3D-PRINTING AND THE WORKING ENVIRONMENT

Jeroen Junte, November 2016

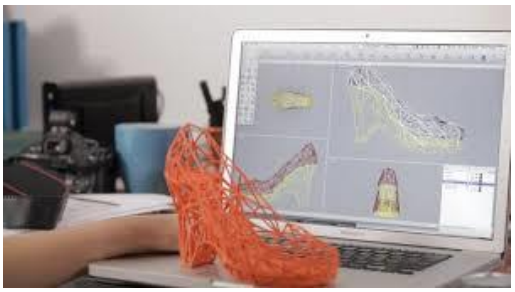
INTRO

This article on 3D printing has been undertaken on behalf of the European Agency for Safety and Health at Work (EUOSHA). It examines some key questions concerning the opportunities and challenges of the emerging 3D printing industry for employers, workers, and the new entrepreneur, who is working from home or informal workspaces. The aim of this report is to introduce 3D printing and explore its possible impact on both the existing as well as a new working environment. Finally, some recommendations will be given on European level as to what measures can be taken to secure that 3D printing benefits a more safe, healthy, and fulfilling work environment, both in the context of the existing employer-worker relationship and of a new, informal self-entrepreneur.

1. WHAT IS 3D PRINTING?

3D printing is the buzzword in innovation and creative industry. But what it is, exactly, remains unclear to the general public. Additive manufacturing, desktop producing, rapid prototyping, digital fabrication—there are different names for this new technology. [i] Because of the fully computerized process of designing and manufacturing products, 3D printing is part of the bigger development of digital fabrication.[ii] However, using 3D printing as an umbrella for a wide range of new digital production—such as CNC milling machines, laser cutters, computerized steel plotters, and many more—is misleading. For example, CNC (Computer Numerical Control) is a traditional technique of milling but the movements of the machine a digitally controlled. Though they all offer the same amount of freedom in forms and uniqueness, most digital fabrication is based on subtracting from a solid material by milling, sawing or cutting. With 3D printing, a product is built from scratch by adding material. The most concise description, therefore, would be additive manufacturing.[iii] In the future these two digital techniques (subtracting and adding) will be used flexibly: a CNC machine and robotics can easily be transformed from subtractive to additive production, simply by alternating the head.

In this article 3D printing will be limited to different techniques in manufacturing products that only exist as a computer file with the use of a machine that is adding raw materials in layers until a finished product is shaped.[iv] This starts with the design of a product on a computer. The document of this Computer-aided design (a CAD file) is basically nothing more than an elaborate print order.



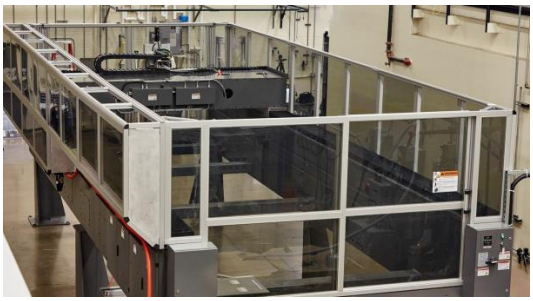
CAD-file

2 HOW IT WORKS

The computer generated design is digitally divided into thousands of layers; this slicing is done with software that prepares a design for a print order. Another way a digital printing file of a product can be made is by making a 3D scan of an existing object. This data can be transformed into a print order with special software. These scanners can cost anywhere between 50 to 50,000 euros. A desktop 3D-printer will cost around 1000 euros.

Ultimaker

A professional 3D printer for prototyping and limited-edition production will cost anything between 2000 and 20,000 euros. When existing warehouse and large-scale production is to be replaced by 3D printing, it will require investments of up to more than a million euros.

