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DEVELOPMENT OF COMPETENCIES OF ELEMENTARY SCHOOL PUPILS USING EDUCATIONAL ROBOTIC KITS

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Abstract

The study deals with educational robotic kits and its influence on the pupils' key competency development during the educational process. The paper further focuses on the problem-solving competency of the pupils in project-based learning with the use of educational robotic kits. First, the paper describes the introduction to the question of robotic construction kits, as well as the key competencies and project-based learning. Subsequently, it establishes the research question and represents the research methodology and the results as such. Together with the results, it presents a literature review of published research in the given field. On the basis of established data, a particular set of educational and methodical materials for project-based learning was designed. The study itself will benefit teachers using educational robotics during the educational process.

Keywords: Key competencies, Robotic construction kit, Project-based learning

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1. Introduction

Robots, robotic construction kits and systems are constantly gaining momentum in the sphere of education. Their usage is also being positively influenced by Industry 4.0 development. Using educational robots affects both the educational process and its participants. This study focuses on key competencies of elementary school pupils as well as on the way these are influenced during the educational process with a robotic construction kit. The paper deals with the effect of robotic construction kits on the key competencies' development of the pupils. Together with the expansion of using the robots and robotic construction kits in the educational process, the following question arises: What is the influence of robots and robotic construction kits on the development of the individual during the educational process using project-based learning as a teaching method.

1.1. Key competencies

The curriculum framework for elementary education has established particular key competencies for the pupils to attain. Key competences are defined as follows: "Key competencies represent the summary of knowledge, skills, abilities, attitudes and values crucial to personal development and employment of each member of the society. Both their choice and conception are based on the values generally accepted within the society, on the common shared ideas about which of the competencies contribute to one's education, contented and successful life and strengthening the functions of civil society." (RVP, 2017). It also mentions the results of the elementary education level from the point of view of the pupils. At the end of compulsory elementary school education the pupil:

- *"perceives various problem situations both at and outside the school, identifies and understands the problem, thinks about discrepancies and their causes, considers and plans the way of problem solving and for that uses his or her own judgment and experience*
- *looks up information suitable for problem solving, finds its identical, similar and distinct features, uses gained knowledge and skills for discovering of various ways of solution, is not discouraged by potential failure and looks persistently for final solving of the problem*
- *solves problems individually; chooses suitable ways of solving; when looking for the solution he or she uses logical, mathematical and empirical methods*
- *in a practical way verifies correctness of the problem solving and applies proved procedures when dealing with similar or new problem situations, pays attention to his or her own progress during problem solving*

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- *thinks critically, makes sensible decisions, is able to defend them, realizes the responsibility for decisions having been made, evaluates the results of his or her own actions" (*RVP, 2017)

This study focuses on pupils' problem-solving competency which, according to Klieme (2001) (as cited in Knetch, 2014), defined as *"target-oriented thinking and taking action in such situations when routine procedures are not available"* (Knecht, 2014, p. 30).

1.2. Robotic construction kits

Robotic construction kits are a useful tool not only for teaching of programming but also for teaching of construction of uncomplicated models and machines. They are suitable for making models and simulation of real systems.

Robotic construction kits and educational robots supply have expanded in past few years and thus the schools can choose the best according to their needs and demands. A short list of selected robots, robotic construction sets and systems available and used in the Czech Republic are stated in this study. Arduino[1] utilizes single-board computers based on microcontrollers ATmega to which the servomotors can be connected as well as the display and many other sensors. From the very beginning, the Arduino project is provided as an open-source, which led to its popularity and wide use, especially in the teaching of programming at high schools and universities. The German robotic construction kit Fishertechnik, using plastic components, and which bears a resemblance to a LEGO set offers both robotic and non-robotic models in various versions using the controllers. For programming of assembled models, the construction kit utilizes its own programme, enabling programming by means of the icons making it suitable even for children at elementary schools (Coufal, 2016). A well-known children LEGO construction set has been already provided with many versions of robotic units to which the servomotors and sensors are attached. Programming is possible with iconographic programs as well. The American construction kit VEX IQ is a similar, yet new construction set, using plastic structural components. This set allows users to plug many more I/O devices to the control unit and besides that, children can operate it by attached remote control, making programming accessible to elementary school children. The construction kit in VEX EDR updated version is available for high school and university students as it uses a more powerful control unit and metal constructional components.

[1] Arduino are small single-board microcomputers developed to support the teaching of computer science in schools. Arduino is based on ATmega microcontrollers from Atmel.

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Traditional Czech construction set Merkur uses special metal components and thanks to connecting electronic parts and microcontrollers, the user can programme arbitrary robotic models.

