Robotics workshops and Contextualised Technological Education programme[1]

Paola Mengoli and Margherita Russo

excerpt by
ECONOMY, EMPLOYMENT AND SKILLS: EUROPEAN, REGIONAL AND GLOBAL PERSPECTIVES IN AN AGE OF UNCERTAINTY, edited by Terence Hogart, Quaderni Fondazione G. Brodolini, n. 61, 2018,
http://www.fondazionebrodolini.it/sites/default/files/pubblicazioni/file/q61_x_web.pdf

1. Introduction

Promoted by a programme of action research at Officina Emilia of the University of Modena and Reggio Emilia, the robotics workshops comprised an experiment run between 2005 to 2013 in the classes of primary and lower and upper secondary schools in Modena, Reggio Emilia and Bologna, involving over 2,700 students and more than 200 teachers. The participants observed, constructed and programmed LEGO® micro-robots, as examples of mechanisms and machines. Numerous promotional events also involved a group of adults and, over a period of time, various training events were realized for trainers and teachers.

The experimentation in the workshops took place in the context of action research which involved a coordinated series of actions. A sub-set of these actions, made up of *hands-on* workshops on machines, on production processes and on industrial jobs, included the robotics workshops. The robots were constructed, programmed and tested in order to promote knowledge of production techniques, the technology incorporated in the products, the expertise and competencies of employees in industry, as well as of the processes of innovation and technological change.

---

1. An Italian version of this paper has been published online by the review *Mondo Digitale* and we would like to thank the Editor for authorising its publication in English. The authors thank Donatella Poliandri (INVALSI) for her contribution with the initial setting up of the project to evaluate the activities with the schools within the action research program of Officina Emilia. They also wish to thank the organizers of the Convention "Giocare a pensare. Metodi e tecnologie per l'uso educativo e didattico dei robot" (Playing at thinking. Methods and Technologies for the Educational and Didactic Use of Robots), held at the University of Milan-Bicocca, May 20th 2017, and the participants in the session presenting an initial processing of the evaluation questionnaires of the robotics workshops of Officina Emilia. Our thanks also go to the two anonymous referees for the comments on the original paper. Whereas preliminary results were presented at the Convention, in this paper the results take into consideration all the questionnaires on the robotics workshops, since in recent months it has been possible to complete their digitalisation.

The entire research project was initiated and developed at the University of Modena e Reggio Emilia between 2000 and 2015. Following the end of the experiment with schools, research focused on the documentation and evaluation of the experience. Here a number of observations on the results of the robotics workshops are presented. The contribution is of a dual nature. On the one hand, an original context is presented in which experiences of technological and computer science education were realised with the use of a micro-robotic kit. On the other, a threefold evaluation of the experience of these workshops is presented: (i) the effect on the overall didactic activity of the schools involved, (ii) the effect on the knowledge, attitudes and abilities of the teachers involved, and lastly (iii) the effect on students' levels of knowledge, on their motivation to expand their knowledge and on the overall satisfaction of the workshop activities.

The paper is structured as follows. In section 2 the objectives of the Officina Emilia research project are illustrated. Section 3 presents the theoretical underpinnings of the project. Section 4 describes the robotics workshops while section 5 focuses on the evaluation of these workshops. Section 6 presents concluding remarks on the feasibility of the experiences of robotics education as a vehicle of contextualised technological education, and puts forward observations about ways of involving students, their teachers and schools. The aim is to simultaneously create significant learning experiences for new generations, in-service teacher training experiences, and innovation in pedagogical practice.

2. Action research

Numerous elements highlight the fragility of the traditional forms of cognitive mediation which for generations have introduced young people to an understanding of the social, economic and institutional context, as well as of the technological and professional context. Families do not seem to be able to transmit the knowledge and interpretations necessary to understand the social context, which is increasingly wide and complex. The same difficulties are to be found in schools. A growing number of teachers obtain their qualifications in different, and distant, geographical contexts from where they are teaching. The content of the courses they have studied, and above all the characteristics of their social relations, do not seem wholly adequate for the delicate task of including their students in the social, cultural and economic context (OECD, 2019).

In Italy, the educational experiences of young people up to the end of high school, is characterised by the poor quality of knowledge and competency in technological fields (i.e. reference to both production processes and products), and in the computer science field. Moreover, the enhancement of technological

education, with an explanation of the social and economic aspects connected to the use of technologies and to the development of scientific knowledge, generally remains beyond the scope of education of young people (Hutchings et al, 2001; Chatel, 2010; Baskette, 2013). These elements influence the level of interest in technical and scientific professions, highlighting also a big gender gap in these fields.

The Officina Emilia action research with schools was directed, above all, at teachers, in the form of support by means of educational actions which were innovative in method and content. All the teachers involved took part in the training course, observed systematically the experimental activities and contributed to their validation.

From 2004 and onwards, didactic modules on robots and digital programming (*coding*) were experimented with. The spread of numerous artefacts that incorporate programmable systems highlighted the need to possess scientific and mathematical knowledge, as well as basic engineering knowledge, for an informed use of many products in everyday use. Moreover, in areas with a marked manufacturing vocation, particularly in the mechanical engineering sector, such as for example Emilia-Romagna in Italy or the Rhine Basin in Germany, it must be ensured that the young work force entering the job market have, at all levels and for all jobs, much higher levels of knowledge and competency than has proved necessary hitherto. Many of the possibilities for firms to continue to foster the processes of innovation and growth in a competitive global market, depends, to a large degree, on this capacity of the educational system (Bellmann and Hubler, 2014; Azevado, et al., 2012; Bosch and Charest, 2010; Barber, 2003; Grubb, 1996).

