Evolution of the academic FabLab at University of Naples Federico II

Leopoldo Angrisani¹, Pasquale Arpaia¹, Guido Capaldo², Nicola Moccaldi¹, Piero Salatino³, and Giorgio Ventre¹

¹ Department of Electrical Engineering and Information Technology;
² Department of Electrical Engineering;
³ Polytechnic School of Basic Sciences,
University of Naples Federico II, Naples, Italy.

Abstract
In this work, after a briefly excursus on two models of academic "learning contexts", the experience underway at the University of Naples Federico II is described. The path from a FabLab 1.0 born on the field, by spontaneous initiative of some teachers and students, towards a new structured and institutional learning is described. This new FabLab 2.0 constitutes an opportunity, based on the international experiences of "FabLab" and "Learning Factory", of facing the educational challenges posed by the transition to the context of "Industry 4.0".

1. Introduction
Switching from teaching knowledge to teaching competences is the challenge not fully faced by the contemporary academic training system. The attention to competences rather than knowledge is certainly due to the transformation speed of the current production system, but also to the peculiarities of the new "Cyber-physical production systems" [1], in the context of Industry 4.0.

Competences are defined here as a combination of knowledge, skills and attitudes appropriate to the context [2]. A multi-dimensional holistic competence approach [3] does not separate cognitive, functional, and social dimensions, recognizes the over-arching role of meta-competences, and offers the opportunity of better exploiting the synergy between formal education and experiential learning to develop professional competence. To allow students to develop competences it is necessary to build "learning spaces" [4] to carry out research, to identify and solve problems, to collaborate with others in managing situations, ponder and evaluate their actions. Over the last few years, two important models for facing this complex educational challenge are the FabLab and the Learning Factory.

In this paper, the experience of the academic FabLab at the University of Naples Federico II is described. The new FabLab 2.0 opportunity, based on the international experiences of "FabLab" and "Learning Factory", of facing the educational challenges posed by the transition to the context of "Industry 4.0" is described.

2. FabLab-based education background
After computation (personal computer) and communications (convergence and mobile phones), the next digital revolution [5] could be in the field of manufactured physical goods (personal
fabrication). From this intuition, the first FabLab was founded at M.I.T. by Prof Gershenfeld in 2001. The FabLab was conceived with the tools and computing power "to make almost anything", with the ambitious goal of infusing new ideas and opportunities into global solutions, and giving a boost to local entrepreneurship and job. A few years later, a FabLAB network was born, promoted by MIT’s mother node. Each new member is equipped with some basic tools (lasers engraving & cutting, milling machine, vinyl cutters and 3D printers) and signs a charter of intent with the commitment of sharing the gained knowledge and experience. Today, about 300 individual Fab Labs have considerable autonomy, as centers of community-driven innovation, where problems can be solved using local materials and those solutions can be shared with similar communities around the world-wide. FabLabs provide tools for community to develop at their own rate and within their own culture [6]. The Fab Foundation at MIT plays a coordinating role and provides services that the independent FabLabs can not obtain or afford on their own.

In 2008, Stanford University launched the project FabLab@School, and started building FabLabs in K-12 schools around the world. This initiative, promoted by Prof. Blikstein, was grafted onto a three decade-old cultural movement based on theoretical and pedagogical pillars: experiential education, constructionism [7], and critical pedagogy [8]. Blikstein’s analysis starts from the observation that “A traditional school science lab depends on a highly scripted instructional model. All students progress in linear fashion” [8]. The new educational proposal is based on open-ended questions as a starting point, with no “correct” answer on the other hand. The uniformity and predictability promoted by traditional models gives way to collaboration and creative problem-solving. FabLearn Labs, which are embedded in technology, permit the acknowledgement and embracing of different learning styles and epistemologies, engendering a convivial environment, where students can realize their ideas and projects with intense personal engagement. With openness and collaboration in education as part of their mandate, FabLearn Labs also create new possibilities in STEM (science, technology, engineering, and math) education in diverse contexts: from universities, high schools and libraries, to grassroots community-driven labs.

3. Learning Factory
Since 2000 learning factories for education, training, and research have been built up in universities. In recent years, learning factory initiatives were elevated from a local to a European, and then to a worldwide, level. In 2014, the International Academy for Production Engineering (CIRP) started a Collaborative Working Group (CWG) on the topic Learning Factories. The Initiative on European Learning Factories, which is an initiative of 10 academic institutions spread all over Europe, defines the term learning factory as follows: “A Learning Factory is a learning environment where processes and technologies are based on a real industrial site which allows a direct approach to the product creation process. Learning Factories are based on a didactic concept emphasizing experimental and problem-based learning”. (Initiative on European Learning Factories 2013) [9]. The word learning in the term, as opposed to teaching, emphasizes the importance of experiential learning. Intrinsically motivated students are more engaged, retain information better, and are generally happier [10]. From a teaching perspective, the learning factory is a complex learning environment, which facilitates a self-contained, high-quality competency development[11]. Some research, however not longitudinal and on small cohorts, show the effectiveness of the factory learning approach compared to traditional approaches [12]. The effectiveness of gamification in teaching, (e.g., the simulation of working contexts), has also been assessed through longitudinal studies [13].

