ROBOTICS in the Primary School – how to do it?

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Abstract. The paper describes how to introduce primary school children to robotics. Robotics is a part of ICT education and is implemented using LEGO constructional material. The principles on which the teaching method is based are outlined. The prerequisite conditions for a successful teaching environment are made clear. The teaching approach described has developed over many years of everyday teaching practice in primary schools in Bulgaria. Robotics is considered, not as a school experiment or short term attraction but in terms of curriculum. In Bulgaria robotics can officially be part of a school's curriculum, important for children's knowledge, children's thinking, and children's experience. It demands a lengthy, organized and systematic process of teaching.

Keywords: Primary school, robotics, IT education, LEGO, programming

1 Introduction

The primary school is the sector of the education system where the child first acquires initial knowledge and skills in a diversity of areas. At the same time the child also develops basic and enduring habits, concepts and attitudes to everything studied, to the teaching itself (including the place, the people and the approach related to it) and the learning as a process of individual intellectual activity. In this sense the primary school is a fruitful territory for any kind of novelties because they are perceived spontaneously and positively by a population free of fears and prejudice. It is at the same time a dangerous territory from the point of view that this is exactly a time when bad habits and attitudes can very easily be formed and reinforced.

The introduction of new technologies in the primary school provides many opportunities; and their application can serve the achievement of various objectives. The new technologies can influence both the educational environment in its complexity and any particular process of leaning and teaching. This is regardless of whether they are introduced as an independent subject of study, or used in a specific manner within other subjects of the curriculum.

Therefore regardless of the early age, new technologies should be presented in the full diversity of their multi-functionality. By this means the child may obtain a general overall, rather than deeper but disjointed, concept of the possibilities offered by the computer as an educational medium. The child will become acquainted with most of the many applications that they may later use.

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2 Robotics as a Part of ICT Education in Primary School

In Bulgaria, a non-mandatory national curriculum for learning to work with computers in primary schools was implemented in August 1998. It was introduced as a "free elective subject." The curriculum, in 11 modules, was written by us and had been developed within our school over the previous year [1]. Its main goal was to use the capabilities of the computer as a powerful new medium to challenge children in the context of normal activities for their age. This goal is attained by a project-oriented approach that we consider fundamental to the process of education. Children implement their ideas in projects that are based on personal experience and important events in their lives. Each project leads to the accomplishment of different types of activities, which are drawn from the school curriculum.

Considering the specific nature of the age-group – it is demanding for any such project to provide for:

- facilities accessible, understandable and attractive to the child;
- a great variety of activities with a permanently active role for the child in the learning process;
- the opportunity to work on topics and issues of interest to the child him or herself, which are directly related to their actual life experience;
- the creation of a particular product that is valuable from the child's point of view, and that is able to "materialize" the invested skills and efforts.

The teaching of robotics is one of the ways to realize this. This is why one module in this curriculum was "Working with computer systems for the control of models". It was based on my work with LEGO Dacta Control Lab [2] (LEGO construction and LOGO programming) in the primary school over the previous six years. This module was optional for technical and financial reasons.

In 2006 learning to work with computers became an "obligatory elective subject" in primary school. This subject was given the name "Information Technology". National standards were set and a new curriculum was written by a team of which I was a member. Both are on the Ministry of Education website, http://mon.bg.

The first curriculum remains an option for primary schools as a free elective subject. So, "Working with computer systems for the control of models", which was not included in the new curriculum for financial, technical, and teacher training reasons, is still possible. It means that every school has the freedom to teach this approved module, if they wish to do so and have the resources.

3 What Do We Want to Do Robotics for?

3.1 To give children a realistic understanding of robotics

Children of primary school age have a conception of robotics that has been formed from imaginary robots in films, TV, children's story books and as toys. This primitive

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conception is very different from the real robots, and their characteristics, that have specific application in the real lives of people. But their interest in this theme offers an opportunity to use their curiosity to learn about robotic reality.

