Acquiring Digital Skills and New Qualifications by Introducing Modern Technologies in Education

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***Abstract*—The paper discusses the need to improve the digital skills of children in schools. EU statistics are provided to illustrate this need. Three directions for introducing the new technologies are considered – in special, non-formal and formal education. The authors' research experience in both special and non-formal education is presented. The state of the art in introducing emerging technologies in formal education is analysed. Different innovative technologies like humanoid and non-humanoid robots, drones, virtual, augmented and mixed reality are considered and their potential to contribute to the learning process is discussed[1].**

Keywords—New technologies, special, formal and non-formal education, STEAM education

I. Introduction

The European Commission has placed at the top of its political agenda the objective of stimulating children acquisition of digital skills, enticing them to follow Science, Technology, Engineering, and Mathematics (STEM) education and careers [1]. There is no doubt that good education is a prerequisite for a better future and the skills acquired at school are a guarantee that no one will be excluded or marginalized. The main goal is children to be creators instead of observers and consumers and the new technologies provide a great opportunity for moving in that direction.

According to the official EU statistics 44% (169 million) of the EU citizens between 16 and 74 years do not have basic digital skills, 22% of EU citizens have a low level of digital skills, and 16% of young people do not have digital skills [1]. Almost every job now involves a range of digital skills, yet employers report a shortage in skilled new starters. 21st century employees need to be able to work with sophisticated machines and IT solutions as part of their everyday activities, from car mechanics to doctors and nurses. Today, 40% of the companies have difficulties finding information and communication technology (ICT) specialists and the prediction is that there will be 500,000 unfilled vacancies for ICT professionals by 2020. In the near future 95% of all jobs will require digital skills. Therefore improving the digital skills at school is a great challenge.

Rapid development of modern technologies will enhance the education by making learning interesting and interactive. New technological realities require a new approach to education and skills. This includes the ability to handle software and complex machines, training teachers with digital skills, providing teaching materials and equipment, Internet access, etc. All this means modernizing the education system by educational innovations in all types of education – formal, non-formal, informal and special.

Formal education is organized, guided by a formal curriculum and leads to a formally recognized credential such as a school diploma or a degree. *Non-formal education* includes various structured learning situations which are not necessarily part of a formal curriculum. This type of education may be led by a qualified teacher or by a leader with more experience as a scientist. Though it doesn't result in a formal degree or diploma, non-formal education is highly enriching and builds an individual's skills and capacities. *Special education* is a form of learning provided to students with special educational needs (SEN), such as students with learning difficulties.

Emerging technologies in schools cannot be a luxury, a privilege for children from families with better opportunities. These have to be for all, part of a school program - accessible for every single child. Several new technologies can contribute to introducing modern methods in education – Humanoid and Non-humanoid Robots, Raspbery Pi, Virtual, Added and Mixed Reality, Motion Sensing Devices, etc. Further in the paper we will mark them with

[1] The paper was presented by the first author at the Symposium „Robotic and ICT assisted wellbeing" of „26th IEEE International Conference on Software, Telecommunications and Computer Networks" (SoftCOM 2018), Supetar, Split, Croatia, 13.09.2018-15.09.2018.

R&ICT (Robotic and Information and Communication Technologies). An important question is how to introduce and use them in the educational process in order to achieve maximum efficiency in compliance with all ethical norms.

In the paper the specificities of the three above-mentioned types of education are discussed from both authors personal experience and from the literature. Different innovative technologies like humanoid and non-humanoid robots, drones, virtual, augmented and mixed reality are considered from the point of view of their capability to contribute to the learning process.

II. II. Application of R&ICT in Special, Non-formal and Formal education

Due to their nature, special and non-formal education require individual and group-specific approaches that imply corresponding targeted methods, while formal education requires a uniform methodology for all pupils. There are many investigations and applications of R&ICT in special and non-formal education in the literature. But research and pilot investigations about the necessity and the methodology of application of most popular R&ICT in formal education is still insufficient. For example, the reported outcomes on the use of robots are, in most of the cases descriptive, since they are based on reports of educators regarding individual initiatives, involving a small sample of participants and not integrated into official classroom activities [4]. Now the robotics in education may be characterized only as a current trend, not as a systematic practice.

