THE INNOVATIVE EDUCATIONAL APPROACH IN THE SUPSI MINI-FACTORY

Fabio Daniele^{1*}, Matteo Confalonieri², Andrea Ferrario³, Lorenzo Agbomemewa⁴, Michele Foletti⁵, Niko Bonomi⁶, Ludovica Rossi⁷, Andreas Graf⁸, Paolo Pedrazzoli⁹

¹Mr, SUPSI, Switzerland, fabio.daniele@supsi.ch

²Mr, SUPSI, Switzerland, matteo.confalonieri@supsi.ch

³Mr, SUPSI, Switzerland, andrea.ferrario@supsi.ch

⁴Mr, SUPSI, Switzerland, lorenzo.agbomemewa@supsi.ch

⁵Mr, SUPSI, Switzerland, michele.foletti@supsi.ch

⁶Mr, SUPSI, Switzerland, niko.bonomi@supsi.ch

⁷Mr, SUPSI, Switzerland, ludovica.rossi@supsi.ch

⁸Mr, SUPSI, Switzerland, andreas.graf@supsi.ch

⁹Mr, SUPSI, Switzerland, paolo.pedrazzoli@supsi.ch

*Corresponding author

Abstract

The manufacturing industry constantly faces complex challenges: fierce competition, shorter product lifecycles, increased variability, fluctuating demand and, lately, pandemic related issues are just a short list. In this continuously evolving scenario, industries are trying to enhance their resiliency, efficiency and long-term planning capabilities through the exploitation of the latest advances in information and communication technology. The resulting demand for a digital transformation impacts each phase of a company's life cycle, from product and process design to the optimization and day-to-day management. In this novel manufacturing environment, the human's activities are still essential and significant but are unavoidably changing their nature, increasing complexity and heterogeneity. In order to deal with the educational needs of handling these new issues, in the last decade numerous learning factories have been developed. Learning factories, as a teaching and learning ecosystem, have shown to be effective for developing theoretical and practical knowledge in a real production environment and are, hence, a suitable testing bed for both validating new technologies and concurrently delivering peculiar training through innovative, hands-on methodologies.

This paper portrays, with a strong focus on educational aspects, the specificities of the learning factory implemented at the University of Applied Sciences and Arts of Southern Switzerland: the SUPSI Mini-Factory. The SUPSI Mini-Factory is a learning factory in the narrow sense, providing a real value chain, where participants can perform, evaluate, and reflect their own actions through a hands-on learning approach. Firstly, the guiding principles, chosen for the SUPSI Mini-Factory development, are clearly introduced and justified considering both the didactical purposes and the arising companies' requirements. Secondly, the equipment composing the SUPSI Mini-Factory are outlined emphasizing their functions, both as individual and as part of the whole system, within the SUPSI educational offer. Finally, the innovative didactic approach enabled by a pervasive use of key digital technologies is presented proving its educational effectiveness.

Keywords: Education, Management Engineering, Learning Factory, Technology

1 INTRODUCTION

Modern industries are facing several challenges, ranging from the integration of new technologies and the consequential upskilling of operators, to the effective exploitation of research and innovation activities. Those elements are cornerstones to survive in a fast-changing market, where, as lately witnessed, the capability to properly handle automation, resilience and flexibility have a key role towards competitiveness. To develop competencies for these novel manufacturing environments, but also to bring academic research closer to real industrial practices, traditional teaching and R&D methods have shown limited results (Abele et al., 2015).

In the last decades, new approaches have arisen allowing, on the one hand, to train in realistic manufacturing environments and, on the other hand, to develop and test R&D solutions in the field: indeed, the use of learning factories has increased in Europe and has demonstrated to be an example of a proper ecosystem where hands-on education, research and technology-transfer between academia and industry happens (Wagner et al., 2012).

