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EDUCATIONAL ROBOTICS: RESEARCH AND PRACTICES OF ROBOTS IN EDUCATION

PEER REVIEWED PAPERS

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THE ISSUE
VOL. 15, N.2, 2019

by Nicola Villa

This issue is focused to the theme **Educational Robotics: Research and Practices of Robots in Education**, edited by Veronica Rossano (University of Bari, Italy) and Rita Francese (University of Salerno, Italy).

All the paper of the theme are introduced in the Editorial by the Editors.

We also publish two additional articles accepted after a peer review procedure:

- **Chen *et al.* -** *Engaging parents Involvement in K – 12 Online Learning Settings: Are We Meeting the Needs of Underserved Students?*
- **Maria Metodieva Genova -** *Designing an effective digital learning environment for teaching English through literature: the learning experience of Bulgarian students*

I want to thank all the authors of the papers selected in this issue for the great job and collaboration, and for the quality of their contribution.

My special thanks to the Editors of the special issue for their increbible sense of responsibility and dedication to complete this publication.

The next special issue of September will be entitled **"Learning Analytics: for a Dialogue Beween Teaching Practices and Educational Research"**. It will collect theoretical, empirical and comparative contributions of educational and didactic research on the main topics covered in the conference on "Learning Analytics, for a dialogue between teaching practices and educational research" held in Rome 10 and 11 May 2019.

You can find all the information of the Je-LKS's call for papers and read all the article freely on the journal's website **www.je-lks.org**.

Nicola Villa
Managing Editor
Journal of e-Learning and Knowledge Society

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EDITORIAL

by Veronica Rossano and Rita Francese

Focus on:
Educational Robotics: Research and Practices of Robots in Education

Educational Robotics is an innovative way for improving effectiveness in learning and teaching processes. While in the past Game-based learning (Prensky, 2003) has been one of the most used approaches in different contexts to enhance the effectiveness of education (Di Bitonto *et al.*, 2012, Brezovszky *et al.*, 2019, Francese *et al.*, 2018, Hung *et al.*, 2018) , at the present educational robotics is one of the most popular at all school levels. The integration of robotics in teaching and learning processes and its effectiveness in achieving specific learning objectives has been deeply studied in the latest years (Mubin *et al.*, 2013, Toh *et al.*, 2016). The success of this approach is based on Papert's Constructionism Theory (Papert, 1980): learning can be more effective when people are active in making tangible objects in the real world. Students are more engaged in the learning process through design, creation and programming of tangible artifacts for creating personally meaningful objects and addressing real-world needs. This is particularly true for digital natives who need to be actively involved in the learning process to make it successful.

There are different kinds of robots used for educational purposes, such as improving social skills or learning to program. For example, humanoid robots, such as Nao, Pepper, Robovie and EZ-Robot JD, are useful for their social interaction skills. Their capability of exhibiting social supportive behaviors by using speech, gestures and emotional expressions with a physical robotic embodiment allow us to make the learning process more engaging (Saerbeck *et al.*, 2010). Moreover, it has been proved that robots are particularly effective when used with children with autism spectrum disorder (ASD) (Amanatiadis et al., 2017), or in language learning (Belpaeme *et al.,* 2015) contexts.

Robotic education is based on the idea of creating artifacts that can be programmed to perform some tasks. For instance, LEGO® Mindstorms allows children to build robots using special LEGO blocks and to program them to solve specific problems. This kind of activity has been proved to be effective in different contexts (Haak *et al.,* 2018, De Vries *et al.,* 2018, Umbleja *et al.*, 2017). Arduino board (Plaza *et al.*, 2018) or BBC micro:bit (Rogers & Siever, 2017) are adopted to allow students to implement IoT-based (Internet of Things) applications. Robotics is widely adopted to support the learning of Science, Technology, Engineering and Mathematics (STEM). Accordingly, this special issue aims at exploring the challenges and opportunities of Educational Robotics and its vast combination and integration in traditional learning processes.

The special issue opens with a paper by **Donato Malerba *et al.***, *Advanced Programming of Intelligent Social Robots*, which describes the main computational methods required to program a social robot and equip it with intelligence to enhance the learning process. Social robots are very interesting in the educational technological field, since they are able to interact with people in everyday environments, using social behavior typical of humans. The paper describes the main skills for social intelligence and proposes a framework of design issues for the advanced programming of social robots, that make social robots effective in educational contexts. A brief state-of-the-art of some applications of social robots in Education is described as a starting point for further research that authors would like to investigate.

Also the paper by **Hagen Lehmann** and **Pier Giuseppe Rossi**, *Social Robots in Educational Contexts: Developing an Application in Enactive Didactics,* discusses how social robots can enhance learning processes. The authors propose a theory-driven approach based on the idea that the combination of enactive didactics and social robotics holds great promise for a variety of tutoring activities in educational contexts. The proposed approach, named Enactive Robotic Assisted Didactics, is used in the paper to give an overview of how humanoid and semi-humanoid robots have been adopted in educational contexts in the last two decades.

The paper by **Berardina De Carolis *et al.***, *Social Robots supporting the Inclusion of Unaccompanied Migrant Children: Teaching the Meaning of Culture-Related Gestures* proposes using social robots to support the integration of unaccompanied minor migrants in a new culture. The idea investigated by the authors is to exploit a social robot for teaching culture-dependent gestures to children coming from other countries. The collateral effect that the research wishes to have is to support the social operator in establishing a contact with these children, who do not trust adults because of the difficulties encountered during their journey. The pilot study was conducted with Italian children, but the results seem promising; the application to this particular context appears to be difficult but hopeful.

There is much scientific evidence to prove the effectiveness of humanoid robots in children with ASD. Following these routes, the paper proposed by

Valentina Pennazio and **Laura Fedeli,** entitled *A proposal to act on Theory of Mind by applying robotics and virtual worlds with children with ASD,* uses robotics and a 3D virtual environment to support the development of social behavior and relations in children with ASD. The final idea is to gradually support the subjects in interactional settings, in order to help them acquire the self-confidence needed to finally interact with a classmate in the virtual environment. The technological mediators would activate communication and improvesocial interaction, that can represent a barrier for the active involvement of children with ASD in the school community. The results of this type of study are difficult to generalize, since the dimensions to be evaluated are multiple and vary depending on the individual child's attitude.

Educational robotics is naturally applicable to STEM disciplines, and in particular computer science and computational thinking skills, but in many cases, it is used also to improve creativity and collaboration among children. This is the objective of the study reported by **Lucio Negrini** and **Christian Giang**, in *How do pupils perceive educational robotics as a tool to improve their 2st century skills?* The paper describes their experience with robot Thymio II, a small robot with a large number of sensors and actuators which can be programmed using a visual environment. The results of the study are very interesting: the girls perceived a greater impact on collaboration and creativity skills rather than on technical skills, while boys perceived a higher impact on their technical skills. This unfortunately means that it is not easy to attract girls to technological studies, so other more attractive activities should be studied to address this current worldwide challenge in the field of STEMs.

Robotic education could be effective not only with children but also to make complex concepts easier for adults. This is the objective of the experience described by **Flaminia Luccio** in the paper *Learning distributed algorithms by programming robots.* The Lego Mindstorm EV3 robot and Makeblock mBot robot were involved in a project-based learning approach at a university to introduce theoretical models and algorithms in the area of distributed algorithms. The students were asked to replace the traditional exam with a practical project using distributed algorithm models to program robots. The activities were engaging for students and their motivation led to excellent final grades and also increased collaboration skills among students.

Finally, experience of tinkering is described by **Antonella Poce *et al.***, in *From Tinkering to Thinkering. Tinkering as support for the development of Critical and Creative Thinking.* Tinkering, is an informal method to engage students with STEM subjects. It is employed to develop students' scientific knowledge and to support thinking processes such as Critical Thinking and Creative Problem Solving. Tinkering often incorporates different kinds of "languages", from painting to coding. The authors propose a pilot study involving STEM teachers and museum educators to measure how Tinkering could influence Creative and Critical Thinking levels. The activities designed concerned different school levels, from primary school to secondary school pupils, and different topics such as Electricity, electro-magnetism and reflection of light. Some necessary materials were given, and the participants were required to plan their own Tinkering activity. The feedback was positive; participants showed significantly higher Creative Thinking levels.

The issue faces several kinds of applications of educational robotics, starting from humanoid robots up to Tinkering activities. Regardless of the technological tool used, all these experiences show a great impact on students' engagement and motivation, which are key components for successful learning processes. One of the main drawbacks of this technology is the cost of these robots, such as Pepper or Nao. Fortunately, at present the cost of hardware is decreasing, thus teachers at all school levels may have access to it. In the future, if public funding is available for financing this type of experience in educational institutions, as happened in the past with the Interactive Whiteboard, robotics-based learning could be applied more widely, giving all our students the opportunity to be more engaged in the learning process.

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ADVANCED PROGRAMMING OF INTELLIGENT SOCIAL ROBOTS

Donato Malerba, Annalisa Appice, Paolo Buono, Giovanna Castellano, Berardina De Carolis, Marco De Gemmis, Marco Polignano, Veronica Rossano, Lynn Margaret Rudd

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Keywords: Social Robot Programming, Machine Learning, Human–Robot Interaction, Education Technology, Affective Computing

Robotics in education is a promising new area: social robots have started to move into schools as part of educational/learning technologies, playing roles in educational settings that range from tutors, teaching assistants and learners, to learning companions and therapeutic assistants. This paper provides an overview of the main computational methods required to program a social robot and equip it with social intelligence. Some applications of social robots in the field of education are reported to show how the use of educational robots may innovate the learning process at different levels and in various contexts.

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1 Introduction: the context and the target

Social Robots are embodied autonomous intelligent entities that interact with people in everyday environments, following social behavior typical of humans. Since they are autonomous, robots should be able to interpret human behavior properly, to react to changes during the interaction, make decisions, behave in a socially plausible manner, and learn from a user's feedback and previous interactions. Social robots are mainly used to improve people experience in diverse application domains. In education, for example, robots have been shown to be successful in diverse contexts, such as math tutoring (Kennedy *et al.*, 2015), social skill training for children with autism (Wainer *et al.*, 2014) and language teaching (Schodde *et al.*, 2017). In particular, the use of robots may increase attention, engagement, and compliance, which are critical components of successful learning (Ramachandran *et al.*, 2018).

This paper provides an overview of the main computational methods required to program a social robot and equip it with intelligence, so that it can be employed successfully to enhance the learning process both in formal and informal settings. The first part of the paper introduces the fundamental skills that should be implemented in a robot to achieve social intelligence, namely sensing, dialogue management, emotion recognition and user modeling. During the interaction, that is achieved through human-oriented sensing tasks and multimodal dialog management, social robots can use machine learning methods to modify the way they provide information, according to the user's needs and emotional reactions. Currently, educational robotics is one of the most promising technologies to improve teaching and learning effectiveness. The second part of the paper focuses on applications that can take advantage of social robots in the realm of education. We report some experiences with the design and the use of educational robots that can inspire new ways to innovate learning processes in various contexts.

2 Skills for Social Intelligence

Social intelligence factors increase the complexity of programming a socially interactive robot. A social robot is expected to sense its surrounding, to handle natural and multimodal dialogs, to recognize and express emotions, and to adapt the interaction to some characteristics of the user. All these skills are the basis for human social behavior models.

2.1 Sensing

Robots can sense the environment by means of integrated sensors or computer vision. For example, the Pepper humanoid robot (Lafaye, 2014) is equipped with both sensors that enable it to perceive the surrounding environment and sensors, like microphones, cameras and touch. Moreover, the tablet PC on the robot's torso allows interaction by means of a touch screen.

Speech recognition techniques are widely used in social robots (Amodei, 2016; Zhang, 2017). Many organizations have launched their own Deep CNN models to improve the accuracy of voice recognition (Xiong, 2017). Advances in this field have paved the way for the development of high-level tasks, such as semantic recognition and semantic understanding, i.e. how to formally represent the meaning of a text, that form the basis for the robot's dialog abilities, as explained in Section 2.2.

Computer vision is fundamental for the recognition of human facial expressions and movements (Canal *et al.*, 2016). The main challenge is to find a representation that can be adapted to a new task with few training data available. State-of-the-art pipelines for single-view action recognition are hand-crafted dense trajectory features and 3D CNN-based features. The CNN-based features are extracted from these intermediate layers and then fed into an SVM for the final classification. In the field of education, problems such as occlusions or poor camera view point can often occur, since the interaction can change abruptly. Therefore, robust multi-view action recognition systems are required (Efthymiou *et al.*, 2018).

Other common computer vision tasks are face recognition and detection of facial expressions and emotions, which are useful to convey the user's feelings to the robot. Specifically, emotion recognition is very important to allow the robot to adapt its behavior (e.g. showing empathy). More details are discussed in Section 2.3.

In general, social robot sensing skills leverage machine learning methods to learn models of human social cognition starting from features extracted automatically from sensory data. The challenge is a fast processing of sensory data, in order to draw conclusions, which may help in the decision of the actions to be performed. Time series algorithms to discover recurrent patterns are mainly investigated in machine learning, in order to address problems of gesture discovery, synchrony discovery, differential drive motion pattern discovery and motor primitive discovery from observations of human behavior (de Jong *et al.*, 2018).

2.2 Dialog Management

In order to obtain a reasonable level of interaction in the conversation, the robot should be able to handle dialogs, that is, modulate the initiative, handle communication interferences, make inferences related to the sentences pronounced by people, plan, organize and maintain the discourse. Starting from the perception (sensing) of the multimodal user input, according to the extracted meaning (semantic interpretation), a dialog manager has to decide (reason) how to respond to the user in a socially believable way, in order to handle the dialog flow (Figure 1). An example of a grounding-based model, implemented to this aim, is given with BIRON (Spexard *et al.*, 2006).

Usually dialog management is based on transition networks, frames (McTear, 1993), information state models (Larsson & Traum, 2000), rule-based models, or planning techniques typical of Belief–Desire–Intention (BDI) agents (Wong *et al.*, 2012). Finite state models are the simplest way to handle the dialog and are suited to applications where the dialog flow coincides with the task structure, however, they lack flexibility. Frame-based approaches are based on the structure of the entities in the application domain. The information state approach has been widely used in conversational systems. It is based on the idea that the dialog flow changes according to the dialog state, that is represented by the current topic, the recent dialog moves and information about the beliefs of the dialog participants. Planning is a more complex approach, but it can deal with changes in behavior that are required when reacting to real-world interaction. A good compromise is a mixture of the two approaches: follow a predefined path, presented as transition networks and replan only when necessary.

Finally, socially guided machine learning can use natural interaction to teach a machine new knowledge and skills (de Greeff & Belpaeme, 2015), while deep learning methods have recently been employed for activity recognition (Mohammad *et al.*, 2018). Machine learning techniques can be used to infer behavioral patterns and interaction protocols. They are explored to identify utterance vectors, typical utterances, stopping locations, motion paths and spatial formations of both human and robot participants in the environment and to train a robot to generate multimodal actions (Liu *et al.*, 2018).

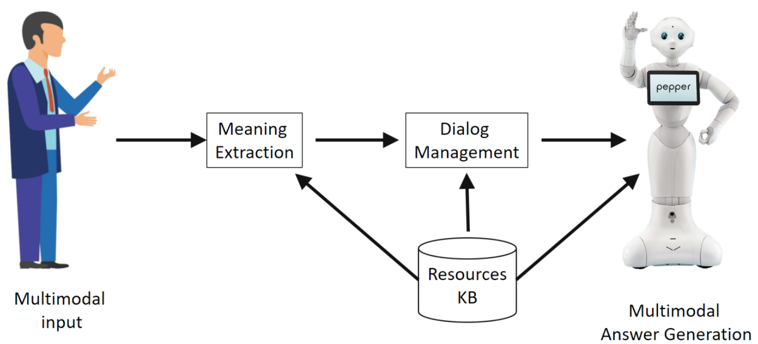

Fig. 1 - Overview of a generic dialog system

2.3 Emotion Recognition

In HRI facial expressions and speech are the most important communication channels that can be analyzed to detect and recognize emotions (Mavridis, 2015).

Ekman *et al.* (2002) defined six basic emotions that are universally recognized from facial expressions, regardless of culture. Other models, such as a Facial Action Coding System (FACS) (Ekman, 1999), can be taken into account when referring to Facial Expression Recognition (FER). A FER system has to be trained on suitable datasets (Ko, 2018) and should include the steps of a pipeline which are typical of this application domain: preprocessing, face detection and registration, feature extraction and classification. Recently deep learning methods have been used in this context, achieving state-of-the-art recognition accuracy and exceeding previous results by a long chalk (Kahou, 2015; Walecki, 2017).

Speech conveys affective information through the explicit linguistic message (what is said) and the implicit paralinguistic features of the expression (how it is said). Speech Emotion Recognition (SER) is basically performed through pure sound processing without linguistic information (Schuller, 2018). Features can be of several types and related to voice prosody, acoustic properties and transformations. In particular, Mel-Frequency Cepstral Coefficients (MFCCs), formants, energy, fundamental frequency (pitch) and temporal features have been used successfully in emotion recognition (Schuller, 2018). Then, as for FER systems, a classifier is trained using machine learning techniques. Also in this domain deep neural networks significantly boosted the performance of emotion recognition models (Fayek *et al.*, 2017).

Face and speech can be analyzed simultaneously and combined to obtain a more robust emotion recognition system by means of fusion techniques (Busso *et al.*, 2004; Zeng *et al.*, 2007; Haq *et al.*, 2008 Sebe *et al.*, 2006; De Carolis *et al.*, 2017a).

Causality analysis is also important for social robots because it allows them to discover the causal structure of a human's behavior during the interaction (Yamashita *et al.*, 2018).

2.4 User modeling

User-adaptive systems rely on a user model, which is a structured representation of user characteristics that may be relevant for personalized interaction (Fischer, 2001; Kobsa, 2001). In the context of social robots, the user profile includes several dimensions, such as age, gender, level of expertise in a given task, emotions, personality and past interactions (Ahmad, 2017), that allow the robot to make decisions. In general, the user model is explicitly designed to facilitate decision-making in the specific field where the robot is involved. For instance, in the health care domain the user profile could store information about the user performance in a given task. In (Tapus, 2009) the robot collected data on the user's reaction time and number of correct answers in a cognitive task and adapted the dialog to motivate the user, according to the results.

Moreover, in the education domain user performance is used to adapt decision-making as well as the verbal and non-verbal behavior of the robot. For instance, in (Brown, 2013) the robot modifies its supportive feedback according to the user's behavioral state (e.g. "unmotivated"), determined by monitoring the student's interactions with the robot when performing a mathematics test.

The application of social robots in public spaces has several challenges from the point of view of user modeling, because the robot is involved in multiple short-term interactions with unknown people rather than in a long-term interaction with a known user. In public areas, such as malls, the user profile stores the information available about the user who is interacting with the robot. For instance, the profile could be acquired by an RFID reader or swiping a fidelity card (Iocchi, 2015). The communication activities and actions are personalized according to the profile, in order to increase the robot's social acceptability.

3 Applications in Education

In the following, we provide some recent examples of the usage of social robots in education (Figure 2), in order to provide a guide for researchers who consider using social robots for different educational purposes:

- Effectiveness: to support knowledge and skill acquisition;
- Engagement: to make children more involved in learning activities;
- Special needs: to support learners with specific difficulties;
- Empowerment of young patients: to educate patients to adopt a healthy lifestyle and to support patients and caregivers in managing specific medical situations;
- Language learning: to support vocabulary learning.

3.1 Effectiveness

One of the main goals investigated in the literature is the use of a human robot as a teacher or tutor to encourage active learning (Bonwell & Eison, 1991), where the teacher becomes a tutor, thus enhancing students' self-confidence and independence. Active learning is used to model a learning agent that can shape its learning experience through interaction with its teacher. Active learning between a robot learner and a human teacher leads to more effective faster learning (de Greeff *et al.*, 2012).

Fig. 2 - Social robots commonly used in education

Leyzberg *et al.* (2012) investigate if the presence of a robot tutor, Keepon (Figure 2), can influence the student's learning gain. The results confirm that the physical presence may imbue the robot with more perceived authority than an on-screen agent.

NAO robot (fig. 2) is used as a tutor in a basic arithmetic learning task. Here again students show a higher level of motivation, which usually results in better learning gain (Janssen *et al.*, 2011). Other researchers have explored the effects of social robots as tutors versus teachers. Howley *et al.* (2014) measure how the social role of both a human and a robot affects help-seeking behaviors and learning outcomes in a one-to-one tutoring setting. The results confirm that the use of pedagogical robotic agents can be more beneficial for learning than the use of human pedagogical agents. Some research investigates the effectiveness of social robots using the peer-tutoring approach. In this setting the social robot acts as the learner's companion. Tanaka *et al.* (2015) develop an application for Pepper to enable it to learn together with children. Baxter *et al.* (2017) propose a robot peer with personalized behavior in collaborative learning tasks with individual children. Both solutions facilitate the learning process and allow children to improve their knowledge and skills.

3.2 Engagement

The effectiveness of using social robots to support user engagement has been widely proved in the literature. Engagement has been identified as a key aspect in Technology Enhanced Learning research, in order to sustain interest, participation and involvement during a learning process (Carini *et al.*, 2006). To be engaging a social robot should proactively involve people in a social context by expressing and perceiving emotions. Another factor that is relevant to engagement is anthropomorphism, since it recalls in the user conversational patterns typical of human-to-human interactions (Bainbridge *et al.*, 2008). In educational contexts student engagement improves learning, therefore, social robots have recently been employed to do so. In (Castellano *et al.*, 2009), the iCat robot (fig. 2) during a chess game displayed affective reactions, in order to improve the user's engagement. To improve the engagement of students, humanoid robots have been used as pro-active tutors (Gudi *et al.*, 2019). The robot can influence the pace of the interaction in a social learning task by increasing the students' learning experience, and thus their engagement even if they do not perceive it (Ivaldi *et al.*, 2014).

3.3 Special Needs

Social robots are often applied in education of students with special needs. Teaching and learning of disabled youngsters pose unique and distinctive challenges. These students demand more time and patience. They require specialized instructional strategies in structured environments, in order to support and enhance their learning potential. Social robots are widely applied to teach basic social skills to children with autism, since they resemble humans but are less complex and seem to be able to manage these issues successfully (Palestra *et al.*, 2017). Wainer *et al.* (2014) employ the KASPAR robot to improve their cooperation skills. Pennazio (2017) used the IROMEC platform to improve human interaction skills. Boccanfuso *et al.* (2017) and Alemi *et al.* (2015) investigate the acquisition of communication skills in a language learning scenario. Pale Social robots are successfully used also in other contexts, for example, to support children affected by dyslexia (Pistoia *et al.*, 2015), or to stimulate social interaction in children with Down's syndrome (Lehmann *et al.*, 2014). They are also applied to people with speech and hearing impairments in sign language learning (Gudi *et al.*, 2019).

