

# Facing the Fourth Industrial Revolution: empowering (human) design agency and capabilities through experimental learning

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## ABSTRACT

The Fourth Industrial Revolution (Schwab, 2014) is a paradigm characterized by the convergence of technological changes that impact the nature of work, the design and materialization of products and services, as well as their market, their structure, and their relations with human agents. This systemic process also changes the design field, its cultural and socio-economic structures, its consolidated domains and practices. We witness both new opportunities for, but threats to, the conventional system of human imaginative and operational capacities that are changing how they can be learned. The re-discussion of the design(er) role affects the structure and meaning of the discipline, as well as the processes, places, and capacities that can generate learning. Design education is a core component of this change. It is so for those who will shortly become designers and for retrofitting the knowledge and skills of practitioners and educators. The article reviews the main studies and theories on the transformation of the production system and the market. The focus is on the structural factors which enable identification of the leading transformational drivers of the experimental learning. These factors are the basis upon which changes in design education and designer skills operating within digital distributed socio-technical systems will be defined.

*Keywords:* Design Education; Experimental Learning, Design Agency, Future Design Skills, Technological Change; Work Automation.

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## INTRODUCTION

Changes in design as an activity, process, and discipline are inextricably bound up with the structure of the current socio-economic system and the transformations in the nature and forms of work that have characterized it since the Second Industrial Revolution. The emerging exponential technological development and innovation (Bostrom, 2014; Hagel *et al.*, 2013) is driving a global process of technological democratization which through progressive integration-substitution between humans and machines is generating changes in the overall equilibrium of design agencies. It has a direct impact on how designers' activities are defined and how they learn new work processes. The central issue of this article is undoubtedly an analysis of the democratization of design and manufacturing technologies

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and its impact on design, production, and distribution processes - with a specific focus on the evolution of making and digital fabrication - and of the increasing impact of machine learning on these same processes (Baumers and Ozcan, 2016). Moreover, the acceleration of innovation impacts on design education and design profession processes, and drives designers to evolve more rapidly, stimulating them by increasing their skills so that they can better adapt to the changes in the methods of production of goods and services. The topic, therefore, becomes the progressive transformation of forms of learning – in particular, those associated with *experiential learning* (Seaman *et al.*, 2017) – and its increasingly central position in the activities, processes, and places that primarily characterize the relationship between design education and industry. A reflection on future design skills evidences three main emerging questions:

- which design skills will emerge, which of them will change and be drawn up in future years;
- how design processes are changing and how they will change in the future, and what new activities and tasks designers will have, in particular, the new relational system between designers and technologies and between design and the production system of goods and services;
- who are, and who will be, the new actors involved in design activities (hybrid individuals and organizations, designs that are not produced by the designer alone or created without a designer or generated by machines, etc.).

## 1. THE BEGINNING OF THE TRANSFORMATION OF DESIGN SKILLS

Like many sectors that developed at the start of the twentieth century, design gradually created and consolidated a model of a profession and education concerning the common process of the spread of the industrialization of the manufacture of artefacts and the creation of market and consumption models. The strong ties between design and the various elements of the manufacturing system created a link to the specific places where the associated educational and professional activities were carried out: the *workshop-atelier* (in the sense of a studio or shop), the *factory* and the *school* and a model of interaction with society that was defined by a system of political-institutional representation – consisting of domestic and international professional associations for industrial design – that was closely connected with, and respondent to, the logics of a nineteenth century model of society. From Bauhaus and Ulm to the emerging Fab Labs ecosystem – the area of interaction among design education, the concept of profession, and the manufacturing system (Blikstein, 2014)

