Indicator 2 - Literature review describing most recent technological state of the art

Rapid development of modern technologies will enhance the education by making learning interesting and interactive. Several new and emerging technologies can contribute to the “Program for introducing modern methods in education”. Usefull R&ICT (Robotics and Information and Communication Technologies) and how to improve the digital skills of children in school are discussed in [1]. We are not talking about computers, interactive boards, laptops and online learning plans massivly applied in school, however for robots, virtual reality and other technologies with high-potential to be used effectively in mass education for learning through experience. The reasons for restricted use of R&ICT are obvious – robots and new devices are expensive, cannot be delivered to any school, there is no developed methodologies and teaching capacity in every school. Commercial social robots currently available in education can be found in [2]. Change from books to Virtual Reality (VR) or Augmented Reality (AR) will create illusion of real-life where pupils can learn by practice in a kind of reality or learn and experiences new motor, cognitive and social skills through serious games or explorations in Virtual School Cabinets.

Our new findings how to contribute in enhancing the education are based on the traditional idea that pupils learn by experiences and interactions with the world. However, when this experience is impossible, unafordable or costly, innovative technologies can offer an illusion of real-life interactions and exploration of places and ideas. Pupil will be engaged with a digital content or *interact with holograms in the world around them*. Learning somewhat means that one has created a strong enough memory trace to keep it and adding more modalities, like touch and audio, strengthens the memory traces [3]. That’s why we search, protocol, test and promote how to use modern technologies and add new modalities to make learning interesting and interactive in order to be effective.

1. Introduction

Our research interests concern how to introduce robots and emerging technologies in 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 in order to overcome the learning difficulties and raise the educational level of the young generation of the citizens for a better future. Three directions for introducing the new technologies are considered – in special, non-formal and formal education. There is no doubt that non-formal and special education meet better the individual needs of pupils. When the new R&ICT technologies are included the results could be impressive. Recently, new approach to work with motivated students is used - to engage them in science by an innovative approach of teaching and learning using hi-tech R&ICT. Moreover, combining a *virtual reality headset* with a *motion sensing device* allows to create a mixed reality that might be used for different educational applications in formal, non-formal and special schools. By using VR and AR pupils in mass education can interact with the teacher, each other and with the virtual objects and thus create experience within this 3D environment by interesting, entertaining and engaging learning. Discovery and learning is most pleasurable when it is shared with someone else and leads to confidence and security for more learning by exploration. Another advantage is the possibilities of these technologies to assess the learning process not only by quality but also by quantity. The innovative technologies under consideration are social robots, motion sensing and virtual reality technologies, equipted by sensors that are programable by the use of software development kit (SDK). Thus researchers can develop educational applications or monitoring tools running on Microsoft Windows PCs or on mobile OS.

The European project SCIFUN [4] addresses the challenge of engagement in science through an innovative approach of teaching and learning. It proposes interesting ideas on how to create, investigate and experimentate augmented reality. In the project document [5] several case studies in different countries how to make learning for fun are presented.
Experimented in several places in the world with humanoid robots as a teacher are conducted, e.g. in Denmark a humanoid robot NAO [6] as educational tool is used [7]. NAO robot has the potential of being used as a playful tool for improving the listening and speaking skills of children with Special Educational Needs (SEN) [8]. The authors of this report have experience from the Robo-Academy project [https://www.facebook.com/robo.academy.bg/] with 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. Another authors' experience in special education [http://ir.bas.bg/metemss/en/index.html] reports that children are attracted by robots spontaneously and this facilitates the assessment process by high-tech technologies.

2. Intelligent sensors and technologies

We propose possible solutions and platforms from the state-of-the art for teaching children by an innovative model for learning and practicing through serious games and/or just „by exploring" (depending on pupil age). Pupils will receive „hands-on experience", i.e. knowledge and skill get from doing something rather than just reading about it or seeing it. Thus they will get experience for any piece of high technology and the most value knowledge that will make them confident in their future life. They will receive an idea how to set up and/or program in practice the modern technologies. Children will get use to integrate the above mentioned technologies.

Platforms to be used:

2.1. LEAP MOTION

How to use
Leap Motion is a device for gesture based computer interaction [9]. Kids have grown up with touchscreens and the idea is instead of needing to touch a screen or use a mouse the controller to track the motion of their hands to control a PC. They will learn and practice by Leap Motion-based serious games and will have an option (depending on their age) to learn the basic how to use the corresponding SDKs to program Leap Motion and to get „hands-on experience" how to develop simple games and applications for motion sensing devices (Leap Motion and MS Kinect). It can be used for designing mixed reality by merging of VR with real-life world by digitally-generated sensory human input. Could be used as input in VR for Embodied Learning Education.