The actions realised in collaboration with schools, within the Officina Emilia action research programme, allowed for the verification of, on the one hand, the possibility of a change in pedagogical practices and, on the other, the effectiveness of the means to foster knowledge of the technological, social and economic context. The aim of this is to develop in students the ability to choose between different pathways of study and work opportunities, as well as to develop their social identity, right from their early years of school.

The closure of the Museum Workshop in 2013 - resulting from the need of the University to reduce costs following national policies which imposed a reduction in public expenditure (Russo and Mengoli, 2017) - coincided with the conclusion of the central activities of the action research programme with schools. The programme continued with documentation activities, in-depth study encounters with other groups of researchers at national and international levels, and with the processing of the data for the evaluation, writing and publication of papers about

the research (Russo and Mengoli, 2013, 2014; Ghose et al., 2013, Russo, 2016). Other lines of research connected with the Museum Workshop experience have continued, above all with reference to the evolution of industrial structure (Russo, 2015), the efficacy of education systems (Mengoli, et al., 2013) and the experience of action research in the context of the politics of local development (Russo and Mengoli, 2017).

3. Theoretical underpinnings

The Officina Emilia action research is to be seen within the context of constructionist learning theories (Harel and Papert, 1991, Papert, 1993, Jonassen and Rohrer-Murphy, 1999). The perspective is that of active and contextualised learning, promoted by educational institutions which, in turn, operate under the influence of the institutional, social and economic conditions of the geographical area and country in which they are located. In setting up the action research the theoretical contribution of Vygotskij (1962) was of prime importance, especially for the interpretation of learning as a process of interaction between the individual and the environment, and of the social interaction and exchange between the less competent and the more expert. Furthermore, the contribution of the works of Dewey was fundamental (especially Dewey 1916, 1933) with regard to learning as an active social process in which manual experience constitutes a core feature that is integrated with reflective activities. A specific aspect of the action research project design was reference to studies on situated learning (Lave and Wenger, 1991), in the conviction that there is no acquisition of significant learning that does not take into account, in a decisive way, the context in which the learning itself, and the learner, are situated in space and time. Situated learning is also taken as the interpretative instrument of the factors that fuel motivation to make the effort to achieve successful learning (De La Garanderie, 1996).

Within this theoretical framework, the empirical background of the Officina Emilia robotics workshops is common to the experiences of *hands on* workshops which were widespread during the eighties in the main museums of science and technology, initiated by the pilot experience of the *exploratorium* of San Francisco[2], which was inaugurated at the end of the sixties (Quin, 1996; Polishuk and Verner, 2017). Through the disassembly and reassembly, also in a creative way, of products and artefacts using tools and instruments, effective educational action in the technological field was developed. In the Officina Emilia action research programme, the workshops on machines and on industrial production,

2. See www.exploratorium.edu/about/our-story (14th September 2017).

which included the robotics workshops, encouraged the exploration of artefacts, machines and the environments in which they are used. A strong connection can be seen with what, almost in the same years, was being realised in the *tinkering* workshops of the *exploratorium* of San Francisco[3]. As to the objectives and content, the empirical basis of the Officina Emilia workshops, including the robotics workshops, these can be found in the educational standards established from its first edition in 2000, by the International Technology and Engineering Educators Association (2007).

4. The robotics workshops

4.1 Objectives

Of the workshops on machines and industrial production of the Officina Emilia action research programme, two robotics experimental workshops were hosted: (i) "A robot that follows a line", for students aged between 12 and 16 years and, with slight modification, for students aged between 17 and 19 years; and (ii) "Robot-Croco-Dile", for girls and boys aged between 8 and 11 years.

The organisation of the workshops envisaged that a class, accompanied by one or more teachers, would go to the Museum Workshop in the morning to do the activities for four hours in the case of "A robot that follows a line" workshop and for three hours in the case of the "Robot-Croco-Dile" workshop. The workshops were programmed as stimulus events as part of a structured educational module of between a minimum of eight hours and a maximum of 20 hours. The teachers who accompanied the classes managed the other didactic activities connected with the workshop, using material and methodological indications given by the research team.

In the "A robot that follows a line" workshop, the students constructed a robot with LEGO® blocks, following instructions with no verbal indications. With only a very general presentation of the software tool, and proceeding by trial and error, the students wrote a program that allowed the robot to follow a black line on a white background. They tested the robot and competed to verify the accuracy of what they had done. A more complex version of the same workshop was hosted for girls aged 15-19 years, within the international program "Roberta"[4].

3. See https://tinkering.exploratorium.edu/ (14th September 2017).

4. Roberta is a project set up in 2002 by the Fraunhofer IAIS (Institute for Intelligent Analysis and Information Systems) in Bonn in response to the dearth of girls enrolling in technical-scientific courses. See http://roberta-home.de/en. (14th September 2017).

In the workshop called "Robot-Croco-Dile", the children constructed an automatic mechanism in the shape of an animal which could move and use a sensor connected to a computer. The languages of the verbal and pictorial descriptions were conjugated with the forms in the flowchart and with the codification of the software WeDo®.

All of the documentation about the Officina Emilia didactic workshops is available on line[5].