3.4 Empowerment

The success and effectiveness of the use of technology to support therapeutic education is increasing. Various ICT solutions address patient empowerment

(Di Bitonto *et al.*, 2012). For example, in medical contexts empowerment refers to the patient's acquisition of knowledge about his/her clinical conditions and the acquisition of a suitable lifestyle to ensure a good quality of life. Social robots, such as NAO, have been applied to support knowledge acquisition in children with Type I Diabetes who have to learn basic knowledge about diet and management of their illness (Coninx *et al.*, 2016; Cañamero & Lewis, 2016). Other experiments have been conducted with children who interact with a social robot to improve their knowledge and habits with regards to a healthy life-style (Ros *et al.*, 2016). A current challenge (Share *et al.*, 2018) is to use social robots as Assistive Technology in the field of care for the elderly.

3.5 Language Learning

Robot Assisted Language Learning (RALL), particularly for L2 (second language) learning, has proved to be more effective in boosting learner performance and motivation compared with just 2D screen-based technologies (Belpaeme T. et al, 2011). The type of applications described in the literature regard mainly vocabulary learning of the L2 language through various models (e.g. robot as storyteller, robot asking questions and checking learners' answers and robot playing charade games with learners). RALL through games has proved to be the most relaxing and enjoyable interaction and therefore the most profitable for L2 learners (Mubin O. et al, 2013). The role of the robot is usually either as a peer tutor or a teacher's assistant. The former role is the most common, but the latter role has often proved to be the most effective for L2 learners, where the teacher is present to explain any possible misunderstandings and the interactions are based on the curriculum already in use in class (Lee S. et al, 2010). The learners' performance gain has also been evaluated by pre-tests and post-tests and their motivation has been assessed by questionnaires (Schodde et al, 2017).

Conclusions

This paper outlines the key components of social intelligence and proposes a framework of design issues for the advanced programming of social robots. The state-of-the-art covers various aspects related to social robot programming and highlights the importance of sensing, user modeling and emotion recognition in accomplishing fundamental tasks related to social robot behavior. The experiences described in several educational scenarios show that the integration of social robots in education may improve student engagement and empowerment, especially students with special needs.

We are already experimenting the role of the robot in education in various forms. With reference to the list of educational applications in education we experimented the use of several robots, and specifically two Pepper humanoid robots to verify:

- effectiveness through a game where the pupil shows a disposable item and competes with the robot guessing how to correctly separate waste;
- engagement by entertaining people during big events at the University of Bari, providing people with directions or information related to the event or the courses and services offered by the Computer Science Department;
- special needs using puppies such as a dog robot, a dragon or NAO humanoid robot to overcome problems related to autism (Palestra *et al.*, 2017);
- empowerment of young patients, using a storytelling approach Pepper introduces juvenile diabetes to young patients and their classmates to make them aware of the lifestyle required by the disease;
- language learning through a game to teach pupils new terms, as well as associations between terms, while playing. We developed an artificial player for a challenging language game: the player is given a set of five words - the clues - each linked in some way to a specific word that represents the unique solution of the game. Words are unrelated to each other, but each of them has a hidden association with the solution (Basile *et al.*, 2016).

Despite the many open questions and challenges that are still to be faced in programming social robots, it is expected that soon robots will have great impact in various areas of education. This increasing impact will not replace human teachers, but will provide added value in the form of a stimulating and instructive teaching support.

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SOCIAL ROBOTS IN EDUCATIONAL CONTEXTS: DEVELOPING AN APPLICATION IN ENACTIVE DIDACTICS

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Due to advancements in sensor and actuator technology robots are becoming more and more common in everyday life. Many of the areas in which they are introduced demand close physical and social contact. In the last ten years the use of robots has also increasingly spread to the field of didactics, starting with their use as tools in STEM education. With the advancement of social robotics, the use of robots in didactics has been extended also to tutoring situations in which these “socially aware” robots interact with mainly children in, for example, language learning classes. In this paper we will give a brief overview of how robots have been used in this kind of settings until now. As a result it will become transparent that the majority of applications are not grounded in didactic theory. Recognizing this shortcoming, we propose a theory driven approach to the use of educational robots, centred on the idea that the combination of enactive didactics and social robotics holds great promises for a variety of tutoring activities in

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educational contexts. After defining our "Enactive Robot Assisted Didactics" approach, we will give an outlook on how the use of humanoid robots can advance it. On this basis, at the end of the paper, we will describe a concrete, currently on-going implementation of this approach, which we are realizing with the use of Softbank Robotics' Pepper robot during university lectures.

1 Introduction

The progressive "technologization" of everyday life is changing rapidly the way we communicate and interact with, and learn from each other. These changes have a profound impact on how we organize our social life, ranging from daily work schedules, or the planning and structuring of meetings, to questions like how new knowledge is acquired. The acceleration of these transformations has been enforced by the now widespread use of advanced mobile technology, like smartphones, and the almost global availability of Internet access. This new level of interconnectivity in itself requires us not only to learn a variety of new social and technical skills, but also to question and redefine some of the seemingly most basic principles of human sociality. Furthermore, it asks us to re-discuss the nature of information, knowledge, truth and moral values.

While our societies are struggling with these new challenges, it is important to prepare the next generations for the issues ahead. In the same way that the increase of the influence of information technology - and the availability of information - is challenging our perspective on the acquisition of new knowledge and skills, the beginning of a widespread use of social robots is challenging our perspective on the ways in which humans are used to interact with each other.

For education these developments mean concretely that the structure of knowledge and the role of the teacher is in the process of changing fundamentally. We believe that this transformation should be primarily driven not by technological developments, but by didactic theory.

2 Related work

During the last ten years different applications and research approaches have demonstrated that the use of robots can be beneficial in didactic settings like kindergartens and primary schools. The application of robots in these contexts has been categorised in different ways. Mubin *et al.* (2013) and Tanaka *et al.* (2015) classify two different modes in which the robots were integrated into school curricula (a) as educational tools in themselves (e.g. to teach children the basic principles of programming), and (b) as educational agents.

One of the first robotic systems used in mode (a) was Lego Mindstorms NXT

(Lau *et al.*, 1999). It has been integrated in middle schools and high schools to teach students the basic principles of what robots are, how they work and how software applications can be developed for them (Hirst *et al.*, 2003; Powers *et al.*, 2006). Different other systems have been integrated since, not only to teach programming, but also physics and electronics (e.g. Balough, 2010; Mukai & McGregor, 2004). When these robotic systems are used as educational tools, the students construct with them specific applications or environments and, in this way, familiarise themselves with robotic technology and learn the underlying principles. This approach is typically based on a "constructionist" framework and the related "learning-by-making" methodology (Papert & Harel, 1991).

The second mode – robots as educational agents – has received increasing attention in recent years due to advances in "socially-aware" technology and social robotics. Different types of robots have been deployed in various teaching scenarios. For example the iCat robot (van Breemen *et al.*, 2005) has been used to teach children how to play chess (Leite *et al.*, 2011). The Keepon robot (Kozima *et al.*, 2009) has been widely used in education and therapy for children with Autism Spectrum Disorder (Kozima *et al.*, 2005). Besides these comic-like and zoomorphic looking robots, many studies have used humanoid and semi-humanoid robots to explore possible functions for social robots in education. The reasons lie in the possibility of endowing robots with non-verbal interaction behaviours, based on gestures and general body movements, intuitively understandable for their human interlocutors. Due to its relatively low cost, the most widely used humanoid robot is Softbank Robotics' NAO (Shamsuddin *et al.*, 2011). However other robots, like RoboVie (Ishiguro *et al.*, 2001) and Tiro (Han & Kim, 2009), have been successfully deployed and tested, and in the process provided valuable insights on the psychological dynamics characterizing social human-robot interactions in educational settings (Benitti, 2012).

Belpaeme *et al.* (2018) have examined the different roles social robots can assume in education. They found that they mainly fulfil the roles of novices, tutors, or peers. When fulfilling the role of novice, a robot allows the students to act as tutor and to teach the robot a determined topic. This helps the children to rehearse specific aspects of the syllabus and to gain confidence in their knowledge. The latter is specifically important when learning a second language (Tanaka & Matsuzoe, 2012). Consequently robots in this role have been used in countries like Singapore, Taiwan and Japan to teach English to children in primary schools (Tanaka & Kimura, 2009). When the robot is fulfilling the role of tutor its function is usually that of assistant for the teacher. Similar to robotic novices, robotic tutors have been used in classes for children learning English as second language. A tutor is defined as an educator of a single pupil or a very small group (Belpaeme *et al.*, 2018). Strategies used in robot-based tutoring scenarios include for example encouraging comments, scaffolding, intentional errors and general provision of help (e.g. Leite *et al.*, 2012).

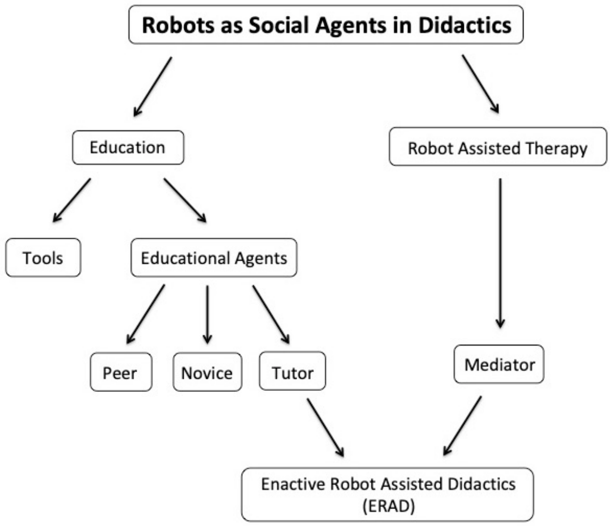


Fig. 1 - Different Functions or roles robots can assume in education

The idea behind having robots assume a peer role for children is that this would be less intimidating for them compared to a tutor or a teacher. In these cases the robot is presented as a more knowledgeable peer that guides the children along a learning trajectory (Belpaeme *et al.*, 2018), or an equal peer that needs the support and help of the children (Tanaka & Kimura, 2009). One of the functions of using robots as peers is provide motivational incentive for the students, based on the care-receiving robot (CRR) design methodology (Tanaka & Matsuzoe, 2012).

Another very important field in which robots have been used to achieve educational goals is robot-assisted therapy (RAT) for children with Autism Spectrum Disorder (ASD) (Feil-Seifer & Mataric, 2008). Robots like KASPAR (Dautenhahn *et al.*, 2009) fulfil the role of social mediator to facilitate social interaction among the children and between them and the teachers (e.g. Iacono *et al.*, 2011). The social mediator role in therapeutic scenarios serves the function of teaching the children appropriate social behaviors via different play scenarios.

In the next sections we will examine how humanoid and semi-humanoid social robots have been used in education in the last 10 years, showing that the majority of applications are not grounded in didactic theory. Elaborating on this insufficiency, we will briefly introduce a theory driven approach – i.e., our Enactive Robotic Assisted Didactics approach – and give an outlook of how we envision the use of the semi-humanoid robot Pepper from Softbank Robotics based on this approach.

3 Social robots as educational agents

Only a few social robots have been used so far as educational agents. This is mainly due to the fact that social robotics (SR) is a relatively new field and educational robotics (ER) has in the past focused on STEM education in schools (Benitti, 2012), as well as on computer science and engineering classes in undergraduate courses at universities (Benitti & Spolaôr, 2017).

For example, after its release in 2014, the Pepper robot was officially introduced only in 2016 into schools. This happened in Singapore, one of the countries that strongly promote the concept of using social robots in education. Since then Pepper has been sporadically used as tutor in English language classes in countries like Japan and South Korea for primary school children, in order to reduce the anxiety in shy children and enhance their social learning experience (Financial Times, 2018).

ER has however produced a number of approaches (e.g. Castllano, 2013) and results that illustrate the advantage of using embodied and socially situated artificial agents in educational settings. Various studies have shown that the physical embodiment of social robots is more effective when compared to the presence of virtual agents, and that it is crucial for a successful and positive interaction between the artificial agent and the human on different dimensions (Kidd, 2003; Bartneck, 2002), mainly related to the robots' physical and social presence. It has been argued that this is due to the increased potentiality for social bonding with an embodied agent (Tanaka & Matsuzoe, 2012).

A lot of the research and applications in which robotic tutors have been used in education were conducted with pre-school and school children. Many of these studies have been conducted in Japan, South Korea, and Singapore in the context of English as second language classes (e.g. Han *et al.*, 2008).

In their review Benitti *et al.* (2012) showed that in almost all cases in which robots were used in universities, they were part of the computer science curriculum and used as tools to teach programming skills to the students. They found that the main robots used where either virtual, or based on the LEGO Mindstorms system. It is therefore not surprising that the most widespread theory reported was project-based learning (Bell, 2010), because professors usually engage their students into activities in which they are building an artefact or product. The second most frequently used approach were "experiential" and "constructionist" learning theories. Benitti *et al.* (2012, 2017) are using "constructionist" as being synonymous with the "learning by making" approach (Papert & Harel, 1991). These and other reviews (e.g. Mubin *et al.*, 2013; Belpaeme et al., 2018) show that robots in the role of tutors are not yet widely used in universities, and that even when they are deployed in schools their application is confined to a few specific subjects. The underlying didactic theories used are usually limited to approaches that are defined by or closely linked to collaborative activities, which involve the use of technology as tool and object, and not as social mediator between the students and the teacher, or as tutor or motivational support for individual students.

In Table 1 we take a closer look at some of the robots that have been successfully applied in different teaching scenarios. We have chosen to focus on humanoid robots mainly because of their capability for expressing emotion states via body posture with their torsos, arms, head postures, and faces in an intuitive and comfortable way. We believe that this makes them a great candidate technology for becoming general educational aids, in particular as we envision it.

4 From social robots towards enactive mediators

When studying the relevant literature on educational social robots, it becomes evident that the vast majority of the robots are used with pre-school or school children, not with university students or in lecture hall contexts. We hypothesize that this is due to the less personal format of lecturing at universities. The large group size of university classes makes a one-to-one interaction impossible and would confine the use of robots to group works with small group sizes. This limitation seems to be more conceptual than due to technical issues. When combining the mediator functionalities of educational social robots with the ability to display relevant information on an integrated tablet in specific situations, it should be possible to create applications that could prove very useful for university level teaching in general.

The direction of our research trajectory points towards an extension of the concept of what robots can be in the didactic process, moving them away from mere tools and towards a central mediator position between teacher, student and new knowledge. Our approach, based on principles from enaction, enhances their relevant implications in the field of education (Shapiro & Stolz, 2018) by operationalizing the robots' the social mediator function during classroom teaching, lectures or group work. In the following part of the paper we will illustrate our approach with Pepper and discuss the theoretical underpinnings of our research.

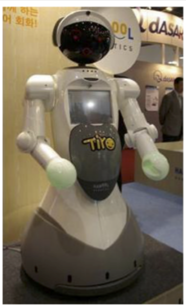
5 Developing Applications for an "Enactive Robot Assisted Didactics"

As previously mentioned, today the use of Pepper – as the use of all other robotic tutors currently deployed in educational settings – is driven mainly by technological feasibility rather than by didactic theory. In the last 4 years there have been a number of studies involving Pepper in educational settings (Belpaeme *et al.*, 2018). In most of them no general didactic framework has been mentioned, and in some cases even custom tailored theories have been chosen, according to the degree they would fit the technical limitations of the robotic platform that was used. At the opposite, our undertaking moved from our "Enactive Robot Assisted Didactics" approach, and, on this basis, focused on the Pepper robot. In other words, the starting points of our approach were research grounded theoretical considerations from didactics, on which we chose our robotic platform and addressed technical issues – not the other way around. We chose Pepper for its great potential for the development of new applications in didactics, and the fact it enables us to elaborate on the key points of the "Enactive Robot Assisted Didactics" approach we are structuring. This is mainly due to the philosophy behind the design and construction of Pepper, which was conceptualized as a personal robot capable to express emotions and communicate with humans via gestures, body posture and speech (e.g. Softbank Robotics, 2018; CNN, 2018). Pepper's smooth motion-generation technology makes it specifically adapt for non-verbal communication, and enhance naturalistic looking dynamics of the movements. Additionally Pepper has an inbuilt tablet that can be used to visualize Internet content or custom made applications.

Since Pepper was introduced 2014, being hailed as the new personal robot that will also be widely used in educational contexts (Benitti, 2012), it has not yet lived up to the expectations in this field. Pepper is at the moment mainly used as information guide in banks, shopping malls and public spaces like airports and museums (e.g. HMS Host, 2018). We hypothesize that this limited use of Pepper in educational contexts has two main reasons.

The first is that classroom or lecture hall situations are much more complex compared to circumstances in which the robot is engaged in one to one interactions and has to provide answers to a limited set of specific questions. It can therefore be argued that one part of the problem relies in the technological limitations connected to social signal processing in noisy environments.

In our view the other part is due to the lack of development of dedicated didactic theories. Currently the application of educational robots in general is mainly based on technological feasibility rather then on sound didactic perspectives and plans of operationalization. This bears the danger of developing an ER detached, or even independent, from insights coming from educational science, instead of relying on the re-invention of didactic processes required by contemporary transformations and related challenges, and today increasingly allowed by the availability of new (social) robotic technology.

Name	Appearance	Communication Channels	Related Work
NAO		- speech recognition - speech generation - expressive whole body movement choreography	- Senft et al. (2017): found that, in order to improve its tutoring capabilities, the robot should be able to adapt to the learning specificities of each of their users - Vogt et al. (2017): found that the robot should remain within Vygotsky's "Zone of Proximal Development" (Vygotsky, 1978), adapting the difficulty of the learning task to the individual level of the child - DeWit et al. (2018): found that using co-speech gestures in combination with tailored learning task yield the best results
RoboVie R3		- verbally via speech generation - non-verbally via preprogrammed social interaction behavior scripts such as shaking hands, hugging and waving	- Kanda et al. (2004): showed that a robot can have beneficial effects on the language learning progress of elementary school children - Köse et al. (2015): successfully used a robot to help children with hearing disabilities sign-language; the study illustrated the beneficial effects of a physical robot on gesture recognition in this context
TIRO		- speech recognition - speech generation - emotional facial expressions	- Han and Kim (2009): used the robot as a physical aid and motivational support during music lessons; showed that the embodied presence of the robot and its coordinated movements were effective during class - Han (2010): showed the robot's usefullness for class management and timing of class activities

Maggie		- Automated Speech Recognition (ASR) - Emotional Text To Speech (eTTS) - Speaker Identification (SI) - dialogue management	- Gorostiza et al. (2006): proposed a multimodal interaction framework, which integrates and synchronizes tactile, visual and verbal inputs in order to enable natural peer-to-peer Human-Robot Interaction - Salichs et al. (2016): used Maggie successfully in different scenarios as assistive robot for patients with Alzheimer's Disease
Pepper		- speech recognition - speech generation - expressive whole body movement choreography	- Tanaka et al. (2015): guided by the *Total Physical Response* (*TPR*) Theory from Asher (1966); found that providing motivational haptic behaviors, like giving "high five" in combination with the use of the tablet created stress-free learning environment - Gao et al. (2018): found that people did not prefer robots that were giving encouraging feedback tailored to their person, but robots that were generally supportive

***Table 1**. This table presents the **related work** on how social robots have been used in recent years in different educational contexts. This work also illustrates that the use of social robots in education is driven by technological development and lacks a general didactic theory of reference.*

6 Enactive Robot Assisted Didactics (ERAD)

These acknowledgments led us to attempt an approach to robotic applications in educational contexts by combining an enactive, participatory didactics approach with social robotic technology. The main underlying goal is to enhance this approach, described in *Table 2*, by strengthening its reticular interactional structure through social robotic technology. In other words, the main idea is to design for the Pepper robot a mediator function that strengthens the communication between teacher, students and the syllabus. As emphasized in *Table 2*, in this approach, for both the co-construction and the validation of new knowledge, feedback plays a central role as it allows the student to compare the knowledge gradually built, with other experiences or other findings that confirm or reject the results obtained. One of the limitations of many interactive processes is the lack of space for interaction and feedback. The absence of feedback produces self-referentiality, which is a characteristic of closed systems and diametrically opposed to the form of interaction between a subject and its environment as it is described in the enactive approach.

What are the key points of the Enactive Didactics Approach?

The Enactive Didactics Approach focuses on the interactions between teacher and student during the knowledge creation process. In this approach the teacher is seen as the focal point that raises the awareness of an issue in the students. Once this is done, it becomes possible for the teacher and the students together to build an answer. The trajectory along which the answer is constructed is sketched out by the teacher. She has the role of mediator between the world of the student and the new knowledge (Damiano, 2013), and the task of activating a cognitive conflict (Laurillard, 2012) that bridges the student's knowledge, the new problems to address and related new knowledge. After the new knowledge is established, it is crucial to validate it. In the enactive didactics approach it is the function of the teacher to verify the epistemological correctness of the constructed knowledge, ensuring that it doesn't contradict the existing knowledge. Such a contradiction could indicate either an error in the construction process, or the emergence of unexplored aspects of knowledge.

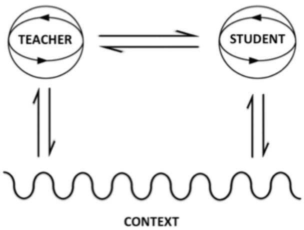


Table 2. *The Enactive Didactics Approach*

As proposed thoroughly elsewhere (Lehmann & Rossi, 2018), one of the ways to ensure continues feedback during the didactic process is to introduce a robotic tutor, which functions as an embodied feedback channel. With the help of robotic tutors the regulation of the learning process can be focused not only on cognitive results, but also on methods, timing, attention and participation. The robot would become the mediator between the teacher, the students and the knowledge to be taught. This switch to a central role of "socially-aware" technology in the form of social mediator robot is illustrated in *Fig. 2*.

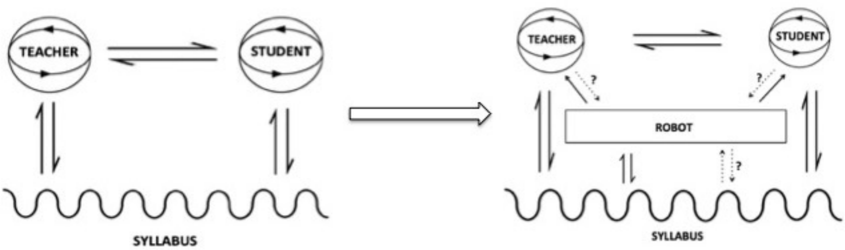


Fig. 2 - Extension of the Structural Coupling characterizing the Enactive Didactics approach by integrating a robotic tutor (taken from (Lehmann & Rossi, 2018))

7 Pepper as social feedback device

In order to develop and implement the ERAD approach sketched above we are in the process of using Pepper in combination with an audience response system (ARS). ARSs are mainly used as direct real-time feedback devices during conference or public presentations. They provide for example statistics about the perception of the presented material by the audience, enable real time polls to specific questions, or help to gather quickly information the composition of an audience. These data or statistics can be projected to a screen as source of information for the person giving the presentation, or it can be projected visibly for the audience and used as a source for discussion. In both cases it enables the listeners to actively participate or even intervene in the presentation process and increase their sense of agency.