This paper addresses the peculiarities of Mini-Factory ecosystem, which is a long-term ongoing project that went online in September 2018 within the Institute of Systems and Technologies for Sustainable Production. Firstly, the Mini-Factory configuration and implementation details are comprehensively portrayed illustrating the manufactured product and its production process. Afterwards, the didactic approach correlated with the Mini-Factory is clearly described and disclosed presenting its educational effectiveness. Lastly, some didactic use cases correlated to European projects are presented and discussed.

2 THE DESIGN OF THE SUPSI MINI-FACTORY

The SUPSI Mini-Factory is an intelligent automated system that produces and assembles personalized tangram game-sets, packaged into diverse boxes: starting from the customer's order, the factory assembles the desired game-set either taking components and boxes from the warehouse or by manufacturing the missing ones. The tangram is a Chinese dissection puzzle, consisting of seven flat shapes, called tans, which are put together to form diverse shapes.

Relying on the previous experiences in the design and development of small scale manufacturing environments (Barni et al., 2017), the guiding principles chosen for the SUPSI Mini-Factory development have been: 1) Modularity; the use of flexible automation enables the demonstration of factory resilient behaviour and easily re-configurability 2) Integration of diverse technology vendors; demonstrating realistic industrial scenarios and overcoming communication barriers 3) Innovation; demonstrating the effectiveness and production efficiency of I4.0 technologies 4) Product customizability; demonstrating aptitude to successfully meet different evolving customer requirements. These carefully selected principles reflect the modern I4.0 vision enabling the usage of such an environment for research purposes, seeking, testing pioneering technological and organizational approaches but, above all, for educational purposes improving the hard and soft capabilities of young engineers.

This fully automated and integrated system provides a reality-conform production environment both to deploy, test and improve technological and/or organizational innovation and to allow an effective competency development of trainees. In particular, students and manufacturing professionals have the possibility to experience a fully I4.0 hands-on approach and to take part in interdisciplinary activities, collaboration, and practical technological transfer between university and industry. The training can be offered on many different disciplines, ranging from automation and mechanics to production management and computer science, emphasizing the hands-on experience gained by applying the knowledge learned at the culmination of engineering education to solve scientific problems related to a real production environment. Accordingly, several research projects focused on education involving different European academic partners have already been enabled by SUPSI Mini-Factory in parallel with its introduction in regular engineering courses tenured at SUPSI.

As well as education and training purposes, thanks to the flexible system architecture, both at software and hardware level, the SUPSI Mini-Factory is a high adding value instrument for supporting applied research through making available an environment to study, develop, test, and deploy fully automated and modular solutions for industrial applications. Accordingly, several research projects involving different industrial partners and spacing among different engineering topics, have already been enabled by the SUPSI Mini-Factory, successfully ending with the deployment of innovative solutions on real industrial sites. It is worth specifying that the intensive and constant participation of the SUPSI Mini-factory in research projects involves also positive impacts on education and teaching. Specifically, all the knowledge and experience

gained through working closely with a variety of industries enables the researchers to precisely define and keep up-to-date the skills needed in today's manufacturing sector and teach them, in a second moment, to the students during classes.

2.1.1 The Product

The SUPSI Mini-Factory, operated by the University of Applied Sciences of Southern Switzerland, is an Industrial Internet of Things (IIOT) system that automatically produces and assembles personalized tangram game-sets, packaged into diverse boxes. A tangram is a Chinese dissection puzzle, consisting of seven flat shapes, called tans, which are put together to form diverse silhouettes, as can be seen in **Figure 1**. The tans, available in multiple forms and colors, come together with a box and a cover, made of plastic material or wood. The Mini-Factory is usually busy with the production of game-sets made to stock, to be gifted to visitors and partners as a gadget. Even if the tangram is not a high-tech product, it is exceptionally suitable for the didactical purposes of the laboratory, since:

- It allows the students enrolled in the management engineering course to be trained at a complexity similar to that which they will later find in manufacturing companies;
- A considerable high number of combinations can be manufactured, enabling a series of activities belonging to the customization process;
- It allows combining internal and external flows of components/materials (e.g., the wooden boxes are ordered from a nearby supplier) creating a scaled supply chain.