The objectives of the robotics workshops, in terms of learning and development of competencies, can be summarised synthetically as follows:

- The ability to identify problems, to choose between alternative solutions, to test the solutions and verify the results;
- Knowledge of the meaning of specific terminology to describe a machine and a robot, as well as knowledge of the principles of algorithms, their formalisation, and the basic instructions of any programming language (basic *coding*);
- Discovery of the fields in which robots have changed work and the living conditions of people, and of the geographical distribution and the characteristics of the firms that design, produce and sell robots;
- Discovery of the technological and scientific competencies necessary for the production, programming and testing of new robots.

The teaching of robotics as a discipline and as a set of specialised engineering competencies is not among the objectives. The main aim is to have all students acquire, irrespective of their school level and of the type of studies they have chosen, a concrete and functional knowledge of the basic elements of the technologies incorporated in machines and products.

The robotics workshops also pursued objectives of learning and professional training for the teachers involved with their classes. In summary, these objectives concern:

- Knowledge of the basic elements of the structure of a machine and of a robot and of the appropriate language to describe them;
- Knowledge of the principles of algorithms, of their formalization and of the basic instructions of any programming language (basic *coding*);

5. The documentation was created using MOVIO, an *open source* web application for the realization of virtual online exhibitions, developed by ICCU between 2012 and 2015. The MOVIO project used the Officina Emilia workshops in the test phases of the application. See www.officinaemiliaconlescuole.it/ (14th September 2017).

- Knowledge of the sources permitting the study of the social, economic and institutional structure of an area, in connection with the technologies used and the emerging organizational models;
- The practice of *hands-on* didactic units, with the use of multimedia materials and collaborative work in small groups.

What is presented above is not so very different from the numerous educational experiences that have been realised in museums, schools and *fab-labs* with the use of micro-robotics material. The action research programme, however, within which the experimentation of the robotics workshops took place set itself the aim of verifying the possibility of achieving two further important objectives: it is precisely these that constitute the peculiar characteristic of the experiences that are described.

In the first place, the robotics workshops were seen as an efficient means of encouraging an active knowledge of the technological, economic and social context, with particular reference to the areas where manufacturing is widespread. Secondly, the workshops, conducted rigorously under the strictures of action research methodology and connected with the in-service training of the teachers, aimed to foster in schools the diffusion of an innovative vertical curriculum which would benefit from the stimulus events, but would also make connections with other curricula and extra-curricular didactic actions.

4.2 An evocative environment

The robotics workshops, as stimulus events of a more complex educational programme, were experimented with, above all, in the Museum Workshop: an environment evoking mechanical processing, designed and realised as part of the action research to make possible: the observation and manipulation of machines, tools and products; bring about encounters with workers and business owners in the manufacturing sector, and develop contacts and connections with local firms. To all intents and purposes, it was a complex environment with space for simulation of the industrial work of the small and medium firms in the industrial districts of north east Italy. In support of the exhibition areas, the documentation Centre produced texts, films and original photographic material that made it possible to benefit fully from the exhibits and installations, and from the possibility of touching and manipulating everything that was exhibited[6].

6. http://www.officinaemiliaconlescuole.it./it/203/robot-cocco-drillo/show/48/186 and http://www.officinaemiliaconlescuole.it./it/203/un-robot-che-segue-una-linea/show/48/246 (29th December 2017).

A simulation replicates an environment, a real system, the actions that are performed within it, and can make it possible to observe the changes that have come about in time, when there are artefacts available from different epochs. A simulated environment allows learners to interact with reality, to verify the effects and changes brought about by their actions, with due regard for individual learning times, as well as to make mistakes without compromising a real production process. A simulation makes use of technological support (hardware and software) to increase the opportunity of understanding how the environment and its artefacts work. (Kurt, 2001; Koehler et al., 2005). In order to function, a simulated environment needs to be constructed and operated by making reference to an informed model, both of the learning process to be activated, and of the reality which is simulated. For this reason, the Museum Workshop was designed in collaboration with numerous professionals and researchers of different disciplines: engineers, physicists, materials chemists, industrial and work economists, experts in industrial organization, learning psychologists, educators and pedagogues, and communication experts.

Simulations are used in many different contexts, generally when there are reasons that make it impossible for learners to have direct experience of the operational environment. This is the case, for example, when an operation has high costs of materials, when the time required for a real experience is long, or when there are ethical or legal constraints (Garris et al., 2002). In the case of Officina Emilia, the main limitation that justified the construction of a complex simulated environment was the difficulty of giving all the students, or at least a large part of them, access to the direct and meaningful observation of industrial production environments. The small firms in the manufacturing districts are characterised by limited space and a high level of specialisation so that it is often impossible to understand the production process if only one firm is observed.

Formative/educational simulations are intended to teach the fundamental elements of a system through observation of the results of actions or decisions, thanks to a feedback process which in turn is generated by concrete simulations. The research hypothesis was that the simulations of assembly, dis-assembly, software programming and testing of the artefacts could help students and teachers to understand technical events and concepts that are not only complex but also cannot be fully observed in a business organisation of small dimensions.

The importance of the industrial environment for transmitting learning became strikingly clear when some of the teachers who had taken part in the robotics workshops in the Museum Workshop with their classes experimented with the same workshops in their own schools, albeit with a version adapted to be re-

alised in the school classroom[7]. Unanimously, the teachers noticed a drop in attention and reduced motivation, particularly in the weaker students, and thus reduced effectiveness of the experiences in the classrooms compared with those carried out in the Museum Workshop.

