Education with micro-robots and innovation in education

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Abstract. Knowledge-driven re-industrialisation in Europe calls for changes in education systems. We address those changes by focusing on the adoption of a context-based approach to place science and technology within young people's daily lives and to promote their understanding of the relevant issues emerging in society. In particular, we propose the use of micro-robots labs in order to: (i) improve a context-based approach to technology education and (ii) spread the knowledge of working conditions, employment opportunities and industrial enterprises activities. We suggest action-research as a feasible practice to boost bottom-up changes in teaching and learning activities, and we focus on the university initiative Officina Emilia as an example. The paper proposes some concluding remarks focusing on hybrid places to foster innovation, involving not only teachers and experts on education, but also researchers in different technological domains and in the social sciences and humanities, manufacturing and services companies, civil society.

Keywords: knowledge driven reindustrialization in Europe; context-based technology education; robotics and innovation in education

1 Introduction

Re-industrialization of Europe is becoming an imperative to support a path of sustainable development characterized by social inclusion and innovation, as remarked also by the Report on EU competiveness [1]. The main rationale for strengthening the manufacturing sector in Europe is that most innovations are produced within it and through it they affect the service sector (in particular business services). Although it constitutes a decreasing share of Europe's Gross Domestic Product (GDP), the manufacturing sector is still the engine of modern economies. Because of backward and forward linkages [2], the manufacturing sector development has a multiplier effect on the growth of the economy [3]: a general increase in productivity of the manufacturing sector makes a contribution to the growth of GDP that is four times higher than that of other inputs.

Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics &
5th International Conference Robotics in Education
Padova (Italy) July 18, 2014
ISBN 978-88-95872-06-3
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The re-industrialization process requires new skills to support changes in technology and organizational models (within the companies and in their networks). These new skills can be nurtured within workplaces. But this is not enough. They should be included into educational pathways, particularly in the upper secondary level.

The ability of actual education systems to create and develop adequate skills does not meet these needs, and the European Commission has pushed for innovation in education aiming toward new skills for new jobs [4].

In this paper we argue that, in order to strengthen re-industrialization, it is necessary to boost innovation in the whole education system, from pre-school to university, not only in the vocational and training pathways. In particular, the education and training system as a whole must take on the challenge to provide or to increase the provision of the ability to (1) apply what has been learned to different contexts, (2) understand the technological, social, economic, historical and cultural heritage of the context in which people live and work, (3) take advantage of the core knowledge of work processes. To reach these goals, the education system has to allow students to have experiences in several different environments and to be aware of the concreteness of the material conditions of life and work [5] [6].

"Officina Emilia", an action-research supported by the University of Modena and Reggio Emilia, has produced educational laboratories, such those with micro-robots, that have fostered significant changes into contents and methods of teaching and learning, by linking science, technology, engineering and mathematics in a more effective way [7][8] At the same time, Officina Emilia's laboratories allow students to develop soft skills – such as time management, proper allocation of resources, efficient team working, problem solving, communication, use of feedbacks from processes. Because of these characteristics, the Officina Emilia's laboratories share many elements with several initiatives carried out over time in Italy and in Europe [9]. Its special contribution is on three related domains: (1) to combine the education with micro-robots with other activities in order to connect technologies with the knowledge of the workplaces and the enterprise activities; (2) to promote knowledge and understanding of the industrial structure of the territories; (3) to involve all young people, not only students enrolled in technical and vocational training pathways. Moreover, Officina Emilia addresses teachers' involvement as a crucial issue for innovation processes in education. Lastly, Officina Emilia embraces the need to support bottom up changes in education through multi-agent and multi-level actions: this is why, an open public hybrid space has been designed to allow students, educators, production and technology experts, policy makers to open their mindset and improve their understanding of the issue and practices of regeneration of competence networks. Public hybrid spaces are increasingly recognized as loci fostering innovation processes, since they provide a venue in which new ideas and insights can emerge by allowing interactions and interpretative ambiguity. As Lester and Piore have stressed [10], these are often the missing dimensions in innovation processes, which are nurtured not only by analysis and problem solving, but also by generative relationships which are based on heterogeneity, aligned and mutual directedness of the

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relevant agents, and appropriate permissions to support agents' opportunities of action [11].

In this paper we first discuss how basic knowledge needs to be generalized in order to meet the re-industrialization and to support citizenship and social inclusion. We address the issue of developing a new approach to context-based technology. We present the Officina Emilia initiatives, with regard to its micro-robots labs designed and tested to improve a context-based technology education. The paper proposes some lessons drawn by the Officina Emilia action-research on how to support changes in education to enhance a knowledge-driven re-industrialization.

2 New basic knowledge to be generalized: the context-based technology education

Skills to be promoted in the education system must address not only employability, but also social cohesion, inclusion and active citizenship [12]. The inability of young people to understand the context in which they live could be one of the reasons why social cohesion of several local communities is too often threatened [13]. A considerable amount of evidence leads to believe that this understanding is dramatically poor among too many young people [14].