The paper presents the analysis and the derived recommendations about application of R&ICT in special and non-formal education based on our own experience from participation in several research projects. For further analysis of specificities, directions and challenges of the application of R&ICT in formal education, results from the literature are analysed. The analysis of the specificities, directions and challenges of the application of two of the most popular and promising technologies in formal education – robots and VR – is based on the results from the literature.

II.1. R&ICT in Special Education

Numerous investigations are being conducted on using R&ICT with children with SEN, but most of them focusing on mild to medium cases of autism, attention deficit disorder, or hyperactivity [2], [3], [4], [5], [6]. It is proven in the literature that the most promising way to use R&ICT solutions in education of children with SEN is to focus on the entertaining role of the technologies in special education, empowering the child to be in control of complex technological devices under the guidance of the teacher.

From our previous and current studies in the frame of the finished METEMSS project [7] and current CybSPEED project [8] based on how children with SEN express themselves verbally and emotionally in play-learning environment supported by modern technologies, we revealed that positive emotions during the play with humanoid [9] and non-humanoid [10] robots can unlock learning skills quite unexpectedly. The play-like activities have been assisted by innovative human-robot interfaces for transmission of intentions and control, based on 3D motion-sensing devices. We used Kinect enabled serious motion-sensing games and the redesign of computer games into motion-sensing serious games for children with limited physical skills. The novel method was developed for Kinect–robot teleoperation based on fuzzy depth data processing and motion retargeting where Wireless Kinect-NAO Framework (WKNF) was proposed for teleoperation [6].

We proposed guidelines how to design supportive educational game-based environment for these children and how to help them getting used to modern technologies and be prepared for the digital age. Humanoid (NAO), semi-humanoid (Minion doll with a robotic hand) and non-humanoid (Big Foot robot, developed at Institute of Robotics - Bulgarian Academy of Sciences (IR-BAS) via 3D technology) robots were used in our experiments.

The children involved in METEMSS have been diagnosed with the following disorders: intellectual disability, autistic spectrum disorders, cerebral palsy or multiple disabilities. In the current MSCA, RISE CybSPEED [8] project entitled "Cyber-Physical systems for pedagogical rehabilitation in special education" a new type of Cyber–Physical System (CPS) has been proposed. We implement robot-based games and creative activities which, on the one hand, allowed the children to learn skills by moving, role playing, and self-expressing and to assist teachers in their assessment of learners by new modalities for children-robot interaction, on the other.

Children are attracted by robots spontaneously and this facilitates the assessment process by high-tech technologies. For example, humanoid robot NAO [9] has the potential for being used as a playful tool for improving the listening and speaking skills of children with SEN by involving a series of tasks developed and deployed on NAO. Video observations help assess children listening, understanding of the verbal language and speaking skills. Ongoing research on integrating intelligent sensors like Emotiv sensor [11] and MS Kinect v2 [12] to NAO sessions will enhance the listening and speaking assessment of these children.

Assessment of learning for children with SEN can be seen as a 'qualitative' type of measurement procedures modified and adjusted to meet the needs of the individual child.

Here we will not discuss in detail the studies, the experiments and the results obtained, but will summarize some of the observations and recommendations of using R&ICT in special education:

