Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company’s public news and information website.

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1. Introduction

In the past few decades, pandemics have tended to rise in frequency. Since the 2002-2003 Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) epidemic has appeared including the Ebola outbreak (2014-2016) in West Africa that provoked more than 11,000 deaths. The SARS CoV-2 (COVID-19) which began in Guangdong province of Southern China, has spread across 188 countries, and has affected more than 8,489,675 total confirmed people worldwide and 454,023 confirmed deaths (June 2020) [1-3]. The current Coronavirus pandemic has expanded the gaps in the education sector globally. The Coronavirus pandemic is new though, but it already has noxious effects worldwide. The outbreak of COVID-19 has created educational disruptions and global health concerns, which have proved very difficult to manage through global health systems. There are more than 1,091,976 confirmed affected learners in more than 123 countries that have closed educational institutions as one of the measures to limit the spread of the coronavirus [4]. Like other countries around the world, in its response to the coronavirus pandemic, Greece has faced two main challenges: providing distance education and managing the postponement of examinations. There have also arisen other obstacles showing that no solution can match all countries. In Greece, the Health Minister announced on 10th March that will shut down all educational institutions to prevent the spread of COVID-19.

The Ministry of Education responded to the crisis calling it an opportunity to put forward long-awaited changes aimed at improving the digital skills of the educational community. The crisis has also coincided with providing people, beyond education, with a wide variety of long-overdue online services. However, this shift towards digital education highlighted the significant consequences of the economic crisis. According to OECD data, 1 in 5 students at Greek public schools does not have access to a computer, while 1 in 10 does not have access...
to the internet. Additionally, 1 in 3 students complained about their supervisors’ technical and digital skills during the integration of digital devices in instruction. Lastly, 40% of Greek students attend schools whose infrastructure could not support an effective online learning support platform [5]. Having identified the abovementioned digital challenges, this paper presents a Hybrid Teaching Model (HMT) framework during the lockdown period in Greece. The applicability of the proposed framework has been validated in a real-life machine shop case study. The HMT model structure is presented in Fig. 1. It has to be mentioned that the proposed model was based on hybrid labs that referred to the digitalization of laboratory operations and to the digitization of the data processes to enable continuous workflows and improve the quality of the lab. At the same time, the participants were home based (i.e. students) and laboratory based (i.e. educators/technicians) taking into consideration the health measures against the spread of COVID-19.

![Image](hybrid-teaching-learning-model.png)

Fig. 1. Hybrid Teaching – Learning Model Structure

The remainder of the paper is structured as follows. Section 2 presents a brief overview of the Teaching and Learning Factory Models, as well as some state of the market applications for online education during the pandemic. Section 3 presents the Methodology of the proposed model. Next, in Section 4 the Implementation of the proposed Hybrid Teaching model is presented. Finally, in Section 5 conclusions are drawn, and the outlook of the paper is provided.

2. State of the Art

2.1. Teaching Factory Model

The concept of the Teaching Factory (TF) is based on the notion of the triangle of knowledge [6-8]. This concept has its origins in the discipline of the medical sciences and specifically in the teaching hospitals paradigm. The TF concept connects industry with classroom to achieve bi-directional knowledge exchange using Information and Communication Technologies (ICTs). The research work in [9] explains how the introduction of cyber-physical systems and Industry 4.0 technology can reshape manufacturing training under the teaching factory model, addressing the growing need for highly skilled workers. As such, a framework that enables the collaborative AR-based product design under the TF paradigm and serves as a digital thread for linking engineering students to clients is presented in [10]. The participants designed and built a Cloud platform for file sharing and storage support. The Cloud platform can also be realized as the layer of communication between the stakeholders. The TF two-way channel of knowledge transfer includes two different modes of operation at the Teaching Factory, namely those of “factory-to-classroom” and “lab-to-factory” [11-13]. The Teaching Factory Network will bring together industrial (factories) and academic (classroom) actors and facilitate the launch of collaborative production training projects of mutual business interest [14] as presented in Fig. 2.

![Image](teaching-factory-model.png)

Fig. 2. Educational Approach: The Knowledge Exchange TF Network

2.2. Learning Factory Model

Learning Factory (LF) as a subset of the Teaching Factory, is a concept relying on the university equipment, with manufacturing facilities resembling the industrial environment inside the university campus, and people from both academia and industry participate in specified courses, in an attempt to promote new manufacturing concepts, trends, and knowledge in the academic environment. There are many LF established between industry and academia but only research work [15] presents a detailed analysis and the state-of-the-art of the topic. The motivations, the social context, and the educational structures of the learning factories are highlighted. Definitions of the word "learning factory" and the corresponding morphological models are discussed. Nevertheless, the need for a new generation of engineers, Generation 4.0 Engineers, arises for a productive transition to digitalization. The Academy will also provide Generation 4.0 Student Engineers with advanced knowledge, skills, and hands-on experience. The adoption of the Learning Factory paradigm is a promising solution. To that end, within the Learning Factory concept, the design and construction of a fully automated and flexible manufacturing cell is presented in [16]. Participating students under the supervision of senior engineers are divided into groups, each one responsible for designing and developing one of the system components and then combined to form the final solution.

