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How will change the future engineers' skills in the Industry 4.0 framework? A questionnaire survey

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Abstract

Industry 4.0 represents one of the most challenging themes for engineering design and also for engineering education. At this moment there are few studies in the field of engineering teaching that aim to investigate how the educational needs of students and of the industrial workforce are changing. On this basis, this research would like to investigate which are the necessary skills and expertise young engineers require to be ready for the Industry 4.0 framework. In particular, a questionnaire was developed to analyze this situation. It has been administered to students enrolled in the first and second year of the engineering undergraduate degrees held in three Italian universities: Brescia, Udine and Cassino. During two different academics years, a total of 463 students participated to the survey. The questions were aimed to investigate some key issues of Industry 4.0, and the students' digital belief and behaviors at their entrance in the university education system. The collected answers provided a picture of the actual situation in these three universities with some relevant considerations about engineering education. So, the fundamental question that authors want to answer is "Are the Italian engineering students effectively ready for Industry 4.0 or do we still work on it?"

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1. Introduction and background

The rise of new digital industrial technologies and the diffusion of the Industry 4.0 framework have also led academia to be interested in possible changes that could involve the academic education of young people in general and, the learning of technical and engineering topics in particular [1,2]. Today's students will work and will deal with an increasingly globalized, automatized, virtualized, networked and flexible world. They will compete for employment on a global market. This way, new competences and skills will become more important [1]. In fact, the adoption of Industry 4.0 technologies will allow manufacturers to create new jobs, to meet the needs introduced by the growth of the existing markets, and to introduce new products and services [3].

Given these premises, the goal of this work is twofold, first to investigate what effectively are the skills required by the digital transformation of Industry 4.0, and secondly, they want to know if a change of direction in the higher education is really needed. At this moment, the fundamental question is “Are our engineering students and educators effectively ready for the Industry 4.0 framework?”. In the following paragraphs the result of an online questionnaire with engineering students are reported.

1.1. Industry 4.0 framework and the nine pillars

Industry 4.0 is formerly known as the fourth industrial revolution, a revolution based on the use of Cyber-Physical Systems - CPS [4]. In this framework several changes have to be expected for the industrial world such as the introduction of novel business opportunities and models, and novel service-based, real-time enabled CPS platforms with the arise of new social infrastructure for the workplaces. The shared vision about the Industry 4.0 framework considers the massive use of smart networked systems and IoT. This way, the focus of Industry 4.0 is to create smart products, procedures and processes. Thus, smart factories constitute the key feature of this framework. In particular, they are capable of managing complexity, are less prone to disruption and are able to manufacture goods more efficiently [4]. In the smart factory, human beings, machines and resources communicate with each other as naturally as in a social network. Smart products know the details of how they were manufactured and how they are intended to be used as they actively support the manufacturing process. Consequently, Industry 4.0 should be implemented in an interdisciplinary manner and in close cooperation with the other key areas and using different technologies drivers. These are formerly known as the nine pillars of the technological advancement, and they comprise the following technologies: Big Data; Autonomous Robots; Simulation; Universal System Integration; Industrial IoT; Cybersecurity; Cloud Computing; Additive Manufacturing and Augmented Reality [5]. On the other hand, training and continuing professional development represent other fundamental key factors for achieving the Industry 4.0 objectives as they will significantly transform job and skills profiles of the workers. As a consequence, the partnerships between businesses/factories and higher education institutions will be even more important in the future. It will be important to open up access to science and engineering studies and place greater emphasis on transferable skills and skill assessment. There are already several initiatives to bridge this gap of new knowledge and skills between the academic and industrial worlds. Two interesting examples are represented by the “Academy Cube” initiative [4,6] and the European Commission “eSkills for Jobs 2016” initiative [7].