In primary school we do not teach geography, history, physics, chemistry, biology, technology as subjects. In disciplines like "Man and Society", "Man and Nature" we introduce simple ideas, principles and terminology from these areas. It is the same with robotics. In teaching robotics we help the children to acquire some simple, basic knowledge, such as:

- the purpose of robots is to do carry out some human activity, replacing a person.
- robots are physical objects with a specific construction and include various types of mechanism;
- robots are operated and controlled by people by a specific computer program;
    - robots cannot do things that are not in the program;
    - robots cannot "think", "act" and "take a decision" independently, they "do" this only within the range of the possibilities in the program;
- robots are equipped with special devices, named sensors, through which to perceive variance in the world around, and to which they can react. The behaviour of robots is bound by the information from the sensors in the way humans are dependent on the information from the senses.
- robots interact with other physical objects;
- if in the program or in the construction of the robot there is a mistake, its behaviour will not be what we expect;
- mistakes can be dangerous for the robot (it breaks), people and objects around.

3.2 To relate to the other school disciplines, where possible

In primary school the disciplines are at an early stage of development. Relationships learned are simple but important. Robotics can use the knowledge from these disciplines and reinforce learning by providing a new situation in which they can use them. Knowledge can be from physics: vibration (oscillation) vs. rotation, energy transformation; from biology: sensors vs. senses; thinking vs. program, muscles vs. mechanism; similarly from mathematics, language, technology, arts, and the world around them.

When we take the knowledge from a subject lesson and use and see it in another context, that knowledge is made richer and understanding becomes deeper.

3.3 To organize a new educative environment in the school

Robotics lessons take place new inviting and challenging environment that helps and makes demands on the children: to think, to act, to have ideas, to create, to be emotionally engaged. Opportunity for these activities is limited in traditional teaching and classrooms. The elaboration of any model places the child in a situation of very dynamic activity. This is not merely the activity of manipulating elements and building a structure. The situation encourages the child to remember, examine, juxtapose and analyze the object in depth both as a whole and in its details; to seek

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and find the relations and interactions between parts; to realize functions, purposes and dependencies. The active action is not merely a complement - it is born and needed by the highly intellectual activity, and the great emotional attachment of the child to what they are doing.

3.4 To transform learning from individual activity into teamwork

Primary school children don't know how to work in a team. They must be taught this. The idea of teamwork is in conflict with the egocentrism that we all have. Therefore children must be convinced that teamwork is necessary. The traditional teaching quite rarely provides natural opportunities and necessity to work in a team. The lessons in robotics gives the teacher themes and situations that make teamwork appear absolutely natural. So the children will agree to subordinate their own wishes to the aims and objectives of the whole team.

The teamwork during these class hours, and the group projects of the class in the lessons, are very important for the children themselves and the school life in general. We begin by working in pairs and then build capacity for teamwork by expanding group size and differentiating and rotating roles.

4 How Do We Do It?

To make robotics lessons meaningful we must give the children the possibility to come know the basic principles and concepts in robotics on their own.

The construction. Children understand this only if they make the construction themselves. They will make many mistakes and each mistake will give a little more knowledge. It is not only about the mechanism inside, it is about the totality of the constructed object and what the function of every single component is. When one day they come to a situation where they want to make a new, original construction, they will use this knowledge and the process will not just be "trial - error" but intelligent and systematic. So, when we talk about robotics the construction is essential.

The programming. If we only make a demonstration of programming – by showing how a robot works – the children will not understand the programming and its relationship with the construction. We cannot have real knowledge about something we don't understand. The children must have an idea about what the robot will do and write the program themselves using the computer. Then they can see and understand the connection between the real physical object and the "abstract" program. Again, mistakes are important, because they make this connection clearer. The errors are quite flagrant and the disappointment – quite strong. The result of programming is very attractive and devoid of abstraction. It is easy to formulate as a prior expectation and clear to describe step by step, as it concerns behavior that the child knows from the real life.

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4.1 Materials

If we want to do robotics in primary school in this way, we need suitable materials. In my experience LEGO offers the best possibilities. LEGO is also a high-performance material environment that has the materials with which the children can build many different constructions, including mechanisms and sensors. There are systems with which children can easily program the models to have the function of real robots.

I have been using LEGO in my classes as a part of teaching about and with the new technologies. It initiates the children into the world of robotics by showing them how to use the computer to operate and control external objects.

The fact that these objects are actually the models they have created, almost guarantees the children's personal commitment to the activity. Basic principles are learned in the course of the practical activity of model making, operation and control. Complicated verbal explanations are avoided.

