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Arts and crafts robots or LEGO® MINDSTORMS robots? A comparative study in educational robotics

Leopoldina Fortunati, Anna Maria Manganelli, Giovanni FerriN

Abstract
With the development of educational robotics, teachers of secondary and high school frequently request clear indications on which type of robot is most effective for strengthening students' mental schemes on the robot. This paper investigates whether using crafts and recycled materials or structured materials to build robots is more effective in terms of pupils' cognition in educational robotics. Some scholarship argues that using crafts and recycled materials to build a robot from scratch is more effective than using structured materials. The design of the educational research applied here, and in which we tested this hypothesis, included two different robotics activities, carried out in Italy with two classes of secondary school. In the first, we asked the students to build a robot from scratch using crafts and recycled materials, while in the other we asked the students to build a robot from structured materials. These two activities were preceded and followed by the completion, by students, of the same questionnaire about knowledge of mechanics, manual skills, conceptualization of robots, and beliefs about the robotization of everyday life machines, which were the learning outcomes identified in this study according to the concept of constructive alignment and outcome-based education. Results show that building a robot from scratch increases pupils' knowledge and manual skills, while building a robot with structured materials increases their awareness of the robotization of machines. Thus, current scholarship's approach is only partially confirmed. To conclude, although pupils' appreciation involves equally both these robotics activities, each of these outlines a specific educational outcome.

Keywords Robot · Educational robotics · Structured material · Art · Craft · Robotization

Introduction

An important dilemma of educational robotics is whether it is better on the cognitive level to use in the classroom an already made commercial robot or to build a robot with the students. Behind this question, there are two different theoretical approaches: the first is connected to the increasing power at the social level of the DIY (Do It Yourself) (Gauntlett 2011; Ratto and Boler 2014) and Makers movements (Anderson 2014; Hatch 2013; Kwon and Lee 2017) that pushes towards the appropriation by people of the skills and competences necessary to make things directly, in first person, and that see universities and schools as places that should be able to produce the technologies they need to use. The second springs from a less radical vision that sees universities and schools as institutions that simply buy the technology available on the market if it is suitable for their scientific needs. Many educational programs in robotics use robots which can be classified (Catlin et al. 2019), according to their characteristics, into classes and subclasses, such as mBot, Bee-Bot (*Use Bot—Turtles*), Nao (*Use Bot—Humanoid*), Joy Robot (*Build Bot—Maker Bot*), Boebot (*Build Bot—Robot Kit*); LEGO® MINDSTORMS (*Build Bot with Component Parts*) (e.g. Mubin et al. 2013; Chioccariello et al. 2004).

This paper lies in the second horn of the dilemma: the choice to build a robot with students. The second horn of the dilemma has, however, in turn another sub-dilemma: to build a robot from scratch and with poor and recycled materials or to build a robot with structured materials such as LEGO® MINDSTORMS? On this issue, there are several experiences and a relevant literature, which comes from robotists and designers (see, for example, Gopsill 2018; Ribeiro and Paiva 2017; Suguitan and Hofman 2019).

The present study is carried out by a group of social scientists with two classes of pupils and investigates which one of the robotic activities—building a robot from scratch and with poor and recycled materials and building a robot with structured materials such as LEGO® MINDSTORMS—is more effective for a better understanding by pupils of what a robot is. Furthermore, it is situated in the field of research, which aims to collect data outside a laboratory, in the real-world, and to observe, interact and understand people while they are in a natural environment, where there is no tampering of variables and the environment is not doctored. With this approach, the possibility of control of all the extraneous variables on the part of researchers is structurally limited, but in return, researchers may gain a deep understanding into the research subjects due to the proximity to them (Bourdieu 1979).

In 2014, we carried out a first study in which we asked pupils to build a robot from scratch and with poor and recycled materials (Fortunati et al. 2014). This study aimed to verify whether the conceptualization of the robot by the pupils changed after the research. The results showed that pupils' conceptualization of the robot changed less than expected.

After a while, we carried out a second study in another school designed with the same cognitive purpose. But this time we asked pupils to build a robot with structured materials such as LEGO® MINDSTORMS. In the present article, our aim is to compare these studies, which were carried out in two secondary schools (Valussi and Lozer) in the northeast of Italy with the purpose of investigating which kind of robot is better to construct in order to improve pupil's mental schemes and their social awareness of robots: arts and crafts robots or robots built from structured materials? With this purpose in mind, we explored not only the conceptualizations of the robot but also more generally the perceptions of the robotization of smart devices and of the machines more familiar to these two groups of pre-teens. Educational robotics is particularly important and debated in Italy because here in the last 10 years schools have promoted many initiatives and curricula on teaching programming and educational robotics. This innovative approach has been encouraged and supported by a specific law called the "Good School" law (Law 13 July 2015).

The need for producing such a comparison was suggested to us by the fact that an analysis of the literature on educational robotics in schools (Caci et al. 2014; Datteri et al. 2013) showed that the cognitive effects and educational value of such activities remain unclear. This result has reinforced what Malec argued in 2001, that is, that there was the need to better understand and measure the real advantages that the courses on educational robotics bring in a curriculum. If the cognitive effects of acquiring programming skills are evident (Ferrari 2016), even if not devoid of problems regarding a gendered, inclusive teaching and learning (Turkle and Papert 1992), that is not the case for the cognitive effects related to educational robotics (Mubin et al. 2013; Benitti

2012; Caci et al. 2004; Catlin and Blamires 2010; Karim et al. 2015; Kennedy et al. 2015; Khanlari 2013; Moricca 2016). The lack of clarity concerning the impact of educational robotics is probably due to the fact that educational robotics is difficult to implement in a secondary school (Fortunati et al. 2020). First, robotics includes an information technology side, and therefore programming. Second, it requires knowledge relating to the STEM (science, technology, engineering, mathematics) disciplines and is therefore highly interdisciplinary. Third, it also requires a knowledge of the physical world, since it is immersed in reality. Fourth, it involves the ability to interact with the physical world by means of traditional engineering tools. Fifth, it requires the development of specific manual skills, such as the ability, for example, to make mechanical couplings and electrical and electronic connections. Robotics needs all of the above in order to build and operate an autonomous machine, from the simplest to the most complex. Furthermore, educational robotics includes several things: using robots for strengthening the learning of specific matters, such as foreign languages, computer science, robotics, technology, and artificial intelligence (Mubin et al. 2013; Malec 2001; Rus 2006).

In addition to this complexity, or perhaps because of it, in Italy, as in other countries, it has become evident that there is a problem of cultural mediation between two very different kinds of people: those involved in robotics, who do not deal with teaching, and vice versa, those involved in teaching, who do not deal with robotics. Consequently, experimentation in most cases lacks a proper design that integrates both an engineering and a social approach, making people with different competence cooperating together for increasing effectiveness (de Vries 2003). Whereby, the design of educational robotics initiatives usually does not include elements necessary for understanding the very broad process of robotization that is currently affecting the entire society. As robotics moves into the sphere of social reproduction (homes, social and health systems, education, entertainment, public administration, and so on) (Fortunati 2017), this appears even more problematic.

One reason for the difficulties of present-day educational robotics is that those who push the STEM disciplines do so by thinking above all of the "technical training" of pupils, with a view to a labor market that will become increasingly 4.0, in which the worker of the future will have to co-operate with a robot (cobot) or be treated like one. It is not surprising that schools wind up being unable to provide students with the critical tools needed to correctly understand the reality in which they live.

Building simple robots requires a complex process of familiarization with the objects' substantial structure, involving specific work tools, the improvement of manual skills, the management of collaborative work practices, the development of several learning processes, and the improvement of pupils' socialization processes (Fortunati et al. 2014). More broadly, this kind of activity, especially when performed by high school students, allows them to develop a more sophisticated conceptualization of the robot (Fortunati et al. 2018). The "learning by doing" approach in educational robotics is quite effective in strengthening pupils' mechanical knowledge and manual skills, also because children positively welcome robots in the educational setting and seem quite entertained by such technologies (Sugiyama and Vincent 2013). The probable reason for children's appreciation of educational robotic activities is that their imagination has been fed by robot movies and cartoon characters (Fortunati et al. 2015), and in their infancy they

have become familiar with toy robots in the form of dolls (Vincent 2013), which represent a form of proto-robot, as well as robot transformers, Tamagotchi. Furby, Lego Boost and so on (Mascheroni and Holloway 2019).