The core of the learning factory concept is a high degree of contextualization (close to real factory environments) and a hands-on experience of the trainees [9]. The learning factory is also a research enabler, where learning factories facilitate the problem identification and solution verification for technological or organisational matters.
3.1. Industry 4.0
The term Industry 4.0 describes the vision of intelligently automated factories, in which workers, the production system itself, products and even customers are connected. New factories will be ad hoc networked, by exploiting real-time, adaptive, decentralized and self-optimizing Cyber-Physical-Production Systems [9]. In this new scenario, workers will have to (i) manage new information, (ii) solve unstructured problems, and (iii) perform non-routine manual tasks. Among the required new skills, the abilities to have an overview of the production system, identifying the boundaries and the internal relations in order to foreshadow the evolutionary scenarios of the system itself, stand out. A traditional teaching approach does not seem to provide answers to the new skills required by the future manufacturing environments. Learning factories and FabLabs, which already have an emphasis on interdisciplinarity and a close-to-practice approach, are well suited to represent the ideal contexts where the new teaching can offer answers to the challenges proposed by "Industry 4.0" [14].

4. FabLab 1.0 at Federico II
At the Federico II University of Naples, since the spring of 2015 [15], dozens of students have been involved in designing and carrying out numerous prototypes for the acquisition of experimental skills such as training on job, transversal to the different Study Courses of the Department of Electrical Engineering and Information Technology (DIETI). Main projects covered the sectors: IoT Monitoring, Additive Manufacturing, and Biomedicine.

The students measured themselves with the technical and communication challenges typical of the presence at events such as Futuro Remoto 2016 and 2017, HackFest of STMicroelectronics 2016 and 2017, Serious Game AIDII Factory 4.0 2016, and Maker Faire of Rome 2017. Students have enthusiastically joined the initiatives though not benefiting of training credits yet.

A fruitful collaboration was opened with the UniNa Corse team and a website was created - http://FabLab.dieti.unina.it/ - hosted on the DIETI server. An educational project was activated in collaboration with the DuckieTown project of the MIT. FabLab 1.0 was awarded by funding from the Region Campania, for an amount of 40,000 euros, in collaboration with the Municipality of Marigliano and the cultural youth association "Per La Tecnica". The innovative aspect of the teaching proposal, in particular, combines making and playing business emulating the actual working processes of a virtual company, operating in IT research and development (R&D). Indeed, companies actually operating on the market have commissioned prototypes providing technological support and technical know-how to enable student-entrepreneurs to achieve the goal, under the didactic supervision of the teachers’ team.

An example of typical activity carried out in the FabLab of Federico II is the project "Smart Industries 4.0" (Fig 1). The complete autonomy of the machines are run through the machine2machine communication according to the paradigms of the Internet of Things. In the prototype, raw materials travel in the basket on a loop formed by conveyor belts where there are four production islands, one for each side. The cart knows what these raw materials must become, and calls to other machines by those who can be worked according to the criterion established by the user. The machine chooses the sequence of activities and at which machining center them, in order to optimize and maximize production. In this way, on the same loop different productions can be assembled.

Currently, the leading group of students of the biennial 2016-2017 reached the Degree. The main tutors, all belonging to the Measurements Group, resigned, due to problems of educational overload. As a result, the students stopped their participation and the activities were strongly reduced.

It was recognized that volunteering and spontaneism are not enough. But, given the success of the experience, we want to move to a new, more structured, and professional phase.
5. Proposal of FabLab 2.0
The new FabLab 2.0 is designed as a curricular and extracurricular intramoenia educational workshop, where the peculiarities of orientation to experimentation and practice, of cultural transversality oriented to the labor market, and of training on the "real" projects are taken up and enhanced. The aim is to create a multidisciplinary laboratory in the premises of the Polytechnic School of Basic Sciences, where activities can be carried out purely oriented towards experimentation, as well as job creation in the field of professions and industry. This laboratory is characterized by the participation of industrial companies capable of proposing activities with a high level of innovation, with applicative repercussions sensitive to market demands. The FabLab 2.0 takes on a dimension of cultural education, according to the aforementioned guidelines, with skills transversal to study courses and departments. FabLab 2.0 is also proposed as an opportunity to carry out work-school alternation projects in collaboration with upper secondary schools. FabLab 2.0 offers students the opportunity to carry out the training activity scheduled before the final discussion of the MSc thesis. An intramoenia internship characterized by a strong interdisciplinary approach, by contact with companies, by the didactic supervision of the FabLab 2.0 Technical and Scientific Committee (TSC). In addition, at the FabLab 2.0, from three up to six training credits can be achieved, which can be attributed to the other activities chosen by the student in BSc and MSc degree courses. FabLab 2.0 is also proposed to all students interested in cultivating the passion of making during their course of study without having this experience as curricular. FabLab 2.0 offers tutors the opportunity to develop innovative educational projects tangent to experimental research activities in order to create continuity between teaching, thesis activities, and research.

5.1. Organization
TSC collects the proposals from the partner companies and in consultation with the tutors defines the list of projects to be implemented. Each tutor is appointed as responsible for a project, but guarantees, for his own specific competence, a transversal support to any other project. The partner companies provide technical know-how and equipment. Each student adheres to a single project by joining a group that operates as a staff of an R&D company. The CTS supervises (i) the definition of the learning objectives, (ii) the construction of the learning space (also through the use of Virtual Reality and Augmented Reality), and (iii) the modality
through which the tutors provide stimulus and support to the teamwork and learning of each student using methods inspired by cooperative learning, gamification, and learning by doing.

6. Conclusions
The ambitious challenges with which TSC and tutors will have to cope will be to find the right mediation between different thrusts: theory vs practice; research vs teaching; job vs training, fun vs engagement, individual activity vs group work, specialization vs multidisciplinary, public interests vs private interests. It is in the skillful mixing of these ingredients that the success of learning competences will be played.

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