The emotional involvement of the child in the model emerging in the course of its creation is transferred to programming, which appears in this case as the final stage of the construction event. This is a strong motivation to maximum concentration, to seek options and for error identification and troubleshooting.

4.2 Organization

The school equipped a computer room with workstations for each pupil and a LEGO room with enough construction material to enable the simultaneous work of all the children. All pupils from 1st for 4th grade have lessons in information technology and LEGO construction and robotics.

In the IT classes the children acquire basic knowledge and skills of working with computer systems and information technologies by creating their own products during their work on various projects.

In the LEGO classes they become familiar with the structural material, the specific properties of each element and its possibilities, by gradually starting to create models. As models become more and more complicated there is a switch from individual to team work.

Like teaching computer skills, LEGO teaching breaks down construction into necessary skills. These are learned, applied, and refined through all four primary classes.

The integration of both subjects in LEGO-robotics starts around the end of the second year. The knowledge and skills acquired in the first year, find their application in the implementation and programming of their first controllable prototypes. This continues to the end of the fourth year. The models become more complex in structure and function. The greater diversity also poses more challenging programming tasks.

Inserting this course to the regular curriculum and providing the necessary technical support to conduct it has enabled all the children to participate on equal terms. They all participate in a continuous and consistent learning activity evenly spread over the entire four-year span of the primary school. This makes it possible to establish continuity between and relations among the year groups.

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4.3 Themes and models

In her/his work the teacher often faces a situation when she/he has to act as mediator between the new educational ideas, technologies, means and materials, and the child the end user for whom they are intended. The teacher reduces the overall idea to a sequence of specific steps and actions in order to make possible its practical realization. She/he negotiates the interaction between the idea and the child for whom it is intended. In construction this is carried out through the topics on which the children work and the prototypes they are creating.

In my work with controllable prototypes I use the LEGO Data Control Lab. For the primary school age group this system provides me all the necessary devices and tools to work with the children in a wholesome way. The only problem is that the published technical schemes of models are not intended for primary school kids and therefore they are not appropriate for them. The models are too complex as structures, the objects to recreate are vague in terms of "behavior", and insufficiently attractive as ideas since children are very unlikely to meet them in their everyday life.

In thinking over the prototypes I bear in mind two things:

a) the complexity of the structure into which the computer-controlled element is going to be integrated, and
b) the complexity of the guidelines to be followed for its implementation.

Thus, I choose models that:

- Can be implemented by the children as a construction task with their available skills and materials;
- Naturally presume the presence of controllable devices motors, lamps, sound elements, sensors;
- Will be attractive in both appearance and "behavior";
- Recreate objects familiar and interesting to the children;
- Recreate "behavior" that could be met in real life, and that is simple and clear enough to be described and then programmed.

4.4 The “situations”

The task is never reduced to the mere elaboration of an isolated controllable model. It should be an element of a situation reproducing as closely and realistically as possible the object's natural environment and its functioning within it.

The design of situations is more motivating, more challenging and more creative than the mere creation of an isolated prototype. It is richer in correlations, interactions and dependencies which should be sought, identified and recreated deliberately; which implies better cognition. The situation around the controllable model and its interlacing with other surrounding objects as it is in real life makes its "behavior" more authentic. The behavior is more understandable as it is somehow dependent on its ambiance and interacts with it. This helps the children to see more clearly the algorithm of functioning of the model and comprehend its purpose. In turn, this gives more sense to programming and reduces the degree of its abstraction. Moreover the modeling of situations is conducive to the organization of team-work. The objects are numerous but they are all elements of a large comprehensive project. Every child

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participates actively in creation, making his/her individual contribution. Another advantage is that there could be more than one controllable object which makes programming richer, more sophisticated and more open to variation.

5 Where to Begin and How Far to Go.

Street lighting. (fig.1).