Developing skills

Sensorimotor skills. Fine and gross motor skills. Controlling robots and digital objects on screens. Promoting more movements in children resulting in exponential neuronal growth because the movements of our bodies (as well the complex gesture made by our fingers) correlates with synaptic connections in the brain and creates rich semantic neural networks.

Age
Children above the Age of 13. LeapMotion website, products and services are not intended for children under 13 years of age.

Formal education
Leap Motion in Education [10] can be used for exploring nature, objects, daily routines, emotions and socilal skills.
Examples: Discovering the secrets of the Universe with VR and Embodied Learning [11].
Leap motion supporting medical education [12]

Special Education
Leap Motion Serious Games.
Examples: [13][14]

2.2. Oculus VR glasses

Oculus VR glasses [15] is a relativly one of the low-cost Virtual Reality (VR) devices with a very good quality. It will be very useful for innovative gaming education based on learning by serious games. Children will have an option (depending on their age) to learn the basic how to use the corresponding SDKs to program and test very simple applications for Oculus VR glasses and thus to "learn by exploration". The sensorimotor system is involved in the process of Embodied Learning and the perceived stimuli are transformed into a more stable memory and cognitive representations. The notion of body includes not only the body itself but also the senses, the mind and the brain, that is the whole of the student's personality [2].

Develping skills
Creating of synaptic connections in the brain and rich semantic neural networks. Emotional involvement. Engagement atention and focusing.

Age
Children above the Age of 13.
The biggest issue when dealing with children and any Head Mounted Display (HMD), is to take into consideration the Inter-pupillary distance (IPD). Devices like the Oculus and Gear VR have lenses at a set distance and allow for minor tweaks to alleviate variation in IPD. Adult averages usually fall around 63mm however there is quite a variation based on gender, race, and age making these values fluctuate between 48 and 73 mm. In order to accommodate this average, the Samsung GearVR lenses are 63mm apart from center to center.(https://www.quora.com/Why-do-you-have-to-be-13-to-use-Gear-VR-and-Oculus-Rift)

Kids can use VR, but be careful (https://www.vrheads.com/kids-can-use-vr-be-careful)

Formal education
Visualization of the lessons by learning in virtual reality [16]. Learn about your favorite Dinosaurs in Virtual Reality [17].

For trainers and simulators: A VR sports training to take athletes to the next level [18]. Using the forklift training software and Oculus touch controllers to move the different levers to operate the forks as in real-life [19].

Special Education
Oculus Rift used in Serious games. Virtual reality rehabilitation for children with special needs [20].

2.3. MS KINECT SENSOR

Using external motion-sensing technologies such as MS Kinect [21] that captures and provide body skeleton joints in 3D coordinates based on RGB and depth data, we profile groups of children behaviour by angles and their derivatives in time and implement a new method for classification as an assistive tool for special educators to gather and collect evidences, interpreting them and acting on interpretations online.

Design of serious games: the first step toward design of a gesture-controlled interactive experience is to capture and analyse the expected movements within the context of the application (game). More details can be found in [22]. Both the quantity (e.g., number of repetitions) and the quality (e.g., trajectory, speed) of movements must be captured and visualised from the depth data of whole body pose changes and emotion recognition via facial expressions.

Developing skills
Sensorimotor skills. Practice body motion and gain skills in art, sport, science, etc. Engagement. Creating of synaptic connections in the brain and rich semantic neural networks. Emotional involvement. Motivates children with a sedentary lifestyle to move with their body in order to achieve the goal of the games or to control robots and digital objects on screens by their body parts. Effectiveness of the use of a Kinect learning game for children with gross motor skills problems and motor impairments.

Age
Children above the Age of 5.

Formal Education
Embodied Learning. Serious games. Trainers and monitoring tools to practice skills in art, sport, science. Monitoring tools.
Examples: Human Gesture Quantification: an Evaluation Tool for Somatic Training and Piano Performance [23]. Structured educational math games [24]. Monitoring tools for body motions [25, 26].

