhattacharya, 2001):

- creation of a student-centered learning environment
- emphasis on artifact creation as part of the learning outcome based on authentic and real life experiences with multiple perspectives

Thus, learners are allowed to become active builders of knowledge while confronting misconceptions and internalizing content and associated conceptions.
Designing a robot to do even a simple task can place extensive demands on students' creativity and problem-solving ability (Druin & Hendler, 2000). Building and programming autonomous robots is an ideal context in which to situate a project-based learning experience where learners work collaboratively to understand the problem, propose viable solutions and construct their artefacts. It is quite important a guiding question or problem to set the stage and the project context to allow for a multitude of design paths. Then, students should collaborate over an extended period of time during a problem solving activity. The result of this collaboration is the construction of an artifact that will be presented to a wider classroom audience. The production of an artifact, that is readily sharable with a larger community of learners, encourages students to make their ideas explicit, whilst allows them to experience science concepts in a meaningful, personalized context (Penner, 2001).
Project-Based Learning encourages learners to engage in complex and ill-defined contexts. From the beginning, learners identify their topics and problems, then seek possible solutions. By participating in both independent work and collaboration, learners improve their problem solving skills thereby developing their critical thinking skills. However, one of the problems that learners face in such learning environments is what strategies to employ, how to start and proceed with the problem they have to face. To this end, different approaches have been suggested (Han & Bhattacharya, 2001; Houghton Mifflin, 2007).
Generally, three phases are suggested in conducting Project-Based Learning: planning, creating and implementing, and the processing (Han & Bhattacharya, 2001):

- in the *"planning" phase*, the learner chooses the project, locates the required resources, and organizes the collaborative work. Through these activities, the learner identifies and represents a topic, gathers relevant information and generates a potential solution.
- the *"creating" phase* is, or implementing the project. This phase includes activities such as development and documentation, coordination and blend of member contributions, and presentation to class members. In this stage learners are expected to build a product that can be shared with others.
- the activities for the *"processing"* the project *phase*, include reflection and follow-up on the projects. In this stage, the learners share their artifacts, obtain feedback, and reflect on the learning process and the project.

Moreover, specific features that need to be considered in organising the above phases are the following:

1. A "driving question or problem" that is anchored in a real-world problem and ideally uses multiple content areas, should serve to organize and drive activities
2. Opportunities for students to make active investigations that enable them to learn concepts, apply information, and represent their knowledge in a variety of ways
3. Collaboration among students, teachers, and others in the community so that knowledge can be shared and distributed between the members of the "learning community"
4. The use of technology as cognitive tools in learning environments that support students in the representation of their ideas: cognitive tools such as robotic kits,

computer-based environment guiding the robots, graphing and presentation applications, web-based resources.

Especially for organizing learners' activity in robotics-enhanced projects we propose a framework consisting of the following stages (see Table 1):

- **Engagement stage**: students are provided with an open-ended problem and get involved in defining the project. This stage requires the identification and representation of a scientific problem. Students work as a class putting their ideas into a question format. As they are doing so, they are identifying and representing a problem and different issues involved (*e.g. brainstorming at class level*).
- **Exploration stage**: students get familiar with LegoLogo, controlling devices and software, make hypothesis and test their validity in real conditions, provide initial ideas. Students are divided in groups in order to answer to simple questions and study specific cases in order to get familiar with the controlling devices and software (*e.g. work in groups with worksheets – structured activity*).
- **Investigation stage**: students search for resources and investigate alternative solutions. Students reconsider the problem and the different issues raised during the engagement stage based on their experience gained through the exploration stage. At this stage students in collaboration with the teacher formulate the driving questions/problems which link with the learning goals of the project. The student groups undertake to solve the particular problems, investigate alternative solutions and argument on their final proposals concerning the artifact and the software the developed (*e.g. work in groups with worksheets, keep diary – open activity)*.
- **Creation stage**: students share and combine their artefacts, synthesize 'solutions' to the project, reflect on their initial ideas. Students present their work in class and then each group work on the synthesis of a final 'product' including the artifact and the software (*e.g. work in groups with worksheets, keep diary – result in a product)*. This work may lead to similar solutions but also to innovative proposals.
- **Evaluation stage**: students share their ideas, products at class level, argument on their final proposals and evaluate them. Alternative solutions are presented at class level and evaluated based on the driving questions/criteria posed in previous stages of the project (stages of engagement, investigation). At this stage students should critically judge their work, express their opinions, compare their works, and reach a common proposal to the project (*e.g. make presentations, discuss, peer evaluation)*. Students should also reflect on and evaluate their collaboration.