1.3. Project-based learning

This study focuses on project-based learning (PBL) as a complex teaching method. In PBL, the key element is always represented by the project. Killpatrick, the founder of the project method, defines it as follows: *"project is an explicitly and clearly designed task that can be presented to a pupil as vitally important by approximating to a real activity in the people's lives"* (Coufalová, 2006). According to Maňák and Švec (2003) in PBL, a practical task is being solved. The task itself is defined by its complexity and connection to the reality of everyday life, being well-known to the participants. A project can be implemented both in groups and individually, but a well-prepared PBL is necessary so that the educational process would not degenerate into mere playing and would not interfere with the educational goals. Tomková, Kašová and Dvořáková (2009) say that *"Project-based learning is a complex method, enabling the pupils to touch the reality, experience new social roles, solve the problems, interconnect and use gained knowledge from all fields of activity during meaningful and useful work. It gives them a unique opportunity for self-realization, it motivates them to work individually, to look for and discover, to cooperate and communicate with the others. It teaches them how to think in context and deal with the problem systematically."* (Tomková, Kašová, & Dvořáková, 2009, p. 7).

The PBL method is extensively used in robotics education as requested by pupils and students (Coufal, 2016). On the other hand, from the point of view of the teacher, it can be initially be seen as quite time-consuming in terms of the lesson preparation and materials-making.

2. Purpose of the Study

The research goal is to investigate research studies in the field of using robotic kits in teaching with a focus on selected competencies of pupils. Based on the findings, methodical and teaching materials for the development of selected competencies using robotic kits in teaching are created.

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3. Research Questions

For the purpose of solving the research goal, the following research question was defined:

- What is the influence of robots or robotic construction kit education on the development of pupils' key competencies?

Within sub-parts of the research in this study, particular sub-topics were stated. They focus on the way and methods of teaching of robotics, robots or robotic construction kits used and other key competencies of the pupils.

4. Research Method

The research survey was divided into three main phases. The first phase represents obtaining data sources with regard to criteria given, the second phase deals with sorting of gained data sources and the final phase introduces processing and comparing information found in the data sources.

For the purposes of this study, the criteria of the research survey were defined as: data source field, data source language, data source year of publication, and data source accessibility.

Data source fields are scientific researches, articles, monographs, and websites dedicated to the topic in question, which are publicly available.

Only English and Czech data source languages are included within the study. Data sources in other languages were omitted. Relevant sources were those published in last ten years (from 2009 up to now). Again, data older than 2009 was not included in the study. The final criterium was the data source accessibility, which are publicly available and free databases of scientific researches, articles, and monographs, as for example: Web of Science, Scopus, EBSCO, Springer, ProQuest, etc. Web browsers, e.g. Google, were also used for locating data sources.

To identify data sources, the following key words in accordance with the research field were applied: robot, robotic construction kit, key competencies, problem-solving key competency, robotic education, project-based learning.

Obtained data sources were processed according to the relevance, importance, quality and relation degree to the sphere of study research goals.

5. Results

The scientific research results of the study present the survey of interesting researches in the field of using robots and robotic construction kits in education focusing on the

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development of pupils' and students' key competencies. A research similar to this study was done by Toh (2016) who inquired into data sources between the period of 2003 and 2013. His published study synthesizes the findings within surveys having been conducted in last ten years and explores the influence of the robots on children and education. It analyzes four main factors: sort of conducted study, influence of the robots on the child's behavior and development, perception of educational robots from the point of view of children, parents and teachers, and children's reactions to design and visual aspects of the robot. The study also shows that influence of the robots can be divided into four main categories: cognitive, conceptual, language and social skills. Even though the research of this paper was oriented differently, some of the gained data could be undoubtedly used.

Altogether 197 relevant data sources were processed in this paper. Their division according to the type is stated in Table 1.

Table 1. Data source distribution

Data source type	Number of data sources
Scientific researches and articles	61
Monographs	94
Websites and articles	42
Total	**197**

Data sources were sorted on the basis of the relevance to searched key words. Further division was based on types of particular key competencies, on used robotic construction kits, robotic sets or robot models.

Interesting and beneficial scientific studies and researches are introduced from data sources mentioned above. The character of cooperation was explored by Yuen et al. (2014) in groups of elementary and high school students when dealing with robotic projects at a summer robotic camp. This study shows how, by means of robotics, it is possible to include group-solving projects in education and it introduces the significance of cooperation in the educational process. The findings can contribute to the application of robotic projects into the educational and to significant enhancement of children's motivation for learning in the STEM field (Yuen et al., 2014).