We are convinced that it is crucial to offer children the opportunity of working with artifacts in order to understand their properties, acquire manual skills, and critically understand the meaning and scope of important trends such as the robotization of society. Given that the current education process tends to dematerialize the products of its activities (most of the work of students today remains invisible, in the form of files), combining practice with theory and the analog with the digital is a good premise to enrich the old knowledge-building practices and bring back visible forms to the learning process (Druin and Hendler 2000).

Educational robotics is part of a large trend in educational studies that aims to pursue knowing-how (Ryle 1983) and to create a critical awareness of technology on the part of youth. As a field of study, educational robotics stems from a long path of previous experiences, carried out at first with media and then with the new media. Reconstructing this path will enable us to understand why educational robotics developed and what are its main assets.

This paper is organized as follows: in the next section we will reconstruct the rise of media education, followed by the new media education and then educational robotics. In the third section we will analyze the current challenges of social robotics and describe the conceptual framework for our analysis. In the subsequent section, we will present the methods applied in this study. Then we will set out our key findings and finally conclude with a brief discussion and some concluding remarks.

From media education to the new media education and to educational robotics

According to the New London Group (2000, p. 9), also reported in Jenkins et al. (2009, p.7), the fundamental purpose of education "is to ensure that all students benefit from learning in ways that allow them to participate fully in public, community, [creative] and economic life." In the last decades, for this purpose, a series of strands belonging to various disciplines have converged to a large field of debate and research. First of all, humanities and media scholars began to pose the problem, especially at the educational level, of how to develop literacy paths related to the various media to fulfill the same purposes as those traditionally prepared for the medium of print (Drotner and Erstad 2014). In the 1970s, a series of 'television literacy' curricula were introduced in the United States (Anderson 1980) and in the late 1980s in the UK media education was progressively introduced within the teaching of English (Bazalgette 1988). Educators at the beginning focused on television and cinema (Buckingham 2003), but then also on radio and the press, frequently employing semiotic models or principles to analyze these media.

Attention was placed on the social meaning and implications of the media and on giving the students the knowledge, skills and competencies that are required for interpreting and using media as well as the critical tools of analysis capable of producing an understanding of the production and consumption of the media in society (Silverstone 1999). In other words, thanks to the contribution of sociologists and psychologists, the

field of media education does not imply only a functional theory but also a social theory of literacies that aims to analyze the social, economic and institutional dimensions of communication and how these affect people's attitudes, experiences, behavior, and practice (Luke 2000). In this framework, another objective was gradually posed, especially by scholars deeply involved in education: to look at these media as tools of learning. In many countries, for example, print newspapers were introduced into classes as an additional tool to be used as a lens of analysis of the present (e.g. Sanderson 1999).

Then, the advent of new media, such as the computer, the Internet, and mobile phones, and their massive diffusion and adoption by children and pre-teens in everyday life, has pushed humanities and media scholars to apply the above mentioned approach also to the study of these new devices. Livingstone, who worked extensively on this topic, defined media literacy as "the ability to access, analyze, evaluate and create messages across a variety of contexts" (Livingstone 2004, 2013), stressing that media literacy is not only a technical concept but also a political one (Livingstone 2004, 2013). In fact, it does not imply only the appropriation of skills and competence by people, but it also regards the notion of their empowerment (Fortunati et al. 2014). Without the technical and critical tools provided by media literacy, the public will enjoy only a minimal part of the possibilities of the new media, or they will be partially or totally excluded by their use.

With the new media, humanities and social scientists were reached by scholars coming from computer science and in general from the STEM disciplines posing other problems and educational concerns and strategies (Turkle and Papert 1992; Papert 1980). These were concerned about the lack of technical and scientific knowledge on the part of youth about these devices, and introduced in this educational debate a series of strategies to fill this gap. In the last 5 years, in the national educational curricula of many European countries (starting from elementary school), changes were introduced to make children and pre-teens understand the complexity of the computer, which they use daily. For this purpose, pupils were taught to assemble and program their own computers.
It is not by chance that the point of departure was the computer: as Rus (2006, p. 15) wrote,

> Most of today's computers have integrated sensors, such as microphones, primitive motion sensors to park the disk drive, light sensors to detect when to automatically illuminate the keyboard or dim the screen, and cameras to collect images from the surrounding environment. Recent advances in the cost, size, performance, and capabilities of actuators shows us that actuation will become native to a computing environment so that today's personal computers (PCs) will become tomorrow personal robots (PRs).

But this debate was extended more recently to the mobile phones: Sugiyama (2013) proposed to see these as quasi-robots, while Vincent (2013) argued that the mobile phone should be considered as a personalized social robot when associated with its user.

In conclusion, the phases of media and new media education and literacy corresponded to the need to raise new generations of citizens capable of mastering and using critically the devices that were already widespread in society (an educational answer to social

needs). The educational environment could count on the fact that students had direct, daily experience of these tools.
The last phase of this historical development, that is, the shift from the new media to educational robotics, concerns an initiative that started at first from the educational environment. The introduction of robots has developed in two directions: robotics for education, in which robots are used as an educational medium, and robotics in education, in which robots are built and used to advance the students' knowledge of what a robot is as well as their overall knowledge of the STEM disciplines and sociocultural perspectives (Lemke 2001). However, the introduction in the school of robotics for educational purposes could not count on the students having the same direct and social experience of these new tools.

Current challenges for educational robotics

The most crucial challenge today for educational robotics is not the outlining of a good theoretical framework (which already exists), but it is the establishment of credible and internationally shared curricula (Johal et al. 2018; Gomoll et al. 2018). The theoretical framework which underpins research on educational robotics is constituted by a number of recognized theories, such as Dewey's (1938) theory of learning by doing, Piaget's (1973) constructivism (manipulating artifacts is the key for children to construct knowledge), Papert's (1980) constructionism (knowledge construction is successful whenever the learner is consciously engaged in constructing a public artifact), and the consequent development of the approach of active learning (Harmin and Toth 2006) and learning by designing (Goldman, Eguchi and Sklar 2004), as well as Vygotsky's theory of social constructivism (1978) which introduced the principle of the scaffolding strategy: breaking up complex tasks into smaller tasks.

However, if we pass from the general theoretical framework to specifics, the particular point of departure, in which the robotic activities we carried out and the subsequent comparison we aim to produce have been rooted, comprises a set of theories that come from the social sciences. Behind the objective of these two robotic activities, which was to determine whether these activities improved pupils' mental schemes for what a robot is, there is the rich literature on cognition we described in a previous article (Fortunati et al. 2014). We mention in the present paragraph not only Dewey's educational theory (1938), which is focused on the principle that a child learns by doing and manipulating objects through meta-cognition and which remains over time an educational bulwark, but also Bartlett's and Neisser's theories on mental schemes (Bartlett 1932; Neisser 1989) that rely on the data one get from experience, the theory of Smith and Semin on socially situated cognition (2004), Gofman's notion of technological frames (1974), which enable people to make sense of a particular technology at the social level and to guide their expectations and interpretations regarding novelties and advances, Orlikowski's and Gash's (1994) concept of technological frames of references (TRF), combining the Gofman-like interactionist approach with the analysis of social structures.

But what is instead completely open is the question of mapping the experiments and robotic activities carried out so far in the educational environment, to measure and evaluate their outcomes, and to compare them in order to reach a consensus on the appropriate tailoring of educational robotics curricula. Our research question, "Is

it better for pupils' mental schemes about robots to build a robot from scratch and with poor and recycled materials or to build a robot with structured materials such as LEGO® MINDSTORMS?" intends to contribute to this issue of mapping and comparing concrete experiences in order to produce knowledge for moving educational robotics curricula to meet appropriately the quality of students' learning needs.