At this point, it is also important to have a look at what kind of skills can be provided in an engineering academic context and those that will be most useful with the advent of Industry 4.0. Usually, the specific and teachable scientific and technical abilities, that can be defined and measured and, that are related to the specific education one has received, constituted the hard skills. For example, typical hard skills of a mechanical engineer are represented by numerical and higher mathematical knowledge; problem solving, creativity and design skills; investigative and experimental skills, information processing, computer programming, and knowledge of specific software tools [8]. Moreover, a mechanical engineer should have other particular hard skills, including a strong understanding of industry standards, and comfort working with computers, because much time is spent designing, simulating, and testing products and/or processes. By contrast, soft skills are less tangible but not less important. Again, with reference to mechanical engineering, important soft skills are represented by strong analytical thinking,

communication skills, teamwork and leadership skills. Nowadays, another category of skills, the digital skills, is emerging and it is facing with academia and industrial world. Digital skills comprise all skills related to digital world from the basic digital literacy skills to the digital skills for the general workforce, till the specific digital skills for the ICT professionals. The basic digital literacy skills are needed by every citizen to become “digitally literate”. These are the skills needed to carry out basic functions such as using digital applications to communicate and carry out basic Internet searches. The digital skills for the general workforce considers all of the basic skills plus the skills needed in a workplace and generally linked to the use of applications developed by IT specialists. While the digital skills needed by the workforce are likely to differ across sectors, there will be some minimum requirements linked to processing information that will be applicable across all sectors. The third category considers the digital skills for ICT professions which comprise all of the previous two categories, plus skills needed to work across the diverse ICT sector. They also include digital skills linked to the development of new digital technologies, and new products and services [8-11].

2. Research and methods

Starting from the previous considerations about the Industry 4.0 framework and the changes that digital transformation will induce in the technical education in general and in the engineering education in particular, the Technical Drawing Research Group of the universities of Brescia, Udine, and Cassino, involved its students of the undergraduate degrees in Automation, Industrial and Mechanical Engineering in a survey. In particular, students were asked to answer to an online questionnaire during the first weeks of the Technical Drawing – TD – courses held in the three universities during two academic years 2015-16 and 2016-17. The main goal of that survey was to collect the opinions of the students, at their first entrance in the university education system. Students were interviewed on various topics which are not usually investigated by the classic university admission/entrance tests as: their digital beliefs, behavior, and habits, and about some engineering graphics skills and drawing competences [12,13].

Table 1. Questions related to the students' digital behavior and the Industry 4.0 framework.

#	Questions' text	Kind of answer
Q17	Which of the following devices do you own? Desktop or Laptop; Smartphone; Tablet; E-book Reader; Mp3 Player; Video game console; Other ...?	Indicate one or more devices or other...
Q18	Which of the following activities do you perform regularly? Send an e-mail; Use Office suite applications (Word, Excel PowerPoint, ...); Read and download documents from the web; Do web research; manage a website, wiki or blog; Use collaborative and sharing application like Google drive, Dropbox, Skype; Use of social networks (Facebook, Twitter,...); Other...?	Indicate one or more options or other...
Q20	What do you think is the level of importance attributed to the ability to interact with the teacher, even during class, through the use of personal digital devices (smartphones, tablets, PCs)?	From 1 = Not Important at All To 5 = Very Important
Q21	Have you ever heard about: Virtual Realty; Augmented Reality; Mixed Reality; Rapid Prototyping; 3D Printing; FABLAB;	Yes, often; Sometimes yes; Seldom; Very rarely; Never Indicate one or more
Q21b	Have you ever heard about: Virtual Realty; Augmented Reality; Mixed Reality; Rapid Prototyping; 3D Printing; FABLAB; Industry 4.0; Smart factories?	Yes, often; Sometimes yes; Seldom; Very rarely; Never Indicate one or more
Q22	What do you think is the level of importance needed for the knowledge of conventional and non-conventional manufacturing techniques (e.g. rapid prototyping)?	From 1 = Not Important at All To 5 = Very Important
Q23	What do you think is the level of importance attributed to the ability of use augmented reality or virtual reality scenarios for mechanical design?	From 1 = Not Important at All To 5 = Very Important

The questionnaire, in its actual form, is composed by twenty-six questions, eighteen of them are close questions related to skills and competences, which students may acquire during TD courses. Then, other six questions are related to their digital behaviors in relation to the knowledge and the use of new digital technologies also concerned with the Industry 4.0 framework. Finally, there are two closed questions about the students' expectations of TD course in terms of improvement of beliefs, knowledge, and two open questions, one is related to the possibility of participation to an engineering design competition, the other asks students their personal opinion on TD in general [13].