Virnes' paper (2014) deals with educational robotics, its description, division, definition and most importantly, with influence on the educational process within interaction with children. Mutual cooperation is separated into four areas. The research was conducted on a long-term basis from 2006 to 2011 in different educational facilities. The paper describes educational robots and robotic construction kits. Robotic construction sets are divided

according to the necessity of programming and controlling when using computers. It also includes description of social robots. The goal of the research was to create a theory of children's interaction with educational robotics. Thus the research questions focus on observation of children's interaction with educational robotics, interaction development, sort of interaction, type of work with educational robotics and interaction impacts. For the research purposes these sets were used: robotic kit Lego Mindstorms NXT, construction kit Topobo and RUBI social robot. The description of research environments followed. The first type of environment was the robotic set Lego Mindstorms NXT workshop for a group of pupils aged 10-14 and their teachers at a special school. Each child was affected by a learning disability: attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD) or speech disorder. The second environment was the workshop for 4-5-year-old kindergarten children using Topobo construction kit. The third environment was represented by RUBI social robot in a preschool educational facility for children at the age of 15-23 months using everyday activities. It also describes the children's interaction with educational robotics, which is divided into four main parts and it shows the work with a representative from each category of educational robots. Furthermore, it presents the results of axial coding in four main areas of the children's interaction with educational robots, and selective coding which showed different types of educational robots used leading to the establishment and description of a theory of children's interaction with educational robotics.

In his study, Slangen (2011) is interested in what the pupils aged 10-12 are able to learn using the robots, supposing robotics being part of technological literacy. In the study, both the cognitive and conceptual analyses were executed for determination of reference framework, establishing robotics knowledge. On the basis of difficulty, four points of view were distinguished: psychological, technological, functional and system controlling. The results are discussed regarding technological literacy of the pupils and learning possibilities in elementary school education.

According to Shih (2013), the robotic construction kit Lego NXT is used more and more in different sorts of courses dealing with creating multimedia educational materials. The task of the research is trying to understand the factors affecting the intentions of the teachers to use the Lego NXT robotic set in elementary schools. Using the TAM model (Technology Acceptance Model), the study gathered data from 17 elementary school teachers in Kaohsiung and Pingtung regions in Taiwan. To test the hypotheses, the SEM method (Structural Equation Modelling) was applied.

In his study, Somyürek (2015) explores the pupils' skills of construction. 66 pupils aged between 8 -14 engaged in experimental research. They used Lego Mindstorms robotic set. The

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goal of the study was to find out the information about pupils' construction skills. The findings can be divided into four areas: active learning, authentic learning, multiple perspectives and collaborative learning. The study was perceived positively, mainly due to three reasons: careful examination and looking for solutions, using the imagination and production liberty.

Kvenild, Shepherd, Smith, and Thielk (2017) also deals with the development of programming and digital skills in the STEM field for using robotic construction kits and for advancement in curricula of pupils from kindergarten age to the ninth grade of elementary schools.

Data sources in this research study corresponded with searched key words, yet at times, a paper frequently headed in different directions, or skirted the sphere of interest of this paper. Therefore, answering the main research study question was not easy. Concerning the question *"What is the influence of robots or robotic construction kit education on the development of pupils' competencies?"* it can be stated with certainty that education with robots influences the pupils' development of key competencies. However, the exact rate of the influence on the development of key competencies cannot be determined on the basis of the studies examined and thus, will be examined in a new research, extending the issues being explained in this paper. With the help of new research, other research questions which can be neither confirmed nor disproved with certainty, can be answered.

Using the information from the data sources in question created the basis for the formation of methodical and educational materials focusing on the development of key competencies with the priority of problem-solving competency. Created materials can be sorted according to their specialization into three groups: materials for programming of assembled robot designed for solving the chosen task, materials for building the robot model construction designed for solving the chosen task and complex problem tasks including both groups of materials mentioned above. Figure 1 shows elementary school pupils dealing with a complex problem task targeting problem -solving key competency. This is how the gained information is directly verified within the elementary school educational process with the help of created educational materials.

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Figure 1. Work of pupils at primary school in solving the problem

6. Conclusion

The study focuses on educational robotics and its influence on elementary school pupils' key competencies development during the educational process. It also deals with the problem-solving competency within PBL when using educational robotics. The initial part provides basic information about educational robotics, key competencies and problem-solving competency as well as about PBL. This is followed by the research questions, the research methodology and results. Depending on given criteria, altogether 197 different relevant data sources were processed according to selected key words and phrases to extract relevant information to answer the research questions.

Hand in hand with results of processed data sources, the paper presents extracted data of researches published in the given area. On the basis of established data, a set of educational and methodical materials for using educational robotics through PBL method was created.

The study can contribute useful information to educators using or planning to educational robotics when teaching. With the help of the data found throughout the study, a new research based on this study's results will be conducted to concretize the established results.

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