DESIGNING AND PROGRAMMING ROBOTS IN CONTEMPORARY DIDACTICS IN POLISH SCHOOLS

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Abstract: *The article presents a solid fastening for educational classes – conducted with the use of sets for building and programming robots – in the European reference framework, in the context of educating key competences. It indicates these contents of applied Polish core curriculum (school curriculum of general education) which might be carried out by the participation of students in the suggested classes with robots. It presents the method of working with sets for building and programming robots which was tested during classes with students of Polish primary and lower-secondary schools.*

Keywords: key competences, curriculum, LEGO MINDSTORMS NXT robots, EduRoboLab method, constructionism, social networking sites, technical education

INTRODUCTION

In order to use the sets for building and programming robots in didactics we have to ask ourselves three basic questions: 'Why?', 'Where?' and 'How to do it?'.

In the first part of the article the author describes the anchoring of educational classes – conducted with the use of robots – in the European reference framework, in the context of educating key competences. This is the answer to the question: 'Why?'

The second chapter indicates the place of carrying out classes with robots (the subjects and the contents of educating), with the currently applied in Poland core curriculum. This is the answer to the question: 'Where?'

The third chapter was created on the basis of the author's own educational experiences. The method of working with sets for building and programming robots which was described here was tested during the work with students of primary and lower-secondary schools. This is the answer to the question: 'How?'.

The contents described in this article might help professionally active teachers independently of what sets for building and programming robots they use in their work. Nevertheless, the author works with sets of MINDSTORMS NXT 2.0 by LEGO everyday.

The registered trademarks were used in order to identify the products and they belong together with the copyrights to their owners.

1. ROBOTS AND TEACHING KEY COMPETENCES

In the attachment *Key competences for lifelong learning – European reference framework* to the Recommendation of the European Parliament and of the Council of 18 December 2006 on key competences for lifelong learning, key competences are defined as a combination of knowledge, skills and attitudes appropriate to the context.

Key competences are those which all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment. (KC 2006: 13)

The Reference Framework sets out 8 key competences:

1. communication in the mother tongue,
2. communication in foreign languages,
3. mathematical competence and basic competences in science and technology,
4. digital competence,
5. learning to learn,
6. social and civic competences,
7. sense of initiative, entrepreneurship,
8. cultural awareness and expression. (KC 2006: 13)

Due to the title of the article it is vital to analyse the mathematical competence, basic competences in science and technology and digital competence. The point of reference might also be the anticipated social competences of students.

The attachment to the Recommendation of the European Parliament, which was mentioned above, presents a range of **mathematical competence** as the one that includes the ability to develop and apply mathematical thinking in order to solve a range of problems in everyday situations. The emphasis here is on process and activity, as well as knowledge. Mathematical competence also involves – to different degrees – the ability and willingness to use mathematical modes of thought (logical and spacial thinking) and presentation (formulas, models, constructs, graphs, charts). (KC 2006: 15)

The attention is drawn to the emphasis of applying mathematical competence in the context of solving problems in everyday situations. How, in the same context, science and technology competences were defined in the cited document?

Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and to draw evidence-based conclusions. **Competence in technology** is viewed as the application of that knowledge and methodology in response to perceived human wants or needs. (KC 2006: 15)

And again the attention is drawn to the emphasis of the application of knowledge and methodology employed in response to perceived human needs. According to the authors of the document it is necessary to aim to be able to reason mathematically and communicate in mathematical language.

A positive attitude in mathematics based on the respect of truth and the willingness to look for reasons and to assess their validity was mentioned in the document. Competences in science and technology include an attitude of critical appreciation and curiosity, an interest in ethical issues and respect for both safety and sustainability, in particular as regards scientific and technological progress. (KC 2006, p. 15)

The added value of the educational process connected with ethics, culture and respect of work and studies is supposed to be reflected in the students' attitudes.

Digital competence involves the confident and critical use of Information Society Technology (IST) for work, leisure and communication.