Special Education
In [27] the first very positive findings from an empirical study about the effectiveness of the use of a Kinect learning game for children with gross motor skills problems and motor impairments are presented.
In [28] the Kinect-enabled serious games that develop fine and gross motor skills are illustrated. Kinect also is used as an assistance tool in the triple configuration child-robot-therapist to enhance the pedagogical rehabilitation. Kinect is used to imitate hand gestures.
In [29] Microsoft Kinect 3D Training Simulation - Virtual occupational therapy assistant (VOTA) is ilustrated. VOTA is developed in recognition of the need for a gaming application

for stroke therapy that is fun, accessible, and meaningful in the context of occupational therapy objectives -- in other words relearning skills that permit functional independence at home. To meet this need, Serious Game developer, Designing Digitally, Inc. created this simulation that incorporates Microsoft Kinect.

2.4 MICROSOFT HOLOLENS

Microsoft HoloLens [30] is the first self-contained, holographic computer, enabling you to engage with your digital content and *interact with holograms in the world around you*. Mixed reality with HoloLens brings people, places, and objects from your physical and digital worlds together. This blended environment becomes your canvas, where you can create and enjoy a wide range of experiences.
An evolution for education - explore places and ideas. A new dimension of creativity and teamwork.

<u>Formal education</u>
Explore places and science.
3D Geometry in the Classroom
Medical Science Training areas relating to anatomy and physiology
Bringing a view of the earth and space.

Free applications are available to be used on the technology Hololens in the education environment. For example, HoloTour:
Description
With HoloTour, you can explore the beauty and history of Rome or uncover the hidden secrets of Machu Picchu. Effortlessly move and look around your real world to naturally interact with the elements of the tour. Immerse yourself with a unique combination of 360-degree video, spatial sound, and holographic scenery that creates a very real sense of presence: you'll believe that you're really there! Melissa, your personal tour guide, will also be there every step of the way. Her expert insight and fun attitude always provides a fresh...

<u>Non-formal education</u>
Explore ideas. A new dimension of creativity and teamwork.

MS HoloLens will be an opportunity not only to use new technology to create what you imagine and explore. Transform the ways you communicate, create, collaborate, and explore. Your ideas are closer to becoming real when you can create and work with holograms in relation to the world around you.

By HoloLens SDK applications are built for mixed reality. SDK for Windows Mixed Reality development use Visual Studio with the Windows 10 SDK. If case of don't having a mixed reality device - HoloLens emulator can be installed in order to build and test mixed reality apps without a HoloLens.

New way of Interactions: With VR headsets pupil are completely cut off from their local environment visually and the AR headsets allow students to be able to see an instructor, each other and also to interact. They will be seeing the same model but from different viewpoints.

<u>Special education</u>

Augmented Reality Treatment For Autistic Children - Develop an augmented reality environment where autistic children engage in activities to develop behavioral skills [31]. By integrating many scenarios, children will have the opportunity to play with others and animals. Expand the product to adolescents be developing more complex scenarios All levels would have different instances to show altruistic behavior some obvious while others being more delicate. At the end of the interaction an empathy score can be obtained.
MR new gaming development could have wide-ranging applications in healthcare particularly in the treatment of those suffering from autism or disability [32].

3. Applications of Social Robotics in education

3.1. HUMANOID ROBOT NAO

The humanoid robot NAO has 25 degrees of freedom and a humanoid shape that enable him to move and adapt to the world around him. It has the numerous sensors in his head, hands and feet, as well as his sonars, enable him to perceive his environment and get his bearings. With his 4 directional microphones and loudspeakers, NAO interacts with humans in a completely natural manner, by listening and speaking. NAO is equipped with two cameras that film his environment in high resolution, helping him to recognise shapes and objects.
To access the Internet autonomously, NAO is able to use a range of different connection modes (WiFi, Ethernet) [6].

The humanoid robot NAO can be controlled with a software Choregraphe. With Choregraphe provides a wide range of opportunities for students in the lower and upper classes. With Choregraphe the students can:
- create animation, behaviors and dialogs, which can able to test through simulation on virtual robot or directly on a real robot;
- monitoring and control of the robot via an interface Monitor
- enrich Choregraphe behavior with their Python code.

The training is conducted with a gradual accumulation of knowledge and complexity of tasks. On Choregraphe for control of robot NAO the program language Python is used. Python has a simple syntax which is suitable for learning by students.

Formal Education

Experimented in several places in the world with humanoid robots as a teacher are conducted – Japan [33], South Korea [34], Finland [35], Sweden [36], Chile [37]. The most of these robots for foreign language learning are used. In Denmark [7] a humanoid robot NAO as educational tool is used.