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reflected long and hard on the association between individual cognitive and operational capacities and the social role – both individual and collective – of the discipline. In economically advanced countries, the development of the post-industrial society (coincident with the spread of ICT) was characterized by the growth of the service sector and a reduction in the number of employees working in industry as a result of the increasing automation of machines and production processes. It accelerated the diversification and disciplinary specialization of design activities by altering the central role of industry in governing the relationship between the design profession and education and establishing a new organizational and strategic development of design professionals and training methods focused more on creative industries and the service sector. The close connection between education and profession was for long the central objective of an implicit political project that gave the training system the task of preparing a class of individuals who would become the (most) creative sector of advanced capitalism's production system. Although it constantly evolved and diversified, it maintained a more or less stable structure for decades, thereby enabling the growth and structuring of design, first as a discipline and then as a field of activity: more design schools and universities, more professionals working in the design market, and greater economic and cultural importance of design in society (Design Council UK, 2015). This mechanism of structural growth in the design field started to change at the beginning of the 1990s. The acceleration in the globalization of goods, together with productive delocalisation and the deindustrialisation of manufacturing contributed to the separation between industry and design's training and professional systems. The gradual decline of industry as the absolute protagonist in the relationship with design accelerated the internationalisation of design education, and contributed to the birth and progressive growth of *creative industries* with the consolidation of a *creative economy* (UNESCO 2013, UNCTAD 2016, Julier, 2017) and the birth of the idea of a *creative society* (Gauntlett, 2011). At the same time, the first idea of a relationship between the design world and the service economy also provoked a conclusive crisis as regards the capabilities required of both individuals and organizations working actively and professionally in the design field. The entry into the crisis of the traditional counterpart of the world of design education – i.e. the world of enterprises and professional firms – drove designers to explore self-employment and self-entrepreneurship. Although this has not been measured it has led to a gradual shift from a design market with few designers and many industries (characterised by stable and long-lasting forms of collaboration between designers and companies) to a market in which design has become a mass profession in a hyper-competitive, globalised industrial context (characterised by a growth in services and platforms for professional disintermediation that

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are transforming traditional relationships with companies). The global massification of the designer has made design activities more distributed, but also more unstable, and it has led to a surplus of supply of design capabilities that have progressively required designers to become more connected and entrepreneurial (social skills), and to diversify their activities, which now range from design to consultancy, and from education to experimental forms of micro- and self-production.

## **2. WORK TRANSFORMATION IN DESIGN AND PRODUCTION OF GOODS AND SERVICES**

The human action of artificializing nature (Leroi-Gourhan, 1993; Latour and Porter, 2004; Arthur 2009; Simondon, 2017) has created a technical sphere that is becoming increasingly broad, pervasive, and rich in relations. Reflections on design and designing and the debate on the artificialization of the world (Mumford 1934; Papanek 1971; Maldonado 1972; Margolin and Buchanan, 1996) have therefore become central elements for reflection on the discipline: in fact, humans have always acted individually or collectively through technology and work, i.e. through gradual mechanisation of the world. Since the birth of cybernetics in the 1940s, this process has been increasingly applied to the concepts of a machine, control, information, and biological and mechanical system, and recently also to design, and the possibility has been explored of conceiving a unified theory of mind and machine. From the mid-1950s onwards, this path began to be pursued through the development of Artificial Intelligence (AI), which opened up the possibility of constructing machines (physical or algorithmic, robots or programs) that could for the first time be considered independent artificial agents. The development of AI, together with that of computer sciences and technologies, has brought the topic of agency and the transformation, strengthening, and replacement of human skills to centre stage: from the simple principle of controlling a closed system to an active and performative view in which machines and computers can work actively in the environment of human experience. This socio-technical view of technological changes coincides with the great wave and cycle of ICT innovation first described by Kondratiev later developed by Carlota Perez (Kondratiev, 1984; Perez, 2003), and finally defined Fourth Industrial Revolution (Schwab, 2016; Ford 2016; Gilchrist, 2016). It means an interconnection of a cluster of technologies for the design, production, and distribution of goods and services increasingly available at a declining cost. This systemic connection effect is creating an extensive and pervasive technological environment which enables a plurality of actors – no longer only firms and professionals – to develop innovations (Tapscott and Williams, 2010; Shirky, 2011; Von Hippel, 2016). The topic of accelerating technological development as the trigger of innovation (Kurzweil, 2006; Bostrom, 2016) is ever-present at

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all levels of the design field. Computerised and algorithmic design technologies enable the generative and exponential development of design solutions, and the exponential evolution of technologies such as 3D printers is accelerating the possibility to materialise artefacts of all types. Lastly, the innovation of procedures and product placement services in new companies is conceived and designed to scale up on the market, exponentially. Thus being generated is a potential system for exponential innovation (Hagel, Seely Brown *et al.*, 2013; Ismail *et al.*, 2014), but (to date) there is no corresponding exponential growth of human productivity and design work. Within our environment, the connection between the artificial population of new agencies is generating a fundamental new condition: the creation of complex techno-human ecosystems that can no longer be viewed as passive or neutral concerning the production of the artificial and design (fig. 1.1).

