Educational-technology based activities for development of algorithmic thinking and programming skills

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Abstract

The conference contribution discusses the research educational project consisting in the creation, realization and the subsequent analysis of the implementation of a comprehensive system of interlinked courses aimed at developing algorithmic thinking and programming skills. The courses include lessons for students of bachelor's and master's degree studies of IT in education. In the courses there are greatly accentuated the principles of constructivism, project-based teaching methods and to a large extent the scope for creative projects and practical activities. In the research project there has been a substantial alteration of the content and implementation the earlier courses or entirely new courses were created, so that the whole system meaningfully enabled the gradual development of algorithmic thinking and programming skills for prospective teachers of IT through attractive activity-oriented projects and activities using modern technologies such as e.g. programmable sets Arduino or robotic kit Lego WeDo and Mindstorms. The part of the research project is a systematic analysis of the content of the training courses, application of teaching methods and outputs produced by course participants. Collected data are continuously evaluated and used to further modify the system.

Keywords: ICT; education; robotics; electronics; cybernetics; constructivism; constructionism.

1. Background and focus of the research

Constructivism, robotics, electronics and programming are the scientific areas which are of interest to many professionals in different specialized institutes inland and abroad. The project is not specialized in very specific areas there. It monitors the sphere of educational robotics, electronics and programming in the context of constructivist approach - i.e. the area of robotics, electronics and programming applied to education linked to the theory of constructivism. Educational robotics is

a specific branch of robotics closely linked with pedagogy using robots (robotic activities, robotic projects etc.) as a means of fulfilling educational goals. Educational robotics is a powerful and flexible educational tool with a great motivational factor which allows students to manage and control the behaviour of material models (robots) through graphical or textual programming languages (Aliminis, 2009). Its potential also lies in the possibility to involve students in solving projects and problem-oriented educational activities. We see the high potential especially in the tools developing technical thinking, imagination and creativity of students, without tying the students to a narrowly limited subject area, but rather with considerable interdisciplinary overlap. At the same time we feel the need for linking the implementation of the selected activities through technological tools with adequate educational concept. In connection with the possible use in teaching in our elementary and secondary schools, our interest has been focused on the area of educational robotics and into the sphere of constructivism, respectively constructionism. For the area of educational use of technology is the theory of constructivism and constructionism particularly stimulating. It is in this sphere that the activities of students are often focused on the implementation of various practical activities that result in a specific product, and in which the students themselves construct their knowledge. The condition for a successfully conceived constructivist teaching is its organizational support from the teacher based on the knowledge of all the aspects of this concept. It is therefore understandable that we intend to develop particularly the approaches appropriated to the concept of constructivism in the training of future teachers of technical and science subjects in the implementation of educational robotics in education. There was a significant impact on the current form by the previously implemented activities, such as international projects (TERECoP, 2006-2009), the research grant of the Charles University in Prague (GAUK P407/12/1732, 2012) and the national subject online contest "Bobřík informatiky"(http://www.ibobr.cz/english-uk) in the field of algorithms and programming, understanding of information, problem solving and digital literacy. The original concept (Tocháček & Lapeš & Fuglík, 2016) was used as the basis and it was adjusted according to actual needs and the results of previous research that continues here.

2. Characteristics of the research

The research project is focused on research and assessment of appropriate approaches and activities that can be used for development of algorithmic thinking and programming skills in educational process. The aim of the research is to analyze the theoretical background, the relevant specifics of didactic and educational aspects of the exploitation of educational-technology tools (e.g. robotics and electronics kits, programming environment etc.) as a means of promoting constructivist and project teaching methods in education and validate implementations of this educational-technology tools in the preparation of future teachers of IT in the context of a comprehensive concept of subjects. For this purpose, there has been asked a research question: What is the importance and potential of educational-technology tools for developing of algorithmic thinking and programming skills at schools? The survey used empirical qualitative and quantitative methods. It is primarily action-oriented research, verifying the examined strategies, based on the analysis of the experimental learning model, associated with the

observations and interviews with the research participants. The empirical part of the research consists of the analysis of experimental educational robotics and electronics projects.

3. Research course

Students of IT in education are acquainted with potential of educational technology tools for developing of algorithmic thinking and programming skills at schools already in their bachelor's degree studies. This means that relevant information and practical activities must in few key subjects. The subjects were designed with regard to activities for development of algorithmic thinking and programming skills. An analysis of this experimental learning model is performed from the perspective of action oriented research, learning elements are validated and reflexively evaluated. The part of the analysis is also observations and interviews with the students as the research participants.