If skills and knowledge are to be used to deal also with problems of everyday and working life, the curriculum has to cope with the realm of technology and it needs to build countless connections with economics, sociology and the study of institutions that enhance the capacity to understand the multiple facets of complexity in society. Although from the 1990s onwards technology education has been promoted as a key element in all curricula, as well as an element permeating every discipline, separate and distinct courses are the most common approach to this type of education, and a certain confusion remains about what is technology [15]. The greatest attention is on information and communication technologies, but other key contents should be included to share a basic knowledge on: (i) materials' properties and their use in industrial production; (ii) techniques of production and characteristics of the industrial products; (iii) skills and work experiences of employers and employees; (iv) environmental quality and living conditions at local and regional level.

Generalizing these as basic knowledge for all young people would support their need to acquire information when they choose their education and vocational pathways, and select their careers. It would also help them to become aware consumers and active citizens.

It is almost impossible to imagine that the contents, the abilities and the skills related to the technologies of industrial production, and technologies embedded directly and indirectly in everyday products, could be carried out only in labs separated from actual workplaces, keeping apart the machines, procedures and work tasks, from the context in which they are embedded. We suggest to adopt a "context-based technology education" [16] in order to address the interdisciplinary nature of learning and to expand contents, abilities and skills. Context-based

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technology education needs to address the labour and entrepreneurship culture, and the knowledge of human work in different places and times. This must not be confused with traditional apprenticeship pathways. In particular, a closer relationship with the workplace does not necessarily mean to train in a specific task. Conversely, it calls into question the definition of multiple complex learning objectives, the choice of appropriate teaching methods and the creation of cooperative relationships between schools and businesses. Particularly important: all the young people have to be involved in such learning processes, and not only those who want to enter the labour market early.

3 Education using micro-robots in Officina Emilia's experience

In this section we describe Officina Emilia's practices of action-research on context-based technology education, with micro-robots labs as a subset of laboratories designed to promote the understanding of the mechanisms, the machines, the know-how and the procedures of small and medium industrial enterprises. In these labs, specific stimuli are implemented to teach and learn how enterprises work, with reference to a specific territory, and which are the job positions in companies (from workshops to laboratories, R&D and management).

The Officina Emilia initiative, supported by the University of Modena and Reggio Emilia since in 2000, builds on research into comparative analysis of education systems and into industrial districts and local development policies. Officina Emilia's action-research aims at addressing the problems of regeneration of technical skills, whose shortage is critical in areas with a strong presence of engineering and manufacturing companies, as in the industrial districts of North-East Italy. It shares hypotheses, methodologies, activities and results with academic and practitioner communities in Italy, as discussed during the national workshop held in Modena in 2013 [17] and in other European countries [18] and worldwide [19].

A coordinated package of education activities, which includes education with micro-robots, has been developed to be implemented by schools within the regional curriculum. The action-research explored (a) how to disseminate the tested education activities in the pre-university education system at regional level, and (b) the more appropriate ICT tools to support hands-on activities complemented with multimedia contents[1].

Hands-on activities with micro-robots, artefacts, objects, products, tools and machine tools used in small and medium size mechanical companies combine the knowledge of production technologies with some meeting with technicians, workers and employers, inside the labs and in the workplaces. All the educational

[1] In relation to this issue, it is worth mentioning the use of MOVIO [20], an open source web application to implement the on line version of the multimedia contents and procedure of the labs; and the production of a specific web application, Homm-sw [21] to create, and share on the web, transmedia narratives co-created by students, teachers, and experts.

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activities are realised in collaboration with schools and a significant number of small and medium size enterprises (in the mechanical and industrial services sectors), as well as the representatives of multinational companies, trade unions and business associations.

A special teaching-learning environment opened in 2009. The Museum-workshop (Museolaboratorio) evokes the industrial workplaces but it is suitable for not-experts, such as students, for initial and in-service teacher training, for the networking activities at regional, national and international level.

Since 2009 until 2012, laboratories have involved approximately 5,000 students from pre-school to upper secondary education. Nearly 170 teachers have been involved in in-service training to promote changes into their everyday work, 12 schools signed a permanent collaboration agreement on innovative education to be developed with the support of the university, and 3 schools introduced Officina Emilia labs in their official curriculum.

The following table shows the involvement of students and teachers in different types of educational activities.

Table 1. Number of students and teachers involved in the action-research of Officina Emilia, by type of activity and grade of school. September 2009 - June 2013

	Primary	*Lower secondary*	*Upper secondary*	*Total students*	*Total teachers*
Age of the students	6-10 y	11-13 y	14-19 y		
Micro-robots labs	952	1.295	530	2.777	78
Machines and industrial processes labs.	1.533	67	141	1.741	80
Industrial plants guided visits	-	-	214	214	9
Museum-workshop exhibits guided visits	-	-	36	6	2
Total students	2.485	1.362	921	4.768	
Total teachers	112	36	21		169

Source: Officina Emilia database. Modena and Reggio Emilia University. 2014.