Non-formal education

In the Institute of robotics – BAS a student training program for humanoid robot NAO is applied.
The base level of education includes: study of the device and technical characteristics of the humanoid robot NAO and Choregraphe software with the accompanying documentation.
The students learn how to use the Python diagram blocks from Box library and Pose library, and they learn through animated methods different robot behaviors.
After the training at this level, students acquire the following knowledge and skills:

- prepare robot for use;
- perform wired or wireless communication with the robot;
- listen to messages about the robot's current status after sound signalization

- use a voice command for the robot by text which is entered in Say text box used from Box library;
- use commands for motions and pose of the robot
- use script box Speech Recognition for a human voice recognition;
- create arms motion by using 3D virtual or real NAO robot and recording positions in frames;
- use tactile sensors located in legs head and arms for a different robot behaviors for instance, change of Led lights, motion, sound commands and others.
- use sonars for obstacle avoidance;
- use sound records for the robot;
- use timeline layers for control of different parts of the robot body;
- use a face detection module for a human face recognition through Face Detection box in combination with sound box commands;
- control robot through NAO marks, recognized by the robot based on entire algorithm;
- create original projects on Choregraphe for human – robot interaction;
- solving tasks for passing labyrinths using NAO marks

On next level the students improve their knowledge skills about robot NAO control using parameters from Python diagram boxes to define voice settings, walk on axis - X, Y and rotation of the robot. They learn for a Python conditional operator “Switch Case” of “Box library” through enter the strings or integer numbers which using for links with other Diagram boxes. Students acquire skills to control robot in an animation mode in conjunction with the Timeline Editor. On this level students learn how to extract data from the robot sensors and they use more complex combination of Python diagram boxes in order to control time for concrete behavior of the robot. Performance of single or multiple repetitions, face recognition after face detection learning session.

Advance level students learn programming of Python on Choregraphe software. They learn to add Python script code in Diagram box in order to improve the robot behavior or they learn to enter Python code in new created Diagram box for specific robot behavior. The students learn the Python script modules to call methods and events which are necessary to control the robot behaviors. The students learn to create parameters and variables of different type in order to define number and type of input-output parameters for each Python diagram box. They learn Python operators - logical, arithmetic operators, comparison operators and etc. loops.

The humanoid robot NAO learning program allows students of different ages to develop their creative and innovative thinking.

The Institute of robotics – BAS has a project “Robo-academy” for development of young talented students. In this project, programming of the humanoid robot NAO for learning tasks is used.

The robot NAO demonstrates lesson in Physics - ball throw at a different angle of rotation of the right arm in order to define flight length of the ball from real experiment compare with theoretical calculations. During the experiment the students tell the lesson and assist the robot to place and grab the ball in his fingers and when the robot has to throw the ball using the robot's tactile sensors on right arm and head. The program for Physics lesson is realized in Choregraphe software using Python script language.

Special education

Based on the project funded by European Economic Area: “Methodologies and technologies for enhancing the motor and social skills of children with developmental problems” in the Institute of Robotics – BAS several techniques are developed to support the therapy of children with special needs. Based on the medical opinion of a child psychiatrist for diagnostic profile of each child with special needs the programs applied for the NAO robot are created.

Programs of the robot movements for imitation the by children with special needs are developed. They are developed in two directions: education and motion activity.
The motion activity programs include physical exercises and song training programs.
To improve the social skills, concentration and cognitive skills of children, game scenarios with the NAO robot are created:

- basketball in which one or two children can participate
- geometric shapes to study the shape and color for individual a child learning
- a child builder for learning by imitation
- dance

3.2. LEGO MINDSTORMS

Lego kits [38] are the most commonly used according to the literature, in all K-12 and universities. Lego Mindstorms EV3 (2013) has a Processor TI Sitara A, M1808 (ARM926E J-S core) @300 MHz; Programming Language EV 3 Software; Sensors Connection - Speaker, Touch, Colour, IR, Motors, Gyroscope and USB, Wi-Fi and Bluetooth, connections. Assembly is the basic feature of Lego kits, however their modular design allows students to create their own robots, thus, helps them improve their visual spatial skills and stimulates them to experiment and innovate. They come with a variety of sensors and allow further expansions. On the other hand, modular design is considered as a disadvantage, since brick components easily go missing. Moreover, there are limited inputs for sensors, thus, the range of potential learning and real-world applications are limited [38].