Methods

To investigate which is the more effective educational strategy, building arts and crafts robots or robots from structured materials, we conducted two different activities. Since the setting was natural, no form of randomization was used at the level of selection of participants. The groups investigated were in fact two classes of pupils already formed. The first activity was performed in a class of a secondary school (Valussi) and involved 18 pupils, while the second was carried out in a class of another secondary school (Lozer), with 21 pupils. Thus, the research setting was, for the Valussi the technical room, while for the Lozer the art room.

We recall that our general purpose is to compare two studies for understanding whether using crafts and recycled materials is more effective than using structured materials to build robots in terms of pupils' cognition on robots. But this general purpose was operationalized in a way that, as recommended by Biggs (2003a, b, p. 2), "the teaching methods used and the assessment tasks are aligned to the learning activities assumed in the intended outcomes." We defined a series of objectives/expected outcomes measured on the basis of pupils' self-evaluation and regarding four areas: (1) mechanical knowledge concerning pulley (one of Aristotle's simple machines), gear and connecting rod as well as an example of complex technology like the mobile phone; (2) manual and designing skills regarding different abilities involved in building the machines mentioned above; (3) perception of robot through the differential perception of toys and human beings; (4) perception of robotization processes regarding everyday life machines. All these objectives have been implemented in specific tasks to be performed by pupils on the basis of what they had understood and learned during the training. Although the performance, tasks, tools and required design were different, we decided to keep the same questionnaire in the two schools because the objective areas were the same and thus we could compare these two research studies. Specifically, at the Valussi, the task was to build a cardboard automaton, which included a narrative and a mechanical part. The narrative part consisted in inventing a character and a story connected to this, while the mechanical part consisted in choosing what type of movement (rotatory or linear or a combination of both) to give to the automaton. At the Lozer, where the pupils had been provided with a P-block pre-assembled with motors and wheels, the task consisted in designing and building a robot by integrating the sensors available in the LEGO® Mindstorms EV3 kit and programming it.

In practice, as we mentioned several times, the activities consisted in creating a robot from scratch, with craft and recycled materials in the first school and structural materials such as LEGO® Mindstorms in the second. In both cases pupils were asked to fill in a paper and pencil questionnaire (pre-test) before the activity; the same questionnaire was completed again after the activity (post-test). The activities required 9 h in the first school and 5 h in the second, and the period between the two questionnaire waves was 4 weeks in the former and 2 weeks in the latter.

The questionnaire investigated several socio-demographic variables, such as gender and age, and some background information such as: "Do you know what a robot is?" (answer Y(yes)/N(no)); "Do you know any cartoons or other TV programs or movies with robots?" (Y/N), and "If 'yes,' please list them;" "Do you know of LEGO® bricks or similar bricks?" (Y/N); "Do you often play with LEGO®?" (Y/N); "Do you know of MECCANO? (Y/N); and finally, "What kind of job or profession would you like to do when you grow up?" (open response).

Next, the questionnaire investigated pupils' pre-test knowledge of mechanics. We posed these questions: Do you know what a pulley is used for? Do you know what a gear is used for? Do you know what a connecting rod is used for? Do you know what is inside a mobile phone? and Do you know how to use a mobile phone? In particular, we investigated pupil's knowledge about the functionality of pulley, gear and connecting road, because these are the tools that pupils would have needed to use during the workshop for producing an artistic robot. In both studies pupils had to design and build small robots (from scratch by hand or choosing the proper building blocks) which require mechanical couplings and connections involving the cited parts. During the workshop, we also introduced the use of those words to enhance the correct domain lexicon. Then we investigated pupil's knowledge about how the phone is made inside and we asked the information about if they know how to use it. The question about the mobile phone was not of a strict technical nature (nothing to do to with processor families, semiconductor technologies, block diagrams or operating systems). We specify that at the Valussi school we had asked pupils to bring at school old mobile phones (in addition to other objects) in order to use them for building the robot. But our fundamental intention was to make pupils realize, after the workshop, how a smartphone integrates different sensors and actuators, in a way, is controlled by a CPU and is programmable, once acquired the necessary knowledge. Here too, respondents were asked to answer these questions by assigning a score from 0 (not at all) to 3 (a lot) and to mark their chosen number with a cross.

After these questions we moved on to manual skills, asking the following questions: Can you use scissors? Can you use a utility knife? Can you use glue? Can you use tape? Can you make a cardboard square? Can you build a pulley? Can you build a gear? and Can you build a connecting rod?

We measured their self-evaluation of the manual skills investigated (use of scissors, utility knife, glue and tape) and then the self-evaluation of their ability to make a cardboard square and to build pulley, gear and connecting road, what they would have been required to do during the robotic activity. In respect to the first three items our interest was to understand if the pupils knew these tools and if they knew at what they served, while for the fourth item –the mobile phone- our interest was to understand if they had some ideas about how this device is made up and if they were able to uses it. Respondents were asked to answer these questions by assigning a score from 0 (not at all) to 3 (a lot) and to mark their chosen number with a cross.

Next, we explored their conceptualization of robots by presenting a list of 16 statements about the robot to be judged on a four-point Likert scale (0=not at all, 1=a little, 2=enough and 3=for sure). The items were: "It has a battery;" "It moves;" "It moves

by itself;" "It is intelligent;" "It speaks;" "It looks into my eyes;" "It looks like a human;" "It looks like an animal;" "It has gears, mechanisms;" "It has an engine;" "I can control it;" "It keeps me company;" "I play with it;" "It is like a cartoon/movie character;" "It is good;" and "It eats and sleeps." These items have been chosen with the idea to include characteristics of toys, robots and human beings, in order to see if the pupils were able to distinguish those of robots. Of course, some item, such for example about the battery, can belong both to toys and robots, but it is, however, interesting to observe their choices. These items moreover enucleate fve dimensions: the first concerns what the robot is made of (e.g. having gears, mechanisms, an engine, and a battery), the second, how the robot is (it is intelligent, it is good), the third, what it is able to do (move, move by itself, look into my eyes, speak, eat and sleep), the fourth, what the robot looks like (a cartoon/movie character, an animal, a human) and the fifth, what the pupil can do with the robot (I can control it, It keeps me company, I play with it).

Additionally, we investigated their perceptions of the robotization of smart devices in everyday use by presenting a list of 12 machines that would be very familiar to them: a vending machine, vacuum cleaner, car, computer, cellphone, validation machine used in a bus, food processor (chopper, blender, grinder), oven, PS3/Xbox, airplane, and robotshaped toy. The children were then asked to indicate how much they agreed with the statement "Each of these machines is a robot" by giving a score from 0 (not at all) to 3 (a lot) and marking their chosen number with a cross.

The questions included in the questionnaire have been presented to all the pupils in the same order. These measures were not evaluated because these items have been created expressively for this research and thus they will be analyzed as single item.

Finally, we explored how pupils experienced the two activities and how much they enjoyed them by presenting four items to be evaluated on a four-point Likert scale (0=not at all, 1=a little, 2=enough and 3=for sure). The items were: "I really enjoyed this activity;" "I had fun;" "I would like to do this activity again;" and "This activity was useful."

The number of students involved in these two robotic activities (N=18 and N=21) made impossible to apply more sophisticate, statistical analyses. The two classes did not differ in terms of gender composition, but differed in terms of age. This ranged from 11 to 13 years and the age averages of the two classes were different: M Valussi school=11.83 and M Lozer school=11.19, $t_{37}=3.284$, $p<.003$.

The data was analyzed by means of t tests for independent and paired samples and variance analysis using SPSS version 22.0.

Results

Let us start with some background data. All the pupils in both schools confirmed knowing what a robot was. Furthermore, 77.8% from Valussi and 76.2% from Lozer stated that they knew cartoons or other TV programs with robots in them. Specifically, pupils cited 50 robot characters in total, including 19 different types of robot. Differences between the two schools were not significant.

LEGO® was known by 94.4% of the Valussi pupils and 100% of the Lozer pupils, but only half of them declared that they played with it. This means that for new generations of pre-teens, LEGO® is a toy that has gone out of fashion. As regards MECCANO (the toy with bolts and metal fingers), only 38.9% of the Valussi and 28.6% of the Lozer pupils stated that they played with it, with no significant differences between the two. Asked about what kind of job they envisaged for themselves in the future, the pupils indicated wanting to be a doctor in fve cases and a veterinarian in two, while a further five each said professional sportsperson, artist (singer, actress, musician, pianist), and engineer (including one robot engineer) (Figs. 1, 2, 3, 4).