It is underpinned by basic skills of information and communication technology (ICT): the use of computers to retrieve, assess, store, produce, present and exchange information, and to communicate and participate in collaborative networks via the Internet. (KC 2006: 15)

Digital competence requires a sound understanding and knowledge of the nature, role and opportunities of IST in everyday contexts: in personal and social life as well as at work. Students are supposed to be able to use IST to support critical thinking, creativity and innovation. Use of IST requires a critical and reflective attitude towards available information and in a responsible use of the interactive media. (KC 2006: 16)

It seems that the creativity and the innovation mentioned above should also be seen in forming new tools ICT. This is the appropriate place for the work of equipment and software specialists: people who are above average competent in the field of computers.

Social competences include personal, interpersonal and intercultural competence and cover all forms of behaviour that equip individuals to participate in an effective and constructive way in social and working life, and particularly in increasingly diverse societies, and to resolve conflict where necessary. (KC 2006: 16)

For successful interpersonal contacts and social participation it is essential to understand the codes of conduct and manner generally accepted in different societies and environments (e.g. at work). The core skills of this competence include: the ability to communicate constructively in various environments, express and understand different viewpoints and the ability to negotiate (creating the atmosphere of trust). The competence is based on an attitude of cooperation, assertiveness and integrity. (KC 2006: 17)

It seems that in the nearest future in our society there must be a transition towards the development of interpersonal relations and building a social capital of groups, firms, organizations and the society. These relations should be built on interpersonal trust. It will not take place without a significant increase of the quality of communication inside the mentioned communities. Teaching social competence in this context appears to be crucial.

Key competences (Figure 1) which were chosen and presented in this study were reflected in the documents describing education in Polish schools, particularly from 2009/2010 when the new core curriculum was first introduced.

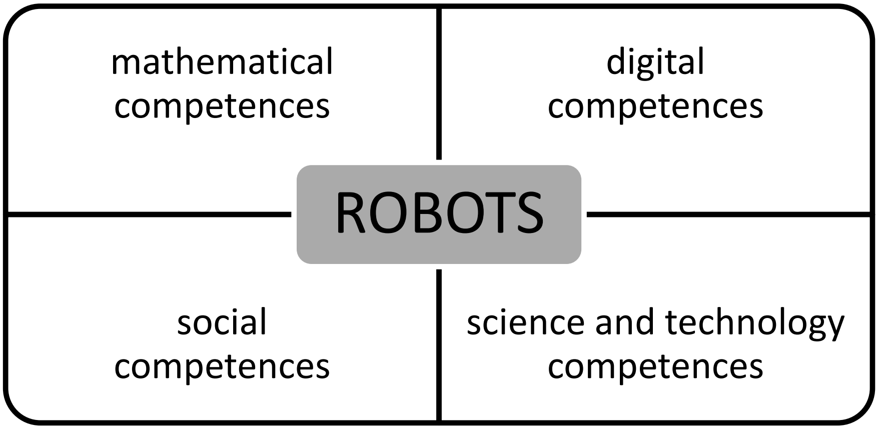


Figure 1. Robots in education and teaching key competences
Source: Author's own coverage

In the following part the author describes Polish regulations concerning children and youth in primary and lower-secondary schools, in the context of educating competences by the suggested classes with robots.

2. ROBOTS AND THE POLISH CORE CURRICULUM OF GENERAL EDUCATION

The proposed workshops during which sets for building and programming robots are offered, are supposed to develop students' abilities described in the core curriculum for primary and lower-secondary schools (Table 1).

Table 1.