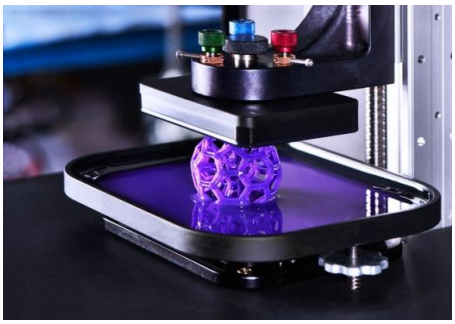


Large-scale industrial 3D-printer

Basically, the actual 3D printing technique can be divided into two different technical processes. The impact they will have on the future of designing, making, and distributing goods is also different: the binding technique is used in the highly advanced professional industry; the extrusion technique is rougher and commonly used in the consumer market and bottom-up experiments in 3D printing.[v]

2.1 Binding

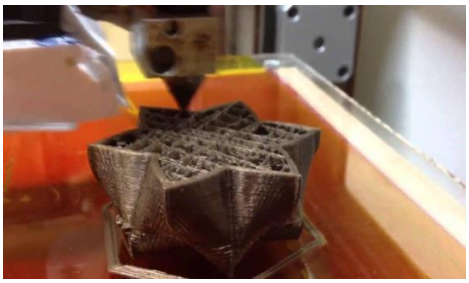
The binding technique uses a print head (equipped with a laser, UV beamer, heater, etc.) to bind a synthetic material that is sprayed out. The quality is higher and a wider variety of materials can be used. It also demands a higher degree of knowledge and precision, and is more costly. These 3D printers are more expensive and the materials used are as well. Binding is therefore mostly used in highly advanced and (semi-)industrial processes.



Stereolithography

2.2 Extrusion

The extrusion technique involves binding material that is extruded in an exact choreography of time and place. This is the most common process used by open-source and consumer-friendly 3D printers that usually come as a plywood building kit (f.e. Makerbot, Ultimaker, Airwolf). The extruded material can be a liquid, powder, synthetic filaments, or organic materials such as ceramics or rubber. Many of these printers are sold as a do-it-yourself kit. Production is faster and cheaper, but the final product is less refined.



Extruded object

3 OLD AND NEW MATERIAL

The first materials applied in 3D-printing were synthetic plastics. The number of materials that can be used with the 3d-printing have increased a lot the last ten years. At first it was mostly synthetic plastics. Now also ‘traditional’ materials such as ceramics, steel, glass and even wood are widely used. Research has shown that desktop 3D printers can pose emission risks of large numbers of ultrafine particles (UFPs, particles less than 100 nm) and some hazardous volatile organic compounds (VOCs) during printing, although very few filament and 3D printer combinations have been tested to date.vi

The materials differ in 3D-printing in an industrial context or in the home environment. In the latter the most commonly used materials are the biodegradable PLA (Polylactic Acid) and ABS (Acrylonitrile-Butadiene Styrene), an oil-based plastic and therefore more toxic in use. Ventilation is recommended with PLA and necessary with ABS.vii

Most commonly used in the industrial 3D-printing process is polyamide (nylon etc) in liquid as well powder form; this is an oil-based plastic. During heating toxic fumes are extruded; ventilation is needed. Polyamide as a powder is sometimes mixed with aluminium (alumide); though less toxic, the use of this material still needs special regulation in safety and health. Other industrially applied materials are polysulfon (PSU) en polyfenylsulfon (PPSU), both synthetic plastics that require safety measurements in ventilation and handling.viii The fastest growing segment in 3D-pritning is the use of metal.ix This requires regulations concerning ventilation, since metal is combined with oil-based synthetics. High temperatures also demand regulations in safety and handling.x New materials are smart materials that react to differences in heat, pressure or light after production. Also new nano-carbons and are expected to be used on a large, industrial scale in the near future. The introduction of these hightech materials requires close investigation on safety, since most of these materials are still experimental.xi

4 THE PROMISE OF A NEW INDUSTRIAL REVOLUTION

We live in a digital era. Social media has upset traditional journalism.[xii] Online shopping is driving traditional shops out of business and ripping our vibrant inner

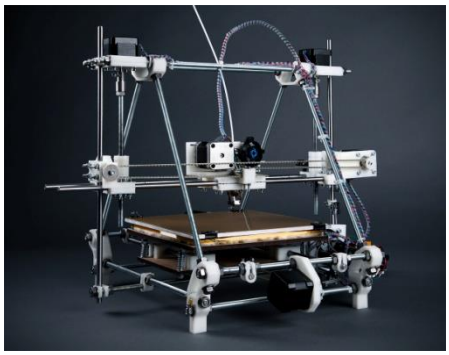
cities apart. Even online shopping is changing work circumstances since it has become highly automized. Robotics will change the way we drive our cars and run our households. And finally, the way we design, manufacture, and distribute our consumer goods in this digital era will be changed by the 3D printer. Expectations of 3D printing were so high in the last years that nothing less than a new Industrial Revolution was imminent. At least, this was the message of the epoch-defining, twelve-page report in *The Economist* in 2012.