Before performing the robotics activities, these two groups knew very little about pulleys and connecting rods, little about gears, and a little more about what is inside a cellphone. More advanced was their knowledge of how to use a cellphone. Regarding their manual skills, all the pupils judged themselves to be very able to use everyday tools such as scissors, a utility knife, glue, and tape, and slightly less able to make a cardboard square. At the same time, they stated that they had very limited or no skills when it came to building more sophisticated tools such as a pulley, gear, or connecting rod.
The Valussi group did not differ substantially from the Lozer group with respect to pretest knowledge of mechanics and manual skills. The only significant differences concerned

Fig.1 Valussi school pupils at work

Fig.2 Valussi school pupils at work

pre-test knowledge of gears ($t_{37}=-2.603$, $p<.05$) and connecting rods ($t_{36}=-2.833$, $p<.01$), with the Lozer group declaring more knowledge than the Valussi group. So, what efect did each robotics activity have on the mechanics knowledge and manual skills of the pupils? The data collected before and after execution of the tasks was subjected to a series of variance analyses with a between factor (the two robot activities) and a within factor (pre-test/post-test).

Fig.3 Lozer school pupils at work

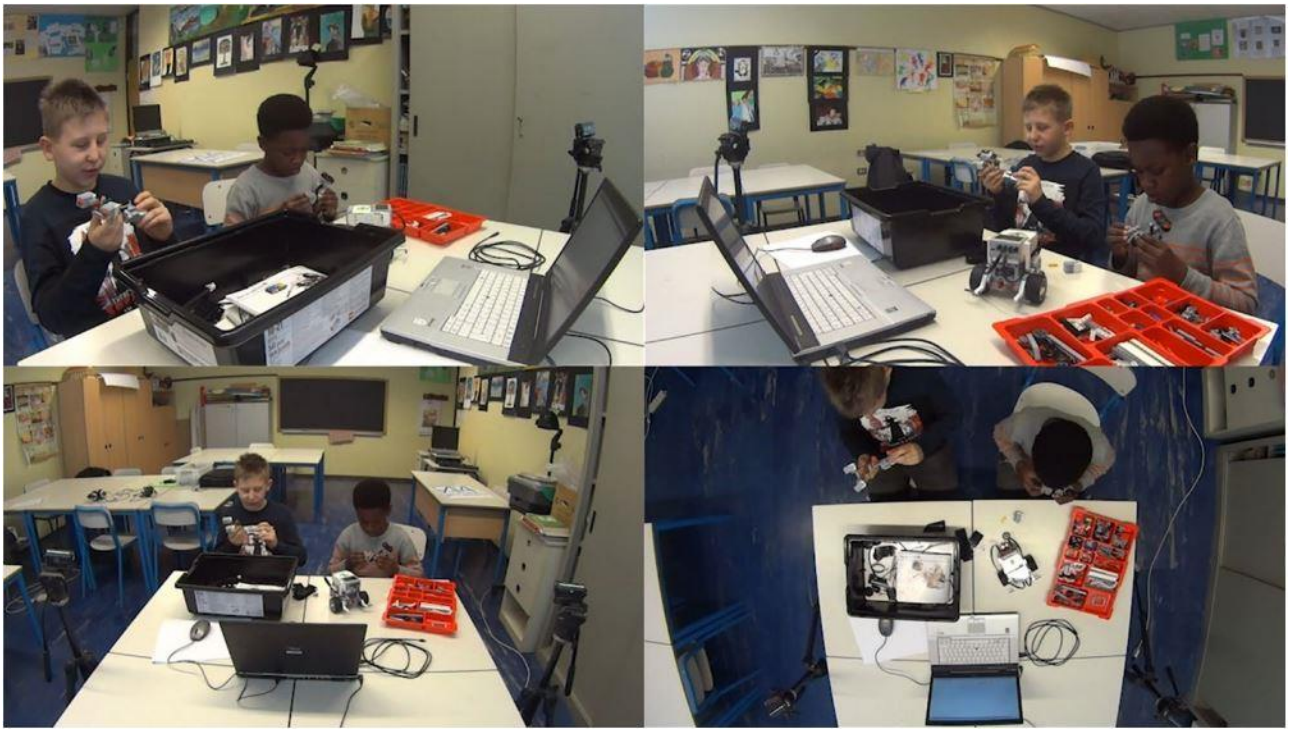

Fig.4 Lozer school pupils at work

As regards knowledge of pulleys and the inside of a cellphone, the main effect of the within factor emerged (respectively $F_{1,35}$=38.445, p<.0001, $\eta^2_{partial}$=.523 and $F_{1,33}$=4.714, p<.05, $\eta^2_{partial}$=.125), with a pre-test average score of .16 (SD=.501) for the pulley and 1.89 (SD =.900) for the cellphone, and a post-test average score of 1.32 (SD =1.082) and 2.29 (SD =1.750) respectively. Thus, both the robot activities had the effect of increasing knowledge of these two tools regardless of the type of activity.

Regarding the gear, in addition to the main effect of the within factor ($F_{1,35}$=20.067, p<.0001, $\eta^2_{partial}$=.364) which, as before, indicates an increase in knowledge between pre-test (M =1.73, SD 1.045) and post-test (M =2.57, SD .502), the interaction between the two factors of the design of the analysis also turned out to be significant ($F_{1,35}$=4.387, p<.05, $\eta^2_{partial}$=.111) (Fig. 5).

This indicates that the increase in knowledge was greater after building the robot from scratch using recycled materials (Valussi school) than after building it with structured materials (Lozer school) (Table 1).

The same was also true for knowledge of connecting rods, which increased significantly following both activities with M =.22, SD .485 at pre-test and M =1.28, SD .944 at post-test ($F_{1,34}$=45.639, p<.0001, $\eta^2_{partial}$=.573). Here too, type of educational robotics activity also differentially influenced the increase ($F_{1,34}$=4.508, p<.05, $\eta^2_{partial}$=.117), with the Valussi average score showing a greater increase than that of Lozer (Table 1). In effect, the pupils who made an arts and crafts robot increased their knowledge of these tools after the activity more so than did those who built the robot using LEGO® Mindstorms materials.

In relation to abilities, both activities influenced the ability to build a pulley, a gear, and a connecting rod as indicated by the main effects of the within factor ($F_{1,34}$=40.888,

p<.0001, $\eta^2_{partial}$=.546; F1,33=39.933, p<.0001, $\eta^2_{partial}$=.548; $F_{1,34}$ 29.827, p<.0001, $\eta^2_{partial}$=.467), with respective average scores at pre-test for pulley, gear, and connecting rod being M =.11 (SD .398), M =.89 (SD .993), M =.06 (SD .232) and at post-test M =1.00 (SD 1.042), M =1.97 (SD =.985), M =.86 (SD .961). However, here it was not only the educational robotics activity that increased pupils' abilities, but also the type of educational activity ($F_{1,34}$=15.484, p<.0001, $\eta^2_{partial}$=.313; $F_{1,33}$=17.748, p<.0001, $\eta^2_{partial}$=.350; $F_{1,34}$=4.590, p<.05, $\eta^2_{partial}$=.119). In fact, the post hoc t tests for paired samples showed that the difference between pre-test and post-test increased significantly (t_s>−4.294, p_s<.01) for all three tools in Valussi school; in Lozer school it increased