Skills described in the curriculum for primary and lower-secondary schools

Area	Curriculum for primary schools (CC 2012a: 9)	Curriculum for lower-secondary schools (CC 2012b: 73)
mathematical thinking	the ability to apply basic tools of mathematics in everyday life	the ability to apply basic tools of mathematics in everyday life and formulate judgements based on mathematical thinking
scientific thinking	the ability to formulate conclusions based on empirical observations	the ability to use scientific knowledge to identify and solve problems and to formulate conclusions based on empirical observations
applying tools of information-communication technology	the ability to apply modern information-communication technologies including those for searching and using information	the ability to use modern information-communication tecnologies in a skillful way, the ability to search, select and analyse information critically
teamwork	the ability to work in a team	the ability to work in a team

Source: Author's own coverage

Although the phrase 'key competences' does not appear in the core curriculum, it is easy to notice that the skills being described meet the key competences introduced in the first part of the study.

In primary school after the first educational stage student is equipped in all the essential skills which are necessary for classes with robots, while designing their own machine or their own robot. After the third year of learning – based on the mentioned core curriculum – students carry out 'the way' of creating objects from the idea to the product: they are skilled to measure the right amount of material; they have skills to assemble models from plastic, use simple constructions and diagrams; they understand the need to organize technical actions – individual and team work. (CC 2012a: 23)

Moreover, these students are able to operate the computer, use selected educational programms, look for and use information. (CC 2012a: 22-23)

The second educational stage which begins after the third year of learning appears to be ideal time to introduce workshops of building and programming robots. During these classes we are provided with the realization of at least some goals of education and active accomplishment of educational contents such as: science, designing and technology and computer studies (computer science), with the solid training of students' skills and attitudes.

On the third educational stage (in lower-secondary school) the offered workshops may become a part of the subject of designing and technology or – while emphasizing programming of ready-made constructions – they seem to be ideal for the realization of algorithmics during computer science classes.

For the subject of designing and technology the core curriculum comprises only the goals of education (basic requirements). It is the teacher who specifies the requirements in detail which result from the selected range and form of classes.

Furthermore, in the supplement to the core curriculum *Recommended conditions and the way of realization*, for the design and technology classes, it is stated that this is the school that draws up and introduces students to the offer of design and technology classes; the sort of classes and the programme which is being carried out should be adapted to the students' interests; the classes might be conducted as regular, weekly meetings or as a project suggested by the teacher or proposed by students, also in the correlation with the project work from other educational classes. (CC 2012b: 326)

Also, the attention was paid to the possibility of combining design and technology classes with the elements of the programme of job pre-orientation for lower-secondary school students.

The regulations which were formulated in this way and which were connected with the organization of design and technology classes allow teachers to draw up their own concepts of conducting design and technology classes on the third educational stage. Design and technology classes enable a relatively full realization of robotic classes, comprising all the stages of work connected with the designing of robots: the specification of conditions, the project, the building and the programming. There are 60 hours of classes in the three years' period of education to the teacher's disposal.

The third educational stage may be considered as a chance or compensation of gaps which came into being on the first and the second educational stage. These gaps may refer to the knowledge, the skills and the attitudes: in the terminology of *European Reference Framework*: the competences.

The suggested classes with robots allow to support the compensation of gaps, particularly in the area of skills and attitudes. Students who are encouraged by their success in designing and building their own robots, may notice the need to complete the gaps or to expand their knowledge. For example it may refer to the mathematics or information technology in the context of the ability of individual programming robotized machines and vehicles which were built by themselves.

In the second chapter the author points out that the core curriculum of general education for the second and the third educational stage allows to introduce the classes of building and programming robots to the educational offer of Polish schools.

3. BUILDING AND PROGRAMMING ROBOTS. METHODICAL AND ORGANIZATIONAL TIPS

In the third chapter the author presents the concept of workshops offered by himself. It was raised on the basis of the author's own experiences. He has been conducting classes with children and teenagers with the use of sets for building and programming LEGO MINDSTORMS NXT 2.0 robots for three years.

It is worth noticing that the proposed format of classes does not extort from the teacher using only sets of LEGO company. The methodical concept will also find application in work with other sets which are available on the market.

A solid anchoring of the offered classes in the applied core curriculum of general education might help teachers in overcoming a barrier which perceives education and play as two completely separate worlds of children's activeness.