The Economist – april 2012

In that time the prediction was that the 3D printer was a new digital tool that will soon be found in every household. That will mean the end of mass production. More accurately put, it was a *post*-Industrial Revolution that *The Economist* predicted. Anyone can download the digital blueprints of a product from the internet and print it at home with just one push of a button. Alterations can be made to the product; people with wide feet can easily print a shoe that is just a little broader. Making this unique, tailor-made product will cost just as much as mass production in a Chinese factory, and thus undermine the existing economic status quo of production. New products will be less in demand; repairing will finally become widespread because spare parts of broken-down appliances can also be easily reproduced at home with a 3D printer. Since production will move into peoples' homes, the time and energy spent distributing goods will be limited. Furthermore, supply and demand will be in check, since people will only print what they need. This means no more stock and overproduction. This new Industrial Revolution could also be green.[xiii]

The timing of this article in *The Economist* was no coincidence. The technique of 3D printing already existed in the mid-1980s. Stereolithography was patented in 1984 by the French scientist Alain Le Mehaute. Still, it took ten more years before the term '3D printing' was coined. At that time only highly specialized industries like medical care, automobile production, and aerospace engineering were experimenting with high-tech 3D printers for prototyping and flexible production. But in the first decade of the twenty-first century great strides were finally being made. 3D printing on a large scale now became possible not only with plastics, but also with metal, conductive

materials, glass, ceramics, and even organic tissues. Large companies like Canon and Siemens began researching the market for consumer-friendly 3D printers. Makerbot, an American company, sold the first desktop 3D printer for just over 1000 euros in 2008, making 3D-printing technology accessible to a mass audience. Around that same time the research project RepRap (replicating rapid prototyper) developed a rudimentary desktop printer that consists mostly of plastic parts that can be made with a desktop printer. The mechanical parts of the RepRap can be pre-ordered online. In other words, the RepRap is the first 3D printer that can replicate itself—and that for the cost of just over 200 euros. The software to run a RepRap is open source and freely downloadable.



RepRap

In short, within a decade 3D printing shifted from being a futuristic way of producing relegated to computer nerds, cutting-edge designers, and high-tech industries to a mainstream, consumer-friendly tool for flexible home production. Or, as *The Economist* put it: the start of a new Industrial Revolution. Just as with previous such revolutions, the impact of 3D printing on the economy and on both a societal and human scale can be enormous. Foremost are the increases in welfare and progress resulting from efficient and tailor-made manufacturing. But the negative consequences of earlier industrial revolutions—environmental pollution, poor working conditions, blurring worklife and increasing inequality—are absent, because 3D printing introduces a local and demand-driven—and therefore more sustainable—method of production. Because 3D printing is rooted in an open-source structure, it is more open to new businesses and small-scale innovation than the traditional manufacturing industry. So it will not only be a greener but also a more impartial Industrial Revolution that empowers the consumer.

The impact of 3D printing can be divided on two levels:

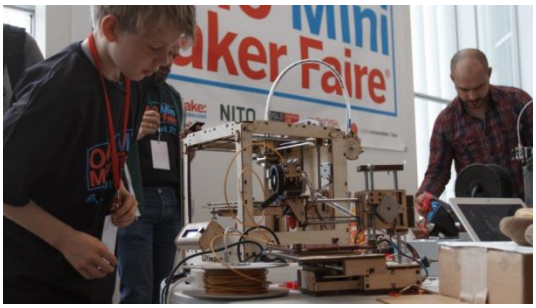
<u>- Societal:</u>

3D printing will strengthen social inclusiveness. With minimal investment, anyone will be able to start a small business from his or her own basement. All that is needed is a computer, a 3D printer, and a fast internet connection. The necessary knowledge, ideas and, for a large part, also the software are freely exchanged. Digital fabrication has spawned a ‘maker movement’ of consumers who are manufacturing products.