The use of these ARSs and the presentation of their results are at the moment inherently "un-embodied", and the use the information depends strongly on the willingness of the presenter to allow the audience to interfere with the presentation. In order to "embody" the feedback provided by an audience we plan to use this technology in combination with the Pepper robot. Concretely for the application in university teaching we are implementing the scenario illustrated in *Fig. 3*.

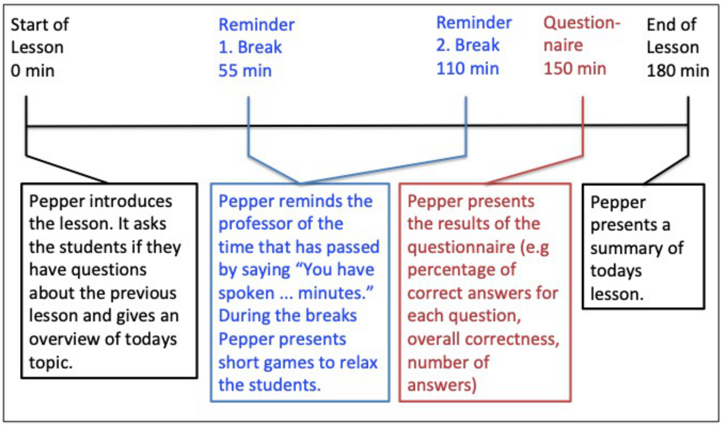


Fig. 3 - Exeplary order of evens during a lecture with Pepper. The robot introduces the course, keeps the time during the lecture, reminds the professor when to do breaks and gives a summary at the end. In the last part of the lecture, the students fill in a questionnaire in Google Forms. The robot analyses the answers and presents the results to the students.

Conclusion

The aim of this paper was to illustrate how humanoid and semi-humanoid robots have been used in the last two decades in educational contexts, and to propose a new "Enactive Robot Assisted Didactics" approach. We discussed recent attempts to classify the different roles robots are having in education at the moment, and identified some of the didactic theories that underlie the development of both the robotic embodiments and the design of the scenarios they are used in. We illustrated that most of these applications are driven by technological feasibilities, rather than by didactic frameworks. Recognizing the insufficiency of this widespread approach, we introduced an approach that follows the opposite path, from didactic theory towards appropriate robotic technology. In particular we discussed how to advantageously use the embodiment of socially aware robots to implement and enforce an enactive approach to didactics at universities, sketching an outlook on an upcoming series of applications that will see the deployment of the Pepper robot in combination with an audio response system in university lecture halls settings.

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SOCIAL ROBOTS SUPPORTING THE INCLUSION OF UNACCOMPANIED MIGRANT CHILDREN: TEACHING THE MEANING OF CULTURE-RELATED GESTURES

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Keywords: Social Robots, Unaccompanied Migrant Children, Gesture Recognition, Kinect

Social robots are being used successfully as educational technologies, playing roles of tutors and therapeutic assistants. In our research, we wish to explore how social robots can be used to tutor a second language to unaccompanied minor migrants and support their integration in a new culture. These young migrants are among those most at risk in the area of child and youth welfare. In this paper, we focus on a particular aspect of a second language teaching that concerns culture-related gestures that are important for supporting the social inclusion of these children. Since gesture learning relies on the understanding of the social situation, in which interaction and repeated practice are essential, social humanoid robots seem to be an adequate interaction mean since they can provide both examples of gesture executions, explanations about the meaning and the context in which the gesture should be used. Moreover, as in other assistive domains, social robots may be used to attract the children attention and support the

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social operator in establishing a contact with these children that very often, after the difficulties of the journey, do not trust adults. Results of a preliminary study show the efficacy of the proposed approach in learning gestures.

1 Introduction

In 2016, 63,280 UnAccompanied Children (UAC) applied for international protection in EU countries. EU have the responsibility of supporting these children and, at the same time, the chance to nurture their potential to enhance their contribution to our societies. Even if in 2018 the number of UAC decreased, social services are key for guaranteeing their protection and development ensuring access to care, education and health, as well as programs fostering their social inclusion. In this context we developed a project aiming at teaching Italian to UAC. In particular, we included in this project the teaching of culture-related gestures.

Linguistic deprivation is very often a prerequisite to social exclusion and learning how to communicate can be the first step towards integration and inclusion in a new cultural context. However, human communication is multimodal and, according to some studies (Poggi, 2006) and in some cultures the vocabulary of hand gestures is much richer, such as Italy. Gestures are used to convey the meaning of a message (McNeill, 1992). There are several types of gestures: metaphoric gestures (i.e. those that explain a concept), deictic gestures (i.e. pointing movements), and iconic gestures among others. However, many gestures are culture dependent and do not have a unique meaning and symbolism. The same gesture can mean something quite nasty and disrespectful to a person from a different cultural background. Hand gestures are a very important part when learning a foreign language. In addition, when UAC arrive in a country, after the migration process, they are very scared and do not trust humans due to the experience they just had.

Social Robots are embodied autonomous intelligent entities that interact with people in everyday environments, following social behaviors typical of humans (Billard & Dautenhahn, 1997; Fong *et al.*, 2003). Social robots are mainly used to improve people experience in several application domains, language teaching among the others (Schodde *et al.,* 2017). Alemi *et al.* (2014) show that children who are taught by a robot as opposed to a human teacher store new words of a second language faster and better in their long-term memory. Moreover, social robots are less complex and less intimidating than humans and may provide an effective support during triadic therapy or intervention. They may be programmed in order to have a deterministic behavior that can be repeated as many times is needed.

In this project, we developed the NaoKi application that uses a social robot for teaching culture-dependent gestures to UAC. As social robot we used Nao, due to its characteristics, which make it suitable for the context, and to recognize gestures in real time we used Kinect, a device able to detect and the user's skeleton. An important component of the application is represented by the gesture database that has been designed using the formalization proposed by (Poggi, 2006).

Results show that gestures and especially their reproduction significantly influence the memorisation of second language (L2) lexical items as far as the active knowledge of the vocabulary is concerned (being able to produce words and not only understand them). This finding is consistent with theories on multimodal storage in memory. When reproduced, gestures not only act as a visual modality but also as a motor modality and thus leave a richer trace in memory.

The paper is structured as follows. The first Section of the paper briefly describes what is a social robot and its use in assistive domains, with emphasis on research work on gesture recognition. Section 3 introduces issues concerning the reception of UAC. Then, we briefly explain the structure of the Italian Gestionary (Poggi, 2006) and than, in Section 5, how it has been used in the NaoKi application. Then we report results of a preliminary evaluation study. Conclusions and future work are discussed in the last section.

2 Social Robots

A social robot is a physically embodied, autonomous agent that communicates and interacts with humans at a social and emotional level. They should be able to interpret properly the human behavior, to react to changes during the interaction in a socially plausible manner. The use of social robots in education have been shown to be successful in diverse contexts (Kennedy *et al.*, 2015, Wainer *et al.*, 2014, Schodde *et al.,* 2017). In particular, the use of robots may increase attention, engagement, and compliance, which are critical components of successful learning (Ramachandran *et al.*, 2018).

Factors of social intelligence increase the complexity of programming a socially interactive robot. A social robot is expected to sense its surrounding, to handle natural and multimodal dialogs, to recognize and express emotions, and to adapt the interaction to some characteristics of the user. Social robots are employed in education with the main aim of engaging students and they are particular successful with those special needs. For instance, social robots are widely applied to teach basic social skills to children with autism, since they resemble humans but are less complex, seem to be able to manage these issues successfully (Palestra *et al.,* 2017; Pennazio, 2017; Duquette *et al.*, 2008).

As far as the efficacy of using social robots in the teaching of a foreign language is concerned, recent research show that it may lead to interesting results (Boccanfuso *et al.*, 2017; Alemi *et al.*, 2015). In particular, (Alemi *et al.*, 2015) employed a social robot as an assistant to teach English vocabulary to Iranian students. They found that the use of the robot assistant significantly improved the learning task. In addition, the robot-assisted group showed improved retention of the acquired vocabulary.

Moreover, some studies suggest that the sociality of the robot increased the learning improving learning outcomes (Alemi *et al.*, 2014; Kanda *et al.*, 2004; Saerbeck *et al.,* 2010; Tanaka & Matsuzoe, 2012). Then, robots open up new possibilities in teaching that were previously unavailable, leaving space to explore novel aspects of language learning, as culture dependent gestures.

Gesture recognition in Human-Robot Interaction has been proposed in (Henriques, 2017) to allow people, especially those with physical limitations, to give instructions to the robot in an easy and intuitive way. The system uses a Kinect for gesture detection, and recognition is performed using a Microsoft software, Visual Gesture Builder. A research similar to the one described in this paper has been conducted on children with autism spectrum disorders (So Wing Chee *et al.*, 2018). Since these children have delayed gestural development, a social robot was used to teach them to recognize and produce eight pantomime gestures that expressed feelings and needs. This study reports that children in the intervention group were able to recognize more gestures and generalize the acquired gestural recognition skills to human-to-human interaction. Also in (Kose *et al.,* 2011) the social robot Nao has been used in conjunction with Kinect for developing a serious game for sign language tutoring. All these studies report how a social robot represent a successful interface for teaching a second language and, in teaching gestures to children, especially to those with special needs.

3 Unaccompanied Migrants Children

In the last years Italy, along with other European countries, has become the landing place for numerous UAC (UnAccompanied migrants Children also defined Unaccompanied Foreign Minors - UFM -, isolated children, separated children). After the first reception phase in communities for minors without a family, the second level reception of the Protection System SIPROIMI – Protection System for International Protection Holders and Unaccompanied Foreign Minors (L. 132/2018, previously called SPRAR - Protection System for Asylum-seekers and Refugees) has the aim of ensuring to children the living conditions appropriate to their age, to be able to undertake a project of life aimed at social integration and autonomy, and the minor will be assigned, through the Juvenile Court, to a tutor.

According to the data until the 31st March 2019, provided by the Foreign Child Protection Services of the Ministry of Work and Social Affairs, in Italy there are 8.342 UAC (MSNA – Minori Stranieri Non Accompagnati -as per Italian language) of which 7.774 are male and 568 female, ranging from 13 to 17 years of age, mostly coming from Albania and North Africa, protected by the L.47/2017.

Due to their age the UAC live a double status: that of a minor and a migrant, experiencing both the difficulties related to the abrupt and rapid passage to adulthood, and to the integration into a new and totally different society. The many difficulties encountered along the way to reach Italy (repeated beatings, threats, abuses, hunger and thirst), have determined in minors' profound traumas that add up to the cultural shock and abandonment of parental figures of reference, essential in the life of any child. For these reasons, the minors show distrust towards the operators and any physical contact, even a simple hand on the shoulder, can generate a sense of agitation in the kid. Reception activities, specifically designed by the government, are implemented with the aim of offering psychological support following the disastrous journey. Among the various activities, whose objectives have been defined based on the characteristic of the target group, the BLUE and GREY activity aim to share key words about greetings and moods (in Italian) and to know customs and cultural habits of the country of origin, respectively.

At this stage, a social robot could play an important supporting role for cultural mediators, who have the important task of trying to understand the child's expectations and lived experience, to transmit information about integration into Italian society, then acting as a bridge between the two cultures. Especially regarding child victims of trafficking, gaining child's trust by the operators is very difficult. One of the major difficulties is to attract and keep the attention of the child that is scared and does not accept physical contact. Most of the young migrants have their gaze down, indicating their emotional situation and their lack of self-awareness, they speak with a low voice and have difficulty in looking at operators. The robot could be of great help both for the operators so that they can enter into relationship with the minors, and for the latter who, through the interactions with the robot as a "game", could learn the first necessary information to start the integration process that, initially is based primarily on the knowledge of the Italian language, which must already be learned in the first reception center. Looking at the activity table, with regards to the BLUE activity, the robot, through games, images and sounds, can facilitate the acquisition of the first words in Italian, useful to be understood. This could be integrated with lessons from the robot on the Italian culture and on that of the different countries of origin, in order to analyze the two cultures, highlighting differences and elements in common. Finally, in this phase the robot can be fundamental in order to facilitate the process of understanding the rules and gestures typical of Italian culture that favor their integration.

Learning the Italian language for UAC is very difficult, both for the complexity of the grammatical structure of the language itself and for the phonetics completely different from the non-Romance languages. The useful language to communicate can be learned in a short time frame. A good solution to be able to favor the formation of friendship ties and at the same time promote school learning could be the robot. Regarding the relationship with the teachers, initially there are problems regarding the linguistic understanding of the work to be performed and the rules to be respected and often the men of the male gender show a certain distrust of the female gender due to their culture of belonging. For these reasons it is important to create individual forms of support, to create appropriate educational programs so that children can feel welcomed and can trust their teachers.

The robot can therefore compensate for the main problem of learning Italian in UAC: motivation and attention. Through the activity of the games the lesson will be fun and highly interesting, capturing the attention of the boy and with the desire to try again the same game/exercise without wanting to give up.

4 Gesture Dictionary

Communication is the process of sending and receiving messages through verbal or nonverbal signals. In verbal communication, the purpose of communicating is almost always intentional, instead, when implemented with other types of non-verbal signals such as, for example, gestures, the purpose is defined as unconscious. The correspondences between signals of our body (gestures, expressions) and meanings are different from culture to culture even if, in many communication systems, facial expressions, physical contact and gaze are almost universal.

The word gesture derives from the Latin gestus which means “to perform”. Therefore, we can call gesture any movement made with hands, arms and/or shoulders. In a communicative act, typical of Italian culture, hands play a significant role in that they can articulate the rhythms of discourse, create pauses, place concepts in the space and express, tacitly, a desire or a thought. Gestures can be of various types:

- **Deictic**, which indicates an object or a person (i.e. pointing with the index finger);
- **Iconic**, which depict, in the air, the form or imitate the movements of an object, an animal, a person;
- **Batonics**, in which the hands move rhythmically from the top to the

bottom to scan and highlight the accented syllables in a sentence;

- **Symbolic**, in which, in a given culture, they have a meaning and a culturally shared translation. In fact, these gestures are said to be socially coded because they are learned from an early age by observing them on a daily basis, than they are often incomprehensible to people of different cultures (Desmond, 1978).

The latter have particular relevance in the application context of this work.

When we talk about communicative gestures, which correspond to a signal-meaning pair, It is necessary, for those who have different cultures, to have a "dictionary" of such gestures, to allow a better translation of the communicative act. To this aim, the "Italian Gestionary", proposed by (Poggi, 2006), is a useful resource since, in it, each gesture is presented through a picture, a description of the movement and the corresponding verbal description, as shown in Table 1.

Gestures can be considered as a semantic information present in the mind of those who want to communicate. It is possible to extract the meaning and use of a gesture by analyzing the Gestionary that, for each gesture, provides:

- **Verbal formulation:** each symbolic gesture is paraphrased or accompanied by a verbal formulation. For example, the gesture of applauding can be paraphrased "compliments!".
- **Context:** describes the contexts in which the gesture is more typically used.
- **Synonyms:** different gestures to express the same meaning.
- **Meaning:** is the definition that aims to highlight the common meaning of a gesture in different contexts, similar to that of word dictionaries.
- **Grammatical classification:** unlike words, in gestures there is no grammatical categories (name, verbs, etc.), but it is possible to distinguish "gestures-sentences", called holoprasics, from "word gestures", called articulated, depending on that have the meaning of a whole sentence or only a part.
- **Pragmatic classification:** concerns only the "phrase-gestures" which are also classified according to their specific performative just like the gesture of praise (the applause, "Congratulations!").
- **Semantic classification:** among the numerous Italian symbolic gestures, many provide information on the world, some of these serve to indicate the times ("yesterday", "after"), quantities ("two") etc. Other gestures can express information about the mind, emotions and degree of knowledge of the person with whom you are communicating.
- **Rhetorical meaning:** also in the gestures the rhetorical figures are present, that is a rhetorical use of the gesture, therefore different from the literal one. For example, the gesture of hitting the chest with the

hand, with the palm facing downwards and the fingers touching, means "I do not digest it", but in a rhetorical way because what is not digested is not a food but a person who metaphorically "can't stand".

Table 1
AN EXAMPLE OF GESTURE DESCRIPTION (POGGI, 2006)

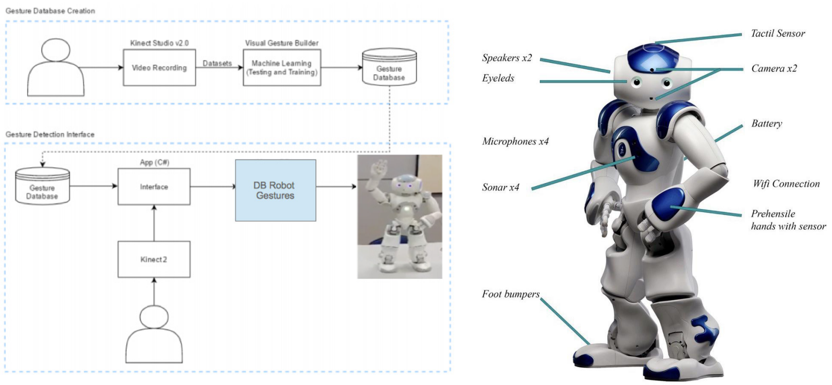
Gesture	Verbal Formulation	Hand shape	Orientation	Location	Movement	Nonmanual components
	I pray you	hands open with palms touching	fingers pointing towards the chin	neutral space	United hands moving slowly forward and backward always keeping your fingers pointing upwards	

5 The NaoKi Application

In order to execute, recognize and explain the meaning of the gestures using a social robot, we integrated the Nao robot with Microsoft Kinect through the NaoKi application (Figure 1a).

The proposed architecture has two main components connected to two different devices. The first one uses Kinect to build the database of gestures and to recognize them when performed during the learning session. Kinect for Windows is a device that allows to recognize and track the body (via the skeletal tracking function) of one or more people (up to 6). The Kinect SDK 2.0 is a library that is essential for recording the video of the gesture to be recognized and, then, converting and analyzing it with the Visual Gesture Builder. Using this technology, the application allows to create a database of gestures that can be recognized and the degree of correctness of the recognized gesture respect to the selected one.

The second component is connected to the Nao robot (Figure 1b), a small-sized humanoid social robot that is strongly used in therapeutic assistance to autistic children due to its characteristics such as physical appearance, autonomy, and programmable behaviors (Palestra *et al.*, 2016). Indeed, an ecological robot assisted treatment for children requires to simulate intelligent behavior and interaction, based on human speech and body language understanding, emotion recognition and eye contact ability, and other typical intelligent behaviors (Palestra *et al.*, 2017). The Nao robot is controlled by a Linux-based operating system called NAOqi. This operating system powers the robot's multimedia system which, as illustrated in Figure 3, includes four microphones, two speakers, and two HD cameras. The main CPU is the Intel ATOM 1.6 GHz CPU located in the head that runs a Linux Kernel and supports the proprietary middle manager of Aldebaran (NAOqi). The second CPU is located in the chest and dedicated to motors functions. Nao can move and perceive its environment using the multiple sensors on its body. The robot is fully programmable through the suite of named software Choregraphe. This software allows, therefore, to program the robot through a user-friendly graphical interface.



a) b)

Fig. 1 - a) The architecture scheme of the NaoKi application; b) Nao's hardware features

Nao is used, in this case, to interact with the children and tutor them in learning the gestures. To do so we enriched the robot gesture database with the coordinates of the gesture in order to allow the robot to play it. To so, we used an interesting functionality of the programming environment (Choregraphe) that of being able to memorize a new movement using the "Timeline" scripts (Figure 2) where, just moving the robot's limbs and then click on "save" it is possible to save the gesture and the behavior and then re-run it when selected.

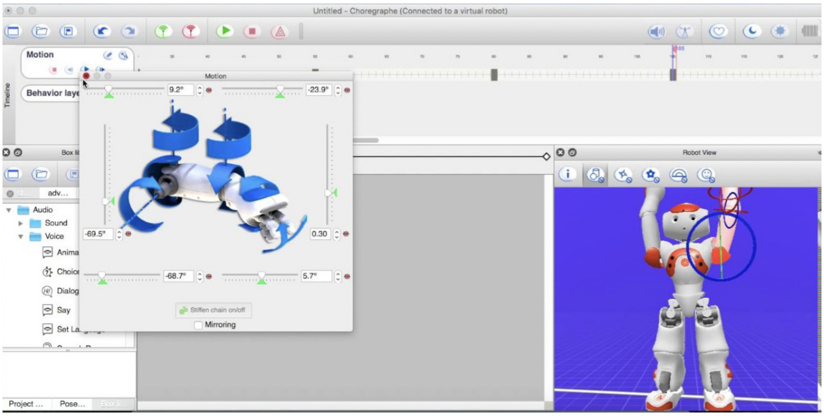
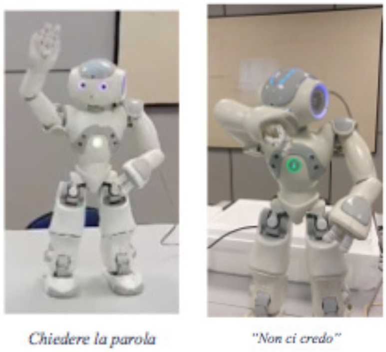


Fig. 2 - An example of the "Timeline Script" used to build the robot's gestures.

The database is running in the background of both components and contains the description of the gestures. It has been structured according to the gestionary presented in Section 3 with, in addition, the coordinates of the gestures recorded by the Kinect SDK and the Gesture Builder and the description of the gesture as programmed in Nao. In particular, we store the movement coordinates of static/discrete (i.e. hand on the forehead) and continuous/dynamic gestures (i.e. waiving to say hello). Another important functionality regards the check of the correctness of the performed gesture. To allow this, we need to query the ".gbd" database (DB Robot Gesture in Figure 1a) containing the coordinates of the gestures recognized by the Kinect; the coordinates are searched based on the gesture and then the curve of correctness and finally the evaluation is done.

The interaction may have three learning goals and may be initiated by the robot or the child. In the first modality the robot may show a gesture to the child, explain the meaning of the gesture and ask the child to reproduce it (Figure 4). In the second modality the child may ask the robot to perform a specific gesture or a gesture conveying a specific meaning. Moreover, the child may ask for an explanation about the gesture meaning, Figures 3a and 3b show Nao that executes two different gestures.

The third modality is to interact freely with the robot by creating both a mix between the first two and introducing other features such as "basic cognitive dialogues" or entertaining the child with small "ballets" made by the robot to always maintain an atmosphere " fun "and comfortable.



"Ask to speak" "I don't believe it!"
(a) (b)

Fig. 3 - Two different gestures performed by the Nao robot.

An example of interaction in which Nao teaches a gesture to a kid is shown in Figure 4. In this case the robot is teaching the gesture "I pray you". First the robot shows to the kid how to execute the gesture and then asks to reproduce it. When the kid performs the gesture, the robot gives him a feedback score that is calculated according to the correctness score calculated by Kinect.