4.3 Background and meaning of the workshop experiences

The robotics workshops are not only an opportunity to reflect on the parts a robot is made of, the main structures of a machine, the basic tenets of software programming, or on the difficulties that are encountered in getting the robots to interact with their environment. Opportune moments for information transmission and of educational dialogue can make explicit the connections between what is simulated in a workshop and the external environment, where people live and work and encounter the use of robots.

What makes the robotics workshops analysed here original lies not so much in the central role of the educational action, which develops basic technological competencies that are increasingly indispensable for everyone, but, rather, the originality is to be found in the initial phases and the final phases of the workshop. These introduce elements of knowledge and interpretation of the characteristics of the economic system under a technological, social and institutional profile, as well as elements of the world of work and of professions / jobs. Right from primary school, students can be introduced to this knowledge through stimulating experiences such as the robotics workshops. Often the new generations do not have easy access to instruments that can help them understand the world they live in and to reflect upon it. This is why the influence of certain factors from the cultural and social context they come from often produces preconceptions and scepticism. This weighs negatively on the choices made with reference to educational and professional courses, as well as on motivation to learn especially with regard to science and mathematics.

During the robotics workshops, with video-installations, films of recorded interviews and appropriate didactic action, the connections between what the students constructed and the robots used in firms, hospitals and airports were made explicit, with opportune adaptations taking age into account. Numerous examples were given to show how these machines interact with men and women who work, and who have seen their conditions change precisely as a result of robots being introduced. This didactic action constructs a background of meaning to

7. See: http://www.officinaemilia.unimore.it/site/home/oe-con-le-scuole/laboratori_online/un-robot-che-va-scuola.html (14th September 2017).

the experience of robotics and connects it not only with the school, but with a much wider perspective of knowledge and skills necessary to live and work (Zanelli, 1986).

During the robotics workshops, but more often in the didactic activities in the classrooms, conducted by the teachers after the participation of classes in the workshops, attention was focused on discovering the firms – not just ones in Italy - that produce robots. In other cases, the ethical aspects of the spread of robotics were studied further, with reference also to the substitution of work undertaken by humans and the use of robots in situations of armed conflict, or in the surgical field. One didactic unit was dedicated to literature and cinema in order to analyse how robots have become part of cultural production.

5. Evaluation

The literature on the evaluation of educational experiences that use robots and micro-robotics is very recent and generally reports good results, but it also suggests doubts and points to the need for further research (Benitti Barreto Vavassori. 2012; Bredenfelt, et al., 2010; Kandlhofer, M., and G. Steinbauer, 2014). The evaluation of the robotics workshops comes under the more general evaluation scheme of actions realised by schools within the Officina Emilia project. Presented here are some of the results, referring to the robotics workshops held between 2009 and 2013 and to the three dimensions considered:

1. The effect on the overall didactic activity of the schools involved;
2. The effect on the knowledge, attitudes and abilities of the teachers involved, and lastly; and
3. The effect on the knowledge of the students, their motivation to continue, and on their overall satisfaction with the workshop activities.

The collection of data for the evaluation of the workshops used four instruments:

1. In-depth interviews with teachers;
2. A questionnaire for teachers when their class took part in a workshop; a questionnaire about the degree of satisfaction of the students of the lower and upper secondary schools; and
3. A questionnaire with yes/no questions, compiled before and after taking part in a workshop, showed changes in the learning of students.

Table 1 records the main data, referring to the instruments used and their number.

Table 1 - Instruments used for the collection of data for evaluation

Instruments used	Number
In-depth interviews with teachers	30 of which 28 complete and usable[8]
Questionnaires of accompanying teachers	121 in digital format[9]
Satisfaction questionnaires of secondary school students	497 in digital format[10]
Questionnaires on learning of students	86[11]

Source: Authors processing of the evaluation instruments of the robotics workshops of Officina Emilia

The evaluative exercise presented in this paper is based on the analysis of the qualitative elements expressed by the participants regarding the changes in their knowledge and actions after participating only in the robotics workshops. The changes in the knowledge of students, the data-collection – at the beginning and at the end of the workshop – permitted a quantitative evaluation of the changes produced.

5.1 Effects on the functioning of school institutions

The participation of classes in the workshops was initially promoted by teachers who, out of personal interest, took an interest in the action research project. After that, the majority of classes of students took part in the workshops following decisions by the respective schools.

---

8. Of these, 18 are primary school teachers, 6 are lower secondary school teachers and 4 are upper secondary school teachers. The interviews were conducted in the school years 2011-2012 and 2012-2013 at the Museum Workshop of Officina Emilia in Modena.

9. Of these, 63 are primary school teachers, 39 are lower secondary school teachers and 19 are upper secondary school teachers. The questionnaires were compiled between 2009 and 2012 by teachers mainly from schools in Modena and Reggio Emilia. The composition by gender is weighted in favor of women (86%) and of mathematical and scientific subjects (35%), followed by humanities (31%), by technical/technological education (18%), and by social sciences (4%). 12% of the accompanying teachers were support teachers or educational assistants for disabled students.

10. 51% of the participants frequented lower secondary schools and 49% upper secondary schools, almost equally divided among grammar, technical and vocational schools. Gender distribution was 53% males and 47% female students.