The whole content of the study branch and of each course as well were developed, from a research perspective, based on a study when designing the educational field with the subsequent accreditation of the Ministry of Education, Youth and Sports of the Czech Republic. The analytical study was primarily based on the aims of the study and the profile of a graduate in the degree of IT in education, and it took into account the contents of the curriculum of similar types of studies and curriculum ties in the field processed using cluster analysis.

In terms of the structure of the study program the subject of Robotics and Process Control is a summary subject containing technical and algorithmic evolving approach, the second such subject subject is I/O Communication and third is the Automation and Cybernetics. The subjects are complex in nature and can be applied in constructivist approaches in direct teaching, and they are pointing out their own teaching method in practice in schools. One part of the courses and learning objects created or modified in a research project is the master's degree course Robotics and Process Control. The content and methodological concept of this course is based on two already carried out studies aimed at verifying the importance of the use of constructivist approaches and educational robotics in the preparation of teacher trainees of IT. These previous investigations have shown that well-designed teaching based on the theoretical basis of constructivism, project-based teaching, active learning, problem-oriented training and tools for educational robotics - specifically robotic kit Lego Mindstorms - has a significant positive impact on the development of algorithmic thinking and programming skills. Originally a purely technologically oriented course of an instructivistic character was, with regard to the results of previous surveys and pilot studies, conducted with respondents from the students, converted to a project and constructivist course with a predominance of didactic and methodological contents. This change positively evaluated by 97% of respondents based on the results of the current research. With regard to the outcome of another partial survey, during which there were applied quantitative methods in addition to qualitative approaches - more than 2/3 of respondents expressed their interest in extending the content component of the course - there has been added a new topic of the field of educational robotics. Newly, there are part of the courses consisting of thematic areas focusing on the use of educational and robotic tools for lower ages - preschool, primary and lower secondary students, while the topics, relevant to higher ages, remain. There was deliberately removed the focus on purely technological area of educational robotics from the subject. It has been moved to

the fully converted bachelor's degree course Software Applications. In this course students acquire and develop the manual, technical and programming skills while working with robotic kits with no ties to the possible use in teaching methodology and didactics. The subject I/O Communication familiarizes students with a work with a single-chip computer Arduino, which is generally open electronic platform, design or to verify the electrical connections and the programming relevant control programs. In the subject Automation and Cybernetics, the students learn about system analysis and synthesis in the design of program modules and systems, general properties of sensors and output elements of technical and robotics systems, the system approaches to algorithmic processes and procedures. For robotics there is applied cybernetics approach to perception and action, robotics and control technology are presented in relation to technical cybernetics (Novák, 2014).

Bachelor's degree study of IT in education contains objects enabling programming in the comprehensive approach that also includes direct use and technical resources. For this approach students are acquainted with the technical and physical elements, technologies and principles in a number of different subjects - in addition to two basic subjects directly relevant to programming based on procedural and object oriented paradigm and website programming there are Electronics and Electrotechnics I. and II., Propedeutic Programming Languages and Digital sound processing. For the purposes of robotically-oriented applications and subsequently conceived constructivist student activities, there are elements added into subjects which reflect algorithmic processes and technologies in relation to robotics: Electronics and electrotechnics I. and II: algorithmic thinking must be demonstrated by students during the analysis of circuits (a choice of alternative solutions and their gradual reduction), thus applying the discursive and convergent thinking. In relation to robotics there are related topics of subjects with the properties of sensors and action elements, with an accuracy of physical values; Digital sound processing: the topics there is appearing signal processing and algorithmic procedures for working with sound; Propadeutic Programming Languages: the task of the course is to familiarize students with the fundamentals of programming technologies, including practical programming. The topics of subjects are constantly changing based on the suggestions of students - in those subjects the students, after they graduate, also express their opinions about the content of the subject and can propose other topics with the reasons for their needs. The current status of subjects is such that on a seven point scale more than 95% of students considered the content of subjects acceptable (evaluated 1 or 2), and only 7 % of students bring new ideas to the content of subjects. This indicates a very good content structure.

In the curriculum of IT in education subjects are also included in the master's level (a master's degree in IT in education) subject Propaedeutic Programming Languages II - Programming languages for educational purposes. The course builds on the similar undergraduate level content, but it is a didactic subject, and not technological. This subject is, at the Faculty of Education, the culmination of a didactic path of the study (i.e. five years of study) concerning the development of algorithmic thinking and programming skills. The aim of this subject is to familiarize students with the problems of teaching programming in technological and mainly in didactic concepts and approach to selected algorithmic procedures for the development of algorithmic thinking of students. This applies to an action-oriented research the most, as well other elements qualitatively based research linked with quantitative findings.