5.1 Preliminary Evaluation

We performed a preliminary formative evaluation test of the application. Even if the application is intended to be used by foreign children, for ethical reasons, we could not involve them in the study. Then, our subjects, were 4 Italian children (sons of some Department staff members with an age from 6 to 10 y.o.) and 6 adult migrants (with an age from 19 to 24 y.o.). We asked to each subject to learn and perform the following gestures for three times: "I pray you", "Hello", "This disturbs me", "Are you crazy?", "I don't understand".

Before the experiment we collected the written informed consent from all adult subjects. Child subjects gave verbal informed consent themselves, and written informed consent was provided by a parent or guardian.

At the end of the interaction we asked subjects to answer to a simple survey about the interaction. The survey was composed of six statements and users were asked to evaluate each of them on a scale from 1 to 5. Some statements concern the evaluation of the interaction in general, some other were specifically concerning gesture execution and recognition. The statements were the following:

1. I was able to interact with the robot

2. It was easy to understand how to perform gestures
3. It was easy to understand the feedback
4. The system had an adequate response time.
5. It had a low number of misidentified gestures.
6. Interacting with the robot was engaging.

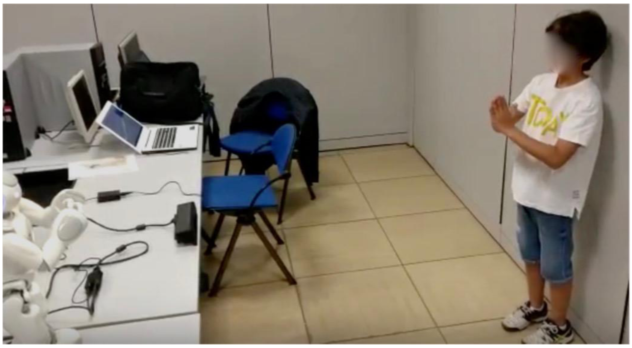


Fig. 4 - An example of interaction in which the child is learning the "I pray you" gesture.

As far as task completion is concerned, each subject has been able to complete the tasks and to perform the required gesture. However, taking into account the average time and the average number of repetitions to execute the gestures correctly, initially subjects needed more time and a higher number of repetitions, as long as they got used to the interactive approach the number of repetitions to reproduce correctly a new gesture decreased as well as the time need to learn it.

In Table 2, we show an example of the data collected during the execution of the gesture "Are you crazy?" and "Hello". In particular, for each test session, the table shows the average time spent in seconds by the subjects to perform the gesture correctly, the number of repetitions done (before performing the gesture correctly).

Table 2
AN EXAMPLE OF COLLECTED DATA DURING TRAINING

Gesture	Time (In second)	Attempts
"Are you crazy?"		
1° session	9	6
2° session	11	4
3° session	2	1

Gesture	Time (In second)	Attempts
"Hello"		
1° session	6	4
2° session	4	4
3° session	2	1

In Figure 5 the results of the survey are shown. They indicate that the interaction was quite satisfactory both from the engagement and gesture learning points of view. The weakest point seems to be related to feedback provided by the system that was not easily understood.

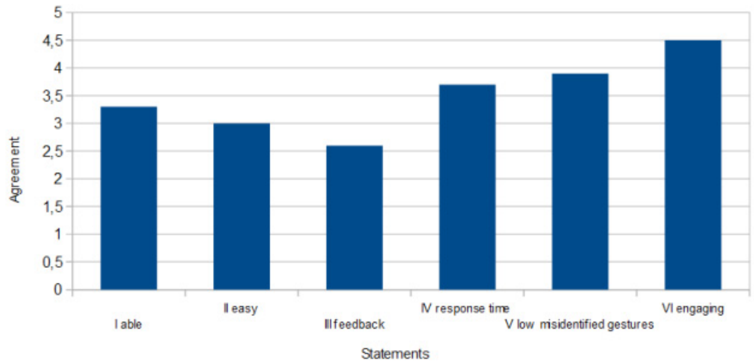


Fig. 5 - A summary of the answers to the survey.

Even if the study was performed with a limited number of subjects, they encourage us in going on with this research.

Conclusions and Future Work Directions

In this paper, we have considered the problem of teaching culture-related gestures to UAC in the context of their social integration in a different country and culture. These young migrants are among those most at risk in the area of child and youth welfare.

Our approach is based on the integration of Microsoft Kinect with a Social Robot, Nao in particular. This approach seems to be particularly suitable to addressing an effective mean to teach gestures in this context since the robot, being humanoid, allows for a believable reproduction of the gesture. Moreover, the interaction and practice can be repeated as many time as necessary. Moreover, as in other assistive domains, the robot has the capability of attracting the children attention and support the social operator in establishing a contact with them that very often, after the difficulties of the journey, do not trust adults. Results of a preliminary study show the efficacy of the proposed approach in learning gestures. In particular, the interaction was judged engaging and quite natural.

We are aware that the main limitation of this work concerns the number and the categories of subjects involved in the evaluation study. Even if there were not UAC, the preliminary results shows the feasibility and efficacy of the approach. In our future work we plan to perform a new experiment. In Apulia, 318 UAC are hosted in communities for minors without a family, across the six districts. This study could be conducted during the school year 2019-20, on 40 UAC included in the classes of the Centre for Adults' Education of Bari, CPIA, which has signed a Framework Agreement for cooperation with the University of Bari. This would be the first experiment of innovative educational methods in Apulia (Della Penna, 2014). In fact, currently in Europe, University of Bielefeld in Germany is the only institution to have started, since 2015, programs of educational robotics to facilitate literacy and social inclusion of foreign students; unfortunately, though, no scientific results of the experiments with the robot Nao have published yet.

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A PROPOSAL TO ACT ON THEORY OF MIND BY APPLYING ROBOTICS AND VIRTUAL WORLDS WITH CHILDREN WITH ASD

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Keywords: Autism, Theory of Mind, Robotics, Virtual World, Social Stories

The article proposes an intervention framed under a single-subject research design where robotics and a 3D virtual environment are used jointly to improve the development of Theory of Mind in children with ASD. The project aims at verifying if the use of a humanoid robot, with high interactive abilities and responses, along with a virtual robot in a social virtual world can enable an improved comprehension of emotions and perspective taking. Specifically the planned activities are designed to gradually support the subjects with ASD in interactional settings in order to make them acquire the needed self-confidence to finally interact with a classmate in the virtual environment.

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1 Introduction

In the present article, the authors describe the theoretical framework and the research design of a developing project. This project has the aim to verify if applying robotics together with virtual reality could improve the cognitive and emotional empathic ability and the cognitive flexibility of children with ASD, acting on the defective aspects of the Theory of Mind (ToM).

The authors believe that the development of an intervention, that includes gradual work sessions (both in complexity and level of abstraction), can first help children with ASD acquire and put into practice social abilities in specific and concrete contexts (use of robotics and social stories) and, then, transfer and use the same abilities in different contexts and with different perspectives (use of the 3D virtual world and social stories).

The literature analysis, reported in the present contribution, has guided the authors with useful suggestions for the application of robotics, social stories and virtual worlds in the development of social abilities in children with ASD.

Working with an interactive humanoid robot (adaptable to different complexity levels, depending on the most frequent requests and social responses, and highly predictable in its behaviours), enables to act in practice on: emotional states; comprehension of believes; imitative ability of the child and antecedents of the ToM, lacking on children with ASD (eye contact, shared attention; intentional proto-declarative communication; make-believe games).

The creation of interactive social stories (common work modality with children with ASD) will be the connection line between the interaction of the child, firstly with the physical robot, and then with the virtual robot to reach a final higher level of complexity and generalization in which the interaction takes place with peers as well. As it will be described, in the next paragraphs, the child will experience different perspectives: from being an external viewer of a scene in contexts where both the physical and the virtual robot are, in turn, the main actors, to reach the role of an active participant together with the robot and, finally, to participate in social stories with the robot and other children.

In addition, the virtual environment lets you create different scenes in which children can experience the same social ability (e.g. park, home, school, etc.) and promotes the development of hypothetical events that can act on different representations (dreams, belief, etc.), that are not necessarily linked with real external events, but that can make them more understandable. The flexible/adaptive virtual environment can satisfy the gradual needs of children with ASD in relation to the sensory stimulation and the amount of details to be provided.

Those children, in fact, need predictability, a low level of information to work with, simple emotional reactions, time to adapt to a new situation, as supported by the ethological paradigm (Tinbergen & Tinbergen, 1983).

In the virtual environment it is possible to create a starting situation, which can be gradually modified and made more complex soliciting a higher cognitive flexibility (Ozonoff, 1995), linked with the ability of socially acting in an adequate way. It is then possible to go back to the tangible/physical context, where the child is requested to transfer in the real world, with a peer or a restricted groups of children, the social and emotional behaviours that he has just learnt, through the interaction with the robot and then with the peers.

The above mentioned aspects justify the choice of implementing a research in which the use of robotics, virtual worlds and social stories is aimed at fostering the acquisition of ToM in children with ASD.

2 Background

International literature highlights how children with ASD present an irregular development of the ToM that makes it impossible for them to understand how other people can know, want and believe something (Baron-Cohen *et.al.*, 1985). This is a metarepresentational deficit, which determines difficulties in communication and in social behaviour, and that is usually seen as an affective problem (Hobson, 1990). That deficit is a consequence of not understanding behaviours in terms of "internal states" on a cognitive level (Baron-Cohen, 1995; Leslie, 1991).

This difficulty has repercussions on the possibility of reaching an adequate empathic ability on both its cognitive and emotional meaning. The cognitive level involves having a conceptual point of view (Shantz, 1983), recognizing someone else's thoughts and emotions; the emotional level determines the impulse of enacting an appropriate emotional reaction to the state on the other person (Davis, 1994), with consequences in the building of adequate social interactions.

As underlined by Happé (1997), the development of social rules themselves, when it happens only on an external level, it is not enough to direct the behaviour in an adequate way, as this requires the ability to interpret thoughts and affective-emotional states of others.

Some studies (Ozonoff *et.al.,* 1991; Ozonoff, 1995) also show difficulties in relation to Executive Function (EF) linked to the voluntary control of cognitive and motor behaviour (Job, 1998), needed to enable the highest behaviour flexibility possible and the interruption and correction of already started actions. Ozonoff (1995) correctly highlighted how behaviour in people with ASD looks rigid, inflexible, stereotyped, with a prevalent difficulty in postponing or inhibiting reactions.

In a 2012 study Oswald showed how the development of the ToM (mindreading, mentalization) in its cognitive and emotional meaning depends on FE, which is a set of cognitive abilities that enable the individual to control and regulate behaviour in reaching goals (Best *et.al.,* 2009). According to Oswald there are two fundamental domains in FE, which act in emergency and in ToM expression: inhibitory control, meaning the need to inhibit your personal perspective when you consider the one of other people; working memory (WM), because of the need to keep at the same time your own perspective and the one of others.

Starting with the detection of those difficulties, recent research (Ansuini *et al*., 2015; Cavallo *et al.,* 2016; Javed *et.al.*, 2019, Lytridis *et.al.*, 2019, Parsons *et.al*., 2002; Pennazio, 2015; 2017; Robins *et al.,* 2005, Robins, *et al.,* 2009; Scassellati *et.al.,* 2018) showed the importance of using robotics and virtual worlds in sustaining the improvements of socio-affective abilities in people with ASD.

2.1 Robotics and ASD

Recent studies demonstrated the usefulness of the application of robotics in the development of insufficient abilities connected to ASD. Such studies confirmed how social robots can open a communication channel (with children with ASD) by directing the attention (ocular contact) and by activating new social behaviours (Boucenna *et.al.,* 2014; Costa *et. al*., 2014; Diehl *et.al.*, 2012; Lytridis *et. al.,* 2019; Robins, 2005; 2009; Pennazio, 2019; Scassellati *et. al.,* 2018)

Robots, thanks to their certainty, emotional and interactive (adjustable) clarity, can be used to help children with ASD to learn social, emotional and imitative abilities, transferring those competencies in the interactions with human partners (Esteban *et.al.,* 2017; Kumazaki *et.al,* 2017; Short *et.al.,* 2017, Tapus *et.al.,* 2007). In some studies (Cunha Costa, 2014), the use of a robotic platform is meant by researchers as an attempt to shorten the distance between the stable and predictable environment of a simple toy and the complex and unpredictable world of communication and human interaction.

Experimental data highlighted how for children with autism is easier to “approach” and “interact with” a “peer-robot” (Pennazio, 2019). In fact the human interlocutor may have impredictable answers and behaviours while the robot can be programmed according to the children needs. In this way predictable and reassuring interaction scenes can be created (they don’t activate the anxiety connected to what the child doesn’t know) (Robins *et.al.,* 2005). Human social behaviour is, in fact, unpredictable and it can be seen as frightening by children with ASD; on the other side, the use of a robot offers a simplified environment that can support a gradual improvement in the complexity of the interaction, depending on the needs and the abilities of the single child.

Positive results were obtained with the use of robots on the following aspects:

- "The social acceptability" meant as the availability of the child with ASD to interact first with the robotic mediator and then with the human interlocutor (De Graaf *et. al.,* 2013; Dunst *et.al*., 2013);
- Learning "motor skills by imitation" that is the reproduction by the child of actions and behaviours done by the robot with communication objectives (Ansuini *et.al*, 2015; Cavallo *et.al.,* 2016; Duquette *et. al*., 2008);
- Maintaining joint attention (Robins *et.al.,* 2005), that is, the ability to keep the eye contact on the same object observed by more people" (Pennazio, 2019).

Such aspects are relevant since they represent some precursors of ToM.

In such studies the robot wasn't meant as a replacement of the human being (Lytridis *et.al.,* 2019), but a social mediator that is located between the child and either the adult or the peer (Cabibihan *et.al.,* 2013; Ferrari *et.al.,* 2009; Lee *et.al.,* 2012) and that covers the distance that generally lies between the predictable, safe and stable world (suitable for the child with ASD) and the complex and unpredictable world of the human communication and interaction (Costa *et.al*., 2014; Dautenhahn *et.al.,* 2004).

The robots used in such studies can be of various types: four-wheeled mobile (Dautenhahn *et.al.,* 2004), anthropomorphic puppets or dolls (Kozima *et.al.,* 2009), animal looking (Stanton *et. al*., 2008), humanoids (Robin *et al*., 2009). The choice of robotic support on the basis of specific characteristics becomes fundamental especially when working with children with ASD. Of course, using robots that do not resemble human looks can cause interesting interactions that stimulate creativity, avoiding the Uncanny Valley effect (Bartneck *et.al.,* 2007).

However, in children with ASD, humanoid robots with high interactive abilities and responses can enable a higher chance of generalization and a higher possibility of recognising and imitating emotions. For this reason the present article describes a research design with the support of the NAO robot.

Many of the studies run in the last years tried to face the deficits of the socio-emotional reciprocity, common in ASD, by acting mainly on single precursors of ToM: ocular contact, imitation, symbolic play, human interaction. A smaller number of investigations researched in a specific way the overall development of ToM, that is the ability of "mentalizing" (of considering the other's behaviour as a result of mental states similar to own, recognizing their existence and regulate own behavior according to them) by associating, for example, the robotics to the creation of social stories (Costa *et.al.,* 2014; Vanderborght, 2012) and to virtual worlds (Pennazio, 2019; Pennazio & Fedeli, 2019)

The proposal here presented is in line with the scientific evidences that demonstrated how the activity with an interactive humanoid robot makes it possible to act on emotional states (recognizing the emotions and the casual factors that determine them) (Costa *et.al.,* 2014; Barakova *et.al.,* 2010), on the comprehension of beliefs (what other people think and believe) and on the development of conceptual perspectives different from own perspectives (any element changes in its meaning if observed from different perspectives).

Moreover the small number of specific studies on transferability of acquired interaction abilities by the person with ASD (Tapus et.al., 2007) from the activity with robots to the human interlocutors is an additional input for the development of the present proposal. This is a relevant aspect for the chance to be properly able to participate in a social context. The learning output acquired in a situation that was specifically created with a robotic mediator is not per se significant; it becomes meaningful when it can be replicated in a real context with human interlocutor (Pennazio, 2019).

2.2 Virtual worlds and ASD

With the phrase "virtual world" we refer, here, to multi-user virtual environments (MUVE) that can be accessed by a computer with a dedicated viewer and in which the communication and the interaction among involved actors occur through an avatar, a graphical 3D representation of the user.

Avatars can be either anthropomorphic or represent non-human characters. In such online environments avatars have, mostly in socially oriented worlds, a strong power of action in the management of their movement in the space and in the creation of artefacts (from whole building to simple objects).

Users can be freely socially engaged in real time with avatars of different "shapes" and characteristics (e.g. human/robot; adult/child; male/female, etc.). Metaphor-free worlds shows a flexibility that can productively be used for users with different disabilities and for educational purposes; the deep immersion, thanks to the embodiment of the user (Fedeli, 2016), makes those environments a precious teaching/learning opportunity for both formal and informal context (Universities, schools, but also no profit organization and associations) as shown by a rich literature in the field (Fedeli, 2013; Gregory, Lee, Dalgarno & Tynan, 2016; Schlemmer & Backes, 2015).

One of the direct affordances of some worlds like edMondo (http://edmondo.indire.it/) is the presence, in the viewer interface, of a tool that lets you change point of view (POV) on the world, a camera control with preset views (front, rear, mouselook): you can focus the attention on a specific target and manage the perspective with which you need to look at the surrounding space for some reason (e.g. if you need your student with ASD slowly familiarize with the environment you can make him take a "mouselook view", that is, a subjective view in which he moves in the space without seeing himself or just seeing his feet when looking down and, later, let him take a rear/front view with a complete visualization of his avatar).

An interesting aspect to be investigated, connected to POV, is the development of the empathetic dimension (Fedeli, 2014) where the virtual world affordances play a relevant role in terms of self and other perception.

Specific projects with adults with ASD were developed (Stendal & Balandin, 2015), but young school students with disabilities seems an age range less explored in the virtual worlds that can be justified with the age barrier to register set by some virtual worlds (e.g. Second Life) or the safety requirements schools need and that cannot be satisfied by virtual environments with massive open access.

Researches in the field of special education in virtual worlds are encouraged by the level of immersion and embodiment of the users through the avatar:

"VCs [stand for Virtual Characters] have the advantage of realistic behavior capabilities on the one hand, and systematic manipulability on the other, hence allowing the simultaneous increase of both experimental control and ecological validity" (Georgescu, Kuzmanovic, Roth, Bente & Vogeley 2014).

The use of virtual characters were object of investigation also in terms of "mimicry" where participants with ASD showed to copy "the kinematics of the avatars' movements, despite being instructed only to copy the goal of the observed action" (Forbes, Pan, & Hamilton, 2016), this makes the interaction in the virtual world as real as the interaction in the natural setting and since mimicry is relevant in everyday social interactions (Chartrand & van Baaren, 2009) individual with ASD can successfully be involved in controlled interaction in the virtual world in order to develop a so called "social resonance", an interpersonal coordination (behaviour, belief, attitude) (Kopp, 2010).

In order to be able to use virtual worlds with children with disabilities it's necessary that all the staff involved (researchers/educators/teachers) provide a safe environment in terms of privacy and wellbeing and this is possible when: (1) the virtual environment interface is usable by the individual with specific disabilities (motor and/or cognitive); (2) the access to the interaction space is limited to people involved in the research/education actions; (3) the staff is aware of the downsides of such technology on a practical/technical level and able to predict them in order to avoid uncomfortable events for the child. For all this reason edMondo was selected as virtual world to be used in the research described in the following paragraphs.

Moreover the review by Parsons & Mitchell (2002) highlights, among the characteristics/affordances that a virtual environment should present in order to be used for the teaching/learning process of social comprehension with people with ASD, the possibility to act within realistic scenes where the same behaviour can be easily replicated in different contexts (home, school, etc.). But the application of such technology still remains a challenge for the school context, in fact "Whilst there has been some progress in testing the relevance and applicability of VR for children on the autism spectrum in educational contexts, there remains a significant challenge in developing robust and usable technologies that can really make a difference in real world classrooms" (Parsons & Cobb, 2011, p. 355).

3 Research design

The study is framed under a single-subject research design (Horner *et al.*, 2005) also referred to as Single-Case Experimental Designs (SCED) as a widely used in the educational setting (Kazdin, 2010).

The research implies a nonconcurrent multiple baseline method, that is, the researchers planned to implement the intervention to different participants in different time frames.

The structure of the process to be followed in the forthcoming experimentation is designed to be addressed separately to 9-year-old male pupils with similar profiles: having attended regularly school in Italy since pre-school with the support of special needs teachers; being diagnosed with high function autism (HFA); show cognitive and language deficits that could not preclude the use of different strategies and technological equipment.

The participation of pupils occurs after having discussed its effectiveness and appropriateness with all involved actors (teachers, parents, etc.) and information about the school history will be relevant to modulate the actions and the project objectives to the specific needs. The data on the pupils' profiles are necessary to test if such technological mediators (real and virtual robots) can jointly support the development of perspective taking and social interaction that can represent a barrier for the active involvement of children with ASD in the school community.

The participant's emotional development will be initially measured through a validated tool, the Italian version of the Test of Emotion comprehension (TEC) (Albanese & Molina, 2013; Pons & Harris, 2000), the same tool will be used during the experimentation steps.

Since pupils with different levels of abilities, like the emotion understanding, can react to the same inputs differently (Sherer & Schreibman, 2005) an early assessment can better help demonstrate the social validity of the intervention in the direction of a generalizability of the results across various participants.

The TEC is organized around 9 components: (1) recognition (labelling), (2) Understanding of external causes of emotions, (3) relationship between desire and emotion; (4) distinguish between own's knowledge and other's knowledge (5) the relationship between memory and emotions, (6) regulation (7) hidden emotions, (8) Understanding of mixed emotions, (9) emotional dimension of moral decisions. The component 7, 8 and 9 will not be applied in consideration of the age and cognitive abilities of the participants. The proposed components can be, in fact, categorized into three developmental phases and 7-9 components pertain to an age 8+. It's necessary, then, to consider the individual differences in the comprehension of the emotions, at affective and cognitive level.

The independent variables through which the 1-6 behaviours will be measured with TEC are:

- the use of an interactive robot in presence: the humanoid multifunctional robot NAO developed by Aldebaran Robotics and equipped with tools that let it develop social aspects of communication;
- the use of an interactive robot avatar at a distance: the social multi-user virtual environment "edMondo", the Italian open sim world developed by INDIRE (National Institute Documentation, Innovation, Educational Research) for educational purposes and only accessed by teachers and their students.

The robot NAO is internationally known in the field of robotics and we will, here, focus on the use of the virtual robot. The use of the virtual world has a twofold objective in the approach to emotions and perspective taking.

The environment can, in fact, be used to record social stories with the support of the participants' peers who will interact with the robot avatar (animated by one of the researcher) through their own child avatars, and finally involve the participant himself in the interaction with the robot avatar and, possibly, with peers' avatars within the virtual environment in real time.