The tangram has not been thought and developed aiming at generating a revenue stream from customers but it is just an appropriate representation of any real industrial product and the 3D printers should be seen as productive modules, which in real manufacturing environment can represent e.g., a CNC machine, a quality control station or whatever value-added in a factory.

Figure 1: the tangram silhouettes

2.1.2 The tangram Production Process

Once the customer has configured the personalized tangram, the scheduler rearranges the to-stock production, to make room for the new order (the customized order, while given priority, coexists with the production of the to-stock tangrams). The system checks the components already available in the warehouse and, if something is missing, commands the production of those elements. The warehouse nominal status is known to the system, but the actual status is verified through RFID tags (3)¹. Likewise, the system checks for the production modules (10) status and capacity to perform the given tasks (the modules self-declare their status and an array of smart cameras (10) accurately define their location, to self-adapt to variation in configuration and position) and assigns the realization of the missing components to the more suitable module. The needed components are retrieved from the warehouse by a cartesian robot (2) and they are moved to the assembly station (11), by means of a carriage driven by a transportation system based on a linear motor (5), which features two carriages that can be moved independently one from the other. The carriage commutes back and forth from the warehouse (1), to collect all the components. On the way in after being produced, the geometrical features of the components are checked by a laser scanner (4), both to perform a quality check, and to acquire the real geometry of the tans, which may differ from the

¹ The numbers refer to Figure 2: SUPSI Mini-Factory components holistic view

nominal one. In the assembly station, a SCARA robot (7) starts the assembly procedure. The SCARA is equipped with an intelligent vision system to correctly pick the tans, even if misplaced, and to detect and correct failures in the assembly process (no mechanical jigs are in place, as the process is fully driven by an extensive use of machine vision). The SCARA is also tasked to retrieve the newly produced tans from the production modules: once the modules are finished printing the required components, the SCARA picks up the printing bed and places it on the detachment station (9). The tans are then brought to the assembly station. The positioning of the selected cover on the top of the box completes the assembly process. The boxed TANGRAM is eventually picked by the SCARA robot from the assembly table and brought to the warehouse by the carriage. In order to complete those operations, the SCARA robot needs different grippers, which are stored in a dedicated warehouse (8), and automatically changed throughout the various operations.

2.1.3 The SUPSI Mini-Factory Equipments

The flexible production and assembly system described is capable to dynamically respond to customized orders, while still operating to stock, and demonstrates a significant amount of adaptability and resilience. The hardware and software components, mapped in Figure 2, are hereby listed in more detail.

Figure 2: SUPSI Mini-Factory components holistic view

1. **Vertical warehouse** (Bosch-Rexroth profiles and custom steel components). It features a grid of 81 slots, each one capable to host a pallet. A central slot acts as gate for loading/unloading and is linked with the rest of the transportation backbone.

2. **Three-axis Cartesian robot** (Bosch-Rexroth IndraDrive Cs motion control and MSK040C/MSK040C Rexroth 3-Phase Synchronous Permanent Magnet Servo Motor). It serves the warehouse as it interfaces and retrieves the pallets, where the components of the tangram are stored on.

3. **RFID system** (X-NUCLEO-NFC05A1). It is mounted on the cartesian robot and it is meant to check the warehouse inventory consistency against the nominal status. Small RFID tags are placed on each of the pallets in use in the Mini Factory; initial assignment of pallets content to its relative tag is done manually by means of a second RFID system placed in the control station.

4. **Laser triangulation sensor** (Micro-epsilon scan CONTROL 2950). It is coupled with an optical linear encoder (Rexroth, IMS2A-KWD-020-SNS) of which the optical stripe is embedded in one of the rails on top of which the carriages move, and installed in the interfacing slot between the vertical warehouse and transportation system. This in order to verify the geometrical features of the produced work-pieces. The laser has two main scopes: (a) perform a quality check of the printed objects, (b) acquire the real geometry of the objects, which may differ from the nominal one, in order to enable a better synchronization between the physical factory and its digital counterpart (see Digital Twin section).