11. Data collection about learning involved four classes and a total of 86 students, of whom 42 were from lower secondary schools (12-13 years and 48% females) and 44 from upper secondary schools (17-18 years and 51% females).

The schools involved were mainly from the province of Modena, and also from the neighbouring provinces of Reggio Emilia, Bologna and Mantova. Altogether the project involved 32 school institutions, of which 17 were primary schools, 6 lower secondary schools and 9 upper secondary schools[12].

The main effect of the activity on schools is measured by the number of school institutions that have integrated the Officina Emilia workshops into their general didactic plans, considering them as significant "stimulus events" and making them part of the educational opportunities available that are communicated to families. Three primary schools, two lower secondary schools and one upper secondary school made this choice, and they represent about 20% of the schools involved.

5.2 Effects of the activities on teachers

The robotics workshops made available to teachers the opportunity to further their basic knowledge of technology, coding, and the economic and social structure of the local and regional context. Moreover, the methodology of a workshop represented an example of an effective pedagogy that can be used in the teaching of numerous courses. The large majority of teachers involved were able to explore the possibility of acquiring knowledge and skills useful in realising meaningful teaching and learning pathways for their students.

In some cases, the teachers taking part in the workshops lacked enthusiasm and refused to collaborate for numerous reasons, prevalently the kind of university education they had experienced, an unwillingness to go beyond the boundaries of their individual subject, and a conception of technological education as being bound exclusively to vocational education. A humanities based university education characterised the profile of the most critical teachers, though not totally or exclusively. A university education in technological and scientific disciplines is not sufficient to sustain the motivation of teachers with regard to the didactic innovations proposed in the robotics workshops. In fact, the knowledge of robotics requires not only the crossing of boundaries between disciplines, but also changes in habits, and the overcoming of deep-rooted stereotypes. It is necessary to understand the connections and relations existing between numerous disciplinary areas, and that not all teachers, regardless of their initial education, appreciate this pathway towards professional growth. Lastly, some teachers who teach engineering and economic disciplines in technical and vocational upper secondary schools, who

12. In the years in which the workshop was most active, Comprehensive Institutes were not yet widespread and therefore primary schools were still separate institutions from infant schools and from lower secondary schools.

are in the habit of promoting specific knowledge and skills that are directly applicable in the workplace, had difficulty becoming involved in educational actions aimed at anybody preparing themselves to enter the world of work or simply wanting to benefit from the potentialities of digital technology.

Table 2 summarises the changes that teachers referred to in the questionnaires compiled after taking part in the workshops[13].

Table 2 - Percentage of teachers who declare some effects of the workshop on their didactical activity (N. 121), multiple choice answers

20%	Before participation introduced the classes to the workshop activity, making explicit the links with the content of curricular subjects.
34%	The workshop activities are a stimulus event for the students and this aids the introduction of curricular topics by the teachers.
28%	The workshop activities stimulate the curiosity of the students and help to improve attention towards curricular activities.
12%	The workshop activities boost the capacities of students to orient themselves in their choices post-lower secondary and post-diploma of upper secondary school.
83%	Following the experience think they will do further work on the topics dealt with in the workshop and/or will introduce associated topics.

Source: Authors processing of the questionnaires of the teachers participating in the robotics workshops of Officina Emilia.

Only one teacher in five introduced the classes to the workshop activity making explicit the links with the content of curricula disciplines. Although this percentage, starting with percentages close to zero, increased during the course of the years of workshop activity, it never reached a high level. The majority of teachers continued to delegate the task of introducing and rendering meaningful the participation of students to laboratory operators. Little more than a third of the teachers involved (34% in Table 2) think that the workshop functions as a stimulus event and benefits their work when they have to introduce new topics connected with technologies, mathematics, and coding with knowledge of the economic structure of the local area. 28% of teachers (Table 2) think that participation in the workshops stimulates students' curiosity and helps improve their attention towards curricula activities. 12% (Table 2) of teachers see par-

13. In the processing, the open answers given by the teachers are codified. Differences between the answers of teachers of schools of different levels are not taken into account. A more detailed picture will be available with the complete analysis referring to all the Officina Emilia workshops, which is currently in progress.

ticipation in the workshops a helpful instrument to develop in students the capacity to choose between different pathways of study and different careers.

The action research set out to verify whether, and to what extent, new content could be transmitted in everyday actions through involvement of teachers in workshop activities with their students. This hypothesis has been confirmed, at least in the short term, given that 83% of the teachers intend to do further work on the topics dealt with in the workshop or to introduce topics connected to it.

5.3 Effect on the knowledge, motivation and attitudes of the students

The confirmation of the hypothesis that the robotics workshops develop an appreciable body of knowledge and skills can be deduced from Table 3, which is based on the processing of the in-depth interviews and on the answers to the open questions of the questionnaire for teachers. The key words located in the interviews and in the questionnaires have been catalogued in five categories: soft skills, creativity, logic, knowledge of technology, work and firms.