In order to make the presence and the social interaction in the environment significant three settings were built: a school building, a home building and a park.

All settings are equipped with the related furniture and objects useful to make social stories like a birthday setting in the house living room with simple target objects (e.g. gifts) that can facilitate the implementation of a script (to give and receive a present with the related emotions to be codified and tested as component 2 of the TEC, "understanding of external causes of emotions").

Social stories (Gray & Garrand, 1993) are a well known strategy in literature to facilitate social skill development with children with ASD, so the video-modeling in all its different connotations (McCoy & Hermansen, 2007) and the recorded session in the virtual world follow paradigms widely accepted in the field and connected to the basic emotion: happiness, sadness, anger and fear.

In terms of primary quality indicators the data for each of the six TEC components will be collected three times during each intervention phase (baseline) (Horner *et al*., 2005).

The use of the technological devices implies an expertise that cannot be easily transferred to school teachers, but since the social validity of the project relies also on its transferability the researchers involved will have a training sessions with teachers and all students to describe the technology used and their use for the objectives of the project.

The research hypothesis are the following:

- Being the ToM deficit in children with ASD a major issue in the development of social interactions and recognition of others as emotional agents the researchers expect that an integration of mediators (humanoid robot, virtual robot and recorded virtual social stories) that offer an immersion in the interaction and, at the same time, a distancing posture could activate joint attention skills and improve the social interaction;
- Being the use of robotics with children with ASD widely discussed in the literature with positive results connected to the mediation of the robot in the social communication the researchers expect that a further additional mediation process between the use of robots and humans, represented by a robot avatar interacting at a distance through a computer interface, can improve emotion comprehension and perspective taking due to the embodiment affordance of the virtual world and the chance to use POVs;
- Being the use of virtual characters productive (Georgescu *et al.,* 2014; Vogeley & Bente, 2010) the researchers expect that the social communication that can occur with the support of the robot avatar, able to express itself orally, through written text and through extralinguistic codes (movement in the space, posture, gestures and facial expressions, use of objects), can offer a more flexible and adaptive learning environment to the pupils' needs.

4 Structure of the planned activities

In the current section, the structure of the plan of action is presented (Table 1). The different modules (5) are briefly described in order of complexity specifying where the use of robot NAO and the virtual world EdMondo are included.

Every module is divided into different activities of growing difficulties, which are considered as met in the moment when the child can execute the activity requests with a number of maximum mistakes allowed by the project plan.

Module 1 is an introduction and, other than enabling the development of the affective relationship between the child with ASD and the mediator (robot), it helps to work on ToM precursors: attention, eye contact, sustaining eye contact on a moving object. Modules 2 and 3 are more focused on the development of cognitive dimension of empathy; while modules 4 is oriented to the development of the emotional dimension of empathy. Module 5 is oriented to showing the child with ASD how to obtain the ability to adequately and immediately respond to different emotional situations, with different partners, generalizing then this ability in a tangible/physical context.

Specifically, activities in module 2, 3 and 4 follow the division suggested by Howlin and colleagues (1999), with the addition of a level focused on the robot and the virtual environment and a reflection on emotional states and the possibility of acting on them. In the first modules the child with ASD uses the virtual world as a viewer of social stories that have as participants the robot and, inside the virtual world, classmates of the child. In the last modules the child with ASD directly acts in the virtual world having the chance to interact with the environment, the virtual robot and the virtual peer.

The adults (teacher/s, researchers) are involved as facilitators during the activity. At the beginning and at the end of the intervention TEC is administered while during the process, in each step of each module, it will be used: (1) an observation grid to assess, for example, the changes in eye contact and the shift of interactions model to the human interlocutor following the indicators present in Robins *et al.* (2005; 2009; 2014); (2) an observation grid to monitor the quantity and kind of prompts given by the human interlocutor to the children and built according to the 7 steps by Vanderborgbt and colleagues (2012).

Table 1
PLAN OF THE ACTIVITIES

Module	Aims	Descriptions	Instruments
Module 1 Prerequisites	Creation of a relation with the robot; maintaining attention and eye contact	Free interactions between the child and the robot (presentation, short requests from the robot, imitation)	Robot NAO
Module 2 Emotions	Recognizing emotions	Structured interaction between the child and the robot, in which they work on recognizing emotional states in the robot.	Robot NAO

Module 3 Causes of emotions	Recognizing causes of emotions	Structured interaction between the child and the robot, in which they work on recognizing emotional states in videos, and in the robot; on the causes that determine an emotion (situations, desires, opinions).	Robot NAO Virtual world edMondo (the child watch social stories that were recorded in the virtual environment)
Module 4 Beliefs	Understanding how other people can perceive, know and believe in relation to specific situations.	Structured interaction between the child and the robot in which they work on: simple visual perspective (people can see different things depending on their positions); complex visual perspective (the same object can appear different to people in different positions), being aware means knowledge; making previsions based on a belief; influence of false beliefs in reality perception	Robot NAO Virtual world edMondo (the child watch social stories that were recorded in the virtual environment with different POVs)
Module 5 Me, protagonist	Ability to generalize learnt content	Social stories that directly involve the child with ASD interacting with the virtual robot and resuming content of modules 3, 4.	Robot NAO Virtual world edMondo (the child access the world and interact in real time with the virtual peer)

Conclusions

Children with ASD show a partial development of ToM, that is the comprehension of mental states and their attribution to people and objects (e.g. in symbolic play). The ToM deficit can explain the anomalies in social relations due not only to the lack of communication skills, but to the difficulty in conceptualizing the emotional states of others.

The proposed plan of research aims at investigating how the affordances of robotics and virtual worlds can affect the emotion understanding (identify, hypothesize, explain) by using different mediators (Damiano, 2016) (NAO/active; virtual environment/iconic; social stories/analogic).

The chosen approach leverages the potential of robots, which can be effectively used to activate communication and increase responses in children with ASD, and add a further step by introducing a virtual robot.

The studies on embodiment in social virtual worlds make it consistent the use of such mediator, but the results in the child's engagement in the virtual interaction need to be analysed taking into account several aspects: the child's confidence with the technological devices (in this case the pc and the mouse control); the connection between the POV feature and the level of immersion in the virtual environment and consequent involvement in the action; the relationship between the graphical representation (avatar) and the child's perception of embodiment (of himself and his classmate). By using an integrated approach from active and analogic mediators to iconic/representational ones it would be possible to test the attitude of the child in conceptualizing the others as emotional agents in their different occurrences, the humanoid robot and the further virtual interaction through avatars could, in fact, represent an highly adaptive method to simulate social stories that engage the child on a cognitive and emotional level.

Endnote

The article is the result of a common vision among the authors with the following responsibilities: Valentina Pennazio is the author of paragraphs: 1; 2; 2.1; 4; Laura Fedeli is the author of the paragraphs: 2.2; 3; 5.

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HOW DO PUPILS PERCEIVE EDUCATIONAL ROBOTICS AS A TOOL TO IMPROVE THEIR 21ST CENTURY SKILLS?

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In the past years, the use of educational robots has steadily increased, in particular due to the ongoing digitalization of modern societies and the new skills that professions require. It has been argued that educational robotics activities have the potential to promote the acquisition of such skills and may increase pupils' interest in STEM disciplines. Despite these results, only few studies have examined the pupils' perspective regarding the pedagogical value of educational robotics in formal education. Therefore, in this study with 91 pupils aged between 13 and 15 years, we aimed at investigating how pupils perceive educational robotics as a tool to improve their creativity, collaboration, computer science and computational thinking skills and to foster their interest in STEM disciplines. Over a period of one semester, the pupils worked with the robot Thymio II and evaluated their experience through a questionnaire. The results showed that boys and girls have different perceptions on which competences they could enhance: while

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boys affirmed more often than girls, that they could improve their computer science and computational thinking skills, the opposite was found for collaboration and creativity. Moreover, the results illustrated that educational robotics activities could increase the interest in coding, computer science and engineering, however, this was predominantly observed in boys.

1 Introduction

Recently, there has been an increased interest of using educational robots in formal education settings. This ongoing trend of introducing robots into classrooms is motivated by several reasons. On the one hand, it has been argued, that educational robotics can provide a hands-on and motivating teaching tool to introduce pupils to science, technology, mathematics and engineering (STEM) (Park & Han, 2016). STEM skills are considered essential for the 21st century workforce and are required for many professions (Erdogan *et al*., 2017). With respect to the challenges ahead of digital societies, there is an increased interest in motivating coming generations to pursue careers in these areas. In this regard, there is a desire to particularly encourage girls. Females are still under-represented in these disciplines (Hill *et al*., 2010): for example, the worldwide average of women researchers in science in 2015 was only 28.8% (UNESCO, 2018). This is also due to social and environmental factors like the stereotype that boys are better than girls in math and science, or social biases that implicitly associate science and math with males and humanities and arts with females (Hill *et al*., 2010). These factors influence girls' likelihood of cultivating their own interest in math and science and pursuing a career in those fields. It is hoped, that early exposure to educational robotics activities, could counteract this trend, since educational robotics can provide exciting and attractive gender-neutral learning environments to arouse interest and curiosity for STEM disciplines in both boys and girls (Weinberg *et al*., 2007).

However, when working with educational robots, the goal is not only that pupils learn about robotics and the related STEM disciplines, but it is also intended that they acquire important transversal skills, such as creativity, collaboration and computational thinking. Those skills together with digital skills are considered fundamental for future workplaces and are seen as key competences of the 21st century (World Economic Forum, 2016). Previous studies have acknowledged that their development can be fostered through activities involving educational robotics. Indeed, in many educational robotics activities the pupils are called to use their creativity to design and construct robots, as well as to develop problem solutions to perform robotic tasks (e.g. Park & Hahn, 2016). Moreover, educational robotics activities often require pupils to work and collaborate in groups in order to achieve their goals, hence promoting collaborative work and communication strategies (Nugent *et al*., 2010;

Ardito *et al*., 2014). Most recently, particular attention has been devoted to the use of educational robotics for teaching skills related to computational thinking. Popularized by Wing (2006), computational thinking involves "solving problems, designing systems, and understanding human behaviour, by drawing on the concepts fundamental to computer science" (p.33) and is considered a fundamental competence for modern societies. In this context, previous work has acknowledged the potential of educational robotics to promote the development of computational thinking (Atmatzidou & Demetriadis, 2016).

Nevertheless, it appears that so far only few studies have focused on the pupils' perspective regarding the perceived pedagogical value of educational robotics activities. In the past, some studies intended to examine if pupils perceived a development of their 21st century competences or an increased interest in STEM disciplines following educational robotics activities. Naizer *et al*., (2014) for example, analysed the interest and the confidence regarding math, science, technology, and problem-solving by 32 predominantly sixth graders schoolchildren during a summer camp, showing a positive impact on females' beliefs about their abilities in those areas. In another study, Welch (2010) could observe in high school students a more positive attitude toward sciences after their participation in an educational robotics competition. Similarly, the study of Theodoropoulus *et al*., (2017) addressed student's attitudes towards STEM and 21st century skills. In their study with 30 pupils, they reported improved collaboration, problem solving and creativity skills as well as a better understanding of STEM concepts, and a gain in programming knowledge in pupils that participated in an educational robotics competition. Another study by Kaloti-Hallak *et al*., (2015) instead, showed that there was no significant change in the pupils' motivation to learn STEM disciplines following the participation in a robotic competition. However, the authors also explained that they could not measure a significant increase, because the motivation was already very high at the beginning. Nugent *et al*., (2010) have analysed the impact of robotics on middle school students' learning and attitudes toward STEM. The pupils participated either in a 40 hours school camp or in a condensed 3 hours event. Results showed that the school camp led to significantly greater learning, whereas the short-term intervention primarily positively affected the attitude and motivation.

However, these studies have included rather limited samples of pupils (Naizer *et al*., 2014; Theodoropoulus *et al*., 2017) or have analysed the perspective of the pupils after comparatively short interventions (Naizer *et al*., 2014; Welch, 2010). Additionally, many of the results were derived from activities related to extracurricular robotic competitions (Kaloti-Hallak *et al*., 2015; Theodoropoulus, 2017; Welch, 2010) or summer camps (Naizer *et al*., 2014; Nugent *et al*., 2010), with some including unrepresentative samples (i.e., very talented and/or motivated pupils), selected either by their teachers or by self-enrolment (Kaloti-Hallak *et al*., 2015; Naizer *et al*., 2014; Welch, 2010). In contrast, pupils' perceptions on educational robotics activities after long-term interventions in formal education settings including all pupils of a class, still seem to be unexplored.

Therefore, this study with 91 pupils aged between 13 and 15 years, aims at examining the pupils' perspective on educational robotics activities in formal education settings: this work investigates if pupils believe that through educational robotics activities in class they can improve their creativity, collaboration, computer sciences and computational thinking skills. Moreover, it examines if the educational robotics activities increased the pupils' interest in STEM disciplines and whether there are differences according to the gender of the pupils. Specifically, this study aims at addressing the following research questions:

1. Do pupils believe that through educational robotics activities in formal education settings they can improve their creativity, collaboration, computational thinking and computer sciences skills?
2. Do educational robotics activities in formal education settings increase pupils' interest in STEM disciplines?
3. Are there differences in the questions 1 and 2 according to the gender?

2 Methods

2.1 Participants and procedure

The study was carried out in Ticino, an Italian speaking Canton in southern Switzerland. The participants of this study were 91 pupils (41 females (45%), 49 males (54%), 1 without indication (1%)) from four different 3rd grade classes of the lower secondary school of Castione, a suburban town in Ticino. The majority of the children (80%) were born in 2005 and were therefore 13 years old during the study. 13% were born in 2004 and 3% in 2003. The rest (4%) did not answer this question. For almost all participants it was the first time that they worked with an educational robot. As a matter of fact, educational robotics and more in general computer sciences are only marginally part of the compulsory school curriculum in Ticino. It is hence often a decision of the teachers to carry out such activities that are classified as general training, i.e., skills that are not part of one or more specific disciplines, but involve all disciplines, and are therefore mostly done in form of school projects that last normally only a few days. For this project however, the pupils could work with the educational robot Thymio II[1], hereafter referred to as Thymio, during a whole semester, since the teachers of the four classes that participated in

[1] Thymio is s an educational robot designed at EPFL in 2010-11. It aims to be gender-neutral: it is all white with a very clean and functional shape (Chevalier et al., 2016).

the survey were enrolled in a Certificate of Advanced Studies in Educational Robotics where they learned how to bring educational robotics into classes. As part of this training, the teachers were asked to perform different robotics activities with their classes to teach them how to use and program Thymio. Therefore, the pupils worked one complete semester with Thymio, most of the time in small groups. The amount of time spent with Thymio however, depended on the teacher and was different for each class. During these activities (e.g. program Thymio so that it can serve a snack during the break; program Thymio in order to create a light painting, etc.), the pupils, while working in groups, had to decide on a strategy to solve the task and then program Thymio to implement their solution.

At the end of the school year, the pupils were asked to complete a questionnaire reflecting on their experience during the whole semester.

2.2 Instruments

In order to collect the data an in-house developed questionnaire was used. The questionnaire included open question items as well as 5-point Likert scale questions (e.g. 1 = "I completely disagree" to 5 = "I completely agree") and simple yes/no items. The pupils were asked to indicate how much they think they have improved in four different dimensions:

- collaboration (3 items, Cronbach's alpha =.671, e.g. "with the robotics activities I learned to work with my peers"),
- creativity (3 items, Cronbach's alpha =.679, e.g. "the robotics activities allow to improve the creativity"),
- computational thinking (CT) (3 items, Cronbach's alpha =.513, e.g. "with the robotics activities I learned to decompose problems in various sub-problems")
- computer sciences skills (CS) (3 items, Cronbach's alpha =.542, e.g. "with the robotics activities I learned how a sensor works").

The Cronbach's alpha values used to estimate the reliability of the scales are between.513 and.679. Although these values are rather low, they are considered acceptable for social sciences and for small scales as evidenced by Pallant (2013).

Furthermore, some questions were dedicated to exploring if robotics activities could improve the pupils' interest toward:

- scientific disciplines (e.g. "the robotic activities improved my interest toward scientific disciplines (e.g. sciences and mathematics))"
- coding (e.g. "the robotic activities improved my interest toward coding"),
- computer sciences (e.g. "the robotic activities improved my interest to-

ward computer sciences (e.g. how does a computer/robot work)",
- engineering (e.g. "the robotic activities improved my interest toward engineering (e.g. how is a robot built))".

2.3 Data analyses

Data analyses were conducted using descriptive statistics to measure the perceived improvement in the different dimensions by the pupils and independent sample t-tests were used to analyse the differences between gender. Cohen's d was used to estimate the effect size. Missing values were pairwise excluded.

3 Results

In general, the pupils appreciated to work with Thymio. Only one child stated that he/she did not enjoy working with the robot and three left this question unanswered. The majority of the children (79%) also agreed or strongly agreed that the activities with Thymio were interesting and only 3% did not agree on this item. The rest of the children did not answer (4%) or affirmed that they neither agree nor disagree (14%). The descriptive statistics of the perceived improvement by the pupils in the dimensions collaboration, creativity, CT and CS shows mean values between 3.45 (CT) and 3.99 (collaboration) on a scale from 1 (no improvement) to 5 (high improvement), indicating that pupils believed that through educational robotics activities they could improve in all four dimensions (table 1). The highest perceived improvements were found in collaboration and creativity, thus in the two dimensions related to transversal skills (table 1).

Table 1
IMPROVEMENT IN THE FOUR DIMENSIONS THROUGH EDUCATIONAL ROBOTICS

	N	Min.	Max.	Mean	SD
Collaboration	90	1	5	3.99	.95
Creativity	89	1	5	3.93	.85
CT	89	1	5	3.45	.81
CS	91	1	5	3.66	.82

Moreover, the comparison of the perspective of female and male pupils, revealed that females compared to males perceived a higher improvement through educational robotics activities in the two dimensions collaboration (4.22 vs. 3.77) and creativity (4.00 vs. 3.89). In contrast, males perceived a higher improvement than females in the two other dimensions, namely CT (3.84 vs. 3.44) and CS (3.52 vs. 3.35) (table 2).

Table 2
IMPROVEMENT IN THE FOUR DIMENSIONS THROUGH EDUCATIONAL ROBOTICS BY GENDER

	Gender	Min.	Mean	SD
Collaboration	Female	40	4.22	.80
	Male	49	3.77	1.03
Creativity	Female	41	4.00	.77
	Male	47	3.89	.91
CT	Female	40	3.35	.92
	Male	48	3.52	.71
CS	Female	41	3.44	.74
	Male	49	3.84	.85

To analyse whether those differences are significant we conducted a t-test for independent samples. The results in table 3 show a significant difference in the dimensions "collaboration" (p=.026) and "CS" (p=.022) while there were no significant differences in the other two dimensions. The effects are medium-sized with respect to Cohen's d reaching an effect size of.49 and.50. Female pupils therefore tend to perceive a higher improvement in their collaboration skills than male pupils, while the latter perceive a higher improvement in their CS skills.

Table 3
T-TEST OF THE IMPROVEMENT IN THE FOUR DIMENSIONS THROUGH EDUCATIONAL ROBOTICS BY GENDER

	T	df	P-value.	Mean Difference	Sts. Error Difference	Cohen's d
Collaboration	2.264	87	.026	.45	.20	.49
Creativity	.584	86	.561	.11	.18	.13
CT	-.979	86	.330	-.17	.17	.21
CS	-2.339	88	.022	-.40	.17	.50

Finally, analyses have been conducted to explore whether pupils believed that thanks to educational robotics activities their interest in sciences, coding, computer sciences and engineering has improved. In general, it emerges that especially male pupils agree that their interest in all four dimensions has improved, though for some dimensions the mean value was just above 3 indicating a rather indifferent answer ("I neither agree nor disagree") (Table 4). The highest mean value for male pupils was found in the dimension "coding" (3.98). Female pupils however, were less convinced about the impact of educational robotics on their interest for the mentioned dimensions. For example, they rather disagreed that the educational robotics activities improved their interest in sciences (2.85) and engineering (2.83). A light agreement was found in the dimension computer sciences (3.41).

Table 4
INTEREST IMPROVEMENT BY GENDER

	Gender	Min.	Mean	SD
Thanks to robotics my interest in sciences has improved	Female	41	2.85	1.08
	Male	44	3.14	1.07
Thanks to robotics my interest in coding has improved	Female	41	3.05	1.18
	Male	48	3.98	1.00
Thanks to robotics my interest in computer sciences has improved	Female	41	3.41	1.34
	Male	48	3.79	1.11
Thanks to robotics my interest in engineering has improved	Female	41	2.83	1.43
	Male	49	3.73	1.10

Also for this case a t-test was conducted to analyse whether the differences were significant. Significant differences were found in the dimensions "coding" (p=.000) and "engineering" (p=.001). In both cases, as shown by the descriptive results, male pupils agreed that their interest has improved, in contrast to female pupils, who rather disagreed (table 5). The effects are medium-large with respect to Cohen's d reaching an effect size of.85 and.70, respectively.

Table 5
T-TEST OF INTEREST IMPROVEMENT BY GENDER

	T	df	P-value.	Mean Difference	Sts. Error Difference	Cohen's d
Thanks to robotics my interest in sciences has improved	-1.209	83	.230	-.28	.23	.27
Thanks to robotics my interest in coding has improved	-4.023	87	.000	-.93	.23	.85
Thanks to robotics my interest in computer sciences has improved	-1.451	87	.150	-.38	.26	.31
Thanks to robotics my interest in engineering has improved	-3.344	87	.001	-.90	.27	.70

Conclusion

The aim of this paper was to analyse how pupils perceive educational robotics activities in formal education settings as a tool to improve their creativity, collaboration, CT, CS skills and interest in STEM disciplines and if there are differences according to gender.

The results showed that pupils were generally interested in working with Thymio and that they believed that through educational robotics activities they could improve their 21^{st} century skills. However, the highest perceived improvements were found in the two transversal skill dimensions (i.e., collaboration and creativity) and not in the two "technical" skill dimensions (i.e., computational thinking and computer science). This result could surprise, since it could be expected that educational robotics has an impact especially on technical dimensions such as CT and CS skills. However, there have been different surveys that highlight how educational robotics activities are used in class with a pedagogical approach that promotes transversal skills like collaboration and creativity (Nugent *et al*., 2010; Ardito *et al*., 2014; Park & Hahn, 2016).

Moreover, the results illustrated gender differences on the perceived impact. Female pupils perceived a higher improvement through educational robotics activities in the two dimensions collaboration and creativity while male pupils perceived a higher improvement in the two technical dimensions, namely CT and CS skills. The differences were statistically significant in the two dimensions collaboration and CS skills. Although the data from this study is not sufficient to comprehensively explain these differences, some hypotheses can be formulated based on the results of previous works. Hill *et al*., (2010) showed how stereotypes and biases influence girls' likelihood of choosing STEM disciplines and how they could have a negative impact on girls' interest toward these fields. It is possible that teachers unconsciously reinforce these stereotypes by assigning different tasks to girls and boys when working in groups or even that the stereotypes lead pupils to choose specific tasks themselves: it might be that girls tend to choose creative tasks that are considered more "feminine" (for example preparing and decorating the playground where Thymio moves) while boys are more keen to choose programming tasks. In this context, it could be interesting for further studies to examine how pupils choose and divide their tasks in groups when working with robots and whether teachers assign different kinds of tasks to boys and girls.