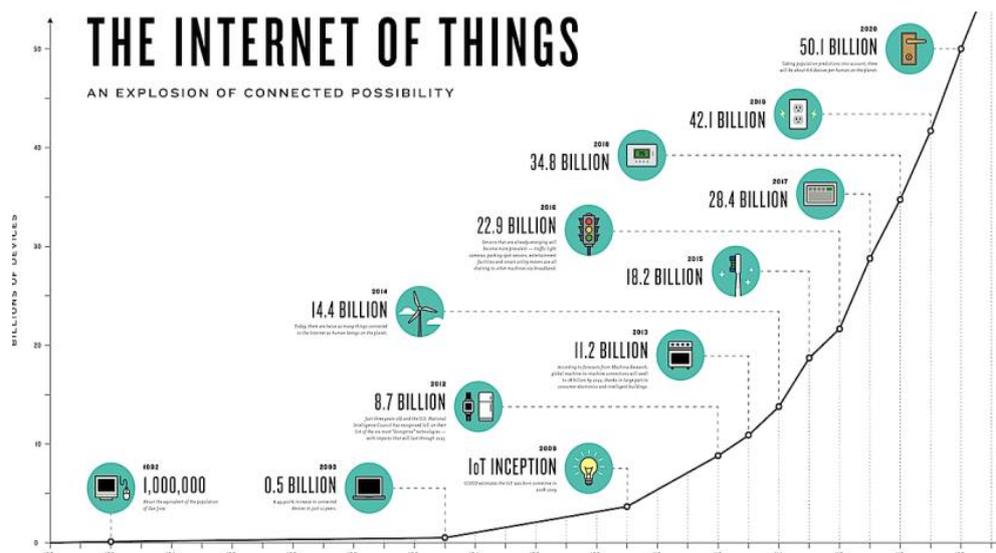


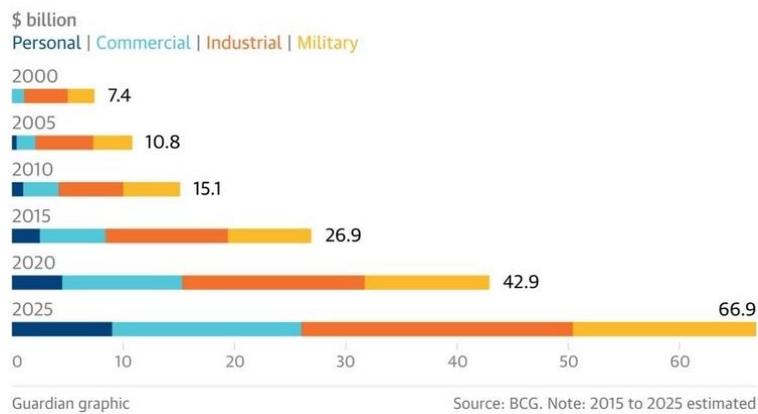
Figure 1: (<https://twitter.com/Blakei/status/524420063391391744>)

## 2.1. Human and Non-human Agency in Changes in Production and Work

Acceleration of technological innovation generates a condition unprecedented in the history of socio-technical evolution: the development of a system made up of an infinite number of artefacts, machines, systems, and networks, united by multiple levels and channels of connection. The agency of this system is no longer merely human and individual; instead, it has become social-collective and technological: a general, fundamental property of tightly interconnected human and non-human systems. The (co)evolution of human and non-human agency is even more evident – on a more competitive than collaborative logic – in systems for producing goods and services, where physical and algorithmic robots are undergoing exponential growth, with a compelling economic and social impact (Fig. 1.2).