The above stages are not serial but in many cases highly iterative, e.g. the creation stage may include investigation or the investigation stage may include creation. The main aim of the different stages and the supportive material provided in each one (such as worksheets, resources) is to engage learners in meaningful design experiences. To this end, we should design for designers – that is, to design things that will enable learners to design things (Resnick & Silverman, 2005). Thus, what is important in designing a project and the appropriate worksheets at each stage of the framework is to promote students to imagine, realize, critique, reflect, iterate (Maeda, 2000), and according to Resnick & Silverman (2005), to encourage students to design and redesign their artifacts, to mess with the materials, to try out multiple alternatives, to shift directions in the middle of the process, to take things apart and create new versions.

Stage	Description	Resources	Result	Proposed Tasks
Engagement stage	Students may be provided with an open-ended problem and get involved in defining the project and main issues involved	An open-ended problem Raw material: sites, newspapers, videos, magazines, stories, cases	Project description Open issues	Study of raw material such as newspapers, magazines, videos, stories, cases Discuss Express opinions/ideas Pose questions Negotiate Brainstorming
Exploration stage	Students get familiar with controlling devices and software, make hypothesis and test their validity in real conditions	Representative examples, general guidelines, educational material, software	Artifacts with specific functionality Diary	Study samples of representative constructions/programs Observe Gather information Experimenting Searching Collaborate / Negotiate / Argumentation
Investigation stage	Students formulate the driving questions / problems, investigate alternative solutions	General guidelines that organize students' investigation / diary. Educational material	Driving questions / problems Artifacts addressing the driving questions Diary	Reflect on previously defined open issues Make hypothesis that they can test Planning Collect evidence Interpret Evaluate Keep diary Collaborate / Negotiate /

				Argumentation
Creation stage	Students share and combine their artifacts, synthesize ‘solutions’ to the initial problem	Guidelines that organize students’ diary	Group products / solutions to the initial problem Diary	Evaluate previous work Share ideas Synthesize a product Keep diary Collaborate / Negotiate / Argumentation
Evaluation stage	Students share ideas & products at class level, evaluate final group proposals, synthesize the final product	Guidelines for peer evaluation and synthesis of a final product	Common accepted product	Present their products Discussion Peer evaluation

Table 1. Stages of students’ activity including the stage title, the tasks that students are expected to perform, resources provided to students, results, examples of students work and educational techniques adopted.

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18. Why do project-based learning? Available at: http://pblmm.k12.ca.us/PBLGuide/WhyPBL.html

Internet resources

1. Houghton Mifflin's Project Based Learning Space at http://www.college.hmco.com/education/pbl/background.html

   A site that supports course instructors, novice teachers, practicing teachers to a) do sustained inquiry on extended problems and projects b) get background knowledge on its theory and use in classrooms, and c) revisit generic teaching concepts.
2. San Mateo County Office of Education: Project-based learning at http://pblmm.k12.ca.us/PBLGuide/WhyPBL.html
3. Project-based learning with technology at http://www.coe.ksu.edu/pbl/8.htm

Worksheet 4.3 (time 50 min)

(The trainees are separated in groups of 4-5 persons. The following written instructions are given to each group)

- exploiting the paper (already uploaded in your eclass)

  Using LEGO Robotics in a Project-Based Learning Environment Mike Carbonaro, Marion Rex, Joan Chambers, The Interactive Multimedia Electronic Journal of Computer-Enhanced Learning *6 (1) 2004*

  talk inside your group and note three main advantages of the project-based learning against the traditional teacher-centered teaching model of the transmission of knowledge (20 min)

- Define one representative to present to the whole class the opinions of your group (5 min)

Module 5
Guidelines
Robotics as Learning Tool: Project Based Learning with Robotics

Introduction

Projects are long term activities that bring together ideas and principles from a number of subject areas. Teaching and learning through project seems to be a complex and demanding activity for teachers and students. As a part of this training course this section aims to provide the trainees with "a hands on" experience in designing robotic projects.

Learning Objectives

During this section we expect that trainees will:

- Reflect upon basic features of a robotic project which is developed according to constructivist and constructionist principles.
- Study an example of a project developed according to the theoretical framework proposed in previous lessons (five stages).
- Analyze each stage of the project according to the type of activities performed by teacher and student.
- Apply the same model to a subject of their interest.