Though the maker movement intersects with hacking, traditional crafts, and scientific experiments, the 3D printer is considered to be the heart of this worldwide trend. The impact of the maker movement on an economic and societal level can hardly be overestimated. What Airbnb has done for the hotel business is what 3D printing can do for industrial production: radical democratization of design, production, and distribution. Also, with the same loss of control of the conditions in which the activities occur.

- Individual

In short, 3D printing enables the individual access to better products. Individual desires and needs can more easily be met. Furthermore, products will be made of replaceable and downloadable elements, which makes it easy to repair them. This producing consumer, or *prosumer*, will be empowered and able to improve his or her everyday life. Probably the most powerful impact that 3D printing will have on the individual will be on a psychological level. As sociologist Richard Sennett pointed out in his book, *The Craftsman*, the making of goods is a deep-rooted need of human beings. It enables self-development, self-esteem, and self-actualization. We are what we make, so to speak. In our modern times a maker movement made possible by accessible digital fabrication such as 3D printing provides the individual with autonomy and offers people possibilities to shape their own lives in both a psychological and material way. This maker movement also provides new social networks and cohesion, since information and knowledge is freely shared. The worldwide Makerfaires are a gathering of these do-it-yourself producers. One could say that 3D printing introduces a do-it-*ourselves* movement.



Makerfaire

5 AN EVOLUTION INSTEAD OF A REVOLUTION

But now, five years after the aforementioned publication in *The Economist*, that revolution still has not started. Far from it. It is not even mainstream.[xiv] Makerbot almost went bankrupt in 2015 and the RepRap has hardly improved since its launch. Because of the unorganized and fragmented nature of the 3D printing industry, there are hardly any figures on its economic contribution on a European scale. Yet there are reliable estimates that, in the more highly developed European countries, not more than one per cent of the population actually owns a 3D printer. But still the larger portion of the 3D-printed products are manufactured at home and distributed within the sharing economy. The industrial 3D-printing is still less than home-production. To give an example, the economic contribution of the entire 3D printing industry in the Netherlands in 2015 was estimated at around 45 million euros; that makes 0.005 per cent of the country's total GNP of 888 billion euros. There is no presumptive evidence that this figure will be significantly higher in other EU countries. The average annual growth of the 3D printing industry over the last five years was thirty per cent. Even when this figure doubles, it will take at least five years before 3D printing can compete with an economic sector like the pop music industry. The impact of 3D printing is hard to predict. But one thing is sure: it will not replace existing industry, but will rather be an addition to it.

A schism in the use of 3D printing is growing. On the one hand, a new, highly advanced and flexible industry is emerging. These companies work in fields such as medical care and the automotive industry, but also in fashion and consumer products in everyday use. On the other hand, small-scale and sometimes almost low-tech, do-it-yourself production is growing. These microfactories and start-ups are initiated by designers, cooperatives, small businesses, and informal networks. But what is still missing is the widespread use of 3D printing on a wider level by consumers. The maker movement consists of skilled amateurs and early adapters.

6 A NEW INDUSTRY WITH 3D PRINTERS

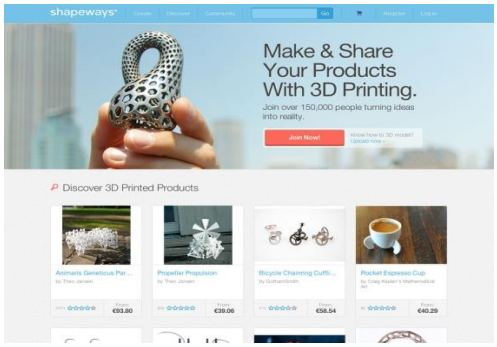
6.1 Opportunities and risks for employers

3D printing offers new business models. The London-based online platform Open Desk does not even have a production unit. It offers a furniture collection by designers from all over the world. All furniture is made from wooden boards. When ordered by a customer Open Desk finds a digital fabrication workplace closest to the customer. After production costs are paid to this the profit is divided between Open Desk and the designer. This way an internationally operating furniture company is hardly more than a help desk needs. Shapeways is a global company where people can have their own designs printed. Professional designers can also upload their designs for consumers to order. When an order is made, the designer receives

royalties paid by Shapeways. This on-demand production factory is now only based in New York, but will soon expand to different locations around the world.