5. **Transportation system** (Bosch-Rexroth NYCe 4000 motion control, TECNOTION TM6Z linear motor). It

features two independent carriages and it is based on a linear motor system. The first carriage can enter the warehouse and is used to transport the pallets along the transport system, while the second carriage transports the SCARA robot along the line, to perform the assembly tasks and to load-unload the production modules.

6. **Control station with PLCs** (Omron NJ501-1400) **and HMI** (Omron NA5). Those are meant to provide logic control and supervise all the different factory components.

7. **4-axes SCARA robot** (Omron-Yamaha R6 XGL 400150). It is used for all the pick & place operations. The robot can automatically mount different tools depending on the needs: a fork for moving the pallets, a small gripper for the tangram pieces, and a larger gripper for the covers. A smart camera (Wenglor Weqube B50S103) is mounted on the robot end effector. The camera empowers smart interaction with the surrounding environment: the workpieces do not have a fixed position on the pallet, as the precise location is retrieved by the camera and sent to the robot, additionally, assembly errors can be corrected on the run. In addition to the vision driving the SCARA robot operations, the grippers themselves are able to provide pressure-based feedbacks enabling the system to be resilient to eventual missed grips.

8. **Automatic tool-change**. A set of different tool-heads for the SCARA robot is coupled with an automatic tool change interface (SCHUNK SWS), which allows the robot to interface with pallets, work-pieces and workstations. During production process, grippers can be automatically changed through the vision system mounted on robot end effector. These grippers have been developed internally, and their structure is produced by the Mini Factory system itself, providing an example of the capability of self-replacing some of its own components.

9. **Detachment station**. A dedicated station allows the automatic detachment of 3D printed pieces from the printing bed. The SCARA, equipped with vision system, cooperates with the detachment station, which deforms the 3D printing bed to detach the components. The exact picking position, strength and movement coordination is managed by an AI system that leverages past detachment experiences to perform an optimized task. The printing bed is designed with a silicone-based rubber coating in order to enable such a process without limiting the material deposition quality.

10. **Production modules**. 1 to 4 production modules can be aligned on one side of the 4 meters long transport system. The current configuration, meant to be highly modular, consists of two 3D printers (that manufacture the tans and the plastic boxes) and the collaborative station equipped with an UR robot (an alternative way to assembly game-set). An array of cameras (Wenglor Weqube B50M110) identifies the production modules functionality and relative position, in order to inform the system about the production options available and automatically compensate for detected deviations from the nominal relative positions. This allows always the SCARA robot for loading and unloading even if production modules are misplaced with respect to the nominal situation.

11. **Assembly station**. Facing the production modules, on the other side of the linear motor system, an assembly table can host up to 3 pallets contemporarily to allow assembly operations. The tool-head warehouse is positioned here as well.

12. **Human-robot collaborative station**. This working station, equipped with a UR Cobot (Universal Robots UR5e), represents an alternative way to assembly the tangram game-set. Specifically, the operator, in collaboration with the UR Cobot, completes the required figure using the flat fragments supplied by the SCARA robot. The Cobot, whose actions are an immediate consequence of the human ones, takes care of inspecting the type of tans placed and their relative positions through the sensors installed and the vision system mounted on the gripper (SENSOPART Visor V20C-R0).

13. **Digital Twin**. The physical Mini-Factory is associated to an evolving digital profile, based on constant synchronization through IoT devices: the Mini-Factory digital twin. The Mini-Factory digital twin is based on massive, cumulative, real-time, real-world data (OPC-UA protocol): these data create an image of the factory process in the digital world, including the product geometrical characteristics acquired by laser scanner, and provide important insights on system performance, leading to actions in the physical world. These actions comprise the support of the Mini Factory production scheduler; in particular, it takes advantage of the digital twin by means of running several simulated production scenarios in order to always provide the most suitable one according to the objective function that has been set (e.g., productivity maximization).