The above-mentioned results can also be linked to the second question addressed in this study, namely if educational robotics activities help to increase pupils' interest in sciences, coding, computer sciences and engineering. In general, it emerges that especially male pupils agree that their interest has improved, especially for coding. Female pupils however, seem to be less convinced about the impact of educational robotics on their interest for those fields. A light agreement was found only for the computer sciences dimension. Significant differences were found in the dimensions "coding" and "engineering" where in both cases male pupils agreed that their interest has improved while females disagreed. These results compel us to reflect on the impact of educational robotics activities on the interest in STEM, since previously it has been argued that robotics should help to promote STEM disciplines, especially in girls (Park & Han, 2016). To reach this objective, teachers should however be aware of the gender differences and on how to stimulate girls in those fields in order to dismantle the gender stereotypes that are most probably already present in pupils.

Summarizing we can say that pupils appreciated to work with Thymio and that they believed that those activities can have an impact on their collaboration, creativity, CT and CS skills. The perceived impact was different for male and female pupils, with males tending to perceive a higher impact on the technical skills and females on their collaboration and creativity skills. However, only little impact could be found on the interest in sciences, coding, computer sciences and engineering and in this case, predominantly boys reported an increased interest.

The present study was conducted with pupils of four different classes of the same school, hence generalization is limited. Furthermore, the questionnaire addressed only a few questions for each of the analysed dimensions and it covered only some elements of the corresponding concepts. For example, the concepts of CT or CS skills are more articulated and cannot be extensively covered with a scale of only three items each. More in depth studies in this field with more reliable scales are hence desirable. Nevertheless, the presented study gives a new perspective on the impact of educational robotics activities that have been carried out during a longer period in formal education settings and gives some first insights on the perceptions of pupils, while differentiating between genders.

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LEARNING DISTRIBUTED ALGORITHMS BY PROGRAMMING ROBOTS

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The learning process of theoretical concepts such as the model of a distributed environment and different distributed algorithms together with their execution and correctness requires time and is often considered by students a hard and non-challenging issue. In this paper we suggest adopting a more practical approach based on real implementations of distributed algorithms with the help of robots. A learning-by-doing approach can, in our opinion, help students acquiring a deeper knowledge of the model and of the algorithms, and can also stimulate them, and let them improve their teamwork skills. In this paper, we present a specific case study of a practical project, run for two consecutive years at the University Ca' Foscari of Venice, inside an International Master of Computer Science course of Advanced Algorithms. The students for their final exam had to work in groups and their task was to design and implement a distributed algorithm to solve an assigned problem, using a Lego Mindstorm EV3 robot

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and a Makeblock mBot robot. In this paper, we discuss the positive effects of such a non-traditional teamwork approach by analyzing the teacher's perception, the feasible impact on the students' grades, and the students' involvement and positive feeling, highlighted by the results of some questionnaires proposed at the beginning and the end of the projects. We finally discuss the limits of such an approach and possible improvements.

1 Introduction

Robots are becoming part of our daily life. We find industrial robot arms used, e.g., in manufacturing, autonomous domestic robots that can interact with the world in human-like ways (e.g., robots that fold laundry, vacuum cleaning robots), medical robots that help elderly at home or are used for surgical operations, transport robots (e.g., autonomous cars), entertainment robots, field robots that explore dangerous areas (e.g., for demining), etc.

In this paper, we concentrate on robots that are used for educational purposes to improve the intellectual growth of students and to increase their engagement in learning activities. In the recent years, we have been facing an increase in the use of robots inside classes and this depends on many factors such as, e.g., the availability on the market of low-costs programmable robots, or the motivational benefits of introducing them inside school or University courses. Barreto (2012) proposes a review of different research articles on educational robotics and shows how, in general, but not in all cases, this teaching technique can act as an element that enhances learning. In particular, this study, together with the one of Eguchi (2010), and McLurkin *et al.* (2013), shows that robotics can be used to increase academic achievement in specific STEM (Science, Technology, Engineering and Math) concept areas through experimentation, and can also improve different skills such as creative thinking, problem solving, decision making, communication, etc. Taylor and Baek (2016) show what type of collaboration interventions can create a beneficial learning environment for students and can improve their learning motivation inside collaborative robotics projects. They also show the impact of the prior robotics experience on the skills development. The study of Alimisis (2013) critically discusses the role of Educational Robotics and emphasizes how robots should be just a tool to foster new skills (cognitive, team working, etc.), and their use should be supported by sound learning theories, a correct curriculum and an appropriate learning environment.

Other more specialized studies show how robots can result as an entertaining platform that can improve the learning process of languages, computers, electronics, etc. (Mubin *et al.*, 2013). In particular, robots can be used to present non-technical scientific subjects such as, e.g., mathematics, or kinematics (Karim *et al.,* 2015, Mubin *et al.*, *op. cit.*), to teach second languages (Chang *et al.*, 2010), to improve the cognitive development of young people (Toh *et al.*, 2016). However, the focus of this paper is on the learning process of technical subjects using robots. Zaldivar *et al.* (2019) introduce an educational platform based on Lego Ev3 robots and on Matlab that can be efficiently used to support the learning process of the principles of classical and metaheuristic optimization algorithms in undergraduate engineering courses. Gyebi *et al.* (2016) present the result of the effects of Educational Robotics on an Undergraduate Computer Science course taught in a University in Ghana. In particular, the authors discuss the impact of robotic-based exercises as opposed to paper-based exercises, the effect on students' understanding of programming concepts, the engagement and the effectiveness of the method. The presented results are positive in terms of engagement, motivation and skills development. In (Damaševičius *et al.*, 2017) the authors discuss a project-based approach using robots that they have experimented during practical classes of the Robots Programming Technologies course of the Kaunas University of Technology in Lithuania. At the end of the project students gained problem-oriented skills, they were able to combine hardware and software related subjects, and they increased interest in the subject. López-Nicolás *et al.* (2009) propose an active learning experience in the field of Robotics, and in particular the design of robots for industrial applications, in the context of a degree on Industrial Engineering at the University of Zaragoza. Results show an improvement in the student's motivation and understanding of the analyzed problems. Finally, Das *et al*. (2019) present an implementation of some distributed algorithms using Lego Mindstorms EV3 robots. The developed project was not only useful to improve the students' knowledge and team work, but also to improve the quality of the proposed theoretical solutions, showing how theory can also benefit from real applications.

In this paper we present a project-based learning approach that was adopted for the exam of Advanced Algorithms at the University Ca' Foscari of Venice, Italy, in years 2017 and 2018. To the best of our knowledge, this is the first time this approach has been used to improve the knowledge and the comprehension of distributed algorithms. We here discuss the positive effects of this approach and also the limits. The paper is structured as follows: Section 1 introduces the case study describing the projects and the technology used. Section 2 presents the results achieved using this project-based approach and discusses the limits. Finally, future work is discussed.

2 Case study

The Advanced Algorithms course contains different topics. The first half includes advanced algorithms such as approximation, randomized and genetics algorithms, local search techniques, etc. The second part is all dedicated to distributed algorithms and the experimental project was devoted to this part. The students had an intermediate exam on the first part, and only those that passed the first exam were admitted to the practical exam. We point out that, our experimentation on robots was not a hands-on practical class, but the experimentations were only included as part of the final exam. The class was divided into two groups. The first group included students that took the traditional written exam; the second group included those that replaced the traditional exam of the second part with the practical project. All students had however to follow the classroom-taught lessons. 26 students attended the course in 2017, and 47 in 2018. Students that took the practical project were divided in groups of at most four people. The project dealt with autonomous robot programming. The main concepts to be learnt were: the robots' model, the change of state, communication and interaction, autonomous movements and autonomous solution of different tasks, i.e., design and implementation of different distributed algorithms.

2.1 The projects

The case study we propose in this paper analyzes two projects one developed in 2017 and one in 2018. The goal of the projects was the solution of two different problems proposed by the teacher, and the development of two different distributed algorithms with mobile robots in a group project-based educational setting.

Project 1: In 2017 we proposed a relay race between two robots: one Lego Mindstorm EV3 robot and one Makeblock mBot robot. One robot (chosen at random between the two of them) had to start the race, had to find the other robot and once found had to stop while the other one had to finish the race. The robots moved along a path and had to avoid obstacles. The path was composed of 3 randomly composed sub-paths (i.e., producing each time different paths). An example is depicted in Fig. 1 left.

Project 2: In 2018 we proposed the simulation of a known algorithm for the search of a black hole in a ring network using one Mindstorm EV3 robot and one Makeblock mBot robot. The black hole is a malicious node that kills all the robots that arrive there, so the robots should try to avoid it. At the end of the algorithm at least on robot should survive and should know the location of the black hole. An example is depicted in Fig. 1 right where the black hole is the black vertical object and the square is the homebase where the robots start the computation and where they meet during the execution of the algorithm.

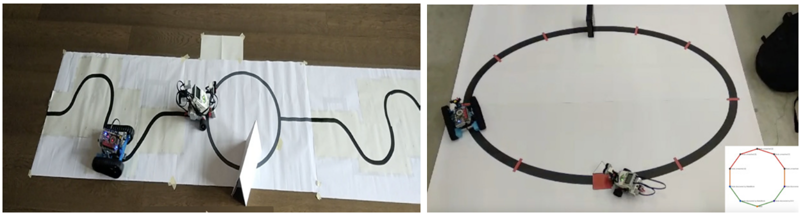

Fig. 1 - On the left a relay race with one mBot robot (on the left) and one Lego robot (on the right). On the right, the search for the black hole with one bMot and one Lego robot.

2.2 The robots

Each group was equipped with two robots: A Lego Mindstorm EV3 robot[1] and a Makeblock 90092 - mBot robot[2]. For the Lego EV3 robots, standard components and sensors were used to build the robots: 1 EV3 programmable brick with and ARM 9 processor of 300 MHz and a Linux-based operating system, 2 large motors, 1 medium motor, 1 touch sensor, 1 infrared seeking sensor, and 1 ultrasonic sensor to detect both objects and the other robot, 1 color sensor to detect colors and to be able, e.g., to follow lines, and 1 gyroscopic sensor. For the Makeblock mBot robot the available components and sensors were: a Me Auriga main control board programmable in *C\C++* language via the Arduino IDE, 2 motors, 1 ultrasonic Sensor, 2 light sensors, 1 line-follower sensor, and 1 gyroscope.

2.3 Technical issues

Both projects had some non-trivial technical issues to be dealt with. The first general constraint was the interaction between two heterogeneous robots that had different hardware and software resources. Moreover, in the first project the difficult issues were:

1. the following of a line by the Lego robot that does not have a 1 line-follower sensor. The students had to design an algorithm to follow the line and different problems turned up because of the folds on the sheet of paper that indicated the path, shadows on the paper, variable ambient lighting conditions, etc.;
2. the detection of an object given that the sensors could not distinguish the difference between an object and another robot.

[1] https://www.lego.com/it-it/mindstorms

[2] https://www.makeblock.com/steam-kits/mbot

In the second project the difficult issues were:

1. the distinction between a normal node of the ring network and the black hole;
2. the exchange of information between the two different robots;
3. the limited power of battery levels that may limit the correct behavior of the sensors.

The students had thus to discuss, collaborate and try to solve all the issues, in some cases they also interacted with the teacher proposing and analyzing different solutions, discussing problems. From all these discussions, the students improved their collaboration abilities and their technical skills, and the teacher had a very positive perception of the interaction and intellectual growth of the students. Regarding collaboration they had first to agree on how to split the different tasks (balancing the work), during the development phase they had to discuss different solutions and problems, and they had to integrate all the tasks into a final solution. From the student/teacher interaction, the teacher had an immediate feedback on how collaboration had helped students to fully understand the problem, and to improve the knowledge on the course topics.

3 Results and project evaluation

To evaluate the students perceived usefulness of this project two pilot tests were conducted running two anonymous surveys proposed as Google Forms, an initial (proposed to all students) and a final survey (proposed to those that participated to the project). The surveys were composed of both multiple choice and open questions. In 2017, 10 students out of 26 participated to the practical project, 12 filled the initial survey and 6 students that did the project filled also the final survey. In 2018, only 3 students out of 47 participated to the project, 21 students filled out the initial survey, and the 3 that did the project, filled out also to the final one. We also collected some information using paper surveys, and verbal impressions and comments from students that participated/did not participate to the project.

The purpose of the initial survey was to gain information about the students' background and knowledge before the project. The final survey evaluated the whole project experience in terms of students' motivation, engagement and level of understanding in the robotic activities:

The questions for respective surveys were divided into:

- *Initial survey*: asked for students' background such as prior education, prior experience in programming and using robots, reason why they eventually chose the project instead of the standard written exam, expectations before doing the project.

- *Final survey*: asked for students' perception about the skills, motivation and knowledge gained. We also asked if they would go through the same experience again.

To assess the students' performance and understanding of the basic of distributed algorithms we evaluated their final project both from a theoretical (with a written report) and practical point of view (with a practical demonstration). The students' engagement and improvement in the collaboration skills were assessed with the final survey.

3.1 Results of the initial survey

In the initial survey of the first pilot test we were able to access students' background. Different questions were posed:

- *Study background*: In 2017, 83.34% of the students had taken their bachelor in Computer science in Italy, 8.33% in Engineering in Italy, 8.33% in Engineering in another country. In 2018, 57,1% declared their prior bachelor in Computer science in Italy, 28,6% in Computer science in other countries, 14,3% in Engineering in other countries.
- *Known programming languages:* In 2017, all students declared the knowledge of C and Java languages, while in 2018, only of C language.
- *Prior experience in programming robots:* In 2017, 91.67% of the students had no prior experience in programming robots, 8.33% in programming Lego Mindstorm robots, while in 2018, 90,5% had no prior experience, 9.5% only in programming Lego Mindstorm robots.
- *General interest in programming robots*: In 2017, 58.34% of the students were generally interested (independently from this course) in programming robots and see real applications of algorithms, the remaining 41.66% were not, while in 2018, 85,7% were interested and 14,3% were not.
- *Reason why they chose the project* (for those that did it): in 2017, 80% of them answered that they chose the project because they thought it was interesting to program robots, the remaining 20% replied it was easier to program robots than to study for a written exam, while in 2018, 66,67% answered that was because the project was interesting, 33.33% because the project was easier.
- *Expectation on the project effects:* the students had to reply to a question by selecting one or more answers. In 2017, 66,67% of the students believed that by doing the project they would improve their knowledge on theoretical distributed algorithms, 41,66% that they would improve

their learning motivation, 33,33% that they would improve their collaboration skills, 25% that they would easily fix concepts, 33,33% that the project could make the learning process of educational activities effective, and finally 41,66% that it could improve their pleasure on studying distributed algorithms. In 2018, 66.7% thought that with the project they would improve their knowledge on theoretical distributed algorithms, 52.4% that the project would make the learning process of educational activities effective, 52.4% that the project could help then to easily fix concepts, 47.6% that it could help them improving their collaboration skills, their learning motivation, their understanding of programming concepts, 42.9% that it could help them improving their pleasure on studying distributed algorithms.

We can thus conclude that, also students had the perception that such a group work project could potentially improve their knowledge and their collaboration skills in an effective way.

3.2 Results of the final survey

After the end of the project we have run with the participants a new survey to assess the students' engagement and perception of this activity. We proposed a multiple-choice question with one or more possible answers.

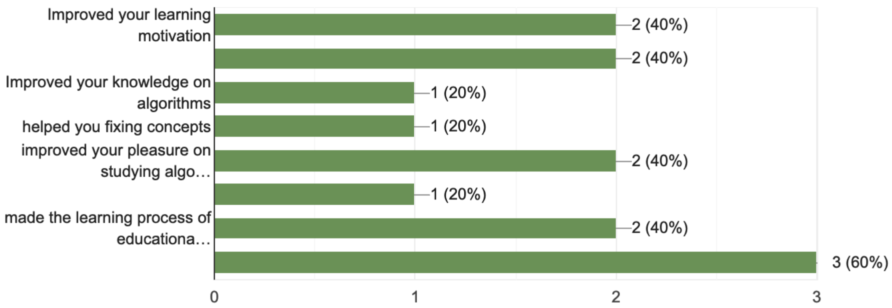

Fig. 2 - Answer to the question: "Do you think that the project with robots has …" in 2017.

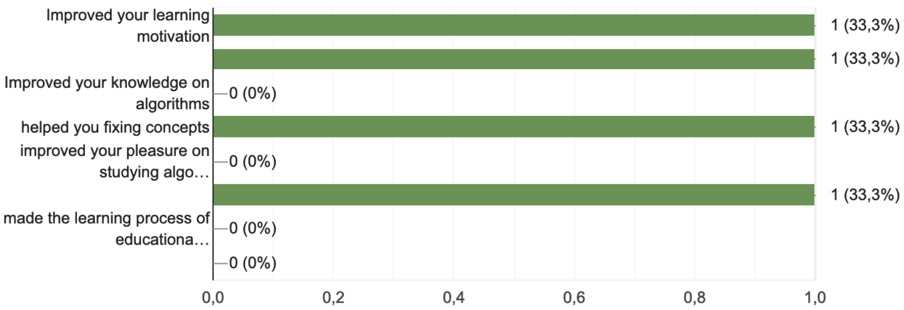

Fig. 3 - Answer to the question: "Do you think that the project with robots has …" in 2018.

Collaboration effect: to analyze this dimension, we asked what the added value in the course was of working in a group (as opposed to working individually). The results are shown in Fig. 4 for 2017, Fig. 5 for 2018. It emerges that the main effect was the increase in mutual support and motivation, and then also the group size was relevant for splitting the work.

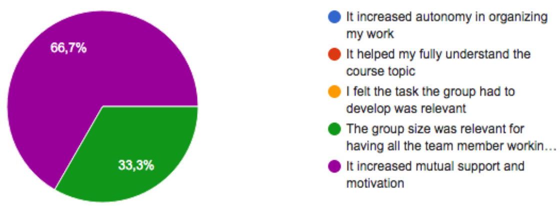

Fig. 4 - Collaboration effects. Results for 2017.

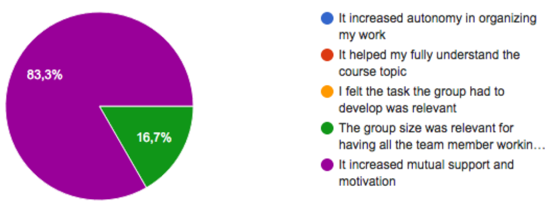

Fig. 5 - Collaboration effects. Results for 2018.

Finally, a question that in our opinion is very interesting is whether they would choose to retake the project again: in 2017, 80% of the students replied yes, but 20% of them replied no and the motivation is that the time they spent to develop the project was too long, while in 2018, 66,7% replied yes, 33,3% replied maybe, only if the project would be more focused on algorithms that have a really well-defined field of practical application.

We can thus conclude that the overall experience for students that did the project was very good, and students had the perception that they had increased their knowledge also on theoretical concepts and their collaboration skills, and most of them would repeat the experience.

3.3 Exam performance

We have analyzed the students' performance on the final exam, comparing the grades of the students that passed the exam in the traditional way, and those that presented the final project. The evaluation of the projects was based on: 1) the group presentation of the project with an oral description, and an execution of the algorithm; 2) a written report for each student, including the hardware and software description, the developed algorithm, and the technical limitations. Note that, those that worked on the project were the ones that passed the first partial exam, so this set does not include the weakest students. Also observe that all students that worked on the project were enthusiastic and made a big effort to obtain nice results and to solve all technical limitations. The presentations were all excellent and also the reports. The teacher's perception is thus that these students acquired all the basic notions of distributed algorithms. In 2017, all the students that did the project had very high grades (with a mean value of 29.7 out of 31. Note that, positive grades in Italy are between 18 and 30 cum laude, we considered 30 cum laude as 31), much higher than those that did the written exams (mean value of 22.82). Moreover, the median value of the class score was 28.5, and all the students that did the project, except one, had a score over the median. In 2018, the grades of the students that did the project had a mean value of 30.66, while those that did the written exam had grades with a mean value of 21.93, the median value of the class grade was 25, and all students that did the project had a score over the median. We can thus conclude that in both years working on the practical project greatly improved the exam performance.

Conclusion

This paper illustrates a new and original approach to introduce students to the theoretical models and algorithms in the area of distributed algorithms using a hands-on approach for the exam preparation. From the results of our tests and an analysis of the students' performance we can claim that Educational robotics and in particular this project-based approach can make the learning process more interesting, can increase the collaborations skills and the knowledge of theoretical concepts. This is also reflected by the excellent final grades obtained by students that participated to the project compared to the ones that only took the traditional written test. One limitation of this approach is that it is time-consuming, thus some students preferred to take the traditional exams. This situation is reflected by the decrease in the number of students that participated to the project in 2018, compared to the ones that participated in 2017. This can also be explained with a word-of-mouth between students of consecutive years. A solution to this problem could be to include the final project as a requirement for all students, and to replace some of the theoretical lectures in class with some practical classes devoted to the final project, thus limiting the self-organized work outside the standard class schedule.

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FROM TINKERING TO THINKERING. TINKERING AS CRITICAL AND CREATIVE THINKING ENHANCER.

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Keywords: Tinkering, Museum, STEM education, Critical thinking, Creativity, Assessment and evaluation

Education research interest in Tinkering, as an informal method to engage students with STEM subjects, has been growing and growing in the last few years. Recent research has highlighted that Tinkering could be adopted not only to develop students' scientific knowledge but also to support thinking processes such as Critical Thinking and Creative Problem Solving. Despite these assumptions, there is still limited empirical research evidence concerning the impact of Tinkering on the development of the 21st Century skills. That is why the Centre for Museum Studies - University of Roma Tre investigated the influence of Tinkering activities on Critical and Creative thinking skills enhancement in museum educators and teachers involved in STEM education. To fill in the above gap of empirical evidence, the Centre for Museum Studies carried out a pilot study at "Città della Scienza" Science centre (Naples), where 30 participants (museum educators and STEM teachers) were involved in a two-day workshop on collaborative Tinkering

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activities. During the workshop, participants were required to take two kinds of pre and post-tests with the aim of assessing Critical and Creative thinking skills development. On one hand, in the Creative Thinking post-test participants showed significant improvement. On the other hand, despite there were no statistical differences concerning Critical Thinking assessment, a slight improvement in the post-test could be quantified. The data collected support follow up research, where the sample of the study could be enlarged and further measures for Critical and Creative Thinking assessment employed.