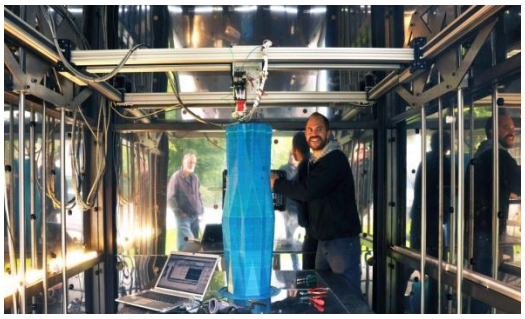
New challenges for companies working on such a large scale with 3D printers involve occupational health and safety.[xv] This concerns issues like gas and material exposures, material handling, static electricity and moving parts and pressures.[xvi]

Also, for reasons of copyright and illegal production, strict monitoring of the workers is needed. When a replica of a *Star Wars* figure is manufactured, this may infringe copyright. But who is liable, the designer, Shapeways, or the buyer? Since 3D printing requires a precise process, the workplace must be clean and organized, and user interfaces must be clear instructions comprehensible. Errors in programming or adjusting and calibrating the printer occur easily. On top of that, a malfunctioning end product will more easily result in legal actions, since the modern consumer is highly emancipated.



Shapeways

Special regards to safety must also be given where new products are being introduced. An example is De Kamermaker, a 3D-printing unit for architecture developed by the Dutch architectural firm DUS Architects. With this extremely large 3D printer, constructional elements of 50x50 centimetres can be printed. But what does this mean for the safety of construction workers? At the technological institute MIT in Boston a research group Mediated Matters headed by Neri Oxman is experimenting with 3D-printed constructions based on natural shapes and configurations. Hybrid manufacturing, where only parts of a product are 3D printed, is also becoming widespread.
What is missing also in the 3D printing industry is a universal standard system for use by individuals as well as the emerging industry. This will enable the sharing of parts, which will benefit sustainability as well as safety.



Kamermaker – DUS Architects

The Italian-Japanese design studio Minale Medae is producing Keystones, a 3D-printed joint that enables you to build your own furniture using standardized wood panels. The strength and tensial strength of these parts must be validated and certified. Many times these new products and techniques are developed by specially trained staff within a company. But who controls authorship of these innovations? When not regulated properly, this can cause tensions between employer and worker.

Keystones – Studio Minale Madae

Innovating an existing production facility with 3D printing will require high investments. The advantage is that investments in moulds or special machinery are no longer needed to test prototypes. New products can be released into the market almost immediately, and with relatively low costs. New techniques also offer new possibilities. The 3D pen is a printer that looks like a pen and enables you to draw in 3D. For health and safety reasons these new handy 3D printers must be thoroughly tested and strictly regulated because the heating can poses health threats. More and more these pens use ultraviolet light.

There is a generation of *millennials* that is drawn to innovative and digital industries like 3D printing and who have different demands concerning quality of work. In general this means that there will be a rising demand for younger workers who have a different outlook on work: free time and self-development are more appreciated than money and job security. Working on short-term contracts is the new standard. To compensate, young workers demand (creative) participation and a dynamic environment.

Such constant innovations and developments require continuous research and development, as well as investments in highly skilled workers and keeping them up to date through training and education.[xvii]

This table shows the changing work conditions between the flexible and on-demand production with 3D-printing and traditional industrial production.

TRADITIONAL INDUSTRY		DIGITAL FABRICATION
Hierarchy	-	Democratized
Centralized	-	Open
Regulation	-	Responsibility
Production-centred	-	Communication-centred
Promotion	-	Training
Financial/job security	-	Freedom and flexibility

6.2 The implications for workers and their jobs

Concerning the future of jobs, the key question with 3D printing (as with robotics and other automated production) is, will it replace or change existing work? Yes and no.[xviii]

Yes, because machines will take over flexible, handmade production. Craft goes digital. With a 3D printer, objects can be made in the complex and elaborate forms that were previously only possible by skilled craftsmen. With the introduction of 3D printing of materials like metal and wood, traditional crafts are becoming obsolete.