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### Global robotic market



**Figure 2: Global Robotic Market (Source: The Guardian, 2015)**

Two recent studies by Acemoglu and Restrepo in 2016 and 2017 (Acemoglu and Restrepo, 2016 and 2017) have described the role of technologies in the increasing competition between humans and robots in work. On the one hand, there are the enabling technologies that complement or enhance the productivity of the skills of certain individuals (Acemoglu cites the enabling role of CAD technologies for designers as a significant example), while on the other, there are the replacing technologies destined to replace lower-skilled human labour, as in the case of industrial robots. Acemoglu and Restrepo's first study, which is based more on theoretical projections, claims that automation has destroyed lower-skilled jobs and replaced them with more specialized and more highly-paid ones (for example, engineers). The relationship among technological development, labour productivity, and employment is, therefore, the most striking indicator of this significant transformation, which has always been considered one of the most challenging and complex issues in the economic literature, but which remains virtually unexplored in the field of design. The relationship among design, automation, and work is, on the other hand, a matter analysed and monitored in studies on the future of employment produced by various domestic government agencies and a number of global organisations such as the ILO, WEF and OECD (WEF, 2016; International Labour Organisation 2015, Arnzt *et. al.* 2016). In their book *The Second Machine Age*, Brynjolfsson and McAfee (Brynjolfsson and McAfee, 2014) also analyse the impact of cognitive machines on manual and intellectual labour. In many occupations, both low- and high-skilled, the development and spread of intelligent, hyper-connected machines are contributing to an overall loss of demand for human labour, in a market that less and less requires and pays for skills replaceable by robots. At the same time, they believe that it is possible to rebalance the situation by means of the continuing education of individuals and the development of three areas of professional skills that cannot be replaced

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by automation and machines: creative endeavours (for example, creative writing, entrepreneurship, and scientific discovery), social interactions (Deming, 2015), physical dexterity and mobility. According to Brynjolfsson and McAfee, these new skills must be accompanied by a climate favourable to entrepreneurship, with new enterprises able to create business and work based on those skills. However, it is the more recent work by Frey and Osborne (Frey and Osborne, 2013; Frey and Osborne, 2016) that has reignited the debate on this topic. Their estimation of automated processes in the USA shows that only one-third of employees in areas like management, engineering, scientific research, and the creative professions are currently considered to be at low risk of being replaced by the machine. Identification of the skills that resist automation is central to Frey and Osborne's study; they analysed 702 professions, and isolated three core competencies (Tab. 1.1): the perception and ability to manipulate objects, creative intelligence (such as the capacity to develop ideas and create artefacts), and social intelligence (i.e. skills such as negotiation, persuasion, care for and helping individuals, and empathy). The level of automation of work is linked to the repetitive nature of the tasks and their dependence on data, and this can undoubtedly also relate to specific tasks associated with a creative job or profession. A small risk of automation, on the other hand, is attached to design, productive, or management activities characterised by processes and outputs that include elements of craftsmanship (or rather, what they call the *human touch*, Frey and Osborne, 2013). It relates to the ability to solve problems in a real-time setting, to design, use, modify/correct technologies, to allocate human, economic, and material resources efficiently, and to work in close contact with other individuals in order to achieve objectives (Nesta, 2014).

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**Table 1: Variables that serve as indicators of bottlenecks to computerisation**

<b>Computerisation bottleneck</b>	<b>O*NET Variable</b>	<b>O*NET Description</b>
<i>Perception and Manipulation</i>	Finger Dexterity, Manual Dexterity, Cramped Work, Space, Awkward Positions.	The ability to make precisely coordinated movements of the fingers of one or both hands to grasp, manipulate, or assemble very small objects. The ability to quickly move your hand, your hand together with your arm, or your two hands to grasp, manipulate, or assemble objects.
<i>Creative Intelligence</i>	Originality, Fine Arts.	The ability to come up with unusual or clever ideas about a given topic or situation, or to develop creative ways to solve a problem. Knowledge and theory and techniques required to compose, produce, and perform works of music, dance, visual arts, drama and sculpture.
<i>Social Intelligence</i>	Social Perceptiveness, Negotiation, Persuasion, Assisting and caring for others.	Being aware of others' reactions and understanding why they react as they do. Bringing others together and trying to reconcile differences. Persuading others to change their minds or behaviour. Providing personal assistance, medical attention, emotional support, or other personal care to other such as co-workers, customers, or patients.

Source: Frey and Osborne, 2013

As further confirmation, it is of interest to note that in addition to design, other planning sectors, from architecture to various branches of engineering and a series of professions that pertain to the creative industries (for example, photographers, craftspeople, and multimedia artists) are concentrated in the same rankings. It can, therefore, be seen from the work of Frey and Osborne that design activities in particular – and creative and planning activities in general – are at present generally at low risk of being replaced by automated machines and technologies. This finding, however, does not avoid the central issue of the transformation of design skills in the context of the production of goods and services, which is moving towards a technologically pervasive mode in all its dimensions. Indeed, it gives designers new professional tasks and responsibilities in their capacity as the (most) active subjects (from a planning perspective) in the framework of changes in work<sup>1</sup>. If we collate the thoughts of Brynjolfsson and MacAfee, Acemoglu and Restrepo, and Autor and Frey and Osborne's studies, a clear issue regarding skills, the profession, and education emerges: automation and robotization will require workers (especially the next generations) to develop new skills that will generate types of work empowered by technologies. In particular, a personal capacity to manage and develop technologies, associated with the development of social and creative intelligence and learning processes, is the key to combating the effects of automation.