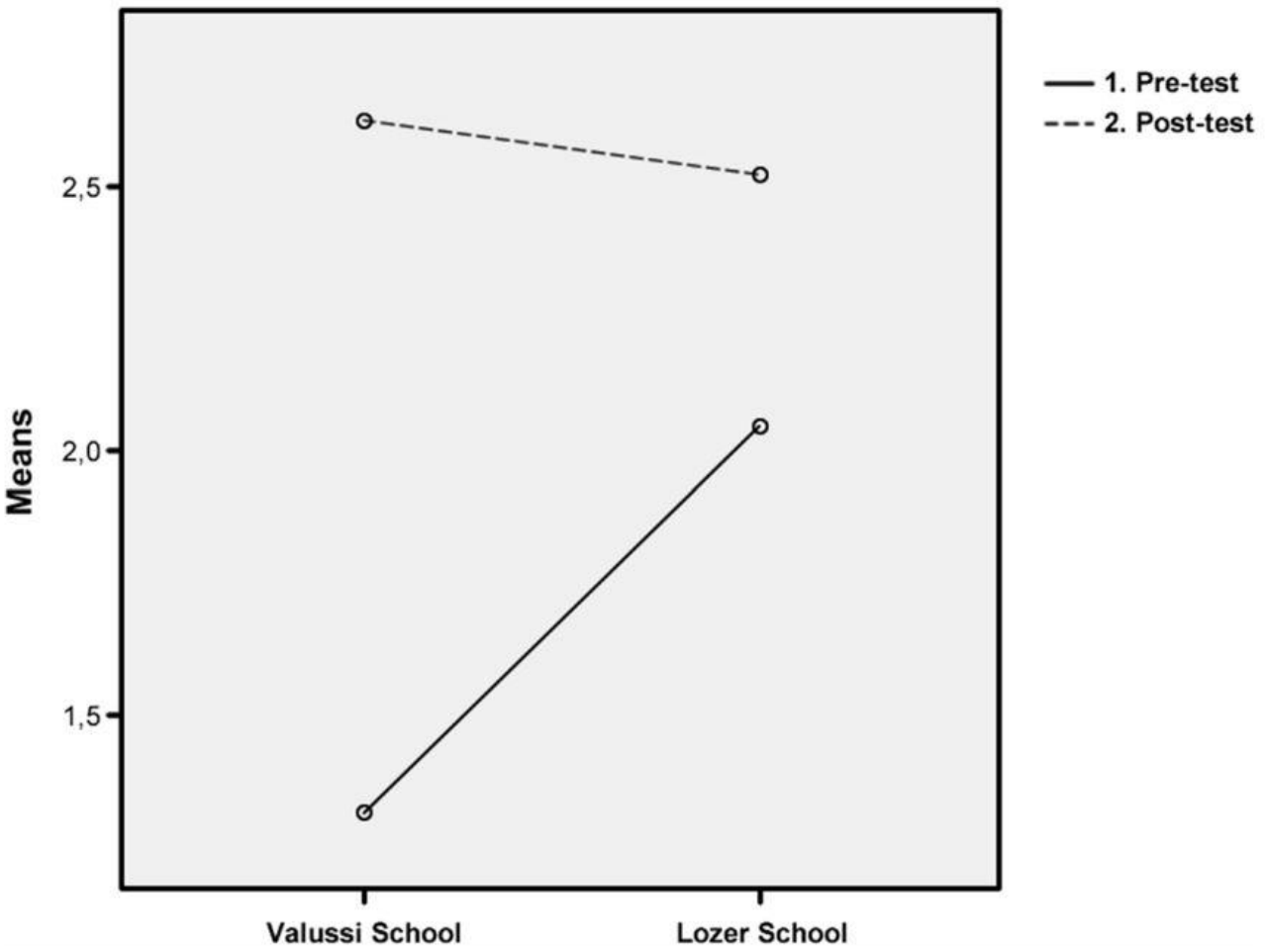

Fig. 5 Interaction between pre-post tests and school. Dependent variable: gear knowledge

Table 1 Knowledge of mechanics and manual skills before and after the activities

	VALUSSI school		LOZER school	
	Before	After	Before	After
Pre-test mechanics knowledge				
Do you know what a pulley is used for?	.13 (SD .500)	1.63 (SD 1.258)	.19 (SD .512)	1.10 (SD .889)
Do you know what a gear is used for?	1.31 (SD 1.138)	2.63 (SD .500)	2.05 (SD .865)	2.52 (SD .512)
Do you know what a connecting rod is used for?	.00 (SD .000)	1.44 (SD 1.094)	.40 (SD .598)	1.15 (SD .813)
Do you know what is inside a cell-phone?	1.67 (SD .900)	2.07 (SD .884)	2.05 (SD .887)	2.45 (SD .605)
Do you know how to use a cellphone?	2.31 (SD 1.014)	2.63 (SD .719)	2.48 (SD .750)	2.57 (SD .598)
Manual skills				
Can you use scissors?	3.00 (SD .000)	2.94 (SD .250)	2.95 (SD .218)	2.95 (SD .218)
Can you use a utility knife?	2.56 (SD .629)	2.75 (SD .577)	2.52 (SD .602)	2.67 (SD .577)
Can you use glue?	3.00 (SD .000)	2.94 (SD .250)	2.95 (SD .224)	3.00 (SD .000)
Can you use tape?	2.88 (SD .500)	3.00 (SD .000)	2.90 (SD .308)	2.90 (SD .308)
Can you make a cardboard square?	2.38 (SD .806)	2.75 (SD .775)	2.33 (SD .856)	2.75 (SD .598)
Can you build a pulley?	.07 (SD .258)	1.67 (SD .976)	.14 (SD .979)	.52 (SD .814)
Can you build a gear?	.67 (SD .979)	2.67 (SD .979)	1.05 (SD .000)	1.45 (SD .488)
Can you build a connecting rod?	.00 (SD .000)	1.20 (SD .000)	.10 (SD .138)	.62 (SD 1.138)

Scale from 0 to 3 (0 = not at all, 1 = a little, 2 = enough, 3 = for sure). Standard deviations are reported in parentheses

significantly only in the case of the connecting rod ($t_{20}=-2.950$, $p<.01$) and even then, less than in Valussi (Table 1).

Thus, the increase in ability to build these tools remained higher for the pupils who built an arts and crafts robot (Valussi school) than for those who built the robot with structured materials. However, we need to read these results in the light also of the different temporal dimensions that the two robotic activities have required. It is true that the time at disposition of both the classes was the same: students in pairs had at their disposal 15 min to create their robot. But, these two activities, being very different, have had a different instructional time: 9 h at the Valussi versus 5 h at the Loze. The time necessary to instruct to operate with non structural material (draw, cut, color, paste and so on) is much longer that that necessary to teach to assemble structural pieces of LEGO. In addition to the difference in the instructional time, it must be considered also another temporal difference: as consequence, the school Valussi, compared with the Lozer school, had twice as much time elapse (4 vs. 2 weeks) between pre- and post-test. The longer instructional time can somehow have advantaged Valussi pupils who had more time to improve their manual skills, but also Lozer pupils had their advantage: the shorter time elapsed between the pre and posttests could have produced a greater continuity of and concentration on the robotics activity.

We move on now to explore whether the cognitive schemas of the robot changed following the two activities and whether the change was different for the pupils who built an arts and crafts robot and those who built a robot from structured materials (Table 2).
Before beginning their activities, both sets of pupils displayed conceptualizations of robots based on the five dimensions we proposed: we mention again that the frst concerns

Table 2 Valussi and Lozer schools: the characteristics of the robot before and after the robotics activity