1 Introduction

More than ever, the education scientific community is interested in developing methods that can engage students with STEM subjects, promoting, at the same time, 21st Century skills. Not only formal, but especially informal education methods are catching the attention of the scientific community, taking into consideration a lifelong learning approach. Among informal education methods, the *Maker Movement* is becoming wide-spread in science education because of its potential to involve young people with STEM (Rocard *et al.*, 2007) and to make scientific knowledge more accessible (Martin, 2015). Research regarding the effect of *Making strategies* on learning is growing, as demonstrated by a review published in 2017 (Papavlasopoulou, Giannakos, & Jaccheri, 2017) where the authors found 3000 scientific papers on the *learning by doing* topic in formal and informal STEM education contexts. It was shown that the largest number of research products on *Making* was aimed to enhance programming skills and computational thinking. Other studies suggested that the current trends of learning through *Making* in art, design, and technology practice can provide fertile ground for developing STEM education. The *Tinkering Movement* emerged in the wider context of the *Making Movement*: despite the common features between them, Tinkering is considered more as a personal disposition towards problem solving, curiosity, scientific investigation, direct experience and experimentation. *Tinkering* can be defined as «a branch of making that emphasizes creative, improvisational problem solving. It centres on the open-ended design and construction of objects or installations, generally using both high- and low-tech tools. At the heart of tinkering is the generative process of developing a personally meaningful idea, becoming stuck in some aspects of physically realizing the idea, persisting through the process, and experiencing breakthroughs as one finds solutions to problems» (Bevan *et al.*, 2015, p. 99).

Tinkering was adopted by science educators not only in formal learning contexts such as schools and universities, but also in scientific centres. Indeed, since 2008 the *Exploratorium* in San Francisco has been developing, testing and refining *tinkering* activities for museum visitors, opening a dedicated *Tinkering* space (The *Tinkering Studio*) that is described as «part exhibition space, part science laboratory and part atelier» (Petrich & Wilkinson, 2013).

The *Tinkering* method is rooted in theoretical frameworks that emphasize scientific inquiry through direct experience, sensor-motorial, and playful practices (Dewey, 1938; Montessori & Holmes, 1912). In addition, *Tinkering* stimulates forms of social and collaborative learning (Vygotsky, 1980; Wenger, 2010) in which participants create and negotiate meaningful goals with their communities using different kinds of mediation tools.

In a recent review (Vossoughi & Bevan, 2014), the authors underlined that *Tinkering* can be effective when inquiry-based learning is combined with aesthetic and creative components; in this way, it is possible to promote participation and inclusion of all the students involved in the *Tinkering* activities. This is an important innovation for STEM education, that has been traditionally based only on written texts (Windschitl, Thompson, & Braaten, 2008). *Tinkering* often incorporate different kinds of "languages", from painting to coding.

From our perspective, *Tinkering* could be a meaningful method not only to develop scientific knowledge, but also to promote 21^{st} century skills. Sheridan and colleagues (2014) reported that after *Tinkering* activities students changed their disposition towards scientific discoveries trying to solve problems with methods never thought before. According to other authors (Vanderslice, 2008), combining *Tinkering* with writing activities could support the process of individual empowerment. The Institute of Museum and Library Services (2009) explained that *Tinkering* makes people more flexible, resilient and creative and helps them to develop critical thinking, problem solving and entrepreneurship skills, that are often defined as the 21st Century skills (see the table 1). In addition, the above-mentioned dispositions of the *Tinkerer* seem to partially overlap with *Critical Thinkers* dispositions (Facione, 1990), such as open-mindedness, scepticism, and truth-seeking. In addition, all the *Tinkering* practises can be defined as "creative problem solving" because they cross the boundaries among science, engineer and art (Vossoughi & Bevan, 2014).

Although many authors reported that Tinkering could support the development of the 21st Century Skills (Kafai & Peppler, 2010; Harris *et al.*, 2017), there are a few empirical studies that verify such a hypothesis (see Husin *et al.*, 2016). Kafai and Peppler asserted that tinkering methodologies could improve both: 1. critical thinking through observing and deconstructing media, evaluating and reflecting, and referencing, reworking and remixing and 2. creative thinking by making artistic choices and connecting multimodal sign systems. Anyway, the authors do not present any evidence which could prove the above statements. The present paper is, instead, aimed to test empirically the above-mentioned theoretical statements in a 'pre and post-test' design research experience (Marsden, & Torgerson, 2012). In particular, the research group investigated the impact of a two-day *Tinkering* workshop on museum operators and STEM teachers' level of Critical and Creativity thinking skills.

Table 1
OPPORTUNITIES THAT TINKERING EXPERIENCES PROVIDE FOR DEVELOPING THE 21ST CENTURY SKILLS. ADAPTED FROM HARRIS ET AL., 2017

21ST CENTURY SKILLS	OPPORTUNITIES THAT TINKERING EXPERIENCES PROVIDE FOR DEVELOPING SUCH SKILLS
Creativity and divergent thinking	Using a wide range of idea creation techniques e.g. planning, sketching, brainstorming; developing unique strategies, tools, objects or outcomes; creating new ways to use materials or tools; setting personal long and short-term goals and planning ways to achieve these.
Communication and collaboration	Incorporating input and feedback from other people (e.g. peers or a facilitator) into their work; developing, implementing and communicating new ideas to others effectively; being open and responsive to new and diverse ideas
Problem solving, Critical Thinking and Strategic Thinking	Posing problems to solve Identifying emerging problems Coming up with solutions or methods to try to find solutions Elaborating, refining, analysing, testing and evaluating ideas Planning steps for future action

Critical and creative thinking skills are not only crucial for people who participate in Tinkering activities, but also, and especially, for designers of *Tinkering* activities. Indeed, museum educators and teachers interested in adopting a *Tinkering* approach need to have a good level of creativity and critical thinking skills to generate, analyse and evaluate the ideas according to the learning objectives (*Tinkering: Contemporary Education for Innovators of Tomorrow*, 2014). In the present study the research group investigates if *Tinkering* could be used with museum educators and STEM teachers to develop some soft skills. In the following paragraphs the results of the experience are described and discussed.

2 Hypotheses and research issues

The efficiency of the training course was assessed in a pilot study with 30 participants (M= 11; F= 19). The group was composed of teachers and museum operators involved in STEM education and invited to take part at the activity developed at "Città della Scienza" Science centre.

Our first assumption is that *Tinkering* is an approach that requires participants to have good creativity levels, since they, starting from everyday materials such as caps, bottles and light bulbs, have to design activities that stimulate learners to reflect about scientific concepts (physics, mathematics etc.). So, the *first hypothesis* is that participants, involved in a co-design activity of *tinkering*, could improve their creativity levels.

Previous studies have also observed a relation between Creativity and Critical thinking (Chan, 2013), and they confirmed that to be good critical thinkers some specific domain knowledge is needed, as in the case of STEM teaching and learning. The *second hypothesis* investigated is that improving teaching methods (through face to face teaching) and creativity skills in the participants, also their critical thinking might increase.

3 Methodology

A professional who wants to adopt a *Tinkering* approach in school and museum contexts needs not only to know the main principles of the approach, but also to have a good level of creativity, in order to design the education activities starting from the available materials and to develop critical thinking skills in participants, allowing them to generate, analyse and self-assess their own ideas according to the teaching objectives.

The Centre for Museum Studies - University of Roma Tre designed a two-day *Tinkering* workshop aimed to fulfil the training needs of museum educators and teachers working within STEM education. These subjects require not only knowledge about scientific contents but also about the teaching and learning approaches to be used in museum and classroom contexts. The workshop was carried out at “Città della Scienza” Science Centre in Naples in February 2019. The objectives of the training activity were the following:

1. to design *Tinkering* learning activities aimed at promoting 21st Century skills;
2. to develop participants’ Creativity skills;
3. to develop participants’ Critical thinking skills.

The workshop was characterized by face-to-face classes and co-design activities in small groups. On the first day, participants were required to take two kinds of pre-test (that will be described in detail in the next paragraph).

After the pre-tests, the *Tinkering* methodology theoretical principals were illustrated to the museum operators and STEM teacher participating in the workshop. Afterwards, the 30 participants were divided into 4 groups, of about 7-8 members each. Each group carried out one of the four proposed activities (see the table 2). About 4-5 people (per group) were involved in realising the objects related to the activity proposed, whereas the other members of the group played the role of observers and/or facilitators. The observers had an observation grid to fill in and used as the starting point for the debriefing subsequent activity. One hour was devoted to work and observation and 30 minutes to reflection.

Table 2
THE TINKERING ACTIVITIES PROPOSED IN THE WORKSHOP

Activity name	Target	Necessary Materials	Possible topics for reflection (non-exhaustive)
Rainbow	Primary School	Basins of different sizes, mirrors, water, cardboard, scissors and markers	Light, Refraction, Reflection.
Card light	Secondary school of first / second level	Led lights, cardboard, markers and coloured pencils, clips, insulating copper adhesive tape, small power generator, battery connector	Electricity, circuits, electro-magnetism
Drawing engine	econdary school of first / second level	Cardboard, markers, coloured pencils, clips, insulating copper adhesive tape, magnetic motor, battery connector	Electricity, circuits, electro-magnetism.
Tracks for acrobatic marbles	For all ages, suitable for museums, large groups	Pvc pipes, balls of various shapes and sizes, cardboard, rolls of kitchen papers	Cinematics, different types of motion (rectilinear, uniform, acceleration) friction and gravity.

On the first day, the workshop ended with a dynamic activity, the “Drawings of light”, where all the participants were able to paint using lights in a dark room. The goal of this activity was to explore the properties of light by combining the artistic and aesthetic attitude of the participants.

On the second day, participants were required to plan their own *Tinkering* activity. They were asked to split themselves into groups based on 4 different targets of interest. 1. Primary school, 2. Middle school 3. Secondary school 4. Science centre Users.

Participants were able to use the same materials made available during the first day in order to design new activities and tools. They were provided with templates to guide the further *Tinkering* activity. Participants were also invited to move freely in the room and exchange materials.

During the afternoon session, they took the post-test and presented the project realised by each group in a plenary session.

4 Data collection and analysis

To test our hypotheses, the data were collected in two different moments, at the beginning and at the end of the training session. Assessment sessions were administered through pre and post-tests. Each time, participants had to take two different tests, one aimed at identifying Creativity and the other Critical Thinking levels. The first kind of test we used was the Alternate Uses (AU) task (Guilford *et al.*, 1978). The AU task is used to assess a specific form of creativity named "divergent thinking". In this task, the participant is required to indicate how many different ways a particular object can be used: for example, a shoe can be used to walk with or it can be used, in a creative way, as a drum. During the present research activity, participants were given 4 different sheets of paper: on the first sheet, they should indicate a code number, which was used to compare the results between the pre-test and the post-test. In the second, third and fourth sheets, on the top left one word was printed (e.g. "key", "pencil" or "boot" - all the words used were taken from handbook provided). Participants had one minute to write on the paper all the possible uses of each word given on each single sheet. When the minute expires, an alarm went on telling them to stop writing. They had a thirty-second break between one word and another. Three main indicators were computed from the AU task: *Ideational Fluency*, *Ideational flexibility* and *Elaboration*. The *Ideational Fluency* score was defined as the number of different uses given by the participant for the three items. On the basis of all the uses identified by the participants, 24 independent categories were defined across all the items. These included broad categories of usage such as ''as a weapon'' or ''to make a dress.'' The *Ideational flexibility* score was defined as the number of different categories identified by the participant across all three words presented. Hence, in order to calculate the flexibility score, all responses of a given item were divided into different independent categories. For example, using an item both as a musical instrument and as a weapon was considered as two independent categories; while using it as a drum and as a trumpet was regarded as the same category. The *Elaboration* score was defined as the average number of words used to describe a specific use. This test was administered at the beginning and at the end of the activity to verify the first hypothesis.

The second kind of test used to assess Critical Thinking skills was a short essay. More specifically, participants had to write a short essay (Poce, Corcione & Iovine, 2012; Poce, 2015) on a passage from *Discours de La Méthode Pour Bien Conduire Sa Raison et Chercher la Vérité Dans les Sciences* (1637) by René Descartes. In order to assess Critical Thinking skills, participants' written productions were evaluated using a Short Essay Assessment Grid, adapted from the Newman, Webb and Cochrane (1997) model (Poce, 2017). The main categories of the analysis include *Communication skills*, *Argumentation*, *Relevance*, *Importance*, *Critical evaluation* and *Novelty*. Three independent evaluators scored the test independently and then the average score was calculated.

This test was administered at the beginning and at the end of the activity to verify the second hypothesis.

5 Results and findings

Results obtained after the *Tinkering* Workshop show improved *Divergent Thinking* levels in the post-test compared to the pre-test (Figure 2). More specifically, Fluency and Flexibility obtained higher average scores.

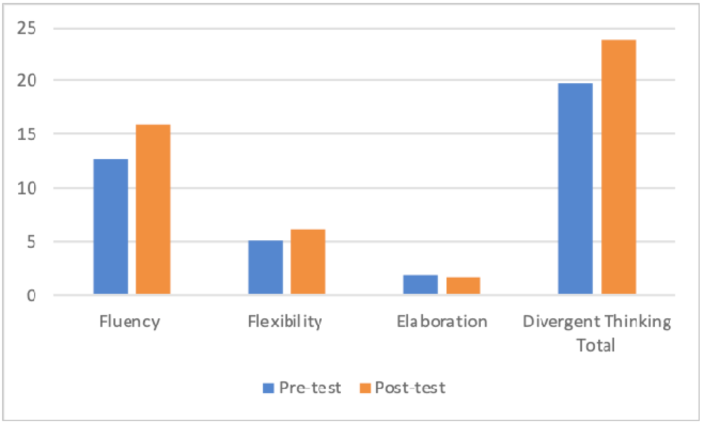

Fig. 1 - Comparison of the scores obtained (Fluency, Flexibility, Elaboration and Divergent Thinking) pre-test and post-test

The non-parametric test of Wilcoxon was conducted in order to know whether the differences were significant or not. The difference for the Fluency and Divergent Thinking Total was significant for sign. < 0,001 whilst for the Flexibility sign. < 0,05. The differences on Elaboration were not significant.

Table 3

COMPARISON PRE-POST TEST ON DIVERGENT THINKING. * Significance is lower than 0,05, ** significance is lower than 0,001

	Fluency	Flexibility	Elaboration	Divergent Thinking total
Z	-3,685	-2,102	-,387	-3,815
Sign. asint. (two tales)	,000**	,036*	,699	,000**

Regarding Critical Thinking scores, any significant difference between the pre and the post-test was found, in general terms. However, it is possible to see a slight improvement on Relevance, Importance, Argumentation, Critical evaluation and Novelty indicators (Figure 2).

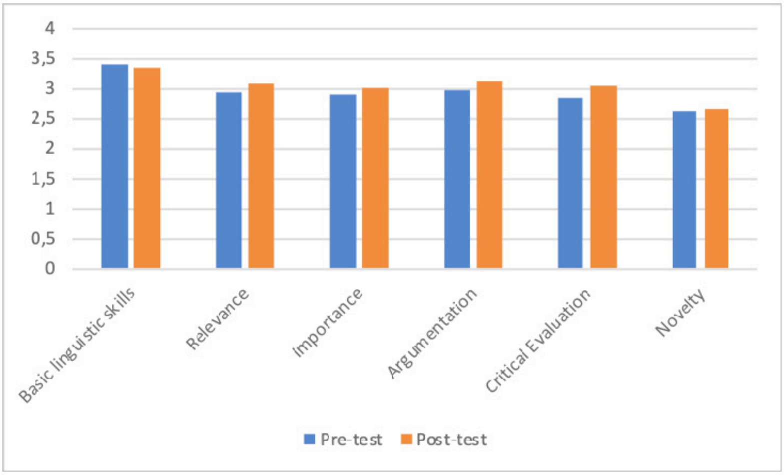

Fig. 2 - Comparison of the scores obtained in Basic linguistic skills, Relevance, Importance, argumentation, Critical evaluation and Novelty between the pre-test and the post-test

Discussion and conclusive remarks

The interest about *Tinkering* as a learning method to engage students with STEM subjects has been growing and growing among educators and scholars. Recent research supports the hypothesis that *Tinkering* could be adopted not only to develop students' scientific knowledge but also to support thinking processes, enhancing Critical Thinking skills and dispositions and Creative problem solving, in an inclusive and cooperative learning environment. Despite these assumptions, there is still limited empirical research evidence concerning the impact and evaluation of *Tinkering* on the development of the 21st Century skills.

This study has tried to start fill this gap in the literature by investigating, in a pilot study, how *Tinkering* could influence Creative and Critical Thinking levels of a group of museum educators and teachers involved in STEM education, who took part in the workshop considered.

Though no generalisation is possible, due to the small group of analysis available and the short time of intervention (just one pilot over a two-day workshop), the first hypothesis described above seems to be confirmed: in the post-test, participants showed significant higher Creative Thinking levels. On the other hand, there were no statistical differences concerning Critical Thinking development and this could be explained with the choice of the assessment tool. The feedback received from participants on the Critical Thinking essay, on the passage from "*Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences"* (1637) by René Descartes, proved to be too much engaging and demanding, especially if performed over two days in a row. This could be one of the reasons why the test did not catch any difference between the pre and post-test.

Data collected showed some limitations of the study carried out but at the same time support follow up activities. Firstly, the pre and post-test design used may be subject to a number of confounding variables, such as history, maturation, test effects and the regression to the mean effect (Marsden & Torgerson, 2012). For this reason, the experimentation is going to be repeated in other settings with larger groups and with a control group. In addition, different assessment procedures to identify Critical Thinking levels would be adopted in order to keep acceptable and stable affective validity levels during performance activities. Correlation tests will be then carried out on the values obtained.

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ENGAGING PARENTS INVOLVEMENT IN K – 12 ONLINE LEARNING SETTINGS: ARE WE MEETING THE NEEDS OF UNDERSERVED STUDENTS?

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Despite historical failure trends and mixed results on the effectiveness of online learning for all students, schools are witnessing the continual emergence of electronic instructional mediums. Research shows that

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students from educationally underserved homes experience less parent involvement (Hill & Tyson, 2009; Smith, 2006), and less academic gains than students from higher social economic families (Smith, *op.cit.*). With the rapid infusion of online learning in traditional learning environments, some may perceive less need for parental guidance and intervention, however research shows that online learning may actually require parents to shoulder an increasing instructional role in their child's learning (Borup, Graham, Davies, 2013; Liu *et al.*, 2010). This quantitative study examines the relationships between online learning, socioeconomic status, and parental understanding and involvement in a diverse k – 12 districts. Findings show that relationships exist between these variables, calling into question the development, implementation and evaluation of such instruction for populations already at risk.

1 Introduction

Parent embroilment in a child's initial education is consistently perceived to be emphatically associated with a child's academic achievement (Hara & Burke, 1998; Hill & Craft, 2003; Marcon, 1999; Stevenson & Baker, 1987; Heymsfield, 2018). According to the National Center for Education Statistics, an 11-year trend shows that low income students, most notably African Americans, consistently score below every other student sub-group surveyed on standardized assessments (NCES 2013) with an average mean difference of 26 points. Often noted are variables related to socio-economic status such as living in impoverished neighborhoods with impoverished schools, being taught by less qualified teachers, using inadequate teaching materials and substandard infrastructure, excessively high turnover of school leaders, and a lack of parental involvement (Howard & Reynolds, 2008). Impacting variables that significantly correlate to student achievement have been the source of substantial study for decades (Coleman, 1966; Tyak, 1974; Wiggin, 2007).

Despite historical failure trends for those most vulnerable and in light of the mixed results on the effectiveness of technology in the classroom for all students (Judge, 2005), Greer, Rowland, and Smith (2014) reported on the swiftly growing adoption of fully online and/or blended learning in the United States. K - 12 online learning, for the purposes of this study, is defined as the use of a computer or other electronic devices to deliver some or all student learning, including course content, course material, and course assessments (Welsh *et al.*, 2003). Many K - 12 online learning tools embody an instructional process where students are more responsible for their learning (Johnson & Galy, 2013) predicated on a students' ability to work independently as a self-directed learner (Manochehi & Sharif, 2010) assuming the need for less parental guidance and intervention. However, research shows online teaching tools may actually require parents to shoulder an increased instructional role in their child's learning (Borup, Graham, Davies, 2013; Liu *et al.*, 2010). Greer, Rowland, and Smith (2014) suggested that the "online product" can become the "primary teacher" and that online lessons dictate increasing parental participation especially in facilitation of "lesson completion" (p. 81). Additionally, misinterpretation of the purpose of the learning tool may lead to teacher expectations that parents make instructional decisions in lesson modifications. Despite the increased need for parental involvement, Borup, Graham, and Davies (2013) offered a research analysis reflecting that parents not only do not comprehend the gravity of their role in K - 12 online learning environments, but even those who may be aware, need on-going training, assistance, and resources.

Research continues to show a significant gap in access to computer use and Internet capabilities between African American and white households. A 2013 report by the US Department of Commerce (as cited in Jaggers, 2014) found that 55% of African American and 58% rural households had Internet access at home, as compared to 74% of white and 81% of Asian American homes. Jaggers also found that students with less academic preparation, particularly African American males, had far more difficulty with online than in face-to face learning. If the ability to access and make effective use of technology is dependent, in part, on a student's socioeconomic status (Sun & Metros, 2011; Stanton-Salazar, 1997), then it would seem that the onset of the digital transformation may deepen the existing inequities.

Parental involvement in the education process continues to be a significant component in student success and studies point to a positive relationship between parent involvement academic achievement (Arnold, Zeljo, Ortiz, 2008; Barnard, 2004; Marcon, 1999) regardless of race or socio-economic status (McCarron & Inkelas, 2006; Barnhard, 2004). Lopez cited Hill and Tyson (2009) define parent involvement as interactions with the schools and children to encourage academic progress and offer support with school activities (2011, ¶4). Research also shows that students from low-income, educationally underserved homes experience less parent involvement (Hill & Tyson, 2009; Smith, 2006) and as a result net less academic gains than students from higher social economic families (Smith, *op. cit.*).

The role of parent involvement in the academic achievement of students has not only influenced the work of researchers, it has also affected the work of policy makers who have attempted to create policies promoting increased involvement (Topor *et al.*, 2010). This study asserts that a significant void exists between theory and praxis of K – 12 online learning environments, further widening the achievement gap between the low socio-economic students and their more affluent peers.

2 Methods

This inquiry focused on relationships between the variables of parental involvement, use of k – 12 online learning, and academic achievement. Of the 9 schools in the sample district, there are 6 elementary schools, one middle school, one high school, and two academies. Eighty-one percent of the students in the district surveyed were considered economically disadvantaged with 57% of the student population considered non-white. The district has ambitiously embarked on a transformation plan to improve student success. Parental participation and effective use of innovative teaching and learning strategies are key components of the plan.

The study sample included 212 parents who participated in an anonymous 32 item self-administered 6-point Likert-type survey including demographic. Three elementary schools were categorized as "lower SES" and two of the elementary schools were categorized as "higher SES." The respondent demographics included 34% African American, 49% white, 24% male, 74% female,

The survey included clusters of reverse coded survey questions to gauge parent perceptions of their technology use, school climate, school participation, and teacher interactions and communication. Data analysis utilized a Pearson chi-square test for independence to ascertain if significant relationships existed between variables. Where chi-square was deemed to be invalid because of low sample size in any square, the Fishers exact two-tailed test was utilized at the.01 and.05 significance level. Some data were considered and included here at a 93% confidence level.