Table 1 reports the relevant questions considered for this work. At this point, it is important to highlight that the questionnaire was first used in a. y. 2015-16 and then it was repeated during the a. y. 2016-17. During the second year some questions were improved, in particular, Q21 was changed in Q21b form to specifically investigate the students' knowledge of Industry 4.0 themes (see Table 1).

The questionnaire was developed using the Google forms application, to easily customize the question form and to automatically collect all the answers in an electronic worksheet in MS Excel format. The data collection methodology was designed to take into account various concerns: to use the same questions by all the three universities; to automate data collection and analysis; to facilitate student access to the questionnaire from the web. The choice of using a questionnaire as a survey tool among students has proved particularly effective and it is also the result of previous experiences implemented by the authors [14]

2.1. Questionnaire demographics and participation

The questionnaire, as previously reported, was used during both the 2015-16 and 2016-17 a. y. In particular, it was administered to undergraduate students (first or second year of degree) enrolled in the BS degrees of Automation, Industrial, Management, and Mechanical Engineering of the three Universities.

Table 2. Students' sample size and constitution for each academic year.

Academic Year	University	N° of students participating to the questionnaire	Male students		Female students	
			#	%	#	%
2015-16	Brescia	106	91	85.8	15	14.1
	Cassino	116	92	78.4	25	21.3
	Udine	74	54	73.0	21	28
	Total	296	237	79.7	61	20.4
2016-17	Brescia	97	88	90.7	9	9.3
	Cassino	-	-	-	-	-
	Udine	70	55	78.6	15	21.4
	Total	167	143	84.6	24	15.4

In Table 2 are reported some significant data of the students' sample for the two a. y. under observation. The number of students that participated to the survey was relevant 463, more of the 50% of the students enrolled in the TD courses for each seat. For the a. y. 2015-16 the sample was constituted by 296 students, 80% of male and 20% of female students. The students participating to the questionnaire are mainly enrolled in the BS degrees courses in Industrial (39%), Mechanical (29%), Automation (17%), and Management (14%) Engineering of the three Universities. Considering their high school of origin, for the academic year 2015-16 the majority of students (54%) came from scientific high schools, followed by those coming from industrial technical institutes (31%). For a. y. 2016-17 the sample was constituted by 85% of male and 15% of female students (without Cassino data). Considering the undergraduate degree students of this a. y. are mainly enrolled in the BS degrees Mechanical (48.5%), Management (28.5%) and Automation (24%) Engineering. Looking at their high school there is a parity of

origin (44%) among students coming from scientific high schools and industrial technical institutes (also without Cassino data).

3. Data elaboration and analysis of collected answers

This section reports the elaboration and the analysis of the collected answers for the questions related to the students' digital behavior and the Industry 4.0 framework.