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### 3. THE FRAMEWORK OF TRANSFORMING SKILLS AND DESIGN EDUCATION: THE DRIVERS OF THE CHANGE

We can extrapolate two key elements from our analysis of the changes in work associated with the acceleration of technological development. These have an impact on development skills and processes and places of education and profession: the empowerment of competencies through an evolved relationship between humans and technologies and strengthening them through new learning practices and environments. In its report entitled *Future of Jobs* (WEF, 2016), the World Economic Forum (WEF) showed that by 2020, approximately 35% of skills would change with pervasive technological development. The growing digitalisation, computerisation, and automation of technologies is impacting, and will continue to do so, on all levels of planning, manufacturing, and distribution processes, and will also extend to the management of corporate activities. A situation with such a high degree of pervasiveness requires the development of specific inter-disciplinary skills: comparison of the development of the skills that will be needed by the market between 2015 and 2020 (Tab. 1.2), shows that the most evident change is associated with substantial growth in the importance of complex problem-solving related both to critical and computational thinking.

**Table 2: Top 10 skills in 2020**

In 2020	In 2015
1. Complex Problem Solving	1. Complex Problem Solving
2. Critical Thinking	2. Coordinating with Others
3. Creativity	3. People Management
4. People Management	4. Critical Thinking
5. Coordinating with Others	5. Negotiation
6. Emotional Intelligence	6. Quality Control
7. Judgment and Decision Making	7. Service orientation
8. Service Orientation	8. Judgment and Decision Making
9. Negotiation	9. Active listening
10. Cognitive Flexibility	10. Creativity

Source: The future of Jobs report – World Economic Forum

The WEF also identified two major future cross-sectorial jobs: these are professions associated with the capacity to work strategically with data, and those linked to the ability to promote and market increasingly innovative and sophisticated technological products, also to new categories of users. Here, we see convergence in the development of a combination of

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creative skills and technical expertise, but also the capacity to use this augmented agency to construct narrative environments (Latour, 2008) that are innovative for companies (and not only them). This task entails the need to exponentially increase and connect skills that a single individual cannot possess. As early as 2011, the Institute for the Future's Future Work Skills 2020 report demonstrated the need for people to develop a predisposition to operate in work contexts applying organizational forms and abilities in continuous evolution. Contexts of this kind require the constant re-examination of the requisite skills and the development of appropriate learning strategies in order rapidly to identify and combine the skills necessary for upgrading personal capabilities.

### **3.1. Technological transformations produce a change in the processes and the places where skills are created and built**

The development of the democratization processes of design and manufacturing means underlies phenomena that are today defined as a movement or society of makers (Gauntlett, 2011). This is a recent phenomenon with a history of little more than ten years (Gershenfeld, 2007; Anderson, 2012; Walter-Herrmann and Büching, 2014; Dougherty, 2016), and it has been fuelled by the exponential growth in the adoption of convergent technologies for digital fabrication and IoT (microcontrollers and microprocessors, and miniaturised control and remote transmission systems, together with additive and subtractive manufacturing tools), the spread of makerspaces and Fab Labs, and the expansion of distribution and promotional platforms such as Maker Faire. The development of the maker culture and movement has fostered the growth of capacities and skills that welds creativity and a capacity for technological experimentation together, and which, according to Frey and Osborne, are the antidote to the uncontrolled automation of work and the development of forms of resilience to/independence from the effects of technological unemployment. In their report entitled *Creativity vs. Robots*, prepared for NESTA UK in 2015 (Bakhshi *et al.* 2015), Bakhshi, Frey and Osborne claim that, the creative professions will become even more resistant to automation in the future (in the United States and the UK, 86% and 87% respectively of creative jobs are believed to be at a small or zero risks of automation). According to this study, technological development will have an enabling and empowering effect on creativity that is seen as suited to strategically intercepting future developments in the field of artificial intelligence and robotics: "... These findings reflect the fact that machines can most successfully emulate humans when a problem is well specified in advance – that is, when performance can be straightforwardly quantified and evaluated – and when the work task environment is sufficiently simple to enable autonomous control. They will struggle when tasks are highly interpretive, geared at 'products whose final form is not fully specified in

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advance', and when work task environments are complex – a good description of most creative occupations..." (Bakhshi *et. al.*, 2015).