	Valussi		Lozer	
	Before	After	Before	After
1. It has a battery	1.94 (SD .929)	1.88 (SD 1.204)	1.95 (SD 1.099)	1.75 (SD 1.070)
2. It moves	2.31 (SD .793)	1.88 (SD .914)	2.25 (SD 1.020)	2.40 (SD .681)
3. It moves by itself	2.00 (SD .966)	1.69 (SD .946)	1.95 (SD 1.146)	2.30 (SD .865)
4. It is intelligent	2.07 (SD 1.100)	2.07 (SD .594)	2.14 (SD 1.062)	2.19 (SD .928)
5. It speaks	1.75 (SD 1.065)	1.38 (SD .885)	2.24 (SD .944)	1.76 (SD .889)
6. It looks into my eyes	1.00 (SD .845)	1.80 (SD .941)	1.38 (SD 1.161)	1.57 (SD 1.121)
7. It looks like a human	1.50 (SD 1.160)	1.57 (SD 1158)	1.24 (SD 1.044)	1.43 (SD .926)
8. It looks like an animal	1.00 (SD .707)	1.85 (SD 1.214)	1.00 (SD 1.026)	1.50 (SD .827)
9. It has gears, mechanisms	2.20 (SD 1.014)	2.07 (SD .961)	2.75 (SD .550)	2.65 (SD .489)
10. It has an engine	2.07 (SD .917)	2.03 (SD .870)	2.00 (SD .858)	2.29 (SD .914)
11. I can control it	1.88 (SD 1.310)	1.50 (SD 1.033)	2.05 (SD .973)	1.81 (SD .981)
12. It keeps me company	1.53 (SD .915)	1.47 (SD .990)	1.05 (SD 1.099)	1.20 (SD .696)
13. I play with it	1.71 (SD 1.069)	1.57 (SD .938)	.89 (SD 1.023)	1.22 (SD .808)
14. It is like a cartoon/movie character	1.33 (SD .816)	1.53 (SD .990)	.81 (SD 1.078)	.76 (SD .831)
15. It is good	1.29 (SD 1.139)	2.14 (SD .949)	1.00 (SD 1.124)	.85 (SD 1.040)
16. It eats and sleeps	0.86 (SD .949)	1.50 (SD 1.286)	.48 (SD .680)	1.14 (SD 1.236)

Scale from 0 to 3 (0 = not at all, 1 = a little, 2 = enough and 3 = for sure). Standard deviations are reported in parentheses

what the robot is made of (e.g. having gears, mechanisms, an engine, and a battery,), the second, *how the robot is* (it is intelligent, it is good), the third, *what it is able to do* (move, move by itself, look into my eyes, speak, eat and sleep), the fourth, *what the robot looks like* (a cartoon/movie character, an animal, a human) and the fifth, *what the pupil can do with the robot* (I can control it, It keeps me company, I play with it). At the same time we must recall that these pupils reported to know 19 different robots belonging to the imaginary conveyed mainly by cinema and television, whereby their conceptualization of robots as well as the type of robot that they created within these two robotic activities probably are strongly affected by the visual robot products they had consumed, given their narrow experience of factual robots. But let us examine their answers item by item.

If we consider the pupils of the two classes together, before the robotic activities they were quite convinced that robots have a gears, mechanisms (M=2.51), move (M=2.28), are intelligent (M=2.11), have an engine (M=2.03). That is, the fundamental nucleus of what a robot is clear to the pupils. They were less convinced that robots speak (M=2.03), move by themselves (M=1.97), they can control them (M=1.97), have a battery (M=1.94), look like humans (M=1.34), they play with them (M=1.25), keep them company (M=1.26), look into their eyes (M=1.22). It is worth to notice that, although there is a huge debate inside the robotic field about robots companions, this group of pupils were scarcely convinced that robots can play with them or keep them company. At the same time, they were unsure about their ability to control the robot. Finally, they were even less convinced that robots are good (M=1.12), are like cartoons/movie characters (M=1.03), look like animals (M=1.00), eat and sleep (M=.63). This vision is clearly affected by the cinema and TV stories, what explains why they thought that robots are not necessarily good, because there are a lot of stories on which robots are dangerous or bad.

After the robotic activities, the image of the robot does not become very different. Pupils are quite convinced that robots have a gears, mechanisms (M=2.40), have an engine (M=2.32), move (M=2.17), are intelligent (M=2.14). They were less convinced that robots move by themselves (M=2.03), have a battery (M=1.81), they can control them (M=1.68), look into their eyes (M=1.42), look like animals (M=1.64), speak (M=1.59), look like humans (M=1.49), are good (M=1.38), they play with them (M=1.38). Finally, they are even less convinced that robots keep them company (M=1.31), eat and sleep (M=1.29) and are like cartoons/movie characters (M=1.08).

Let us give a frst, descriptive reading of what happened regarding the five dimensions of robots we investigated with these items after the two robotic activities, although the average scores are not statistically significant in many cases. Beginning with the first dimension that concerns what the robot is made of (e.g. having gears, mechanisms, an engine, and a battery), the direction of scores changes according to the type of activity. At the Valussi school, the creation from scratch of an automaton is an experience that includes very few of these components (for example, the movement to the automaton was impressed not by means of a battery but with a pulley) and this can explain why the scores of these three items decrease, there. At the Lozer school, the creation of a robot with pre-structured materials increases the score regarding the engine, but decreases in respect to both gears and mechanism and battery. This probably happens because, although all these three elements
are included in the LEGO kit, pupils focused their interest on and attributed more importance to the engine. Although most ideas of robots for today and the future are equipped with some kind of battery, these pupils ignored this.

Concerning the second dimension, how the robot is (it is intelligent, it is good), after these robotics activities, pupils maintain and even reinforce (at the Lozer school), the idea that robots are intelligent. More than it depends on the real intelligence of the two built robots, perhaps this belief derives from the awareness that in any case the creation of robots has presupposed the acquisition and exercise of a complex thought. By contrast, they have contrasting reaction towards considering the robot good. Creating the robot from scratch probably makes the pupils feeling the automaton as their creature, thus in principle good, while working with structured materials maybe creates

more psychological distance towards the outcome –the robot- and they are less keen to consider it automatically good.

Passing to the third dimension of robots, what they are able to do (move, move by itself, look into my eyes, speak, eat and sleep), here there is a lot to say. As to the second and third items "It moves" and "It moves by itself", the almost equal score or lower, although not statistically significant, maybe can be explained by the fact that within the creation of the artistic robot at the Valussi the movement had to be imparted manually by pupils (driving a crank handle), and at the Lozer school with the LEGO® Mindstorms the pupils learnt that the robot movement depended on their programming. As to the item "It looks into my eyes", eye-to-eye communication is typical of human behavior and it is no coincidence that research based on brain scanning has shown that the exchange of glances quickly triggers a "social network of the brain" that involves fundamental areas for emotion processing and attention (amygdala and fusiform convolution) (Kajimura and Michio 2016). In principle, the pre-post scores attributed to the robot are low, but it is strange that this score increases after both the robotic activities. A reason for that can maybe be found on the fact that in the Valussi activity the narrativity played a big role in the workshop and thus the robot character invented was simulating to look into the eyes of the observer, while in the Lego macroblock two telecameras are inserted in place of the kind of robot eyes. The effect is that they seem to look into the eyes of those who look at them. In respect to speak, neither the artistic robot or the Mindstorms robot are equipped to talk and then this also can explain the lower score on this concern. Regarding the three items constituting the fourth dimension, what the robot looks like (a cartoon/movie character, an animal, a human), it seems that pupils after the robotic activities have understood more that robots can assume different forms, such as anthropomorphic and zoomorphic. By contrast, the score about robot similarity to cartoon/movie character has increased obviously within the artistic workshop, while has decreased equally obviously with the Lego activity. Finally, as to the three items shaping the fifth dimension, what the pupil can do with the robot (control it, have company and play with it), the scores after the robotic activities indicate a kind of divarication. After the artistic activity pupils are even less convinced that they can control them, play with them and have company from them, while after the Lego activity they strength the idea that they can play with robots and have company from them. However, they weaken the idea that they are able to control them, maybe because they understood also the difficulty connected to the control activity. Passing now at a level that is no longer descriptive but inferential, it results that only two items revealed statistically significant differences between the pupils of the two schools: for the items "I play with it" (t_{36}=2.186, p<.05) and "It sleeps and eats" (t_{36}=2.363, p<.05) the t tests for independent samples indicates that Valussi pupils attributed higher scores than did Lozer pupils (Table 2).

Variance analyses show significant main effects of the within factor for the items "It speaks" (F1,35=5.119, p<.05, $\eta^2_{partial}$=.128), with M=2.03 (SD=1.013) at pre-test and M=1.59 (SD .896) at post-test; "It looks like an animal" ($F_{1,31}$=6.842, p<.05, $\eta^2_{partial}$=.181), with M=1.00 (SD .901) at pre-test and M=1.64 (SD .994) at post-test; and, "It eats and sleeps" ($F_{1,33}$=8.213, p<.01, $\eta^2_{partial}$=.199), with M=.63 (SD .808) at pre-test and M=1.29 (SD 1.250) at post-test. None of the interactions were significant. In other words, after the two activities pupils were less likely to hold with their previous

belief that all robots could speak and more likely to consider them as being similar to living beings (animals or humans).