Bearing that in mind one might negate the sense of using toys (blocks, vehicles) in the teaching process. Among teachers there are attitudes which are characterized by far-reaching scepticism in reference to using LEGO blocks in teaching.

A total opposite of the mentioned attitudes, full of mistrust towards toys and play in education are professor Resnick's views.

Mitchel Resnick (Massauchetts Institute of Technology, USA) orders schools to resemble a kindergarten. To support his thesis he presents several views.

In kindergarten children spend most of their time there creating things: they draw, build and tell stories. Moreover, in kindergarten children cooperate in a group or have a lot of flexibility, can aspire to their interests. Finally, which seems to be the most vital thing, most of our human creative work originates from matters which we really care about. (Mikołuszko 2011)

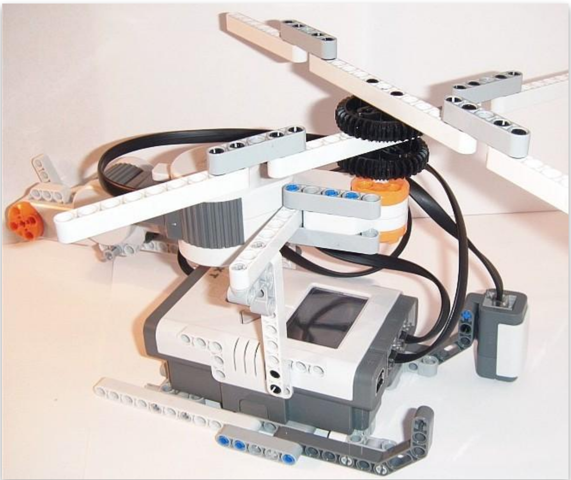
New technologies in teaching should be used in such a way that could allow to arouse the child's interest in a pupil, a student or an adult, on every stage of education; to encourage or extort active attitudes.

According to Resnick a superior aim of teaching is educating creative thinkers. It is not the point what and how much a man knows but whether he thinks creatively and whether he can find new solutions in new contexts. (Mikołuszko 2011)

The spirit of a kindergarten – which according to Resnick is supposed to be the target form of our education – is reflected (among others) by playing with blocks.

In the classes that the author suggests blocks are not random. LEGO blocks were chosen because they are a brand that is well-known and valued by most parents and their children. LEGO is a brand that is recognized and positively associated all over the world. Therefore, it is worth using this marketing capital in education.

LEGO MINDSTORMS NXT (Figure 2.) is an idea which is expected to 'revive' constructions made of LEGO Technic blocks. The basic assembly element of the robotized set is a central unit NXT (Brick), equipped in 32-bit processor, four input ports for plugging sensors (e.g. touch, colour) and three output ports for plugging



servo motors.

Figure 2. LEGO MINDSTORMS NXT 2.0: A helicopter built by Mikołaj (10 years old)

Source: Author's own resources

A graphical programming environment was prepared for LEGO MINDSTORMS sets (Figure 3.). Programming comes down to building graphic schemes (visual programming). Students may influence their robot's actions by modifying its controlling programme.

A free graphical environment Lego Digital Designer (currently in version 4.3) is intended for designing (3D) in real time LEGO MINDSTORMS NXT.

As a part of the project The Laboratory of Robotics (http://www.roboty.bilesko.pl), which was created and is led by the author of the article, a method of conducting classes with LEGO robots: EduRoboLab was drawn up and tested. This is a modern form of educational classes during which students:

– create objects of their further research such as machines or vehicles,
– carry out research of created models,
– remotely control the work of designed models,
– program autonomous robots,
– work in small teams – preferably in pairs,

– use the Net as a source of inspiration – a transfer of ideas, not solutions,

– substantiate their projects in a form of multimedia,

– publish descriptions of their research.