14. **AR/VR**. Each of the Mini Factory components, including IoT devices, that produce data (e.g., status, performance, etc.), stream them to an OPC-UA server, which is accessible not only via direct access to the server itself but also through portable Augmented Reality goggles (i.e., Microsoft HoloLens 2). Consequently,

the reality of the factory is enriched with real time data visualized on each of the factory modules that are automatically detected by the goggles through the usage of QR codes stamped on each different module.

15. **SCADA.** The supervisory control and data acquisition is a computer system for gathering and analysing real time data. For SUSPI Mini-Factory application, the iFix suite of GE has been selected. Latest version is fully compatible with the OPC-UA protocol, which allows an easy integration with the existing architecture. All the devices can be easily monitored and controlled; moreover, data can be safely stored guaranteeing consistency and allowing live or post analysis.

16. **CYBER PHYSICAL SYSTEMS.** Various additional computational systems used to monitor and control dedicated parts of the factory, allowing in general a better compatibility between the devices, easy scalability, redundancy/backup, security, off-line testing, and reduced computational request on the main PLC. Examples of such system are secondary industrial PLCs, Windows and Ubuntu based PCs, Raspberry and smartphone, whilst applications space between RFID antenna control, OPC client-server support, 3D printer remote control, 3D printer filament usage monitoring, data collection and analysis, off-line and real-time simulation.

2.2 The technologies at the Service of Education

Didactics is one of the main drivers for the development of the SUSPI Mini-Factory. The main idea is to give students the opportunity of a real hands-on education by challenging them with authentic manufacturing issues on an actual plant, with a particular focus on the industry 4.0 paradigm. This represents both an opportunity to enrich with a valuable experience the management engineering curricula, and to meet the competencies needs of the companies that will hire them in the future (Abele et al., 2018).

In the SUSPI Mini-Factory trainings, students develop technical, methodological, and implementation-oriented competencies through the learning scenario accurately designed based both on instruction and demonstration strategies. Didactics aims at enhancing the student's cognitive skills through both onsite lessons and laboratories, done directly in the factory environment, and remote lectures.

During practical lab course, researchers, in the didactical double role of presenter and instructor, lead student classes in customized trainings about engineering fields, including: (a) PLC programming, (b) plant supervision, (c) mechatronics, (d) IoT, (e) production scheduling, (f) 3D printing, (g) vision systems. The cognitive foundations of these disciplines, needed to complete the hands-on activities, are provided during theoretical lectures with the support of specific didactical material.

Moreover, thanks to the functional digital replica of the factory that allows an accurate reproduction of the factory behavior offline, students could work on the master PLC, programming and testing their code, without risks of collisions or, in general, of creating damage. The digital simulation system also enables students to experience and work in parallel without the need of taking turns on the actual plant with the other groups, avoiding waste of learning time.

At the end of each course, depending on the thematic faced, students' competences are evaluated with a specific exam methodology that could range from a written or oral knowledge test to practical presentation of a didactical project based on the automation. Often, the students are challenged with practical projects carried out directly on the real equipment of the Mini-Factory. The hands-on activities allow students to both acquire confidence in working with real industrial machines and gain specific vertical competences, as reported in **Table 1**.

Table 1: the competences gained through the direct use of Mini-Factory equipments

#	Mini-Factory Equipment	Course	Competences gained
1	Vertical warehouse	Industrial Control	<ul style="list-style-type: none"> Order management IT systems
2	Three-axis Cartesian robot	Industrial Control Mechatronics	<ul style="list-style-type: none"> Programming skills Design of a mechatronic system
3	RFID system	Industry4.0	<ul style="list-style-type: none"> Programming skills