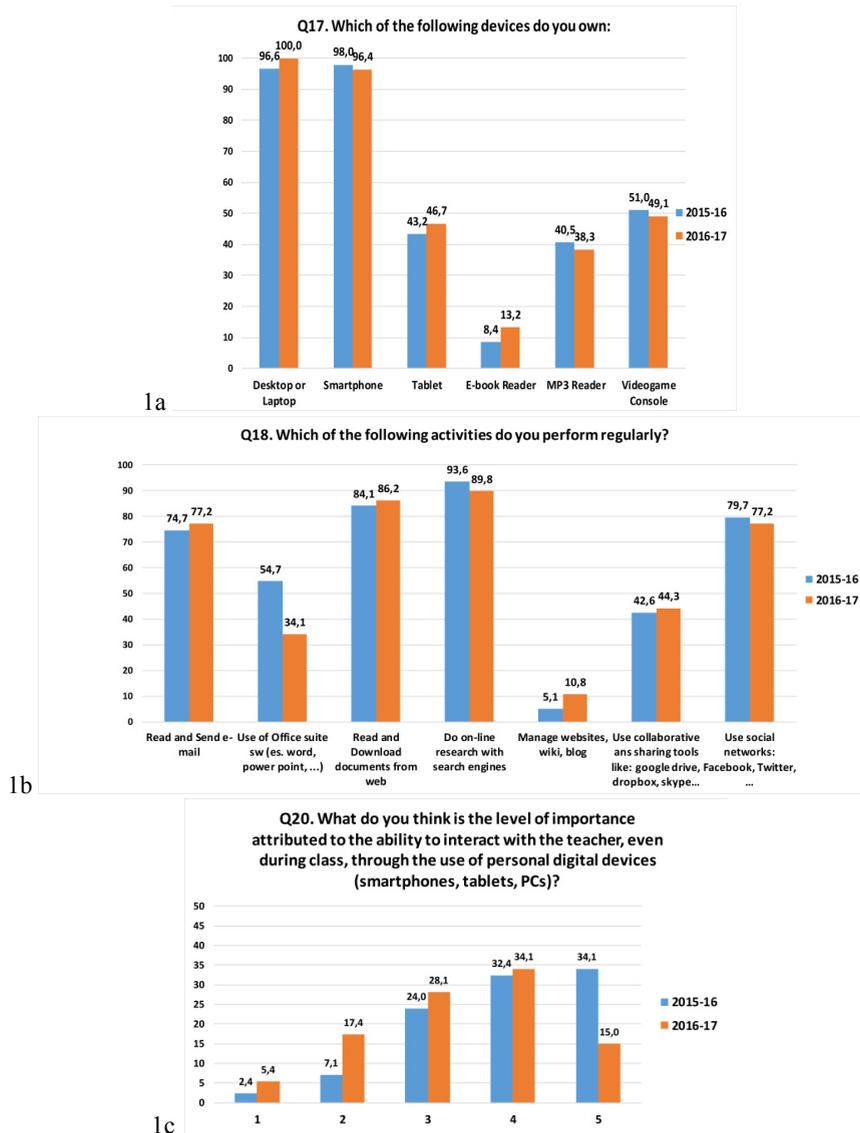


Fig. 1a. Data elaboration for Q 17: students' digital device ownership; 1b. Data elaboration for Q18: students' mostly performed activities; 1c. Data elaboration for Q 20: opportunity to interact with instructors.

3.1. Questions on students' digital behavior

Questions Q17, Q18, Q20 consider the students' digital behavior. In particular, these questions highlight the students' digital habits, investigate their typical digital behavior and ask for their consideration in function of an increased interaction with instructors by using digital devices during the classes.

In particular, Q 17 give us the idea of which digital devices students own. Q18 give us an idea of what are their usual digital habits and which basic digital skills they own. From Q17 (Fig. 2a) emerged that students' favorite digital devices are desktop/laptop PC and smartphone (over 95%), followed by videogame console (50%). This shows that young people own different kinds of devices (PC, smartphones and videogame console) that allow a good level of interaction with the digital/virtual world. Considering Q18 (Fig. 2b) it is possible to have a look on how the "digital habits" of our students are changing. In fact, they usually "live" in the Internet virtual world while they do not make extensive use of Office applications (from 54% to 34%), even if the last kind of tools are very used in the real working world. It has also to be notice a significant increment of the students which manage websites/wiki or blogs (from 5% to 10%). Q20 considers the opportunity to directly interact with the teacher during classes by using some digital devices. More of the 50% of the students assumed that this opportunity seems to be very important (average score 3.88 for 2015-16 and 3.35 for 2016-17) (Fig2c).