3 Findings and Discussion

As with many studies, the inquiry answered some questions and created more. This, as the first of 3 parent studies to be conducted, assisted in creating more targeted areas inquiries for the second data collection in early 2016. Selected results are presented showing several areas of significance with recommendations for further study. Finding show that significant group differences do exist between school level (elementary vs. secondary), Socioeconomic status (by school area), and by race.

While secondary parents were significantly more likely to agree that their children use a computer to complete their homework at home ($p < 0.008$ $X^2 (1)=6.9319$), elementary parents were significantly more likely than secondary parents to communicate more often with the classroom teacher on their children's work, whether face-to-face or written, relative to both on line and other assignments ($p = 0.0375$). Elementary parents were significantly more likely than secondary parents to agree that their culture and values were respected at school, but African-American parents as a group were significantly more likely to disagree that their culture and values were respected at school *($p < 0.05$ X^2 (2) =5.9793), (p=0.0415)*. And while not statistically significant, white parents were more likely to agree that their children would be comfortable talking to someone at school if they had a problem ($p = 0.0693$). Elementary school parents were significantly more likely than secondary parents to assign their school a grade of "A," whereas secondary parents were more likely to assign their school a "B." White parents were significantly more likely to agree to checking school e-mail at least two times per week *($p <0.0001$ X^2 (1) =25.35)*. African American parents were significantly more likely than white parents to agree that their child would be the first generation to attend college *($p < 0.01$ X^2 (2) =9.9169)*.

Stewart (2007) referenced a myriad of research showing that students make higher academic gains when parents are actively involved in their child's schooling. Citing the research of Ma, Stewart (*Ibidem*) notes that "**students' sense of belonging influences academic achievement.**" (p. 184). Building a positive school climate is a critical component in creating a sense of belonging and Cohen, McCabe, Michelli, and Pickeral site an increasing body of literature indicating a positive school climate is "**associated with and predictive of academic achievement**" (as cited in May & Sanders, 2013, p. 45). School environments where parents who do not feel culturally valued may lack the climate characteristics that support building necessary relationships. If parents are expected to shoulder increased responsibility in their child's online learning (Borup, Graham, Davies, 2013), then a lack of connection between parents/ home and school may exacerbate an already fractured, but essential interaction. Marcario (2012) reported that experts believe the first line of defense for parent help is seeking assistance from the teacher. Is a parent who feels valued more likely to seek assistance? Is a positive climate -parent – teacher relationship a prerequisite for parents to seek assistance? Are there other means by which parents may gain additional help? These key questions relate to how the lines of communication are affected when parents feel their culture may not be respected or valued. Finally Jaggers (2014) cited that a growing body of literature reflects that educators "**caring, connection, encouragement, and guidance are critical…..to support student success**" (on p. ¶13.)

Socioeconomic status and race continue to be a significant variable in educational achievement and studies have shown that "***performance is strongly associated with the socioeconomic status of the child and district***" (May, 2006, p. 43). A myriad of characteristics is attributable to low socioeconomic status, one of which is parental educational attainment. The Department of Education (2011) reported whites are 33% more likely to have a college degree than African Americans. The U.S. Department of Education also reported a relationship between maternal educational attainment and academic achievement citing a positive connection between student literacy and mothers who were educated (2009). While the results of this study did not explain why white respondents were more likely to check their child's school e-mail, but one could posit that more educated parents may be more aware of the need to check school websites. Another assertion reflects that whites are more likely to possess home technology, with white households being 25% more likely to have Internet than African American homes (Jaggers, 2014).

The first-time college graduate dynamic is complex. Fifty percent of the college population is comprised of first-generation attendees, of which 45% are African American and 49% are Hispanic, while only 28% of whites report parents who did not receive education beyond a high school diploma (US Department of Education, 2010). Assumptions can be drawn relative to parents lacking exposure to opportunities to gain the knowledge to support their children's on-line learning environment. Given current research, we may surmise that students in non-college graduate families may already suffer many existing roadblocks such as their initial preparation and readiness for schooling.

Conclusion and remarks

In sum, if academic achievement is the barometer for success, the educational experience in the United States continues to be one of inequity. This opportunity to learn gap reflects a historical and persistent trend of students in the American system of public education who are "academically at risk and cannot complete on a level playing ground" (May, 2006, p. 39). Underserved populations, most notably African Americans and Hispanics, are more likely to be born in economically depressed and disadvantaged environments to young parents, enter school less prepared than their white peers, lack exposure to educational experiences, suffer from homelessness, neglect, and high mobility rates, (as cited in May, *op. cit.*). As we seek avenues to increase the opportunities for underserved students to achieve, such as online learning, we must provide solid and valid evidence that our strategies meet the needs of the students most vulnerable. The research that is presented, before a series, is related to the attitude of the parents towards the school and their willingness to cooperate. After this stage, providing an answer to the question is benefitable for further studying.

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DESIGNING AN EFFECTIVE DIGITAL LEARNING ENVIRONMENT FOR TEACHING ENGLISH THROUGH LITERATURE: THE LEARNING EXPERIENCE OF BULGARIAN STUDENTS

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Keywords: motivation, foreign language learning, digital learning environment, English through literature.

The present article will focus on motivation in foreign language learning, digital technologies and creating an effective digital learning environment for supporting the process of learning and reaching desired outcomes. Besides that the author will make an attempt to summarize personal experience of integrating digital tools and resources in teaching English as a foreign language through English through Literature Approach. A detailed description of the strategies for instruction and the learning modalities used in the 21st century classroom with 11th grade students from Bulgaria is presented.

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1 Introduction

During the last few decades, technology has had a profound impact on every walk of life. Processes like globalization, digitalization, etc. have brought to issuing new educational policies for enhancing literacy, as well as implementing new approaches in education.

What teaching and learning strategies will assist a given student population in the 21st century to develop further competences and acquire new ones, including new language skills? Taking into consideration the Digital Agenda for Europe (2014), which is one of the seven flagship initiatives of the European Commission for sustainable growth, this can be achieved by using the full potential of ICT. On the other hand, according to the National Strategy for effective implementation of ICT in Education and Science (2014 – 2020), the goals can be accomplished through fostering foreign language learning, team work, creating and sharing good pedagogical practices with ICT tools.

Motivation is of paramount importance for achieving positive results and success in learning, especially in difficult subject areas like languages. This is one of the most complex tasks foreign language teachers nowadays face in order to reach the goals set in curriculum. In the Bulgarian context, motivating students to read extensively literary texts written a couple of centuries ago for native speakers is doomed to failure. On one hand, demotivation results from language difficulties, despite the fact that most students have self-assessed themselves as independent users, i.e. B2 or B2+ under the CEFR - levels considered a starting point for using Language through Literature Approach. On the other hand, a boring plot or topics irrelevant to the life of 21st century teenagers, lead to unwillingness or flat refusal to read at all. The article offers possible teaching strategies to integrate digital tools and resources with the aim to raise students' motivation to participate in class and develop basic skills for interpreting literary texts.

2 Motivation

2.1 What is motivation?

The two words often used to define 'motivation' in dictionaries, and closest to our understanding of the term, are enthusiasm or willingness to perform tasks. The problem of motivating students is not a recent one – towards the end of the 20th and the beginning of the 21st century, scholars became interested in students' motives for losing interest in studying in general. 'Motivation may be construed as a state of cognitive and emotional arousal, which leads to a conscious decision to act, and which gives rise to a period of sustained intellectual and/or physical effort in order to attain a previously set goal or goals' (Williams & Burden, 1997, p.120).

Psychologists investigated the connection between motivation and foreign language learning (Gardner *et al.*, 1997). They tried to explain the processes that motivate language learners (Silver & Bufanio, 1996); they suggested techniques (Burden, 1995) or designed models for motivation in foreign languages. For example, in the model offered by Dörnyei (1994), the components are presented on the Language Level, the Learner Level, and the Learning Situation Level. The last one is comprised of motivational components specific for the course, the teacher and the group of learners. Another model in L2 is that of Williams and Burden (1997) who give a detailed list of motivational components: intrinsic factor (perceived value of activity, sense of agency, mastery, etc.) and extrinsic factor (nature of interaction, learning environment, etc.). Dornye (1996) shortlisted ten strategies, known as the Ten Commandments for Motivating Language Learners: setting a personal example with your own behaviour, creating a pleasant atmosphere in the classroom, presenting the tasks properly, developing a good relationship with the learners, increasing the learner's linguistic self-confidence, making the language classes interesting, promoting learner autonomy, personalising the learning process, increasing the learners' goal-orientedness, familiarise learners with the target language culture.

To expect a positive shift in reading habits and the ability to interpret literary texts, it is important to encourage reading. This can be done in a couple of steps. Experts suggest that the initial motivation, i.e. the stage preceding reading itself, consists of: first, discussing the need to read authentic texts in L2; second, giving the students the opportunity to choose the source, because this makes them more independent and responsible personalities (Dörnye, 2001). Since the Bulgarian syllabus is designed around representatives of various literary trends in British and American literature, it is not possible to follow the second step. Thus, motivating students to read becomes a real challenge for the teachers who are obliged to develop students' language skills by using a variety of literary texts (fiction, poetry, drama) and English through Literature Approach. The latter is not only used for supplementing the subject matter – it is an instrument for engaging student's attention and improving their skills in a better learning environment, i.e there's an element of entertainment, essential for arousing their interest and motivation.

3 Digital technologies

Since the early 2010s, new technologies have been called 'digital - a term used to describe the possibility to 'transmit signals faster and more accurately than analog signals' (Kaplan-Leiserson, 2006). Nowadays it has become a buzz word not only for manufacturers of various electronic devices and IT specialists, but for policy makers, researchers and educators. It's not surprising that many specialists have tried to define digital technologies. From the number of definitions two have actually caught our attention because of the long list of devices enumerated and the functions they can play in education. The former refers to a definition given by TESOL, i.e " the use of systems that rely on computer chips, digital applications, and networks in all of their forms" (TESOL 2008, p.3) and whose functions are to store and process data: for example, electronic tools (computers and laptops), electronic devices (DVD players, interactive whiteboards), mobile devices (cell phones, iPhones, tablets), social media, multimedia, applications, cloud computing. The later comes from Education Brief 5, in which digital processing systems "encourage active learning, knowledge construction, inquiry, and exploration on the part of the learners, and which allow for remote communication as well as data sharing to take place between teachers and/or learners in different physical classroom locations" (Cambridge Education Brief 5, 2015).

3.1 What is digital learning?

A number of terms have been coined to define learning with new technologies. The most commonly used ones during the first decade of the new millennium are e-learning, computer-assisted leaning, Web-based-learning, virtual learning. In an e-learning environment the bulk of the content is delivered via Internet, satellite broadcast, audio-video tape, interactive TV and CD-ROM (Kaplan-Leierson, 2006). With the appearance of digital technologies, the term that has become popular is digital leaning. Digital leaning environments are comprised of sets of technology-based methods which can be implemented for supporting the learning processes and instruction (Wheeler, 2012). No matter what term is used to describe the integration of technologies, it is a totally new environment where both teachers and students use them to interact with each other; the former use ICT to support instruction and enhance learning, while the latter use electronic applications and digital devices to learn, collaborate and create.

3.2 Digital technologies in the 21st century classroom

The primary goal of introducing new technologies on the market was to facilitate business in general. However, both, educational policy makers in OECD, UNESCO, European Commission, etc. and educators have quickly recognized the potential of digital technologies for 'education, for promoting research and implementing effective teaching practices (*EU Digital Agenda 2020)* and begun to invest in infrastructure and training. At conferences and formal meetings, experts from various institutes, centres or private organizations have started drafting programmes or making recommendations how to integrate digital technologies in education. To acknowledge the important role of digital technologies, as well as their effectiveness in teaching and learning, other experts have tried to rethink some of the concepts and approaches in pedagogy (Scardamalia & Bereiter, 2008).

It's not possible to enumerate all the attempts to share personal experience with digital tools and resources. However, we can illustrate the enormous importance of digitalization in education with a few examples of useful models. To help language teachers, learners and educators to use technologies in various teaching and learning settings (face to face, online or a mixture of the two) the National Educational Technology Standards (NETS) and TESOL have designed Technology Standards. Next come three extremely popular models in recent years - the Substitution, Augmentation, Modification and Redefinition (SAMR), the Replacement, Amplification and Transformation (RAT) and Substitution Technological Pedagogical Content Knowledge (TPACK) models designed to assisst teachers in integrating and assessing the use of digital technologies. Another model worth mentioning is that of Gaffney who has attempted to summarise the benefits and drawbacks of digital technologies. Out of the eight principles of the author, the following ones are related to the present article: relevance of the digital curriculum resources, appropriateness of the technological tools to deliver them, capability of teachers to use them, motivation and interest of students to learn with them. (2010, p.1 and p.21).

4 Teaching English through literature in Bulgarian context

Teaching a language through Literature is one of the many approaches used nowadays in foreign languages. The author will not discuss its advantages since that is irrelevant to the article. It is the approach around which the Bulgarian curricula for XI and XII grades of schools with intensive classes in English are built; students are acquainted with prominent representatives of British and American literature (Shakespeare, Byron, Coleridge, J. Austen, Dickens, O. Wilde, W. Irving, Hawthorne, M. Twain, Fitzgerald, D. Mitchell, R. Barnes, T. Morison) and their most popular works. Using language as a source of information about the target culture, the curriculum aims at developing students' reading, critical thinking and productive skills (speaking and writing) on a higher level so that students become fluent users of English. This is not an easy task not only for students but also for teachers. To reach the desired outcomes, teachers must come to grips with the understanding that they should alter the learning process and their methods of instruction. They can support learning by using strategies to increase students' engagement. In practice that can be done by making use of innovative technological tools and resources and involving students in tasks which require other than language skills.

Which factors will lead to enhancing students' motivation to read and interpret authentic literary texts? According to the results from an end-of-year questionnaire about appropriate teaching and learning strategies and student motivation, completed by a group of 33 students, integrating new technologies and creative tasks can have a positive effect on student performance in class. Considering these, as well as the syllabus and its goals, the level of language fluency of the students and the concept of the 21st century classroom, on one hand, and Dörnye's and Williams-Burden's frameworks, on the other, the author decided to balance between an ordinary face-to-face modality and a flipped classroom, designing tasks towards accomplishing the final goal through specific strategies of instruction – using digital tools/resources and students' digital competences.

5 Practical suggestions for effective digital learning environment

There are no strict directions how to implement new technologies in the classroom on institutional level (Ministry of Education or Regional Inspectorate), nor are there guidebooks to follow. Bulgarian teachers have the absolute freedom to decide alone whether to use or not technology, what digital tools and resources to use, how and where to integrate them.

The continuous updating of the latest technologies and digital educational tools poses a serious challenge to teachers: they can't play the role of digital immigrants any more; they should be prepared to work in an absolutely new environment where digital technologies are not a necessity but a reality; they need to possess a number of digital competences. To meet the requirements of the new Z or Alpha generations, teachers should be able to use the same digital tools. The list is enormous and it is impossible to include every single tool for the mere reason that they become outdated quickly. The digital tools and resources described in this article comprise only a small part of the existing ones.

From the hundreds of digital tools on the *Directory of Learning & Performance Tools,* published on the official pages of the Centre for Learning & Performance Technologies, the author has used: digital devices (PC, IWB, Tablet, iPhone, Android phones), emails, Google apps (Google Disc, Google Forms, etc.), blog (Seesaw), video channels (Vimeo,YouTube), platforms (My Mixes, Storybird), flipped classroom. The list of digital resources consists of presentations, tutorials and short instructional videos, animation, trailers, digital media.

5.1 Why digital media

The main digital tool in my classroom is digital media with free access to different online resources, which actually turns them into Open Educational Resources. Since the syllabus is structured around selected classical works from the British and American literary canon, the choice of digital resources is defined by two factors: first, each literary work is used for the creation of a script, which consequently is filmed or animated, i.e is meant for a specific audience in terms of age; second, each literary work has had a couple of film adaptations, i.e the plot has been interpreted according to the scriptwriter's and director's understandings.

The potential of digital media, the power of film as a 'visual story', the availability of a few film adaptations of the literary work on the syllabus are a prerequisite for a more effective work with authentic texts. This is not a simple compare-contrast technique of two channels of information (an authentic literary piece on paper and a film based on it), rather interpretation of some basic techniques in cinematography for conveying meaning through images and sound, for arousing emotional or psychological reactions in the audience such as camera distances (long shot, medium, close-up, etc.), camera angles and movements, mise en scene (lighting, colour, facial expressions, body language, costume), sound and music. Although film directors and producers shoot a scene with the intention to show the action, capture mood and build atmosphere, the visual story in every film adaptation is different: the events are shown in a distinctive way, the accentuation is different and their effect on the viewers is entirely different too.

Being acquainted with the basic instruments of film analysis, students are able to interpret the director's view – why he used a specific technique, what effect he wanted a scene to have on the audience. The short extracts from the film adaptations that the author used have the following advantages from a technical point of view: free access on You Tube Channel; easy integration in the curriculum; possibility to be watched again at any time, from anywhere; their length is defined by the teacher. From a pedagogical point of view the extracts are an ideal instrument in the classroom because the combination of picture, sound and tasks related to the text give each student opportunity to participate in activities directed to comparative analysis (comparing and contrasting plot, setting, characters, shots, angles, mise en scene,dialogue, etc.)

Despite these cons of using digital media, the lack of Internet connection or the poor quality of the older film adaptations can disrupt work.

6 The learning experience of Bulgarian students

6.1 Strategies and stages

All the activities and strategies for foreign language instruction through English through Literature Approach are in conformity with those described in academic literature. The activities are student-centred and the teacher is in the role of an assistant and moderator. New strategies are used during the different stages of the learning process. For example, instead of the traditional face-to-face modality in the form of a lecture and complex metalanguage for literary analysis (Collie & Slater, 1987), the author uses short video tutorials in a flipped classroom, discussions on presentations given by the teacher/ the students or on digital video related to a literary work. All kinds of questions are asked and discussed – questions referring to facts, opinions, criticism (Sage, 1987), because the main goal is fostering communicative skills in the target language.

The work usually falls into three stages: pre-reading, interactive activities with text and round-up activities. What is meant here by text is not only extracts from works of literature, but digital video, animation, trailers, interview, musical pieces, etc., i.e. items which provide information related to a given writer and his work. The three stages comprise a cycle usually spread over six to eight classes depending on the syllabus and the number of digital tools/ resources used. Each cycle starts with a video tutorial presented by the teacher, and continues with integrating digital resources (film adaptations, animation, etc.) and ends with a creative task. In other words, during the three stages the students go from low order to high order thinking skills, i.e. go from remembering, understanding and applying through analyzing and evaluating to reach the highest level of creating (Digital taxonomy of Churches, 2008).

To achieve the best results and highest efficiency, experts advise to plan carefully the first stage and use the maximum number of activities: to introduce the topic and new vocabulary; to put questions related to the author, the period; make assumptions of the plot, setting, characters, themes, etc., all of which provoke students' curiosity and motivate creative writing. The aim is to prepare students for the next stage – interactive work with the text (Pulverness, 2003).

6.2 Pre-reading stage

During this first stage the author uses the 'flipped classroom', a type of blending learning, during which the learners watch a short video tutorial asynchronously either at home or another place different from school. They use any electronic device (computer, laptop, tablet, IPhone, Smartphone, etc,) or application. The instructional video can be accessed on a video channel or via links posted on the students blog. The asynchronous method of instruction allows students to watch the tutorial more than ones depending on their needs.

The tutorial presents a given literary period, the historical background, literary trends, outstanding representatives, etc. in a succinct way (5 - 10 minutes), summarizing the most important information on a specific topics accompanied by a set of questions for discussion in class.

Alternative pair or small group activities accessible via email or link on the class blog are: a. step-by-step tasks linked to the writer, main themes, etc. shared on Adobe Spark Page accompanied with a set of questions for discussion in class; b. Project Work on making an interactive presentation of a particular author/literary work on the syllabus - students are given guidelines (time, number of slides, etc.), criteria for assessment, plus instructions how to organize their presentation.

6.3 While-reading stage

The second stage is related to specific tasks to develop students' speaking skills, especially discussions, debating,.

Film adaptations: film adaptations, animation, trailers, etc. digital resources can be accessed freely on YouTube. They are meant to be watched in class; the length of the video extracts depends on the excerpts of literary works included in the course book, as well as the duration of the class.

The tasks are structured around extracts from the film adaptations and fall under the compare-contrast type of analysis. After watching the extract and taking notes, the students participate in a discussion and share personal opinion. Eventually, they read the extract in the course book and look for similarities and differences with the extracts watched.

Building vocabulary activities: the tasks are aimed at enriching students' vocabulary on topics from the literary works on the syllabus.

6.4 Post-reading stage

The students practice the language by being involved in activities to develop productive skills, namely writing skills; they are placed in the writer's shoes and modify, expand or add more to the text; students create interactive presentation, a clip or a short video. The final stage is usually in the form of homework assignment – individual, pair work or small group. Depending on the topics discussed, students are assigned different creative tasks aiming at:

- developing writing skills: rewriting the story from another perspective, switching between genres, for example, keeping a diary, writing letters, poems, short one-act plays.
- interpreting part of the literary work by means of a short video clip or

interactive presentation; the students are given a frame to follow (topic, length, setting, characters). However, they have the freedom to show their imagination by using personal experience and knowledge about the world.

- getting acquainted with peer work and giving peer formative assessment of the final product; students are obliged to publish their assignment on the blog, and then comment on and assess what has already been published.

After sharing the assignments on the students' blog (*Seesaw*) or *Storybird* platform, all students receive feedback from the teacher or classmates; each student is obliged to comment on their classmates' work and assess it informally.

Conclusion

The above described strategies in the foreign language classroom come from personal experience with 33 seventeen/eighteen-year-old Bulgarian students of English who were demotivated to learn in the traditional way. Completing a couple of cycles, most participants provided a positive feedback on the used teaching strategies. Over 75 % of them were fully engaged in various creative tasks with new technologies, which is an indirect indicator of the effectiveness of the suggested practices. The first trial of the listed strategies wasn't accompanied with any tools for measuring their impact on the students. However, the author is in the process of implementing the same set of strategies on a larger group of students for a longer period of time, as well as attempting to collect data from that experiment through qualitative and quantitative evaluation tools.

By suggesting that rationale, the author has made an attempt to engage the students in enjoyable activities in a much friendlier digital learning environment. Apart from that, various digital tools and resources have been integrated with the aim to support learning and foster fluency in the target language. What really matters is not so much the strategies used themselves, as the idea that these strategies lead to meeting specific goals. 'Technologies should not be considered as a way to change the medium of instruction in the classroom; rather, it is the teachers who should know how to use technologies innovatively' (Caron, 2008, p. 287)

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