Table 3 - Skills and knowledge developed by the students during the robotics workshops

Skills and knowledge	Specifications and characteristics
Skills	
Soft skills	Precision, collaboration, communication, orderliness, cleanliness
Creativity	Construction of artifacts, choice between different shapes, use of space
Logic	Classifications, flow diagrams, algorithms, computational thinking
Knowledge	
Technology and work	Stages of manufacture, production technologies, software in machines and in products, history of techniques, economic development
Work and firms	Organisation of work, history of work, social development, entrepreneurship

Source: Processing of the interviews with teachers participating in the robotics workshops of Officina Emilia (N. 28) and of the answers to the open questions in the questionnaire for teachers (N.121)

All the teachers interviewed recognised that the workshop activity students took part in favours, in an almost generalised way, the practice of precision, orderliness and collaboration, even in the less motivated students. Other skills and knowledge are developed in a less decisive way. The persistence of the positive effects on the students can be attributed to the possibility of reinforcing the behaviours, knowledge and skills gained during the workshops.

As to learning, with particular reference to the development of knowledge (Table 4), despite the fact that the results of the tests administered to the participating classes with a before-after strategy were flattering even for the less intellectually able students, they are not statistically significant because they cannot be attributed exclusively to the experience of the robotics workshops. In fact, the data-collection questionnaire, which was a simple one with just a few yes/no questions, did not highlight the other elements that determine those results, such as: the social condition and previous school experience of the students, the quality and quantity of parallel didactic interventions and the other extra-scholastic experiences of the students. Although the quality of these results cannot be relied upon, it is worth noting that participation in the workshops develops (or consolidates) some basic knowledge, both in terms of the technical structure of a robot and the social and economic connections deriving from the use of robots in the world of work and in everyday life. It is important to observe that, without being able to measure its statistical validity, differences by gender or age (13-14 years and 17-18 years) in students were not evident.

Table 4 - Correct answers given by students about their knowledge before and after the workshop (N. 86)

Questions about knowledge	% correct answers	
	Before	After
Does a robot always and inevitably have the form of a humanoid?	15%	80%
Does a robot need to be programmed?	31%	98%
Does a robot use one or more sensors?	12%	99%
Can a robot replace the work of one person or more?	55%	87%
Are robots used in hospitals?	8%	97%
Are robots produced in Italy?	5%	99%

Source: Processing of the tests about learning, for students of lower and upper secondary schools participating in the robotics workshops

As for levels of attention and interest, reference can be made to the satisfaction survey questionnaires compiled by students who took part in the workshops.

Although over 69%, of both female and male students, express a high level of interest in the workshop (see Tables 5 and 6), the gender differences should not be underestimated. There are in fact elements which confirm that girls show themselves to be less willing to become involved in experiencing of technologies, due to the stereotypes that surround them at school, in the family, and in society at large.

Initial interest and curiosity, before participation in the workshop was fairly high, but a first gender difference emerges: 96.6% of the female students (Table 5),

compared with 92.9% of male students (Table 6), state that they are interested and curious. There were more sceptics among the male than among the female student, but whereas the male students who were sceptical or indifferent and allowed themselves to become involved expressed a positive opinion about their experience, a small minority (3.4%) of female students who were sceptical and indifferent at the beginning expressed a low degree of interest after taking part.

Table 5 - Answers of female students who participated in the robotics workshops about expectations and degree of interest after participation (N. 88)

Female students	After/Degree of interest			
Before	Low	Medium	High	Total
I was curious and interested	1.1%	26.1%	69.3%	96.6%
usual things/I was indifferent	3.4%	0.0%	0.0%	3.4%
Total	4.5%	26.1%	69.3%	100.0%

Source: Processing of the satisfaction survey questionnaires of students participating in the robotics workshops of Officina Emilia

Table 6 - Answers of male students who participated in the robotics workshops about expectations and degree of interest after participation (N. 126)

Male students	After/ Degree of interest			
Before	Low	Medium	High	Total
I was curious and interested	0.0%	24.6%	68.3%	92.9%
usual things/ I was indifferent	2.4%	4.0%	0.8%	7.1%
Total	2.4%	28.6%	69.0%	100.0%

Source: Processing of the satisfaction survey questionnaires of students participating in the robotics workshops of Officina Emilia

Table 7 - Answers of the students who participated in the robotics workshops about the desire to do further study on the experience (N. 497)

	Female students	Male students	Total
I expect to do further study at school	43%	45%	44%
I expect to do further study individually	25%	25%	25%
I do not expect to do further study	22%	19%	20%
Other answers	1%	1%	1%
Did not answer	9%	10%	10%
Total	100%	100%	100%

Source: Processing of the satisfaction survey questionnaires of students participating in the robotics workshops of Officina Emilia

As many as 44% of participants expect to follow up the experience with further study at school (Table 7), and a quarter expect to be able to do further study autonomously. Only 20% of the participants (with a slightly higher percentage among the female students) state that they have no interest in further study.

With these results, a greater gender differentiation might have been expected. In fact, above all the gender segmentation between different types of high schools might explain the different expectations about further study at school. It may be that the male students in the industrial pathway of upper secondary schools can reasonably expect, on the basis of the subjects in their curriculum, that there will be opportunities for further study of topics of a technological nature (linked to the industrial structure of the local area), but the girls who want to undertake further study they have to rely more on personal or extra-scholastic resources. This is because, more so than their male counterparts, they attend courses which do not foresee the study of technological subjects.

From Table 8 a clearer element emerges in favour of the differentiation between the two genders. The percentage of students who recognise that they have increased their knowledge is distinctly higher among male students (73%) than among female students (67%).