Formal education
Lego is utilize in the majority in regular education [39]. Lego programming is easy to learn, both for student and teachers. It increase motivation on computer science. Explore ideas. A new dimension of creativity and teamwork

Non-formal education
Lego Mindstorms EV3 (2016) increase motivation on computer science in a bachelor course in mechatronics [40]. Students had to program too much and lost the actual content of the exercises. Motivation and fun factor were not increased, due to the workload for the EV3 programming

Special Education
Authors in [41] explore the potential of robotics as an educational tool in special needs education. Qualitative case studies are used to increase knowledge about programmable LEGO NXT and Topobo robotics constructions kits in special needs education, and about the social robot and Topobo that are used in early childhood education when possible learning disabilities have not yet been diagnosed. This study aims to provide suggestions about how robotics might be used to recognize disabilities at an early stage of education and to compensate for them in learning. A useful training protocol for controlling LEGO robots via Speech Generating Devices is proposed in [42].

3.3. WALKING ROBOT „BIGFOOT“ (developed in IR-BAS)

In general, walking robots move in unstructured environments with different obstacles however they have been used sucseefuly in teaching process in non-formal education in the frame of Robo-Academy project [https://www.facebook.com/robo.academy.bg/] and in special education in METEMSS project [http://ir.bas.bg/metemss/en/index.html].

These robots often have a large number of degrees of freedom [43]. The stability of walking robots is a major problem because it determines the conditions under which the robot will not roll over. The stability is divided into two types - dynamic and static. Static stability means that the robot does not need to make any movements to maintain balance. It requires the projection of the center of gravity of the robot to lie on the polygon formed by the support points of the robot's feet. To achieve statically stable walking, the robot must have a minimum number of four legs because at least one leg is in the air while walking. Statically stable walking means that the robot can be stopped at any point from the gait cycle without rolling over [43]. We are investigated solutions for walking robots with a simple mechanical and control system that have good functionality in unstructured environments. The shape and material of the feet are important, they can change the gait, improve traction and the ability to overcome an obstacle. It is interesting to study the contact between different parts of the robot's body and the surrounding environment [44]. Kinematic, static and dynamic approaches to analyze the mechanical design of mobile robots to overcome obstacles are used. A new design of a walking robot with two degrees of freedom is presented, which overcomes obstacles with a simple control system [45]. A 3D printed model of the robot finds application in developping specialized games for children with specific needs [46]. Another application is related to education in robotics - students in computer technology use Arduino platform to control the robot and, due to its simple design, easily develop software for it.

3.4. ANTROPOMORHIC ROBOTIC HAND (developed in IR-BAS)

Two variants of robotic hand have been designed and used sucseefuly in teaching process in non-formal education in the frame of Robo-Academy project [https://www.facebook.com/robo.academy.bg/] and in special education in METEMSS project [http://ir.bas.bg/metemss/en/index.html].
The development of 3D printing technology has increased the interest in developing and exploring humanoid robotic hands closer to biological analogues [47-49]. Power is used to propel the hands, and the tendons are replaced by threads [50]. Experiment with a variety of form-type finger-joint joints using 3D printed elastic elements [48,49]. Some of the developed hands are used in prosthesis and rehabilitation, others in the development of humanoid robots. One of the main problems in designing a humanoid hand with fingers is the large number of degrees of freedom concentrated in a small volume (about 500 cubic centimeters) and a requirement for a small mass. The development of the technologies in the drive mechanisms in recent years allows the construction of miniature components, but it is still not possible to place such a large number of adequate mechanisms in the limited volume of the hand. Moreover, the synchronous control of the large number of electric motors is not easy. It is obviously necessary to make a reasonable compromise with the number of propulsion devices. Looking for small-sized energy sources and great reliability.
-There is a wide variety of movements that one performs through the hand, which is difficult to realize by mechanical construction.
- Most of the gestures are related to complex coordinated finger movements. In some cases it is necessary to describe the trajectories with the fingers or speed control is needed. Precision servomotors and specialized algorithms are used to manage them.
- Problems related to servomotor management: A suitable microcontroller is required which offers parallel control of at least 6 servomotors, has a convenient interface for communication with a computer and is reliable enough; An important factor is the compactness of the control circuit board, which is mounted near the robotic hand.
Issues for the reliability of the elements: Constructions are complex and built up with a large number of elements in order to achieve the desired spatial movements, which is a prerequisite

for lowering reliability; For the transmission of the movements at a greater distance, threads and elastic elements [50, 52] are often used, which tend to change their qualities over time. The referenced articles discusses the development of 3D printed hands that solve some of the problems mentioned and are mounted to a robot. Different variants of model management and application are considered [51,53,54].