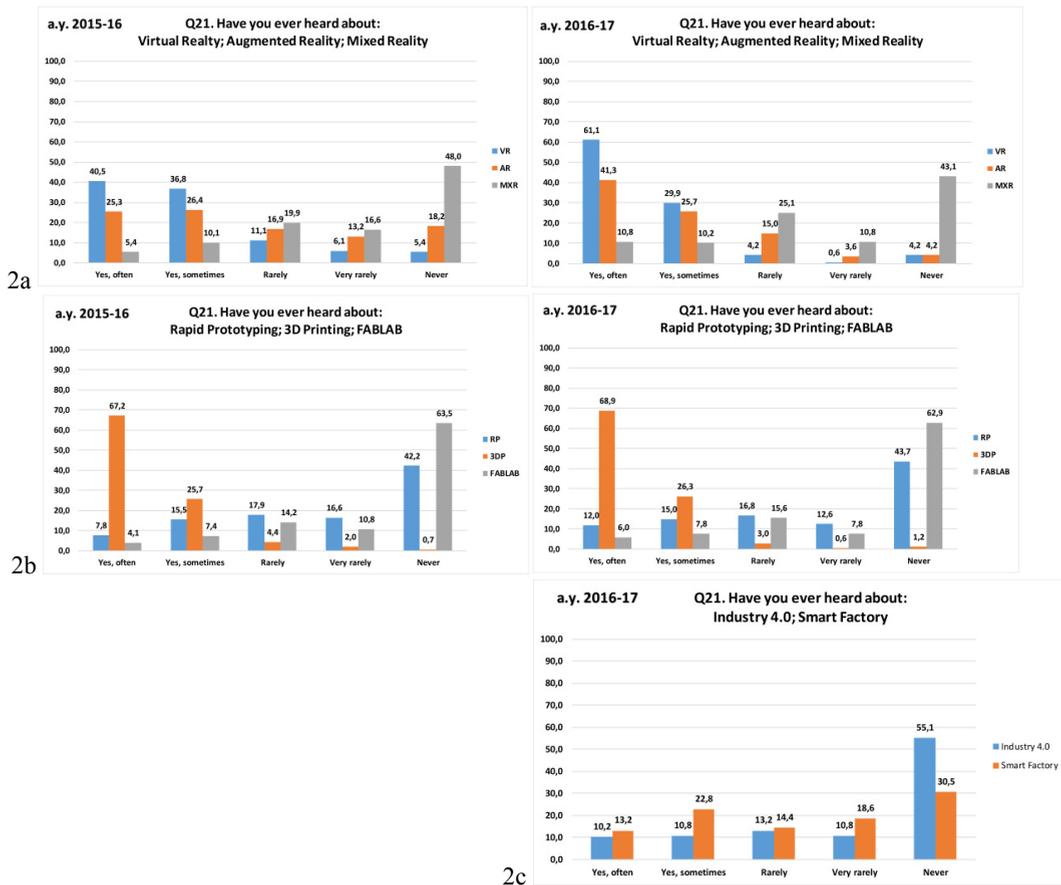


Fig. 2a. Data elaboration for Q21Virtual, Augmented and Mixed Realty a.y 2015-16 and 2016-17; 2b. Data elaboration for Q21 Rapid prototyping, 3D printing and FABLAB a.y 2015-16 and 2016-17; 2c. Data elaboration for Q21Industry 4.0 and Smart factory, a.y. 2016-17.

3.2. Questions on students' knowledge and perception of Industry 4.0 framework

Questions Q21, Q22 and Q23 are related to the students' knowledge and perceptions about Industry 4.0 framework and the emergent pillars of technologies. In particular, Q21 (Fig 2a) highlights how familiar are the concepts of Virtual (77% - 91%), Augmented (50% - 67%) and Mixed Reality (15% - 21%) to our students. What emerged from the collected answers is that students recognized concept as Virtual and Augmented Reality but in general they never heard about Mixed Reality. The situation seems to be slightly improved for the a.y. 2016-17 where there is a better understanding of the terms by the students (second percentage value in brackets). On the other hand, terms like Rapid Prototyping, 3D Printing and FABLABS (Fig 2b) maintained the same trend. It is curious to notice that, while the students are very familiar with the term 3D Printing, on the other hand, they have no idea of what is Rapid Prototyping, which represents the historic technological filed in which 3D Printing represents only a particular category. The knowledge of the most relevant terms for the Industry 4.0 framework (Industry 4.0 and Smart Factory) showed that there is still a lot of work to be done for making young people aware to these new issues and giving them more structured information (Fig2c).