			<ul style="list-style-type: none"> • Data science • Networking
4	Laser triangulation sensor	Industry4.0	<ul style="list-style-type: none"> • Programming skills • Sensors • System integration
5	Transportation system	Industrial control Mechatronics	<ul style="list-style-type: none"> • System integration • Design of a mechatronic system
6	Control station with PLCs and HMI	Industrial control Industry4.0	<ul style="list-style-type: none"> • Programming skills • Critical thinking • Strong communication
7	4-axes SCARA robot	Industrial control Mechatronics	<ul style="list-style-type: none"> • Programming skills • Design of a mechatronic system
8	Automatic tool-change	Intelligent manufacturing	<ul style="list-style-type: none"> • System integration • Communication protocols
9	Detachment station	Intelligent manufacturing	<ul style="list-style-type: none"> • System integration • Communication protocols
10	Production modules	Industrial control	<ul style="list-style-type: none"> • Additive manufacturing • Production systems
11	Assembly station	Intelligent manufacturing	<ul style="list-style-type: none"> • Production scheduling • Lean production
12	Human-robot collaborative station	Intelligent manufacturing	<ul style="list-style-type: none"> • Programming skills
13	Digital Twin	Industrial Control	<ul style="list-style-type: none"> • Programming skills
14	AR/VR	Intelligent manufacturing	<ul style="list-style-type: none"> • IIoT systems • Monitoring applications
15	SCADA	Industrial systems for supervision and data acquisition	<ul style="list-style-type: none"> • Programming skills • Plant monitoring • Data management • Business intelligence
16	CPS	Industrial control	<ul style="list-style-type: none"> • Programming skills

		Industry4.0	<ul style="list-style-type: none"> • IT systems • System integration
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Moreover, the Mini Factory enabled opportunities in the field of didactics paved the way for collaborations in international research consortia in the field of education through the framework of EIT manufacturing as detailed in the following paragraph.

3 DIDACTIC USE-CASE: REGULAR BACHELOR AND MASTER ENGINEERING COURSES TENURED AT UNIVERSITY OF APPLIED SCIENCE OF SOUTHERN SWITZERLAND

Students of management engineering are not experts in programming, but it is useful for them to understand the logic behind PLC and SCADA, as they are widely and commonly used in many factories.

Students are introduced to ladder language in the Industrial Control course, by both a theoretical and applied approach and, as already said, the acquired knowledge is applied to actual cases by using PLCs with simulated response generated by the Digital Twin, allowing parallel work and avoiding damage to machines. However, this still requires very accurate programming skills, which is not the focus of this academic curriculum. In order to overcome the technical barrier and focus mainly on the logic and optimization of the production sequence, a paper-based approach has been developed: students are given paper strips, each one representing a single factory operation written in a ladder and structured text format. The strips should be put in the right order and with the appropriate input parameters based on the task objective. Complexity can be easily incremented, e.g., by allowing parallel operations. The generated sequence can then be easily implemented using the actual software and the whole code tested, previously on the Digital Twin and then on the real plant. This approach was found to be very appreciated by the students and knowledge acquired quickly and easily.

SCADA on the other hand is introduced in the Supervision and Intelligent Manufacturing course. SCADA systems are used to monitor and control a plant or equipment in industries such as telecommunications, water and waste control, energy, oil and gas refining, pharmaceutical, and transportation. For our factory, the iFix suite of GE has been selected. The latest version is fully compatible with the OPC-UA protocol, which allows an easy integration with the existing architecture. All the devices can be easily monitored and controlled; moreover, data can be safely stored guaranteeing consistency and allowing live or post analysis. Students of management engineering are able to test their theoretical knowledge about SCADA within a real environment. iFix offers client and server configurations, meaning that students can develop their own interface (as a client) and use common field data (collected by the server). During the course, students are introduced to the software through practical examples, both of generic plants and related to the SUPSI Mini Factory. The course ends with a project where each group of students focuses on a particular topic regarding the Mini-Factory, such as warehouse, transport system, SCARA robot and cobot, energy consumption. They are asked to develop a part dedicated to supervision and data collection, as well as a control part to perform simple operations directly on the Mini-Factory (**Figure 3**).