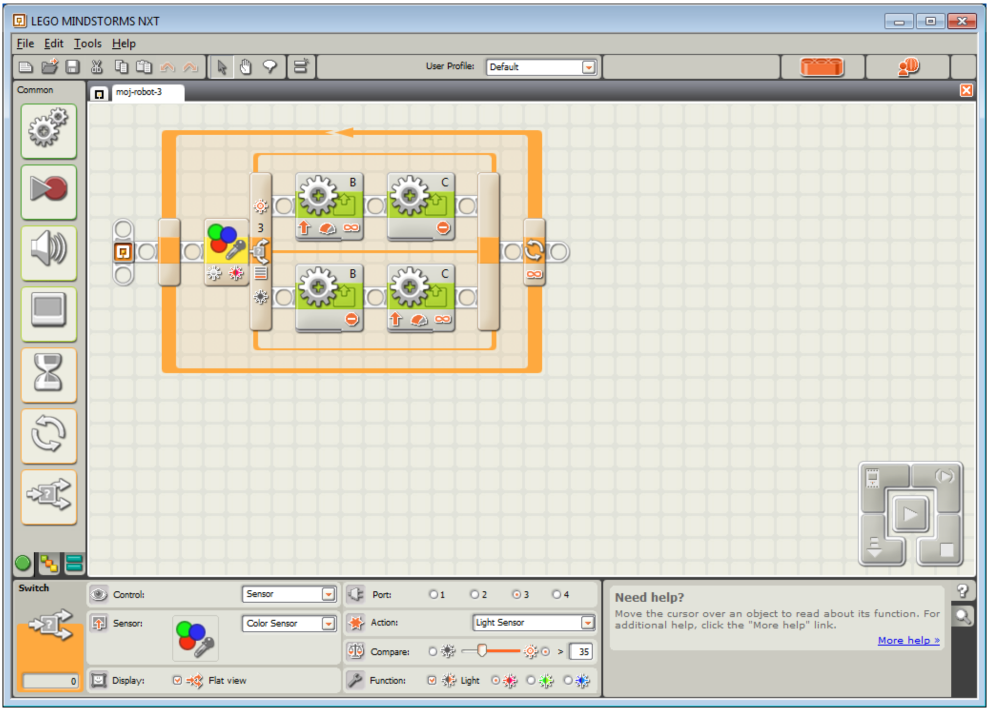


Figure 3. A graphical programming environment for LEGO robots: NXT-G
Source: Author's own resources

The specification of the method is best described by:

– nouns: workshops, laboratory, research, technology;

– verbs: I try, I search, I create, I experience.

The method is based on the experiences which originate from the work with children and teenagers of Polish primary and lower-secondary schools. It is recommended for primary school students (children from the 4th grade and older) and lower-secondary school students. The best effects are achieved while working in teams of 2-3 students, in groups of 15 students (5 workstations). While working with students at 5 workstations the teacher's-instructor's attention is fully engaged in the classes.

The offered method of conducting classes refers to the thesis of constructivism: knowledge is an individual construction; learning is an active and a constructive process; student is active, teacher supports, offers and advises. (Kapounová 2012: 22)

Obviously, it has its advantages and disadvantages. On one hand – for the student – their own activeness is more accepted by themselves than an abstract lecture, on the other hand – for the teacher – the results of teaching are almost impossible to control. (Kapounová 2012: 22)

Cooperation is highly emphasized by constructivism: both among the teacher and the students, as well as the students themselves; the suggested method of work also fulfills this demand.

A sound support for the suggested method of working with sets for building and programming robots is Seymour Papert's theory of constructionism which originated from the basis of constructivism.