Makers' skills often relate to an approach based on 'tinkering' – that is, a method or approach that has the ability to create things by experimenting with science and technology – or a heuristic approach based on experiential learning. This is a learning model based on experience and realised by means of actions and experiments and the use of creative and practical abilities in order to attain a purpose or resolve a problem (Blikstein, 2014), as applied to the solution of complex interdisciplinary problems such as the development of interactive technologies and products. In this type of learning, pragmatic knowledge is developed by means of technologically-enabled *learning-by-doing* and *learning-by-interacting* processes by single individuals associated with open, multi-generational peer-to-peer communities that stimulate the development of skills that are at the same time individual and collective, and include skills, such as empathy, which the production system regards as indispensable for operating in eco-systemic organisational contexts that are increasingly oriented to open innovation.

The strategic notes in the report entitled *The Future of Work. Skills and Resilience for a World of Change*, which was drafted by the EU Commission in 2016, starts precisely from the assertion that the abundance of specialized, accessible, comprehensive skills fuels development of the open innovation paradigm in organizations. The models of the *platform enterprise* (Evans and Gawer, 2016) and the *platform economy* (Kenney and Zysman, 2016) develop through the growth of outsourcing and the combination of on-demand and *project-based work* in which diverse groups of professionals with complementary skills are assembled and disassembled to collaborate on specific tasks. This model, which has been called the Hollywood Model or the *Open Talent Economy* (Deloitte, 2016), is also increasingly characteristic of design activities, and it is well-suited to profiles like those of makers. In a similar context, makers learn to work with technologies, using them synergically so as to adapt them for an experimental or productive purpose, and while they are learning how to use, modify and create them, they understand their complex and transformative nature in the evolutionary sense (Arthur, 2011 and 2014). Making is therefore the final result of a group of highly inter-disciplinary activities that involve many different domains, such as mechanics, robotics, informatics, electronics, design, and material science, through the use of an empathetic collaborative approach in which pragmatic and manual skills also play a part, activating project-based processes in enabling physical locations (Fab Labs or makerspaces). This open form of the ability to design, which is directed towards problem setting, and not

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just problem solving, combines planning and programming cultures and therefore extends to all levels of the creation, materialization, and distribution ideas, thereby generating innovation also in the social field (Ehn, 2014).

In particular, *learning through design – design-based learning* (Mehalik *et al.*, 2008) – enables figures like makers to develop *personal leadership* (Bianchini and Maffei, 2012), while the development of a system of technical-scientific-planning skills empowers them as regards both their ability to become personally responsible for innovation processes and to trust in their abilities (or those of others) to work in uncertain contexts on the development of original solutions and self-employment and self-entrepreneurship activities. Increasing leadership skills within new forms of work is the central theme of the study conducted by the EU and entitled *High-tech Leadership Skills for Europe - Towards an Agenda for 2020 and Beyond* (EU Commission, 2017). The report highlights that in the high-tech economy it is necessary to increase the number of leaders, stressing that technological leadership is inseparable from creative leadership (Puccio *et al.*, 2010).

Among its policy recommendations, the report *The creative economy and the future of employment 2030* (Bakhshi and Windsor, 2015) in the *Manifesto for the Creative Economy* cites the development of a government strategy that seeks to develop a strong bond between STEM and Arts (and therefore from STEM to STEAM) within the training system, with the purpose of creating a convergence between the creative and high-tech economies able to increase the quality of employment. In a recent article for NESTA (Mulgan, 2017) which refers to the positive and negative impacts of the combination of globalization, technological progress, and liberalization of the market on individuals, Geoff Mulgan makes the empowerment of individuals, and therefore their agency, a matter of central importance. Among the competences, there is the stimulus, in particular among younger workers, to acquire a capacity to transform their surrounding reality that combines the approach of makers with that of design-based learning, together with the embedding of entrepreneurial abilities in educational processes.