Figure 3: an example of a SCADA application supervising the Mini-Factory

4 DIDACTIC USE CASE: EIT MANUFACTURING – M-NEST-I, MIRRORLABS PROJECTS

The characteristics of SUPSI Mini-Factory enable the opportunity for participating in research projects targeting the usage of learning factories in education. These projects realize educational tools to be implemented in existing different learning factory infrastructures among EU universities. These projects include MIRRORLABS and M-NEST-I.

MIRRORLABS (EIT Manufacturing) develops a common, easy-to-use ICT infrastructure for the existing equipment, in the learning factory labs of various EU universities. In particular, for SUPSI Mini Factory, it has been introduced a learning path for the education of students on human-robot collaboration and AR/VR applications leveraging on the usage of respectively ROS industrial robot control infrastructure and Unity virtual 3D model development platform. This project has empowered the Mini Factory human-robot collaborative station with the possibility of controlling the cobot with such an architecture and introduced the possibility of visualizing real time data streamed from each of the Mini Factory modules through the AR goggles (i.e., Hololens 2). These applications represent now the core of courses on I4.0 tenured at SUPSI.

M-NEST-I develops a distributed network of learning factories in order to make possible synergies among EU universities towards the formation of shared learning paths, where institutions with complementary facilities contribute together to provide a comprehensive training offer for university students and SMEs. These learning paths are composed by single educational nuggets, which are self-standing small portions of a course designed to be complementary to each other and to be tenured by different institutions in a coordinated manner. At SUPSI, leveraging on the Mini Factory, several nuggets have been developed in the field of automation, intelligent manufacturing, supervision systems, product traceability, and data analysis.

5 CONCLUSION AND OUTLOOK

Learning factories embody an opportunity, in terms of rapid integration of new technologies and upskilling of operators, for modern manufacturing industries. Representing a teaching and learning ecosystem, learning factories have shown to be effective for developing theoretical and practical knowledge in a real production environment and are hence a suitable testing bed for both validating new technologies and delivering peculiar training through innovative hands-on methodologies.

The SUPSI Mini-Factory is a learning factory in the narrow sense. Its configuration and all its characteristics, framed in the solid academic description model for learning factories provided by Abele et al, have been presented in this paper. Born from both the necessity of having a playground for the SUPSI Industrial Engineering faculty, where students can apply theoretical learnings, and from the necessity of having a testing bed where researchers can test new Industry 4.0 solutions and concepts, the SUPSI Mini-Factory is an evolving laboratory with the primary purposes of studying, researching and developing methods and tools for the design, analysis and management of products, processes and production systems.

The intelligent automated system produces and assembles personalized tangram game-sets, packaged into diverse boxes, starting from the customer order. Each step of the tangram game-set production process exploits equipment belonging to the most recent technologies of the I4.0 paradigm, including an RFID system, a laser triangulator, AR/VR, a digital twin and a human-robot collaborative station. All equipment is included in the courses allowing students to both acquire confidence in working with real industrial machines and gain specific vertical competences.

The characteristics of the SUPSI Mini Factory enable the opportunity for participating in research projects targeting the usage of learning factories for educational purposes but also enable the participation in applied research competitive public tenders involving external industrial/research partner.

The SUPSI Mini-factory is entirely operative for daily activities but its expansion, in terms of innovation, technologies integration and modularity, is constantly under development. Specifically, projects, regarding the introduction of an injection molding machine and an autonomous mobile robot (AMR) towards the realization of a hybrid production process (i.e., involving together mass production and rapid prototyping technologies) efficiently managed through a mobile human-robot collaboration workstation, have been already funded. The next research challenges will mainly regard both the commissioning and continuous integration of these machines and the improvement of the existing I4.0 technologies enablers as digital twin, activities scheduler and system adaptive behavior making SUPSI Mini-Factory, increasingly, a common i4.0 playfield for education and research purposes.

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