General description of this section

The section 'Robotics as a Learning Tool' may cover 14 teaching periods (45 minutes). An outline of this section can be found in Table 1.

Table 1 Outline of the section ‘Robotics as a Learning Tool’

Duration	**Theme**	**Materials**
Part 1: Introduction		
1 hour	Important features of a project Methodology for organizing a project	Worksheet 5.1 Text 5.1 Slides 5
Part 2: Working out a real project		
1 hour 2 hours 2 hours 2 hours 1 hour	I: Work on Engagement stage II: Work on Exploration stage III: Work on Investigation stage IV: Work on Creation stage V: Work on Evaluation stage	Worksheet 5.2.1, Text 5.2 Worksheet 5.2.2, Text 5.2 Worksheet 5.2.3, Text 5.2 Worksheet 5.2.4, Text 5.2 Worksheet 5.2.5, Text 5.2
Part 3: Creating a new project		
3 hours	Develop a new project based on the proposed methodology	
Part 4: Evaluation		
2 hour	Presentations of new projects - Discussion	

1. Part 1: Introduction on the important features of a project

Trainees are working in small groups (4-5 people) on Activity 1 for 15 minutes.

Activity 1 **15 minutes**

(Working in groups of 4)

In previous sessions of this course we have thoroughly discussed the constructivism learning approach and its implications in teaching. Concerning Robotics in Educations we have illustrated features of learning by constructing artifacts and we have discussed the constructionism approach in teaching and learning.

Make a list of seven features that a robotic project should have in order to serve constructivist and constructionism perspectives of teaching and learning.
Be prepared to present your list to the rest of the class.

(Worksheet 5.1)
After the end of this activity trainees present their list to the rest of the class and the trainer summarizes their answers (20 minutes). If it is necessary, trainer can add more features in the list. (Additional information can be found in file text 5.1).

Methodology for organizing a project

Trainer presents with a slide show (file slides 5.1) the five stages of a project. This presentation can be enriched with as short description of each stage. Trainees also could be asked to combine the list of features they have created and these five stages. Stages and their description can be found in the file text 5.2.
Robotic projects with these features could be developed in five stages:

Engagement stage
Exploration stage
Investigation stage
Creation stage
Evaluation stage

2. **Part 2: Working out a real project**

At this stage trainees are going to work out a real project in order to explore and elaborate on its main stages through an authentic experience. As an example of such a project we propose the project "Setting a Bus in motion". It is designed for students of secondary education and its duration is 12-14 teaching periods (45 minutes). A general outline of the project is presented in Table 2.

Table 2: "Setting a Bus in motion"- Project outline

Stage	**Duration (teaching periods)**	**Teaching Theme**
Engagement stage	2	Public Transport A robot bus
Exploration stage	4-5	Getting to know the structural materials Construction of a robot car Programming a robot Use of light sensor
Investigation stage	2-3	Construction of the bus Suggest a solution
Creation stage	1-2	Synthesize and Create
Evaluation stage	1-2	Presentations & Discussion

A general description of each stage according to the teaching strategies we used and the activities that students and teacher perform at each stage can be found in Table 3.

Table 3: Strategies, tools and activities in each stage of the project.

Stage	**Teaching Strategies-Tools**	**Students activities**	**Teacher activities**
Engagement stage	Stimulate interest with pictures, videos or newspaper articles. Make real world connections Discussions in plenary session. Discussions in small groups. Handouts.	Share experiences with peers and teacher. Provide ideas for creation of questions and artifacts. Define the project. Determine collaboratively evaluation criteria.	Provide open ended activities. Facilitate discussions. Summarize. Emphases.
Exploration stage	Guided investigations. Introduction of new tools, skills and materials. Handouts.	Follow instructions. Experimenting. Observe. Gather information.	Create a learning environment. Give assignments. Provide structured

		Conclude. Compare.	set of inquiry steps for learner to follow. Reinforce learning.
Investigation stage	Formulate the problem and analyze it. Choose one problem to investigate (one for each group). Diary.	Ask and refine questions. Refine evaluation criteria. Select appropriate tools. Planning. Experimenting. Applying knowledge in new situation. Evaluate. Communicate ideas and findings to others.	Challenge students by asking questions. Mediate group work.
Creation stage	Select resources. Create final artifacts. Diary.	Synthesize. Collaborate and negotiate. Evaluate. Draw conclusions.	Ensure individual and group learning.
Evaluation stage	Presentation. Peer evaluation. Rubric.	Presenting final product. Evaluate. Compare. Give and take feedback.	Facilitate group evaluation and self-evaluation.