Table 8 - Percentage of female students and male students who declare that they have acquired new knowledge following their participation in the workshop[14]

	Female students	Male students	Total
N.	88	126	214
Increased my knowledge	67%	73%	71%
Did not increase my knowledge	33%	27%	29%

Source: Processing of the satisfaction survey questionnaires of students participating in the robotics workshops of the Officina Emilia

The overall evaluation of the participation in the robotics workshop is excellent both for males and for females: with most students – both male and female - giving an average grade of around 9 (out of 10) (see Table 9). It is worth pointing out that the average evaluation of the whole population of participants does not vary between males and females, but instead varies in relation to the individual's perceived increase in knowledge. Students who have a positive opinion of

14. The question was not posed in the same way in all the questionnaires and therefore the processing refers only to a part of the questionnaires.

the knowledge acquired in the workshop evaluate the activity of the workshop relatively highly (9.4 out of 10 in Table 9) compared to students with do not recognise an increase in knowledge (8.3 out of 10 in Table 9). This is the case for both male and female students.

Table 9 - Average satisfaction grade (in tenths) and opinion about knowledge acquired (N. 214)

	Female students	Male students	Total
Average grade assigned by those who state "I did not increase my knowledge"	8.2	8.4	8.3
Average grade assigned by those who state "I increased my knowledge"	9.3	9.4	9.4
Average grade assigned by all the participants (N. 497)	9.0	9.0	9.0

Source: Processing of the satisfaction survey questionnaires of students participating in the robotics workshops of Officina Emilia

6. Final considerations

The experience presented seems to show that didactic activities which envisage concrete actions help the imagination and predispose positively towards learning of a technological nature. These results highlight a certain gender difference. It is well-known in the literature that girls and female teenagers show greater disinterest towards technologies and risk not being adequately supported even by teachers, who in turn are mostly women, thus fostering hesitations and doubts about the need to have technological competencies (Ajello, 2002).

The experience of Officina Emilia, with the robotics workshops, allowed for the investigation into the possibility of opening a new educational space allowing young people to make better connections between what they do at school and the experience of adults in the workplace, while also acquiring a better understanding of technologies. The evaluation of the robotics workshops makes it possible to say that the positive results observed can be attributed not only to the didactic use of micro-robotics materials, but to a combination of at least three elements that characterised the workshops. The experience of robotics education benefited from the construction of experiences - individual and small group ones - of a *hands on* nature, which reinforce inductive practices, the capacity for critical observation, the construction of feedback and the relational capacity to work together. Secondly, the activities which make explicit the relations between the learning outcomes and knowledge of the technological, economic and social

characteristics of the local area in which the student s live, created a meaningful context which stimulated attention and interest. Lastly, the effectiveness of the robotics workshops derives from the environment in which they were realised: the Museum Workshop evoking mechanical engineering and industrial production. The possibility of experiencing first-hand the machines, materials, semi-finished products and products, together with the multimedia information about workplaces sustained interest in technologies, human work and its organisation. Especially for the older students, participation in the robotics workshops opened the door to the desire to undertake further study.

The action research programme of Officina Emilia with schools, in particular with the robotics workshops, provided a contribution which was appreciated by teachers in three main spheres. The first has to do with the creation of appropriate instruments to draw the attention and interest of the younger generations towards mathematics, sciences, technologies and engineering – which are all important fields of study - and of experience for the future of work, as well as for the informed participation in collective choices. The second sphere is the support of innovation in the didactic programmes the teachers realise in school working towards the construction of a curriculum which puts at its centre, as a special object to be understood, the social and economic characteristics of the context, and thus the technologies, the kinds of work and the organisational typologies of firms. The third sphere is that of the knowledge triangle[15] and, in particular, the programme of action research that contributed to defining and validating the means of constructing effective and fruitful connections between the didactic programming of schools and the functioning of institutions, firms and organisations in society.

References

Ajello, A. M. (2002). *Le differenze di genere negli studi su apprendimento e sviluppo*. POLITE. Saperi e Libertà.

Azevedo, A., G. Apfeltharer, and D. Hurst. (2012). *Competency Development in Business Graduates: An Industry-Driven Approach for Examining the Alignment of Undergraduate Business Education with Industry Requirements*. The International Journal of Management Education, no. 10: 12-28.

Barber, J. (2003). *The Informally Trained Mechanic Skill Acquisition in the Workplace*. Journal of Vocational Education and Training 55 (2): 133-48.

15. See the research program developed by OECD (2017) and presented at the convention in Paris in September 2016 – see https://www.oecd.org/sti/inno/Knowledge-Triangle-agenda.pdf visited on 14 September 2017.

Baskette, K. G. (2013). *Technological Literacy for All: A Course Designed to Raise the Technological Literacy of College Students*. Journal of Technology Education 25 (1).

Bellmann, L., and O. Hubler (2014). *Skill Shortage in German Establishments*. IZA Discussion Paper, no. 8290.

Benitti Barreto Vavassori, F. (2012). *Exploring the Educational Potential of Robotics in Schools: A Systematic Review*. Computers and Education 58 (3): 978-88.

Bosch, G., and J. Charest, (eds). (2010). *Vocational Training International Perspectives*. New York: Routledge.

Bredenfelt A., A. Hofmann, and G. Steinbauer (2010), *Robotics in Education Initiatives in Europe: Status, Shortcomings and Open Questions*. In Proceeding of SIMPAR Workshops, November 15.

Chatel, E. (2010). *Economics as Social Science in French Lycees: A program Shaped by the Evolution of a School Discipline*. Journal of Social Science Education 9 (2): 52-63.