*The Future of Work: Jobs and skills in 2030* (UKCES, 2014) is a strategic document drawn up by a UK government commission to define skills of the future in various sectors (the professional and business services sector, the digital and creative sector, retail and logistics, education, manufacturing, construction, health, and social care). From a cross-sectoral point of view, the following emerge as general abilities: data literacy, hybridisation of skills, business skills for project-based work, learning to learn, risk and network management skills for collaborative business models. In particular, in the digital and creative and in the

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manufacturing sectors emerge specific skills for design activity that still indicate a predominant inter-disciplinary hybridization with digital technologies, also within a logic of boosting designers' capacity to interact with users and the market (Tab. 1.3).

**Table 3: Future Skills in creative and digital sector and manufacturing**

Computerisation bottleneck	O*NET Variable	O*NET Description
Creative and digital sector	New forms of mobile and home-working crowdsourcing platforms for creative workers.	Increased inter-disciplinary thinking and ethnographic skills for user/market experience and product design.
	Increased use of ICT and digital technologies in design (e.g. simulated environments).	Entrepreneurial and self-organization skills.
Manufacturing	Job losses for low skills due to automation and digitalization.	Relevant skills for technology integration, including skills in design, simulation and data analytics.
	Need for (up-skilled) technicians to manage automated production systems.	Core engineering skills.
	High skills engineers to manage the transformation of the manufacturing sector.	High-level communication and collaboration skills to work in multi-disciplinary teams.
		Multi-disciplinary technical, commercial and management skills.
		Innovation, commercialization skills.

Note: reworked from an original table published in *The Future of Work: Jobs and skills in 2030*

#### 4. THE FRAMEWORK OF THE TRANSFORMATION OF DESIGN SKILLS AND DESIGN EDUCATION: NEW CAPABILITIES

Two primary considerations emerge from an analysis of the scientific literature and the most important studies on the transformation of work associated with the acceleration of technological development. The first of them, which is general in nature, is that while design work is at low risk of automation because the human component is (still) indispensable to creative processes, it shows a constantly growing level of integration with the technological world. This potential new structure has two consequences: it shifts the sector's centre of gravity from a more humanistic to a more techno-human, or post-human, dimension (Braidotti, 2008). It means that design is, and remains, a human activity which, if its creative and operating processes are technologically hybridized, will be able to work in an increasingly integrated manner in areas of business like industry or in sectors such as healthcare and transport, in which automation and a non-human agency will become increasingly important. The second consideration is that the skills identified by Frey and Osborne as resistant to change are already syntonic with some of the more recent transformations of skills relating to design. These three elements are co-present in a profile that has been called designer=enterprise (Bianchini and Maffei, 2012), which combines

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individual designers who act as productive organizations, and are characterized by the following capacities:

- a *creative intelligence* applied to all phases of the ideation, materialization and distribution of ideas and to the development of corporate organizational forms that make strategic use of a group of technologies (for example, tools and platforms for digital fabrication and the Internet of Things);
- the *ability to materialize ideas* by manipulating existing technologies, both hardware and software, to adapt them to their particular purposes;
- a *social-relational intelligence*, in terms of the ability to develop open and distributed forms of production based on collaborative networks, and the capacity to personalize products through new forms of personal relationship, which may also be mediated by technologies.

The features and capacities of the *designer=enterprise* undoubtedly have points of contact with the culture and profile of makers and the development of forms of crafts and self-production supported by the parallel development of digital fabrication technologies (Micelli, 2011). Today, figures such as designer-producers and designer-makers are the prime evidence of a broader framework of transformation of hard and soft skills. In this regard, besides the above-mentioned NESTA, the Craft Council UK, in its report entitled *Innovation through Craft: Opportunities for growth* (KPMG for Craft Council UK, 2016), working on boosting the role of craft innovation in the domestic economy, has drawn attention to two aspects:

- enhancing the potential of craft innovation (or innovation through craft) in frontier sectors of industries such as synthetic biology or digital manufacturing (considering that in the past ten years, the contemporary craft culture has already seen a cross-fertilization process involving design and maker culture);
- the merger of craft skills and skills present in the engineering, science, and technology sectors, with the aim of translating sector-based hybridization into training programs.