2.3 Global Education Platforms in the COVID-19 Pandemic

The COVID-19 outbreak influenced all aspects of human life worldwide, ranging from education, science, athletics, culture, travel, religion, social interaction, economics, industry, and politics. One key goal of this research work is to analyze the effects of COVID-19 on education, and how to handle this challenging situation and transform it to an opportunity towards a hybrid and permanent digital education alternative. As a result, a state-of-the-market for global learning platforms...
and tools is summarized in this chapter. It must be mentioned that never have so many children been out of school at the same time and disrupting learning. However, UNICEF works with partners to keep educational institutes safe and provide e-learning, in classrooms or at home, online, and offline [17]. Fortunately, nowadays there are many free (or low-cost, easy-to-use) connectivity platforms that make for a variety of remote learning solutions. Large-scale regional attempts to use technologies to promote distance education and online learning across the COVID-19 pandemic are growing and developing rapidly. UNESCO provides an extensive range of distance learning options, including instructional apps, networks, and tools aiming at empowering parents, teachers, educators, and school administrators to promote e-learning and provide social support [18]. Furthermore, a list of national learning platforms and tools is also available [20]. Spain's Educlan [21], for example, is an online portal funded by the Ministry of Education, which offers educational services during the time of suspension of classes due to coronavirus. Moreover, The Swiss Joint Website Education of the State Secretariat for Education, Science and Innovation and the Swiss Conference of Cantonal Ministers of Education has information, links, and tools to promote distance learning [22]. Next, in China, where the pandemic began, the Minister of Education and the Ministry of Technology joined their efforts to ensure that Chinese students managed to study while classes were interrupted due to coronavirus outbreaks [23]. Next, Nordic countries to support online learning have summarized over forty (40+) solutions from Estonia to Denmark that can be used for free [26]. It must be mentioned that Finland developers have contributed once again in this effort towards digital and e-learning solutions. More specifically, Koulou.me offers free applications and resources to support distance learning during the pandemic.

### 2.4 Distance Learning Courses

Distance learning has become the most effective option, so that institutions of higher education will constantly deliver high-quality teaching and consistent communication to students. Most campuses such as ETH Zurich [15], EPFL [16], and Imperial College London [17] have now accepted more restriction relief and are in the process of slowly reopening campus houses, facilities and laboratories. In some cases, such as in EPFL [18], the summer exams will be conducted in person, as well as in Cambridge University [19], and Cranfield University [20], for some subjects. The majority of top global institutions will follow a hybrid educational model for the Fall 2020-2021 semester, which is a mix of online and in-person learning such as Columbia University [21], Stanford University [23], MIT [24] and Imperial College London [25]. The Global university overall status for the first semester of the academic year 2020-2021 is presented in Figure 3. Based on the literature review and the State of Global Universities Overall Status for Fall 2020-2021, the establishment of a hybrid TF lab was followed by our laboratory to ensure that the students will be gain the necessary experience and knowledge.

### 3. Proposed Hybrid Teaching Model

Virtual education is a general term for online teaching and learning with the aid of digital services and platforms. Efficient online education relies on factors such as fast and reliable internet connectivity, learning software, digital skills, affordability, and exposure to technology. To that end, this research work presents the framework of a hybrid teaching-learning model (Fig. 7), that has been successfully applied and validated during the lockdown period. The applicability of the proposed Hybrid Teaching-Learning Model has been validated in the Laboratory of Manufacturing Systems and Automation.
at University of Patras. More specifically, the following presented “Laboratory to House” model developed to successfully complete the laboratory courses of the Manufacturing Technology course according to the Mechanical Engineering and Aeronautics Department curriculum. The object of this laboratory was to assemble a Radio Controlled (RC) Car that was designed within the semester. The proposed framework consists of a Cloud Platform that acts as a server and handles the needed data and the “clients” (University Supervisors and Students) who can connect to the Collaborative Cloud Platform through smart devices (i.e personal computers, tablets, smartphones and so on). The proposed system architecture has been described in the context of Learning Factory in [10].