Trainees should go through the project stage by stage and complete the assignments described in the worksheets. At the end of each stage they are stimulated to complete the following table (Table 4) with ideas, interesting elements they found in the project and new ideas that they think as important (Worksheet 5.2.1, 5.2.2, 5.2.3, 5.2.4, 5.2.5).

Table 4

Stage	**Teaching Strategies-Tools**	**Students activities**	**Teacher activities**

At the end of each stage they share their thoughts in a plenary session and they complete their tables.

3. **Part 3:** Creating a new project

At this stage trainees are expected to use the methodology for designing robotic projects in order to develop a new project**.** Trainees, working in groups, are promoted to use the tables they have completed during part 2 in order to develop a new project. As time is not enough for full development of the project, a short description with activities of the project could be enough.

4. **Part 4:** Evaluation

At the end, each group presents its project. They get feedback from their peers and the trainer according to the description of each stage they have formulated during part 2.

Worksheet 5.1
Project –Based Learning

20 minutes
(Working in groups of 4)

In previous sessions of this course we have discussed thoroughly constructivism learning approach and its implications in teaching. Concerning Robotics in Educations we have illustrated interested features of learning by constructing artifacts and we have discussed the constructionism approach in teaching and learning.

Make a list of seven features that a robotic project should have in order to serve constructivist and constructionism perspectives of teaching and learning.
Be prepared to present your list to the rest of the class.

Text 5.1
Project –Based learning: Important features

In previous sessions of this course the constructivism learning approach and its implications in teaching has been thoroughly presented. Concerning Robotics in Education interesting features of learning by constructing artifacts have been illustrated. Finaly constructionism approach in teaching and learning has been discussed. At that point we suggested that the appropriate way to implementing robotics in a learning process is through projects. A robotic project with the following features may serve constructivism and constuctionism approach to teaching and learning.

A robotic project may focuses on creation of a product (artifact) that reflects learners' abilities and learners' understanding. Therefore project activities should be organized around a question (driven question) or a theme which can guide learners progressively through the learning process. The driven question or theme of the project should be open ended in order to serve different learning goals and different learning styles. It is also very important for a successful project, that the theme of the project is significant and meaningful for the learners. For example, projects which deal with real life problems provoke students' interest and motivation.

In a project learners are actively involved in the formation of the driven question and in the description of the final product. Clarification of the goals of the project and the criteria for assessment of the final product (rubrics) are collaboratively agreed by student and teachers in the beginning of the project. Learners organize their work by themselves and they work autonomously over extended periods of time.

Teacher is a facilitator /mediator of the learning process. S/he creates a learning environment and provides support for the learners. S/he allows them to take as much responsibility for their own learning as they can. Teacher keeps the balance between guiding his/hers students through learning activities and challenging them with interesting questions for further investigation.

Communication in group level and in the classroom is an important element of a project. Learners express their ideas and test their understanding through their collaboration in small group or in the classroom. Feedback from each other and the teacher give learners the opportunity to improve their work and meet the learning goals of the project.

Text 5.2 Methodology for organize a project in robotics

Engagement stage:	- students are provided with an open-ended problem and get involved in defining the project. This stage requires the identification and representation of a scientific problem. Students work as a class putting their ideas into a question format. As they are doing so, they are identifying and representing a problem and different issues involved (*e.g. brainstorming at class level*).
Exploration stage:	- students get familiar with LegoLogo, controlling devices and software, make hypothesis and test their validity in real conditions, provide initial ideas. Students are divided in groups in order to answer to simple questions and study specific cases in order to get familiar with the controlling devices and software (*e.g. work in groups with worksheets – structured activity*).
Investigation stage:	- students search for resources and investigate alternative solutions. Students reconsider the problem and the different issues raised during the engagement stage based on their experience gained through the exploration stage. At this stage students in collaboration with the teacher formulate the driving questions/problems which link with the learning goals of the project. The student groups undertake to solve the particular problems, investigate alternative solutions and argument on their final proposals concerning the artifact and the software the developed (*e.g. work in groups with worksheets, keep diary – open activity).*
Creation stage:	- students share and combine their artefacts, synthesize 'solutions' to the project, reflect on their initial ideas. Students present their work in class and then each group work on the synthesis of a final 'product' including the artifact and the software (*e.g. work in groups with worksheets, keep diary – result in a product).* This work may lead to similar solutions but also to innovative proposals.
Evaluation stage:	- students share their ideas, products at class level, argument on their final proposals and evaluate them. Alternative solutions are presented at class level and evaluated based on the driving questions/criteria posed in previous stages of the project (stages of engagement, investigation). At this stage students should critically judge their work, express their opinions, compare their works, and reach a common proposal to the project (*e.g. make presentations, discuss, peer evaluation).* Students should also reflect on and evaluate their collaboration.