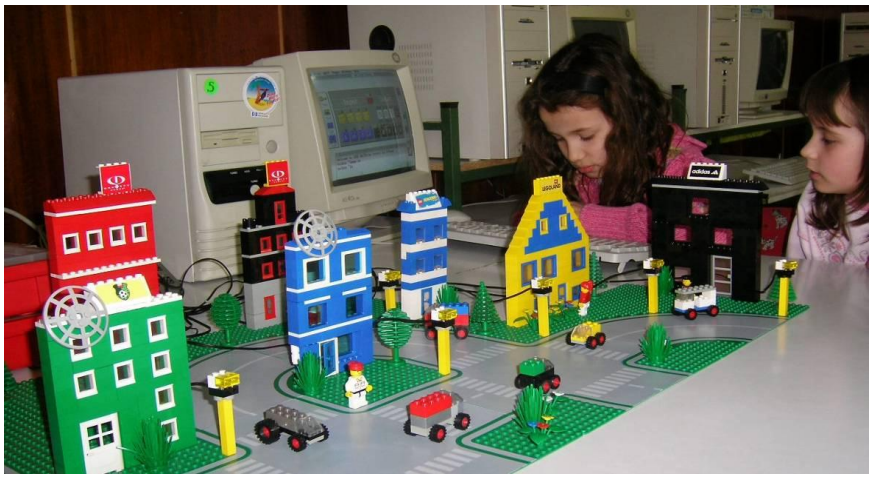

Fig. 1. Staring to program their street lights using LEGO DACTA Control Lab Logo.

I use street lighting first, to teach the elements of the operation and control system including: computer, interface block, model with integrated control device, and cables for the connections in between. The purpose and functions of each of these elements is explained.

The modes of cable connection to the different devices and the test port functions are shown. The operating algorithm, main interface of the operating program, introducing the control commands and their execution in direct mode of operation are demonstrated.

Children's own experience they have all seen the street lights and know that the lamps are switched on every evening and switched off in the morning and they are aware that this is being operated centrally and not by employees walking about in the streets to make this manually. The project includes the construction of a city with streets and street lamps placed along them.

Controllable devices lamps.

Commands *talk to*, *on*, *off*, *wait*, *repeat*.

The work on this project is continued into the third year, by including use of light sensor in order to associate the lamp operation to a particular condition. This entails the natural necessity to introduce the *waituntil* command. The work is no longer in direct but procedure mode.

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Traffic light. The project incorporates the elaboration of a small village with one main street with a pedestrian crossing with a traffic light on it. One side of the street is bordered by the houses. On the other side are the shop, the post office, the restaurant and the school. The traffic light is necessary to help people reach the place they live, work and amuse themselves without risk of accidents (fig.2).

Fig. 2. Building the street, and connecting and programming the traffic lights

Children's own experience they know the traffic rules, they have observed how the traffic lights work day and night, they can describe the algorithm of operation and associate it to their own behavior as pedestrians. Analysis of the traffic light operation in night mode blinking orange light.

Refreshing the commands of the previous session, their meaning and the consequences of their execution.

Controllable devices lamps.

Commands Work in direct mode where the children try their own various hypotheses about the sequence of commands to put the traffic light in proper operation. The traffic light is in continuous daytime mode of operation. Introduction of the *onfor* and *forever* command.

A similar project is worked on in the third year. The project can be further developed by including a light sensor and linking the traffic light functioning to a condition, according to which it is switched from daytime to night mode and vice versa, as was done with the street lamps.

Windmills. Introducing a new controllable device the motor.

Functions to drive the windmill propellers.

Learning how the motor is incorporated within the windmill structure. (fig 3.).

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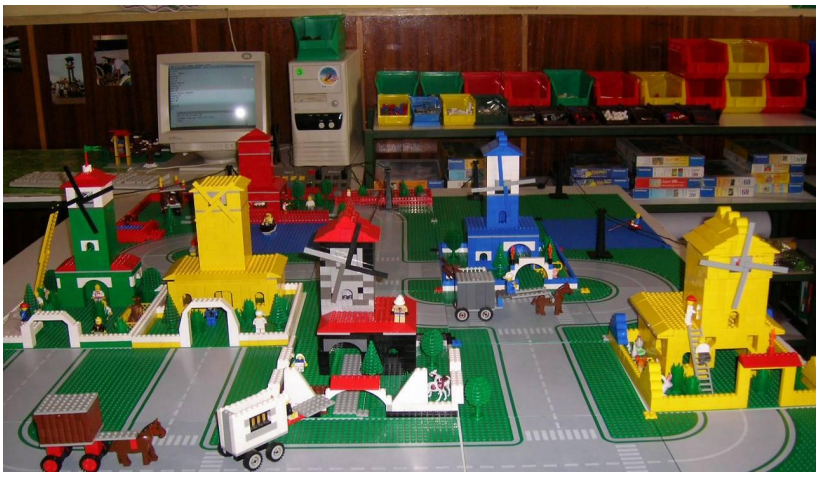

Fig. 3. The windmills

Discotheque. A group project the purpose of which is to make a model of discotheque with air conditioning and programmed lighting (fig.4).