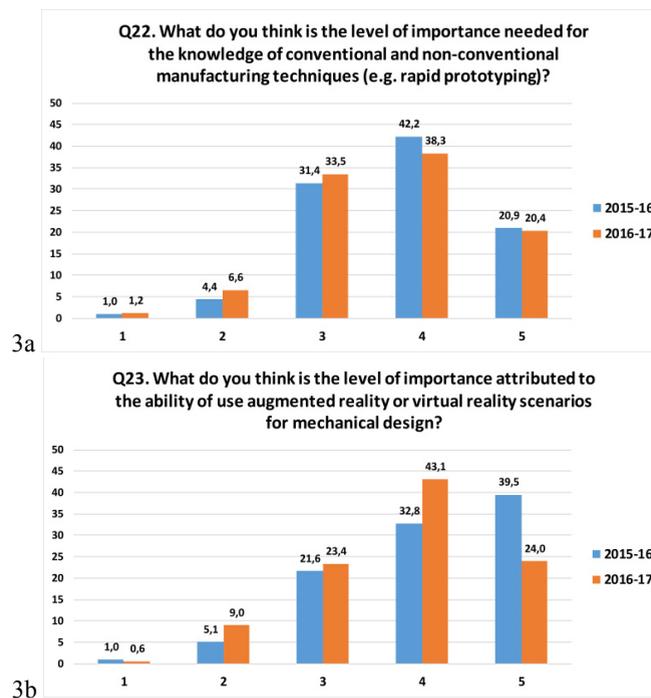


Fig. 3a. Data elaboration for Q22 – level of importance of conventional and non-conventional manufacturing techniques; 3b. Data elaboration for Q23 – level of importance of use of Augmented or Virtual Reality techniques.

Q22 (Fig 3a) gave an idea about the opportunities that our students see in the use of conventional and non-conventional manufacturing technologies (mean score in 3.7 for each year), while Q23 (Fig 3b) is focused on the need of changing the level of interaction with teachers and instructors during lessons (mean score 4.4 for 2015-16 and 3.8 for 2016-17). The collected data shown a certain sensitivity and interest, increased in the years, towards these possibilities.

4. Conclusions and future developments

The preliminary results of this work highlighted some interesting aspects concerning the students' digital behavior and their consideration about Industry 4.0 framework. In particular, the data describing the students'

relationship with digital devices and their level of knowledge of some specific topics as Virtual, Augmented and Mixed Reality, 3D Printing, Smart Factories are very significant in understating what students think. First of all, these results may suggest the need to create a broader and better structured knowledge of the basic concepts related to this new industrial revolution. Then, this knowledge should be improved and integrated, considering revising the educational contents of the courses, especially with regards to technical topics. One interesting possibility is represented by the introduction of novelties in the teaching and learning methods encouraging their digitization, and introducing smart interaction between the various actors involved. Good examples of applications carried out in this direction are represented by the works in [15-19]. All of these observations in function of the consideration that, the main important asset of the Industry 4.0 framework is people. In fact, the workforce represents a critical component of the digital business transformation. And above all we must not forget that actually, culture and education are the main keys on which to leverage for promoting awareness and knowledge of these issues. In future, the authors plan to revise and extend the survey by submitting the questionnaire both to teacher and instructors to consider if there is also an effective application of digital skills during university classes. It is also expected to submit shortly, a modified version of the questionnaire to local SMEs and craft firms for investigating how Industry 4.0 digital skills and new technologies are perceived in their business sectors.

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