According to this theory the most effective method of creating new skills is including pupils or students in actions during which they can create a specific and an interesting product. It concerns some kind of expanding constructivism which emphasizes solving problems practically, with the use of not only mind but also hands. (Lapeš, Tocháček 2012: 21)

Papert claims that doing is a good way to learn but we learn best of all by the special kind of doing that consists of constructing something outside of ourselves: a child building a tower, writing a story, constructing a working robotic device or making a video game are all examples of constructing and the list goes on indefinitely. (Papert 1999: XIII)

While describing the theory of constructionism, in the paragraph concerning the second great idea of Papert (technology as a material) Andrzej Walat states that having technology at one's disposal we can make much more interesting things and while making them we can learn much more. It is mainly connected with digital technology: all computers, including LEGO controlled by a computer. (Walat 2007)

The next methodological trail: using the Net as a source of inspiration, the necessity to testify the students' work and publish the results. This is a sign of the inspiration of the connectivism, learning by applying social networking sites, learning while we are connected.

Students will not only be receivers of materials available in the Web. They have to create them, share with others, assess their friends' work, search for ideas. To achieve this goal they can use a free social platform NXTLOG 2.0 of LEGO brand (available in English language). They can publish materials on the school's site or on their blogs.

Moreover, in the EduRoboLab method one can notice elements of a strategy of solving problems known as computational thinking. Computational thinking, which is accompanied by the processes of solving problems with use of computers, can be described in the following way:

- a problem is formulated in the way that enables solving it with the help of a computer or other devices,
- a problem is based on a logical organization of data and its analysis,
- the solution of the problem may be received by using algorithmic approach,
- designing, analysis and realization of possible solutions leads to receiving the most effective solution,
- the acquired experience while solving one problem may be used to solve other problems. (Sysło 2012: 3-4)

Workshop classes conducted by the EduRoboLab method (for example with using LEGO MINDSTORMS NXT sets) seem to be a good opportunity for arranging teaching situations in which students learn to think computationally. A different role than usually is anticipated for the teacher here: partly of an instructor, a guide and a coach.

These classes are also a tangible evidence for the use of the acquired knowledge, which has to be applied by the student cooperating in a team: by designing, creating and programming their vehicle or a machine. This may influence the raise of his motivation for learning scientific and technical subjects.

It may be noticed that the form of conducting classes derives from various patterns of teaching and learning, making it possible for the teacher who conducts the classes to decide how much of each element wants to use.

The presented classes provide the development of new interests and are an opportunity to get to know the specification of professions such as a mechatronic or a computer specialist. By participating actively in the workshops students make the first step on the way to the fascination with robots, by the development of their passions till the conscious choice of the field of study and choosing future profession. (Kurytnik 2011)

Workshop classes, in which sets for building and programming robots are used, are an interdisciplinary form of the realization of core curriculum. These classes may be combined with the realization of educational projects (short or long termed) which are recommended in the curriculum as a form of working with students yet on the level of primary school and required on the lower-secondary school level.

CONCLUSION

Professor Maciej M. Sysło from the University of Wroclaw focuses his attention on difficulties which come out in the development of information education in Poland. One should completely agree with the following statements:

1. The realization of algorithmics as a part of the subject computer science at lower-secondary schools is rare.

2. Education with use of computers rarely refers to real applications which students come across everyday.
3. The offer of extra classes of the subject computer science in schools as well as the offer of after school classes is rather small. (Sysło 2011: 4)

The classes which were described in this article, the method of conducting them and the tools used for research (robots) seem to be a remedy for problems which are diagnosed in this way because:

1. Intuitive graphical programming environment was drawn up for the sets of LEGO MINDSTORMS NXT. Students do not learn the syntax of the exact language of programming but algorithmic way of solving problems. This can encourage teachers and students in an obvious way to programming.
2. While designing, building and testing their machines and vehicles students have to face real problems such as: stability and durability of the created construction, the kind of the drive which was used, the need to equip in necessary sensors, the problems of the stage of testing and introducing improvements and many others.

   Additionally they have to learn cooperation in small groups and achieving goals in teams.
3. The classes described here are an incredibly interesting form of regular classes, and after school classes. The classes which are conducted in the form workshops guarantee active participation of students while keeping the suggested number of groups and teams.

The proposed classes are ideally connected with the actions which have been recently undertaken in our country and which aim to popularize the technology and scientific classes among the young Polish generation.

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