The contribution of this framework lies in the fact that the teams of students can collaborate, design, share files and communicate about their assigned project in real-time. Moreover, a set of services is offered through the Cloud Platform such as Virtual (VR) and Augmented Reality (AR) applications to visualize the final design as well as a similarity tool to compare CAD Files. The Graphical User Interface (GUI) is presented in Figure 4. The application displays a series of assembly steps for the RC car. The first assembly consists of fourteen (14) steps in total. The second assembly consists of 6 steps. Finally, the third assembly, where the first two subassemblies are joined, consists of a single step. Upon completion of each assembly sequence, the user is prompt to proceed with the next assembly sequence. Furthermore, a screenshot of the AR assembly GUI is presented in Figure 5.

Fig. 4. Main Menu GUI

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Fig. 5. AR assembly GUI

4. Case Study

The TF pilot involved a “real-life” engineering challenge to be elaborated by engineering students under the supervision of the University Professors and technicians. Twelve teams were formed, each consisting of 18-20 student engineers. Each team developed its own process planning, scheduling, and simulation process during the Semester via Hybrid Laboratories and via the Collaborative Platform provided by the LMS.

Fig. 6. a) Real-time Remote-Control Car Assembly, b) Real-time Technician’s Field of View

The Teaching Factory pilot was conducted in separate sessions for each team, where the student teams interacted with the expert engineers using video conference tools (i.e. Skype for Business) and guided them to complete the final assembly of their personalized remote-control car. A Figure of the Real-Time Assembly of the Teaching Factory pilot application is presented in Fig. 6a. Next, in Fig. 6b a screenshot of the technician’s field of view during the live assembly session is presented. It has to be mentioned, that the real-time monitoring and the guidance of the technicians was based on the application described in [38], where the “guide side” (i.e. students) had real-time communication with the shop floor technician to provide step-by-step instructions. In parallel, the real-time assembly was streamed in a Skype for Business meeting channel. Finally, through the combination of the abovementioned ICT technologies, each team was able to guide the machine-shop technicians to assemble the final product in less than two (2) hours, in comparison to the real-life assembly labs in previous years, that each team needed almost three (3) hours to finalize the assembly.
5. Discussion

Digital manufacturing technologies are an imperative set of support tools in a continuous effort to reduce the time and cost of product development as well as to expand the options for customization of the product [39]. Therefore, the shift towards the new digital hybrid model that has been proposed in this research work is a great opportunity for the users (i.e., students, professors, researchers etc.) to rapidly develop their soft skills, as that would be prompted by the situation. If students show that they can work differently, creatively, and express their learning in new ways that educators still working from a conventional way of thinking, their role in the education process will be re-assessed. Moreover, the Coronavirus pandemic has prompted millions of students to study and learn from home. This is not a new phenomenon because our homes have long been the epicenter of learning, especially in the field of informal education. According to the Education Challenge (2020), most university students often choose to study in the comfort of their houses, so students tend to have everything at their fingertips without having to leave their seats. Apart from the cost of accessing online education, several other considerations, such as network problems, inadequate power supply, disruptions, lack of digital soft skills, inaccessibility, and security concerns, may also obstruct a smooth “home learning” model. Therefore, even though the abovementioned challenges, the hybrid TF lab was an opportunity for learners to advance their problem-solving skills and their digital capabilities as well. More specifically, the students had to work in groups during the lockdown period. Therefore, improved their collaborative skills in order to design, develop, test, redesign if needed and deliver the requested files to complete the course based on the academic curriculum. Moreover, another novelty of this paper is that for the first time that the students were able to download an AR application in order to visualize all the assembly steps as well as to check their final design in a real scale hologram through an Android smart device (Fig. 5).

6. Conclusions

This research work presented a framework, as well as a Hybrid-Teaching Model under the Teaching Factory concept during the SARS-CoV-2 lockdown. The success of the Hybrid-Teaching Factory pilot was considered to be mutually advantageous on both sides; the prospective engineers were able to successfully complete one important project of the Mechanical Engineering Department curriculum, while the Professors, research and technical staff developed and worked in a collaborative platform that provided useful services such as Augmented and Virtual Reality Applications and CAD files similarity checking. It can be noted that this opportunity during the pandemic lead to the rise of collaborative e-learning platforms, promoted public-private partnerships and developed soft skills, such as flexibility, adaptability, and responsibility.

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This is a resupply of March 2023 as the template used in the publication of the original article contained errors. The content of the article has remained unaffected.
In addition, the proposed application allows the use of different platforms to facilitate implementation in any industrial environment at a low cost. Finally, future steps will be focused on the integration of 5G technology in order to allow students from different universities to collaborate.

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