The course content reflects mainly changes in technology and general concepts of teaching programming. These are mainly the results of changes in the approach to teaching in elementary and secondary schools directed from a passive user-oriented approach active creative approach, known as "computing". In it, the algorithmic thinking and programming skills are effectively developing, because they are the very principle of this approach. The mentioned trends in the Czech Republic are contained in the Strategy of digital literacy of the Czech Republic for the period 2015-2020, indicating changes in teaching at all types of schools in the Czech Republic. Based on the survey of students enrolled in Propaedeutic Programming Languages II, about 3/4 students of internal study and 4/5 students of combined studies prefer the teaching style "computing".

In the presentation and publication of results, there is also the great emphasis on popularizing activities, especially towards the general public and not only in the educational and professional sectors. These are usually national or international activities organized by universities, the Academy of Sciences and the Ministry of Youth and Sports. In particular, the "Day of Science" (http://www.sciprag.cz/), "The Gaudeamus" (http://www.gaudeamus.cz/?id=en/main) and " Scientific fair" (http://www.vedeckyjarmark.cz/). All these are frequently attended by professionals and the public. New successes in 2016 are that educational robotics are integrated into the workshops held under the "Google Edu Groups" (http://www.gug.cz/cs/geg) and the Department of Information Technology and Education, Faculty of Education, Charles University in Prague has set up a local office, "GEG Prague" (http://www.gug.cz/cs/geg/skupiny/praha). Robotic workshops organized here are primarily focused on primary and secondary school teachers, but students and general public can also participate.

4. Used technologies

Within the professional and didactic training at the Department of Information Technology and Education, Faculty of Education, Charles University in Prague, there are objects oriented in the educational robotics in bachelor's and master's degree studies. In bachelor's degree studies, the emphasis is placed primarily on technical, technological and programming activities. The master's degree study is mainly oriented on the didactic aspects and the use of educational robotics in education at primary and secondary schools. As the default hardware - software platform there was selected a range of products Mindstorms NXT from Lego, especially with regard to availability, price, parameters, connectivity with common IT equipment, reasonable demands for knowledge and skills (especially manual) of users and great variability in usability in practice. Most of the products mentioned require users to invest in hardware and software. Especially in terms of usable and accessible design, control and programming software, however, you can find a variety of legal free alternatives to commercial software. Within the specialization and certain heterogeneity, this basic concept is expanded to other platforms and systems, which are included in teacher training and also in the further training of teachers at elementary and secondary schools. For the primary and lower secondary school, as a useful tool for the development of algorithmic thinking is used to program "Scratch" / "Imagine LOGO", complemented by a programmable system "Bee-Bot" and "Lego WeDo." At the secondary school there is implemented "Lego Mindstorms NXT / EV3" (optionally

supplemented with a programming platform "ROBOTC"), "Enchanting" (Lego Mindstorms NXT programming in Scratch) and design software "Lego Digital Designer". For the area of secondary education is used primarily "Arduino" (in combination with the design program "Fritzing") and "S4A" (Arduino programming in Scratch). As a support, there is available in print and electronic form the methodical material "Educational Robotics" including a proposal for a school project.

5. Conclusion

The contribution has reported on the concept, the progress and results of the investigation focused on supporting the development of algorithmic thinking and programming skills in preparing teacher trainees of IT. It dealt with the description and evaluation of the newly created integrated system of courses using theoretical background and methodological approaches for the development of algorithmic thinking and programming skills of students. Based on the evaluation of the data obtained during the findings, it can be stated that the concept and the system of created related courses within which the use of relevant educational technologies and tools led to the development of algorithmic thinking and programming skills. It was verified that there is great importance in this area, primarily the tools of simple programmable electronics, robotics, and selected educational programming environment. Successfully applied in the subject area are primarily constructivist approaches, project-based teaching, active learning and problem-oriented education. As a highly important factor in the success of fulfilment of the objectives of developing algorithmic thinking and programming skills of students is the connection of subjects within the system, both in content as well as methodology. The states also shows that the educational and methodological resources included in the developed curriculum content are highly applicable and that they contribute to the development of algorithmic thinking and programming skills in educational process, as it was verified.

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