3.5. CUBELETS

Cubelets are robot components [55, 56] - small color coded cubes that people magnetically stick together to form a variety of simple robots (a kind of modular robot). This could be the first programmable robot of a kid above 4 years old.

The Cubelets Robot Blocks are devided in 3 groups – Sense, Think, Act. This contributes to a fast and easy way to inspire kids to become better R&ICT thinkers. Children understand the cause and effect relationship between the Sense Cubelets (which act as inputs to give the robot instructions) and the Action Cubelets (which are the output of the robot). Think Cubelets, like the Blocker and Inverse, can be used to create new behaviors in robot creations and add an extra challenge. Placing Think Cubelets in your robot construction changes the data flowing between the Sense and Action cubes, adding complexity to the robot [58]. Cubelets Blockly offers a great introduction to coding using Google's visual programming language and for more advanced computer science students, Cubelets Flash can be used to program Cubelets using the C language. Cubelets Flash is a simple application for Mac and Windows that lets you drag C programs onto any Cubelet in a robot and reprogram in real time. By connecting Bluetooth Cubelet to PC computer by the power of *Cubelets Flash* new advanced behaviors for the robot constructions can be created! Why is it called *Cubelets Flash*? Each Cubelet contains a tiny computer called a microcontroller. Typically, when engineers change the programming in a microcontroller, they call it "flashing". More for Cubelets Robot Blocks can be seen at Cubelets official web site [55].

<u>Formal Education</u>

Cubelets are engaging and intuitive and an ideal start into computational thinking in Robotics. Complex lessons made simple. Pupils can design and redesign robot constructions with ease, using the robot blocks to model real-world behaviors and to introduce pupils into a new world of creativity and learning by exploration. For instance, free lessons can be find here: https://www.modrobotics.com/education/lesson-plans/meet-your-cubelets-units/

<u>Non-Formal Education</u>

Programing Cubelets by *Google's visual programming language for Cubelets Blockly* and *Cubelets Flash* to program Cubelets using the C language is an ideal and engaging software and hardware platform for more advanced computer science pupils. High School teachers integrate Cubelets into their lesson plans all the way through 12th grade, with many schools even using Cubelets for Professional Development with Teachers and Administrators.

<u>Special Education</u>

The authors in [57] analyses play and playfulness in children with Cerebral Palsy (CP) using mainstream robotic toys (one of which is Cubelets) supported by adult play partners. Five mainstream robotic toys were selected and used in play situations with six children with CP interacting with two adult partners. The play situations were coded through the Test of Playfulness (ToP) and the Test of Environmental Supportiveness (ToES), to analyse the role of robotic toys, adult partners and environment in supporting play and playfulness in children with CP. The children obtained high ToP scores, showing that they were intrinsically motivated to be engaged in the play situations with Cubelets.

Children above the Age of 4.
What is the suggested age range for Cubelets? The recomdations are cited form [58]:
- For kids up to 6, we recommend using mostly Sense and Action Cubelets.
- For kids over 6, the addition of Think Cubelets adding complexity to the robot.
- Pre-teens and teens can reprogram and control their robots with the Bluetooth Cubelet. The new OS 4 platform allows for a faster reaction time between Cubelets, as well as improved Bluetooth capabilities.

3.6. DASH & DOT ROBOTS

Dash and Dot [59] are robots that can sense, act and think and can be used in education successfully [60]. Students use block coding on four different iPad apps to control their robots. Maker materials can be added such as LEGO, tape, cardboard and more to transform your robots. Dash and dot also have educational accessories that can be purchased to support art, music and engineering.

Formal Education
Teachers looking for a new educational tool for teaching robotics and programming to younger students or interested in developing child's curiosity of new technologies have durable and child friendly robots and a safe and easy way to encourage STEAM learning in classrooms.
Ready solutions for how to apply Dash and Dot in education are available: DASH AND DOT CLASSROOM PACK [61]. Robots that you can code, shared classroom model serving up to 36 students with the Classroom Pack that includes:
6 Dash robots, 6 Dot robots, 6 Launchers, 6 Building Brick Connector Sets (4 connectors per set), 6 Accessory Packs, 6 Challenge Card Box Sets, 1 Learn to Code Curriculum Guide.

Special Education
The authors in [57] analyses play and playfulness in children with Cerebral Palsy (CP) using mainstream robotic toys (one of which is Dash and Dot robots) supported by adult play partners. Their experimental findings are that Dash and Dot are not proper for children with CP.

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