- Progress in learning a motor or cognitive skill is important, but is secondary to the therapeutic process. The most important in special education is the entertaining role of the technology and the emotional involvement of children;
- By empowering the child to be in control of complex technological devices and giving instructions in a 'natural' manner – speech and gestures - the child learns how to react to environments. This is expected to result in better adaptation to the outside world and the social environment of each individual child;
- The R&ICT device has the ability to initiate the discourse with the child in its functioning as an educational assistant to the teacher;
- Before processing the work with R&ICT, a profile of each child has to be created including personal information and information about child motor skills, cognitive skills, social skills, etc.;
- Analysis of the feasibility of different technological solutions for every child should be made depending of the individual SEN;
- Detailed description of R&ICT devices to be used and the respective activities for each child have to be determined in advance. It is very important not to bore them, or tire them, or be too demanding because their emotionality is very fragile and emotional outbursts are possible;
- The task of working with the child requires patience and multiple repetitions and is very tiring for the therapist;
- Strict observance of all ethical norms and principles relating to processing personal data is mandatory;
- Written permission from parents for conducting the experiments is obligatory;
- The use of R&ICT allows detailed measurements and monitoring to be made. In combination with the expertise of the therapist and the parents, it can produce satisfactory results in the educational process.

Still many challenges have to be solved during the process of application of R&ICT in special education. One of them is that teachers needed to be given more methodological support, equipment and training in order to improve their skills in quantitative observation and to develop more individualized methods for work with children with SEN.

II.2. R&ICT in Non-Formal Education

There is no doubt that non-formal education meets better the individual needs of pupils. When the new R&ICT technologies are included the results can be impressive. Recently, new approach to work with motivated students is used, namely engagement in science through an innovative approach of teaching and learning.

The authors of this paper have experience from the Robo-Academy project [13] with a main goal - training and promotion innovations and high-tech developments among young people from the specialized technological schools in the field R&ICT in Bulgaria by combining expertise of professional scientists, the pedagogical skills of teachers and the creativity of talented students. After the launch of the project many discussions and workshops between creative young people and teachers and mentors were carried out in the Institute of Robotics at BAS. Modern technologies such as 3D printing, humanoid robot NAO, non-humanoid Walking robot, humanoid arm, MS Kinect sensor, Emotive, Raspberry pi, Arduino and others are included in the educational process. After that specific R&ICT projects for groups of students were formulated. The projects are:

- Integration of brain-computer interface and humanoid robot - Brain-computer interface translates non-invasive EEG brain signals into robot commands. Two innovative technologies are integrated – EMOTIV and NAO robot.
- Development of 3D printed robotized hand for gestures - original humanoid hand, printed on 3D printer, capable to perform gestures, controlled by sensor glove. Possible application - special education;
- Programming of humanoid robot NAO for educational goals – programming NAO by using Python language in the Choregraphe software;
- Design of mobile sonar with wireless control - design of mobile sonar for measuring by using Arduino. Possible applications - for measuring in a dangerous and overheated places; that has time limit between charging;
- Design of robot with six legs – 3D printing robot with 6 legs with optimal energy consumption;
- 3D printed Leonardo Da Vinci's Mechanisms.

After the projects was launched, practical exercises in specific R&ICT under consideration were held - 3D printers in robot prototyping, how to create details of 3D robot models - FDM technology, software suitable for creating 3D robot models, sensors, programming robot NAO, using MS Kinect sensor, Motion Capture Devices, Emotive for tracking EEG signals, Raspberry pi, Humanoid arm etc.

The implementation of the projects include designing 3D models and prototypes, choosing sensors, creation of specific robot and automated systems, programming, control, making experiments and discussions of results.

The results were presented in front of a larger audience of students, to stimulate them to follow STEM education and careers. All lectures and exercises were adapted to students according to their age. Project teams participated at several regional and national exhibitions and conferences, at which the project results were presented and demonstrated. The students also participated in a number of radio and TV interviews to popularize the scientific approach in non-formal education.

The following conclusions and recommendations can be made for the use of R&ICT in non-formal education at this stage:

- Initial discussions and workshops with students are obligatory in order to establish their interests and level of competence;
- Choice of a set of R&ICT to be used in the projects can be made according to individual skills and capacities of the participating students;
- Careful creation of Working groups and Mentors is necessary;
- This is project – based learning and all project stages must be respected – project description, project implementation, project communication and dissemination of the results;

Non-formal education with the use of new technologies contributes to improving skills like team working, skills for project-based working and learning, improving creation potential, programming, making experiments, making presentations, communication skills and for better professional orientation of young people.