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## 5. EXPERIMENTAL LEARNING AS A KEY TO FUTURE CHANGES IN DESIGN SKILLS AND DESIGN EDUCATION

The impact of technology on our experiential environment, as seen through the transformations in the nature of products, the production of goods and services, and forms of work, requires not only the more traditional approach to design, but also a humanistic vision able to integrate, and to be incorporated with, the STEM disciplines. In recent years, the OECD has produced or supported the development of studies focusing on transformations in work and skills about the digital economy. The pervasive development of ICT in all areas is increasing the demand for specialist profiles such as programmers, application planners, network managers, and data analysts. Moreover, workers will also require a broader set of skills complementary to ICT if they are to prosper in the digital economy. It requires solid literacy, calculation, and problem-solving abilities, but it also needs independence, coordination, and collaborative capacities complementary to ICT skills (Grundke *et al.*, 2017). The EU Commission (EU Commission, 2016) cites a classification of the most-requested skills based on a study carried out by LinkedIn Global in 2015. The data show a clear prevalence of professions in the IT field and set the term *design* about interfaces, algorithms, and processes associated with software development. This is what may give design the potential to operate in an evolved manner with technologies for design, production, and relations with users and the market. One example of this is the recent development of CAD applications with tools for generative design combined with artificial intelligence and cloud computing which are connected to digital fabrication processes characterised by an increasing level of robotization and integration with IoT platforms available to end users (as in the case of the MX3D start-up: [www.mx3d.com](http://www.mx3d.com), fig. 1.5).



**Figure 3. MX3D Production Unit (source: <https://mx3d.com>)**

The issue that emerges is the development of a range of new skills that is, a combination of creative, organisational, social, and technological skills that permit individuals to design and

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experiment with and the technologies, to develop processes for designing in new ways, and to create and complete post-industrial artefacts that merge design, craft culture, and technology. New skills require a combination of design sector culture and thought, computer-algorithmic culture and thought, and scientific thought. These skills can be developed and strengthened at a personal level (individually or collectively) by means of hybrid practices such as 'making' being applied to education and the profession, and located in hybrid places where there is cross-fertilisation among individuals with different profiles and professions and training, scientific, professional, entrepreneurial, and cultural activities. Three possible directions for the development of new Skills can be hypothesized:

- skills that enhance the designer's capacity to act and interact systemically with companies, users, and the market. These skills are well-suited to the design of new experiences for users in contexts such as augmented reality in various domains, new digital identities for clients, and automated services using intelligent machines. But these are also skills that enable a designer to use data strategically to develop highly-skilled and personalized services, to carry out more in-depth studies on client behavior, and to design projects that include experience in the use of products based on artificial intelligence so as to predict or anticipate users' tastes or needs;
- skills that enhance the designer's capacity to operate in open organizational contexts. These skills increase the ability to manage innovation processes, in particular creative skills associated with management of companies' cybernetic infrastructure: that is, the creative and strategic management of all a company's machine learning, as well as the skills involved in managing hybrid innovation processes characterized by a combination of design, science, and technology, and those to do with the design of intelligent systems that enable exponential innovation by companies;
- skills that enhance the designer's capacity to specialize for work in production contexts with convergent technologies. These skills enable a designer to operate in fields such as biotechnology, bio-fabrication, and bioelectronics, and to use 3D design and production methods (from design to printing and sales, gaming, or learning, or the use of artificial intelligence to design products better or make them more intelligent).

This more comprehensive idea of *Experimental Learning* concerns not only the development of new skills also their growing transformation through interaction with the places allocated to their learning and those in which design-materialization-distribution activities are carried

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out. Experimental learning requires evolved forms of experiential learning that complement peer-to-peer and machine/computational learning relations. This made possible by the inter-connection among:

- *experimental skills*, which enable the individual to develop forms of craft and hands-on innovation that combine design, technology and science;
- *experiential skills*, which enable the systematization and enhancement of the learning that springs from all the individual's work-life experiences;
- *entrepreneurial skills*, which enable the design and re-design of a job or business activity;
- *heuristic skills*, which enable the individual to use algorithmic processes to exponentially accelerate the possibility of developing design solutions with exponential complexity.

The above-mentioned set of skills characterize designers simultaneously as *adaptors* and *innovators*. This attitude linked to the transformation of work, within an increasingly organized system of project-based and on-demand activities, highlights another matter on which design education should reflect. New forms of work will increasingly resemble what designers have learned in recent decades in order to survive in the market. Especially because they no longer work for industry alone, designers have developed the social and organizational skills that now serve them to operate in an empowered and resilient manner through a technological symbiosis. *Makers, designers=enterprises*, and other species of independent innovators can represent a first step of an evolutionary path. To paraphrase Manzini (Manzini, 2014), all this means that “every worker in the future should act or be like a designer...” design skills will probably become the protagonists of the transformation of skills in general, becoming key resources for any form of future work.

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