But no, this will not inevitably lead to more unemployment. Firstly, 3D printing will also introduce new jobs, for example, in the design and production of hardware (e.g., 3D printers) and, more importantly, in creating the software that enables machines to carry out various tasks.[xix] Also, 3D printing can easily open up the global market. At the same time, production is increasingly done locally. So labour that was previously outsourced to low-wage countries will now return to Europe. This means, however, that schooled workers will be in demand, whereas the demand for labour workers producing simple handicrafts is declining. This means the gap between educated and less-educated workers will rise.

A major change in actual working conditions will be made by the dominant use of plastics in 3D printing. Good regulation and certification of these synthetic materials is essential. Production with 3D printing is expensive, but also time-consuming.

As with other digital technologies (robots, artificial intelligence, etc.), the consequences for those who perform these routine tasks can be devastating. The work can be boring and highly uncreative, like watching paint dry. At the same time, the 3D-print technique is still relatively complex, asking a high degree of concentration. Mistakes are easily made, and the smallest errors will lead to major failures in the final product. This means that companies must make extra efforts to keep personnel motivated.

With all the innovative buzz surrounding it, 3D printing is an alluring industry. As with many start-ups, workers are tempted to put in long hours; also, the line between work and non-work activities can easily become blurred. Most of the companies working in 3D printing are young and fast-growing, and therefore less organized. With a variable staff, organization among workers is difficult. This raises concerns about reasonable waging, working hours, and safe and clean working conditions.

7 STARTING YOUR OWN BUSINESS AT HOME

A new, informal chain of production is introduced with 3D printing. This democratic ‘maker movement’ enables people to start their own business from home. But just as Steve Jobs was an experienced computer entrepreneur when he started a company from his garage, most the small companies and start-ups in 3D printing are run by semi-professionals. Together they form a highly disorganized industry that is hard to regulate. An individual 3D-printing entrepreneur can be working from his or her home or from an informal office space (garage, etc.) that is unfit as a professional environment. Ergonomics, clean air, working hours, and a healthy balance between the home and the workplace are under tension.

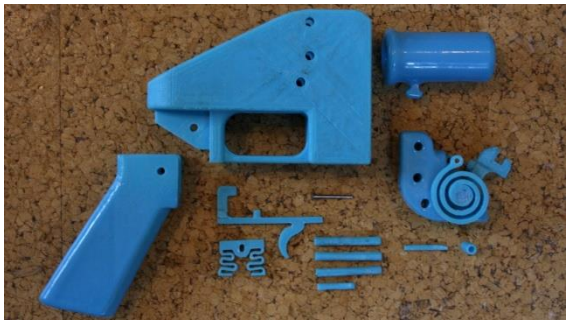
By far the biggest challenge of 3D printing for the self-employed worker is insecurity. When everybody can become a 3D printing manufacturer, the competition between these *crowdworkers* can be devastating. The market has shown tremendous difficulties in regulating the price of these 3D-printing services. This economic stress is further enhanced by the lack of social rights and financial regulation. What seems to be a creative forefront can in fact become a new digital proletariat. In this *gig-economy*, as it is called in the United States, self-employed 3D printworkers will hop from one commission to another. There is a serious risk of a new class of modern day journeyman emerging. Even the home manufacturer who keeps control of sales and distribution by offering their product on online platforms like Etsy.com or Ebay.com is not safe. The old-fashioned time clock is replaced by the pressure of online ratings. The promise of a post-capitalist economy can become a form of hypercapitalism where many people control the production but nobody controls the lower limit of social and economic security.

In most cases, though, it is not the consumer but the designer that has taken over the role of small-scale manufacturer. Many of these self-producing designers consider

3D printing to be cold and impersonal. As a result, they are ‘hacking’ 3D printing and making it less digital and more machine-like. This calls for strict regulation. What is problematic about this is that it usually involves a new type of machinery, so existing regulations do not fit. For example, the Dutch start-up Studio Joris Laarman has transformed robotic arms into flexible metal welding machines. With this low-tech 3D printer they are now building a pedestrian bridge over a canal in Amsterdam. The British start-up Amalgamma is using robots to print concrete structures.