II.3. R&ICT in Formal Education

Present day R&ICT education is focused mainly on the support of additional education of children and is restricted to the sphere of extracurricular activities. We are not talking about computers, interactive boards, laptops and online learning plans, proliferating in schools, but for robots, virtual reality and other technologies with high potential to be used effectively in mass education. The reasons for their restricted use are obvious – robots and new devices are expensive, cannot be delivered to all schools, there are no developed methodologies and teaching capacity in every school.

Our research interest is now targeted to introducing robots and emerging technologies in mass education. The questions of interest are whether it is necessary, whether it is possible and how to accelerate the process of introducing R&ICT in mass education. Project RONNI [14] aimed at promotion of application of R&ICT in mass education in order to overcome the learning difficulties and raise the educational level of the young generation of the citizens for a better future. New innovative teaching strategies and methodologies, transferable across the region, will be proposed to support effective learning, including humanoid and nonhumanoid robots, VR, flying robots, etc. The team made a survey "Assessment of enhanced R&ICT for education" in order to determine specific target group preferences – children, parents or experts.

Two general approaches for introducing R&ICT in mass education have been identified to now:

The first approach is a traditional approach by following all mandatory steps of introducing a new subject in curricula and its assessment, complying with all existing standards. This process is accompanied by a number of difficulties, is time consuming and is more applicable for the technically oriented schools [15]. **The second approach** can be used to achieve mass R&ICT education, namely to design R&ICT - enhanced learning content, not only in existing STEAM subjects, by connecting it with the regular curriculum for all graders in the school. This approach is more flexible and is adequate to the emerging technologies. Examples of the second approach are given in the literature [16].

The two approaches are analysed below in the context of concrete technologies with high potential to be used effectively in the mass education in the near future, namely – Educational Robotics and Virtual Reality.

a) Educational Robotics

Restriction of robotics classes to the sphere of extracurricular activities exists and courses in robotics are included in the educational program only in specialized technical schools. Paid robotics courses, organized by external firms, are becoming more and more popular to fill up the existing gap in schools. The directions and methods of teaching robotics in schools are currently not sufficiently defined. At the same time robots have already become an integral part of society. Knowledge of the foundations of robotics has to become a basic element of youth education and to enter the content of the school curriculum. Educational robotics can be considered as a new educational technology with three components of training: *(a)* robotics as an object of study; *(b)* designing and programming of robots; *(c)* robotics as a means of teaching, development and upbringing of students.

A three component educational process, applicable mainly to technical schools and illustrating the first approach, is considered in [15].

1st component: *Robotics as an object of study* - history of robotics and its development prospects, the place and role of robotic systems in modern society; foundations of philosophy and methodology of robotics; modern robotic solutions; robot properties as a "sense of touch", "sense of smell", "sense of sight", "hearing sense", "speech", "memory", "nervous system", artificial intelligence; robots communication, etc.

2nd component: *Designing and programming of robots* - robots and their systems - sensors, actuators, control, robotic demonstrations and experiments, creation of a virtual model of robot, 3D printing of robots, performing tasks with concrete objective by using constructed robot, etc. Different type of robots are available on the market for this purpose - Lego education WeDo, Lego Mindstorms, EV3 [4]. Experimental results show that these robots are stable and reliable and are welcomed by the majority of young people.

3rd component: *Robot as a means of teaching, development and upbringing* - educational functions of robots in combination with others technologies. There are many examples in the literature for using humanoid robots as a teacher [16], [17], [18], [19]. By now the most of these robots are used for foreign language learning. In Denmark, for example, a humanoid robot NAO is used as an educational tool [20].

Reviews of recently published scientific literature on the use of robotics in schools are given in [21] in order to: *(a)* identify the potential contribution of the incorporation of robotics as educational tool in schools; *(b)* present a synthesis of the available empirical evidence on the educational effectiveness of robotics as an educational tool in schools, and *(c)* define future research perspectives concerning educational robotics. After systematically searching online bibliographic databases, ten relevant articles are located and included in the study. The articles reviewed suggest that educational robotics usually acts as an element that enhances learning. However, this is not always the case, as there are studies that have reported situations, in which there was no improvement in learning.