The Officina Emilia micro-robots labs usually last four hours and belong to the two following groups.

"A robot that follows a line" is a laboratory for young people from 12 to 19 years old, where teams of 3-4 students build a robot with LEGO® bricks, following instructions without verbal directions. Then, each team writes the software program to make the robot follow a black line on a white background. Teams test their robots and compete to assess the performances and the strategies adopted in programming. During the lab, students watch videos and/or meet technicians or entrepreneurs producing or using robots. A more complex version of the same lab was tested inspired by the "Roberta" international program [22]. This lab is dedi-

cated to girls between 15 and 19 years and includes the construction of four different robots, using different sensors.

"Robot-Cocco-Drillo" is a micro-robots lab for children aged between 8 and 11 years old. Students construct an automatism, in the form of animal, able to move. They learn to use a sensor in connection with a computer. The languages of verbal description, iconography, the flowchart and the programming software WeDo® are compared. Children listen to stories about workers and robots helping them to do hard work, or robots used to do surgical operations and to explore distant and dangerous lands. The last part of the laboratory is realized by the direct observation of machine tools and industrial artifacts. The age of participants allows to draw attention to the quality and weight of the materials.

The activities of educational robotics involved extensively the students enrolled at lower secondary schools (11-13 year olds). Teachers used these labs to support the pursuit of two objectives. The first is the enhancement of technology education, which they believe was adversely affected by the Italian reforms of the education system of the 2000s. The second is to help students and their families to make informed choice, at the end of their middle school period. Teachers expressed a strong need for data and tools to effectively introduce the students to the industrial structure of the area where they live, and which influences their educational, training and professional opportunities.

The experience of Officina Emilia with the schools shows that the hands-on activities, and the opportunity to observe a workplace under appropriate guidance, widens the horizons of thinking, helps the imagination, supports self-esteem in confronting technological challenges (in particular with regard to girls approaching technologies they consider as largely outside their interests), opens to insights in several domains (as in reconnecting what students do in the labs with their parents' or relatives' jobs, which they generally do not consider of any interest and they learn to appreciate in a different perspective).

The same experience highlighted a remarkable gender issue. 63% of the students who attended the Officina Emilia workshops are boys and this higher percentage than girls is a consequence of the higher involvement of technical and vocational schools, with a lower concentration of girls. But it is also the consequence of the higher rate of girls skipping technology labs. Vice versa, the proportion of men among teachers is clearly a distinct minority (9%). The participation of girls to the micro-robots labs was slightly higher than the average, but the girls experience of technologies challenges any innovation in the education system. Even the massive prevalence of women among teachers, often with an initial education in humanities, asks to urgently and effectively address the settled preconceptions about women's education that are reflected in the behavior of the younger generation.

4 Some concluding remarks

New skills are needed to cope with the changing and unpredictable situations inside organisations and society, and to foster re-industrialisation. These new

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skills must be grounded on the interweaving of knowledge in different fields, on technical skills, on social and economic understanding and on relevant soft skills. The demand for new skills requires new learning processes and these must feed on the contributions coming from Vygotsky [23][24], Dewey [25][26][27], Papert [28] and Hutchins [29]. Contextualized knowledge and open learning environments, with multiple opportunities and cooperative ways of working, are crucial for any successful learning processes. Education and training have to meet these challenges.

Let us summarize what seems to be relevant in supporting the necessary changes. The teachers are the internal resources of the education system to be involved in innovation programs. Often, they do not find effective programs and additional resources to implement innovative processes. In this situation, the processes of innovation, spontaneously budding within individual schools, are compromised, as well as the capacity of schools to accommodate the best practices that can be learned by peer exchanges. To quickly promote the changes needed, we need to identify which other actors can produce such changes. Regional authorities and the universities can play an important role in supporting the innovation in the education system and improving its effectiveness. Some Italian regional governments proposed guidelines for the curricula in order to support the development of new skills, other regions have delayed any decision or decided to let their schools freely choose how do this in the best way they can. Universities have the institutional task to train teaching staff and they may extend their support toward multidisciplinary research (and in some cases they already do) by helping with the design of curricula and by supporting educational planning, the creation of materials, the assessment of the education processes.

In the absence of support and guidance, a low rate of innovation can be expected even if education needs require urgent attention. To pave the way of reform initiatives, there are feasible, faster and incisive changes which can be started involving local and regional actors. The Officina Emilia action-research highlights two main ingredients to support innovation. First, having an available hybrid place (fostering innovations) worked as a stimulus for teachers to produce effective education practices, with relevant agents (from university researchers to manufacturing and services companies, education agencies, civil society) acting through the action-research. Second, the robotics labs, among others, emerge as an effective means to foster a multidisciplinary perspective, crucial for the new challenges that education faces in supporting re-industrialization.

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