De La Garanderie, A. (1996). *La Motivation Son Eveil Son Développement*. Paris: Bayard editions.

Dewey, J. (1916). *Democracy and Education: An Introduction to the Philosophy of Education*, New York, Macmillan.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. Boston: Houghton Mifflin.

Garris, R., R. Ahlers, and J. E. Driskell. (2002). *Games, Motivation and Learning: A Research and Practice Model*. Simulation And Gaming, no. 33: 441-67.

Ghose, R., M. Mattioli; M. Russo (2013). *Homm-sw. Networks-of-stories to value tangible and intangible heritage in museum.* Digital Heritage 2013 - Marseille, France - 29.10-01.11 2013. Proceedings of the 1st International Conference on Digital Heritage, Institute of Electrical and Electronics Engineers, Inc., Piscataway, NJ Piscataway, NJ USA, Vol 1.

Grubb, N. W. (1996). *Working in the Middle. Strengthening Education and Training for the Med-Skilled Labour Force*. San Francisco: Jossey-Bass Publishers.

Harel I., and Papert S. (eds.) (1991). *Constructionism*, Norwood. New Jersey. Ablex.

Hutchings, M., M. Fulop, and A. M. Van den Dries, eds. 2001. *Young People's Understanding of Economic Issues in Europe*. Stoke on Trent UK: Trentham Books.

International Technology and Engineering Educators Association, ITEEA (2007), *Standards for Technological Literacy. Content for the Study of Technology.* Reston, VA: ITEA.

Jonassen, D. H., and L. Rohrer-Murphy. (1999). *Activity Theory as a Framework for Designing Constructivist Learning Environments*. Educational Technology Research and Development 47 (1): 61-79.

Kandlhofer, M., and G. Steinbauer. (2014). *Evaluating the Impact of Robotics in Education on Pupils' Skills and Attitudes*. Proceeding of the 4th International Workshop Teaching Robotics. Teaching with Robotics & 5th International Conference Robotics in Education, 101-9.

Koehler, M. J., and P. Mishra. (2005). *What Happens When Teachers Design Educational Technology? The Development of Technological Pedagogical Content Knowledge*. Journal Educational Computing Research 32 (2): 131-52.

Kurt, Y. M. (2001). *The Effect of a Computer Simulation Activity versus a Hands-on Activity on Product Creativity in Technology Education*. Journal of Technology Education 13 (n.1): 31-43.

Lave, J., E. Wenger (1991). *Situated Learning: Legitimate Peripheral Participation*. London. Cambridge University Press.

Mengoli P., G. Dente, D. Teloni, G. Damioli (2013). *Vocational Education and Training in Italy*, FGB Working Paper, n.3, ISBN 978-88-95380-13-1.

OECD (2017). *Knowledge Triangle*, Springer.

OECD. (2009). *Creating Effective Teaching and Learning Environments: First Results from TALIS*. Paris: OECD.

Papert, S. (1993). *The Children's Machine: Rethinking School in the Age of the Computer*. New York: Perseus Books Group.

Polishuk A., Verner I. (2017). *Student-Robot Interactions in Museum Workshops: Learning Activities and Outcomes,* In: Merdan M., Lepuschitz W., Koppensteiner G., Balogh R. (eds) Robotics in Education. Advances in Intelligent Systems and Computing, vol 457, Springer, Cham.

Pozzoli, S. (2009). *I luoghi, le persone, le macchine, il lavoro, Videoinstallazione per il Museo-laboratorio di Officina Emilia*, Università di Modena e Reggio Emilia.

Quin, M. (1990). *What Is Hands-on Science, and Where Can I Find It?* Physics Education 25 (5): 243.

Russo M., Mengoli P. (2017). *A hybrid space to support the regeneration of competences for re-industrialization. Lessons from a research-action*, in Montanari F., Sgaragli F., Teloni D. (eds.), *Cities as engines of innovation: A transatlantic journey EU-USA*, Quaderni Fondazione G. Brodolini, n 59: 39-53, Roma.

Russo, M. ed., in collaboration with Pozzoli S. and Tantillo F. (2016). *Documenting work through videos. A project by Officina Emilia with nine engineering firms in the province of Modena (2008-2010)*, DEMB WP Series, n. 93.

Russo, M. (2015). *Distretti, piccole imprese e sapere diffuso nei sistemi produttivi della meccanica*, M. Salvati e L. Sciolla (a cura di), *L'Italia e le sue regioni: l'età repubblicana. V. II: Territori*, Istituto della Enciclopedia Italiana, Roma, pp. 147-160 ISBN: 9788812005314.

Russo, M., Mengoli P. (2014). *Education with micro-robots and innovation in education* (4th International Workshop "Teaching Robotics & Teaching with Robotics" (2014) - Padova, Italia - July18, 2014) (Proceedings of 4th International Workshop "Teaching Robotics & Teaching with Robotics" & 5th International Conference "Robotics in Education" 2014) (IT+Robotics srl Vicenza): 152-159.

Russo, M., Mengoli, P. (2012). *Innovazione nei sistemi educativi per migliorare la qualità dell'istruzione*, Economia & Lavoro, Vol. 1: 7-23.

Vygotskij L. S. (1962). *Thought and Language,* Cambridge Mass. M.I.T. Press.

Zanelli, P. (1986). *Uno "Sfondo" per Integrare*. Bologna: Cappelli.