Here, we go on to the results concerning the children's perceptions of the robotization of various everyday technologies. We asked children to indicate whether they considered each in a series of technologies to be robots. The mean values derived from the scores given to this set of statements before and after the robotics activities can be found in Table 3. It is worth noting that prior to the activities, pupils in both schools generally perceived a low degree of robotization in everyday machines. Those perceived to be the most robotic were the vending machine, vacuum cleaner, computer and validation machine. Furthermore, there was considerable homogeneity in awareness of the robotization of these everyday machines, with the exception of three items. The t test for dependent samples indicated that for the vending machine (t_{37}=2.571, p<.05), vacuum cleaner (t_{37}=2.969 p<.01), and validation machine used in buses (t_{37}=2.684, p<.05) there was a significant difference between the pupils of the two schools. To the first two machines Valussi pupils attributed higher robotization scores than did Lozer pupils, while to the third machine the opposite was true.

Analyses of variance revealed only three significant interactions between the two design factors (pre-test/post-test and type of robotics activity). Specifically, these interactions concerned the vending machine ($F_{1,34}$=8.318, p<.01, $\eta^2_{partial}$=.197), the vacuum cleaner ($F_{1,34}$=6.901, p<.05, $\eta^2_{partial}$=.169), and the validation machine ($F_{1,34}$=6.189, p<.05, $\eta^2_{partial}$=.154). Post-hoc analyses by means of t tests for paired samples showed that evaluations of the robotization of these machines did not differ in Valussi school but were

Table 3 Are they a robot?

Machine	Valussi school		Lozer school	
	Before	After	Before	After
A vending machine is a robot	2.19 (SD .834)	1.63 (SD 1.025)	1.55 (SD .999)	2.40 (SD .681)
A vacuum cleaner is a robot	2.31 (SD .946)	2.00 (SD .730)	1.30 (SD 1.031)	2.30 (SD .923)
A car is a robot	1.69 (SD 1.078)	1.75 (SD .856)	1.50 (SD 1.100)	2.15 (SD 1.089)
A computer is a robot	2.06 (SD .998)	2.13 (SD 1.258)	2.00 (SD 1.155)	2.47 (SD .905)
A mobile phone is a robot	1.73 (SD 1.223)	1.93 (SD 1.100)	1.88 (SD .993)	2.29 (SD .985)
A validation machine in a bus is a robot	2.00 (SD .966)	1.69 (SD .793)	1.15 (SD 1.040)	2.00 (SD .918)
A food processor (chopper, blender, grinder) is a robot	1.69 (SD .793)	2.13 (SD .957)	1.50 (SD 1.051)	1.55 (SD 1.146)
An oven is a robot	1.25 (SD 1.125)	1.44 (SD 1.365)	.85 (SD .875)	1.55 (SD 1.191)
A PS3/Xbox is a robot	1.69 (SD 1.078)	1.94 (SD .998)	1.70 (SD 1.129)	1.80 (SD 1.105)
An airplane is a robot	1.86 (SD .949)	2.07 (SD .829)	1.42 (SD 1.216)	1.42 (SD 1.170)
A robot-shaped toy is a robot	1.75 (SD 1.183)	1.81 (SD 1.109)	1.15 (SD 1.268)	1.05 (SD 1.050)

Scale from 0 to 3 (0=not at all, 1=a little, 2=enough, 3=for sure). Standard deviations are reported in parentheses

significantly different in Lozer school (t_s>2.482, p_s<.05). Moreover, this was not an effect of the robotics activity per se but of the type of activity (Figs. 6, 7, 8).

After building a robot with craft and recycled materials (Valussi school) evaluations of these three technologies as robots remained unchanged, while after building a robot with structured materials (Lozer school) perceptions of their robotization increased.

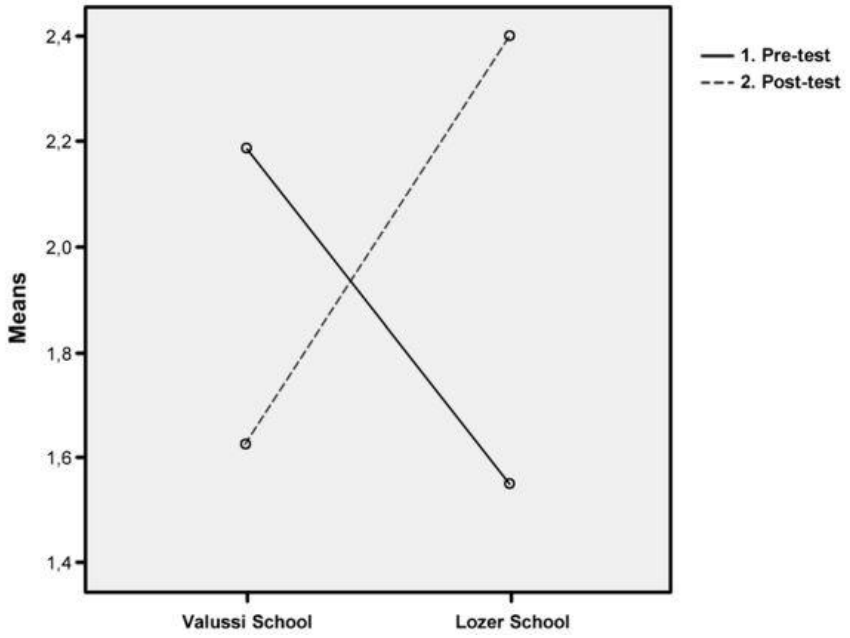

Fig. 6 Interaction between pre-post tests and school. Dependent variable: a vending machine is a robot

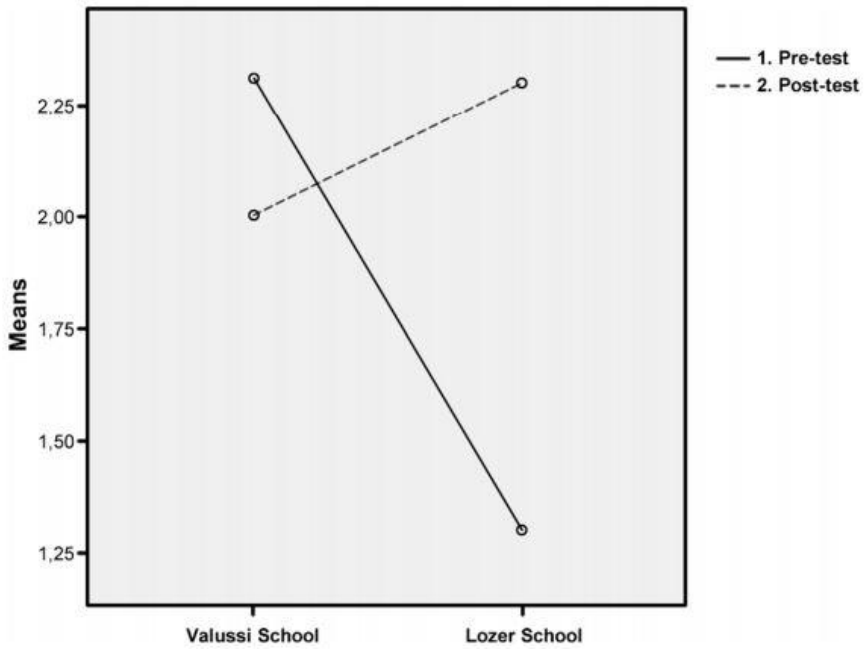

Fig.7 Interaction between pre-post tests and school. Dependent variable: a vacuum cleaner is a robot