Worksheet 5.2.1
Working out a real Project

I. Work on Engagement stage

Activity 1 **35 minutes**

"Setting a Bus in motion" is a robotic project designed for students of secondary education. Its duration is 12-14 teaching periods (45 minutes). The project follows the project model presented in previous sessions and it is developed in five stages.
We suggest you to read the description of the first stage (Engagement Stage) of the project and carry out all the activities described in the corresponding worksheets (Worksheet 1, Worksheet 2).

Activity 2 **10 minutes**

At the end of the Activity 1 discuss in your group the following issues:

1. What kind of difficulties may a teacher face during the implementation of this project?
2. What kind of difficulties may the students face during the implementation of this project?
3. Complete the following table with activities that may be included in the Engagement Stage.

Be prepared to share your thoughts with the rest of the class.

Engagement Stage

Stage	Teaching Strategies-Tools	Students activities	Teacher activities
Engagement Stage			

Description of the Project

Setting a Bus in Motion

Introduction

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

Goals

This activity may meet learning goals in the fields of Physics, Mathematics, Technology and Informatics, while fostering, at the same time, skills and attitudes.

Learning goals:

Learners, upon completion of this activity, will be able:

- 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 material (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:

Learners, upon completion of this activity, will be able:

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

Attitudes:

- to acknowledge and evaluate the contribution of science and technology to modern man’s welfare.
- to work in groups and collaborate with respect to everybody’s individuality.

Duration

The overall activity may cover 12-14 teaching hours, if wholly developed. However, a teacher may choose to cover just some of the activity stages and, in such a case, its duration becomes shorter.

	Duration
Engagement stage:	2 hours
Exploration stage:	4-5 hours
Investigation stage:	2-3 hours
Creation stage:	1-2 hours
Evaluation stage:	1-2 hours

Age group

This activity is meant for Secondary School pupils (Grades A, B & C) who have a basic knowledge on computer functions (familiarity with a operating system, saving and retrieving files). Lastly, it is assumed that the learners concerned have very little experience in robotics or none at all.

Inclusion in the school curriculum

The activity 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 (speed measurement) and Mathematics course (circle perimeter, ratios) of Secondary School.

Software/Material

Educational robotics require both, the use of suitable building material for the construction of robot models and the use of suitable software for their programming.

For such kind of activities, the structural material proposed is that of Lego Dacta. The robot model programming may be done with Lego MINDSTRORMS Education NXT.

Activity Description

The following description concerns a proposed application course in class. Its goal is to display tools 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 activity includes five development stages which are not always clearly distinct, but constitute a wider developmental framework.

Engagement Stage

2 hours

The inclusion of this activity in the rest of the curriculum may be done through the general issue of Public Transport. Public Transport, a subject matter of the course in

Technology, 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 a neighborhood.

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 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 in order to encourage the use of Public Transport?

Is Public Transport friendlier to the environment?

First Teaching Hour

In **Worksheet 1** 5 pictures are given, each one can rise discussion on various issues.

Picture1: 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 motivate 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 motivate 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 motivate discussion on 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 motivate discussion on safety matters. (**homeless.lib.uic.edu/.../London-Transport.htm**)

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

Second Teaching Hour

In the second teaching hour, students are asked to construct a robot bus to serve a specific 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 children in the previous teaching hour, 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 a 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 unit, the functions that we want the robot bus to perform and the route that is to cover are expected to have been clearly described.

As an example, Worksheet 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 connection with other means of transport (train).
Less downtown pollution and noise.	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 that the basic characteristics of a robot structure should be discussed. 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, the actions to be taken and perform them (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 during the time passengers get on and off the bus. It is expected to develop 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.

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

Setting a Bus in Motion

Worksheet: 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. Complete yourselves 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
1.

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

Setting a Bus in Motion

Worksheet: 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 be 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.