In [22] authors present a constructionist approach to introducing robotics in the early childhood classroom. This approach asserts that people learn better when they are engaged in designing and building their own personally meaningful artifacts and sharing them with others in a community, i.e. the moto is “learning by designing”. They introduce a methodology for teaching pre-service teachers to integrate technology in the classroom and describe four different experiences in which pre-service teachers designed and integrated robotic projects done with LEGO Mindstorms and ROBOLAB to engage their young students in exploring and learning new concepts and ways of thinking.

In [23] several promising instructional models for teaching engineering in P-12 classrooms are presented as examples of how engineering can be integrated into the curriculum. While the introduction of engineering education into P-12 classrooms presents a number of opportunities for STEM learning, it also raises issues regarding teacher knowledge and professional development, and institutional challenges such as curricular standards and high-stakes assessments.

b) Virtual Reality, Augmented Reality and Mixed Reality

The second considered technology with high potential to be used effectively in the mass education which is already used in many schools is Virtual reality. VR technology is an ideal example of using the second mentioned approach because it can be implemented in all subjects. Using this approach includes materials for instructors that facilitate the selection of themes, goals of education, related subjects and curriculum, compliance with STEAM learning, overall plans, evaluation criteria, evaluation plans, and instruction/learning course plans in each session, and materials for students for introduction of themes, thought-sharing, thought-representing, thought supporting, and thought-reflecting activities.

Virtual reality (VR) can be referred to as immersive multimedia or computer-simulated reality. It replicates an environment that simulates a physical presence in places in the real world or an imagined world, allowing the user to interact in that world.

Augmented reality (AR) is a live, direct or indirect view of a physical, real-world environment whose elements are *augmented* by computer-generated sensory input such as sound, video, graphics or GPS data.

Mixed Reality (MR) brings a new dimension to students - physical interaction. MR content allows students to physically interact with a huge range of exciting 3D models - holding a human heart in your hands, getting up close and personal with a black widow spider, or stepping inside a medieval house. MR allows you to manipulate and view the model exactly as if you were holding it.

By using VR, AR and MR pupils in mass education can interact with the teacher, each other and with the virtual objects within this 3D environment and thus create experience by interesting, entertaining and engaging learning [24]. VR technology is an ideal example of using the second mentioned approach because it can be implemented in all school subjects.

Oculus VR glasses can be used in all subjects - geography, history, chemistry, engineering, mathematics, arts and culture, zoology, astronomy, anatomy, biology, architecture, design, languages learning, etc. combining a *virtual reality headset* with a *motion sensing device* allowing to create a mixed reality that might be used for different educational applications in mass and special schools [24]. Learning means that a strong memory trace is created to keep the learned material. Adding more modalities, like touch and audio, strengthens the memory traces. Several VR platforms are already on the market. In order to work properly, each platform should have the following elements:

- Playlist or Catalog with sample of VR and AR lessons, all aligned to the national curriculum for each class, which is continuously renewed**;**
- Videos are all sequenced simultaneously, so every student can see the video at the same point, allowing teachers to describe and comment it;
- Kids can use VR, but the teachers have to be careful [26];
- Real-time tracking of headset movement and orientation, providing valuable feedback to teachers and possibility for continuous control by the teacher and to have a view of exactly where each student is looking in their headset;
- Option for automatically lock into the selected activity from the playlist.

Conclusions

Three directions for introducing the new technologies are considered in the paper – in special, non-formal and formal education. The authors' research experience in both special and non-formal education is discussed and conclusions are derived based on previous and current research, revealing the big and unexplored yet potential of R&ICT. The introducing of emerging technologies in formal education has specificities to be accounted for in future schools enhancing pupils digital knowledge. Different innovative technologies like humanoid and non-humanoid robots, drones, virtual, augmented and mixed reality can contribute to the learning process if used in a competent and creative manner, which is set as future direction for research.

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