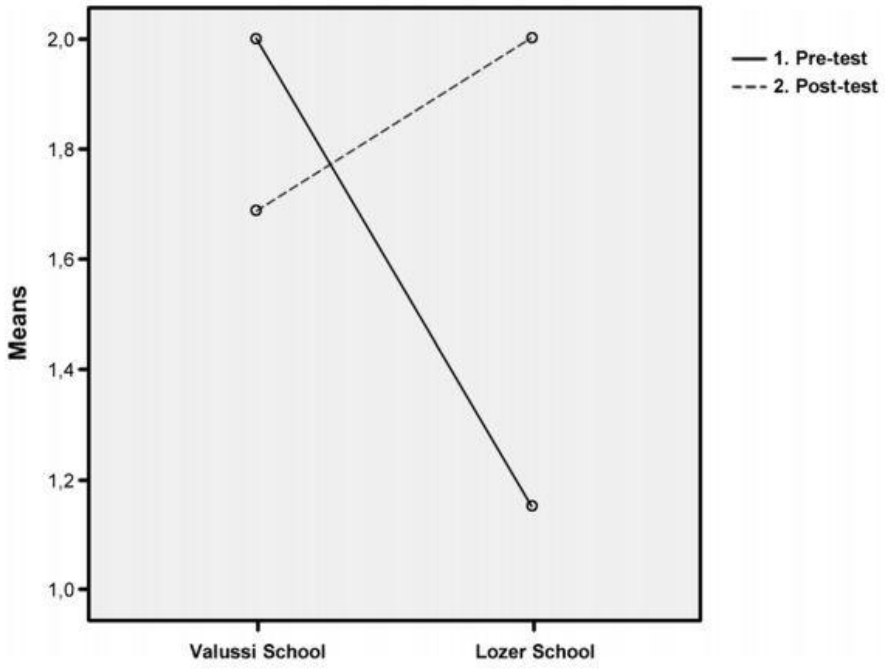

Fig. 8 Interaction between pre-post tests and school. Dependent variable: a validation machine is a robot.

Finally, we asked the pupils to evaluate the educational robotics activities they had performed. It is worth noting that their evaluations were enthusiastic. To the item "I really enjoyed this activity," Valussi pupils attributed an average score of 2.78 (SD .548) and those of Lozer school 2.85 (SD .366); to the item "I had fun," respective scores were 2.94 (SD .236) and 2.70 (SD .470); to the item "I would like to do this activity again," respective scores were 3.00 (SD .000) 2.90 (SD .308); and finally, to the item

"This activity was useful," respective scores were 2.83 (SD .383) and 2.60 (SD .598). The *t* test for independent samples showed that there was no difference between the scores given by the pupils of Valussi, who made an arts and crafts robot, and those given by the pupils of Lozer, who built a robot from structured materials. This implies that pupils have appreciated both the robotics initiatives their school organized, there being no evidence of a preference for an arts and crafts activity over a more structured one.

Discussion

As we anticipated in the introduction, the question of whether building a robot from scratch is preferable to building one from structured materials, or vice versa, is important since many teachers are waiting for an indication from the scientific community as to the best strategy to adopt in educational robotics activities.

From the comparison of these two studies some indications have emerged which, in our view, represent a good, intermediate outcome. In particular, from this study it has emerged that the two robotics activities we proposed to pupils have been cognitively beneficial. This benefit can be measured in terms of an increase in knowledge of the mechanics of less familiar tools (pulley, gear, connecting rod) and of what is inside a cellphone, an improvement in manual skills (especially the ability to build a pulley, gear, and connecting rod), and finally a slight change in conceptualizations of robots in that after these activities pupils' initial belief that all robots speak declined while by contrast their image of a robot as being more similar to living beings (animals or humans) increased.

However, in some cases the type of robotics activity matters. This was certainly the case for the gear and connecting rod tools, about which pupils' knowledge increased more after building an arts and crafts robot from scratch than after building a robot with structured materials. As regards pupils' skills, here too these increased more after building an arts and crafts robot from scratch than after building a robot with structured materials. In particular, this increase related to all three tools (pulley, gear and connecting rod) for pupils building an arts and crafts robot from scratch, while for those using structured materials the increase affected the connecting rod only and was lower in magnitude besides.
In contrast, evaluation of the robotization of machines was not affected by the robotics activity per se but by the type of robotics activity. Awareness of the robotization of the vending machine, vacuum cleaner, and validation machine showed a greater increase among pupils who built a robot using structured materials (Lozer school) than among those who built one using craft and recycled materials (Valussi school). Our impression is that the artistic robot remains more anchored to the narrativity of current visual products with robots and does not enable pupils to translate their outcome in social terms. By contrast, the robot created with Lego materials is much more similar to a true robot, something that recalls a robotic machine, and thus stimulates pupils' awareness towards the process of robotization that is taking places at social level. In other words, according to SOLO taxonomy (Biggs 2003a, b), the students at the Valussi school seem to have acquired a more integrative understanding, while at the Lozer school the students have acquired a more extended understanding.

What we understood and learned from this study goes beyond the small issue we have investigated and deals with the broader theoretical framework we described at the beginning of this paper at a meta-research level. Keeping the point of building a robot from scratch in schools is important also to reaffirm the notion that public institutions but also new generations should become producers of technologies instead of only consumers of them. This is a way to connect the education system with large sectors of society that are trying to learn to produce technologies in order to empower themselves as citizens. Beyond of what pupils learnt at the Valussi school in concrete terms and that is measurable, we should value also the fact that these pupils had to confront the problem of designing and building a robot with crafts and recycled materials. These pupils have been conceptualized as potential producers, not only as consumers of structured materials.
Using structured materials, although pupils are able to create in this way robots which get closer to true robotic machines, situates the school and his students within another perspective. The school in this case buys the kit from the Lego from and invites pupils to use it for building a robot, of course within the constrains and rigidity of materials already structured. At the Lozer schools pupils were conceptualized only as potential consumers, which is another story.

The point that emerged as critical in these two studies, due probably to the small problem that we investigated, is the deficiency of our educational path. There is the need to understand deeply why pupils' mental schemes on robots did not improve substantially after the robotic activity (was the measure tool wrong or the robotic activity wrong: no sufficient time, no sufficient explanations etc.) and why the awareness of the diffusion of robotization process in the society did not work at the Valussi. Most likely it is necessary to redesign the instructional effort, to be done not only in technical terms but also in social and educational terms.

Conclusions

To conclude, building a robot from scratch has increased pupils' knowledge and manual skills, while building a robot with structured materials has increased their awareness of the robotization of machines. Thus, Eisenberg et al.'s (2004) notion that creating a robot from scratch using crafts and recycled materials is more effective than using structural materials because the latter kits enable users to re-produce only static, limited, and largely prefigured robot shapes, seems only partially confirmed in this study.

Our research is unfortunately unable to give a definitive answer on this subject, because it presents several limitations. First, as we mentioned at the beginning, this is field research (very much common in the social science studies), which imposes the a priori renunciation of the control of extraneous variables. Second, the number of pupils who participated in these robotics activities was rather small, which means our results are not generalizable. Third, the pupils' answers were self-reports and it was not possible to produce objective data to integrate them with. Thus, their answers are subjected to a series of well-known bias, such as that related to social desirability. Furthermore, the measures used by us do not represent validated tests or scales, of which it is possible to evaluate the reliability, but they are all elaborated for this research and treated as single items. Fourth, the time of execution of the two activities was slightly different

because the activity of constructing and operating the moving mechanisms of a robot from scratch using recycled materials takes more time than that required to build a robot with structured materials that have been designed to function properly with little effort. This can have affected pupils' post-tests in different ways. However, this limit is difficult to overcome even in future research because building a robot from scratch and building it with structured materials are in themselves activities that require different times. By the way, in terms of pupils' appreciation of robotics activities, the results show that pupils appreciated both equally.

Regarding future directions for research, there is a need to repeat this exercise with greater numbers of pupils of different age ranges and test Eisenberg's theory (Eisenberg et al. 2004; Eisenberg and Buechley 2008) with both further field research and experiments. Furthermore, it would be worth to take into account the recommendation made by Sun and Sundar in their study (2016) to propose a moderate level of self-assembly, instead of providing a fully assembled robot to the users. In other words, if robot users are put in the condition to set up and customize the robot by themselves this will be likely to generate higher satisfaction of the robot products. Additional work for understanding how these different activities influence students' understanding and conceptualization of the five dimensions of robots could be also another important direction for future research.

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