Introducing a new device – temperature sensor and associating it to the operation of the fans. The lights programming here requires maximum attractiveness and diversity. The *forever* command is introduced.

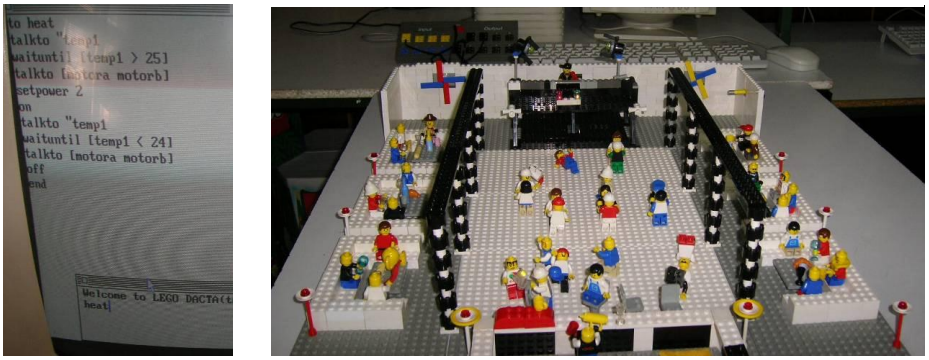

Fig. 4. Ventilator control procedure for the sensor and motors, at the back of the discotheque

Police action. This project is worked on in the fourth school grade. It is intended to recreate a story with a plot. The situational model includes a street with several houses and a police station. One of the houses is equipped with alarm system. A light sensor is installed in the anteroom against the front door. There are signal lamps installed in the police building. A prototype of police car is made, which embodies an engine and siren. Another car prototype with an engine is made for the thieves.

The class is divided into teams of 2-3 children: The team constructing the house is in charge of programming the sensor control; and the team designing the police service is in charge of the signal lamp programming etc.

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Christmas Town and Amusement Park. These are collective projects with the participation of all the children from 1st to 4th grade. The first is made before the Christmas holidays and the second for the school year end.

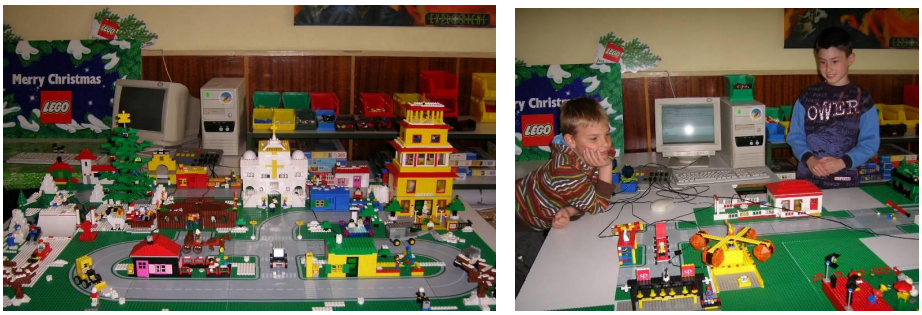

Fig 5. Christmas town, with programmed lights on the tree and the amusement park with rides.

The models are large and every class takes joins in by implementing some part of the common subject. The 4th grade pupils are in charge of the programming.

6 In Summary

I look at robotics as an important part of education in ICT. The primary school robotics lessons give us the possibility to make the educational environment different and more interesting than the traditional classroom. In this new environment, children construct physical, computer and mental models. They learn through construction. To make this work, the learning process and the materials used are organized to systematically develop skills and knowledge, as in a traditional curriculum. The teacher is more of a partner, however. In the paper I have illustrated how this is done. Organizing the robotics education as a work on personal projects, which leads to the creation of an end product with a personal meaning to the child, provides a different context in applying knowledge and skills; and guarantees the child's personal activity during that education. Robotics is not an experiment in schooling nor an attraction.

I look at robotics as part of the curriculum, important for children's knowledge, experience and thinking - a long, organized and systematic process of teaching.

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