3D-printed bridge – Studio Joris Laarman

These new types of small enterprises offer dynamic but highly insecure job opportunities. In this fast-developing industry the innovation of today can be tomorrow’s obsolescence. In companies where the legal division between the designer, the manufacturer, and the entrepreneur are diffuse, liability in case of malfunction or inferior quality is unclear. This creates uncertainty in liability. With all sorts of products that become freely available by (illegal) downloading from the internet, piracy and copyright infringement are imminent.[xx] Apart from these legal issues, this also poses new ethical dilemmas. The Liberator Gun is a handgun that can be printed on a desktop 3D printer after downloading free print instructions from the internet.[xxi] Regulations and reliable worker contracts are needed.



Liberator Gun

A special mention must be made of the ‘fablab’, a cooperative workspace with digital as well as analogue devices. The fablab (an abbreviation of ‘fabrication laboratory’) plays an important role in the empowerment of individuals, enabling them to create smart devices for themselves. It is, one could say, the missing link between home 3D printing for personal use and new businesses. A fablab is open to the general public under the condition that the production process is documented. With more than 250

fablabs worldwide (over 100 in Europe), one of the largest open-source databases on 3D printing and other digital fabrication is being created. The number of fablabs is still growing. Most are non-profit and offer free services for individuals, such as courses and workshops; commercial fablabs are also multiplying. Since these workspaces run on an informal basis, the required working conditions are not always met. With sensitive devices like laser cutters and computerized milling machines, special considerations must be given to safety in these workplaces. Also, a minimum age and maximum working hours must be regulated.

Fablab

8 FUTURE SIGNS

New innovations will have a profound impact on 3D printing and the working environment. The five most important innovations that will be introduced are:

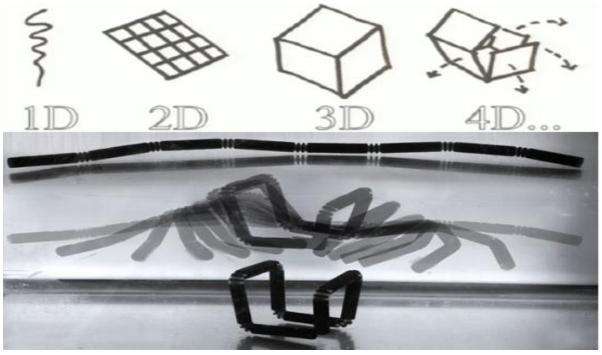
- Food

Flexible production and freedom in creation offer great opportunities in the food industry. Currently, mostly liquid foods, such as chocolate and pancake batter, are used with 3D printing. In the near future 3D printing will be used for raw food that will undergo later treatment, such as heating, or will be processed by natural processes like fermentation or germination. This will pose new challenges to hygiene, safety, and general working conditions (clean air, ergonomics, etc.)

3D-foodprinting

- 4D printing & smart materials

Smart materials have one or more properties that can be significantly changed in a controlled way by external stimuli, such as temperature, force, light, moisture, pH, and electric or magnetic fields. When manufactured with a 3D printer, these smart materials can form objects that respond in shape, tactility, or hardness. This process is referred to as 4D printing, since the objects will change again over time. These changes can be imposed by a sensitivity on light, pressure or temperature by these materials. Some of these materials may have a 'memory'; this means they will change back to their original shape when the circumstances changes again. Many of these materials are highly experimental, and the posed risks on health and hygiene are uncertain. This calls for strict regulation.[xxii]



4D-printing

- Bio-printing

The 3D printing of organic and/or living tissue is referred to as bio-printing. These bioprinters output cells from a bioprint head that moves left and right, back and forth, and up and down, in order to place the cells exactly whererequired. Over a period this permits an organic object to be built up in a great many very thin layers.xxiii In addition to outputting cells, bioprinters can also extrude a dissolvable gel to support and protect cells during or after printing. There have been numerous successful experiments of printing 'living' materials containing fungus or algeas. As with smart materials, this technique poses risks to health and hygiene. Furthermore, it raises ethical issues.xxiv

Bio-printing

- Nano-printing

By combining 3D printing with nanotechnology, it will be possible to shape objects from a nano- or molecular level. In theory this means that through additive manufacturing it will be possible to manufacture any form of object of any kind of material, in any shape or volume. This technique, however, is still theoretical; no predictions can be made as to the impact on the work environment.

Nano-printing

CONCLUSIONS

The everyday impact of the 3D printer on physical safety in the workplace will be limited. It hardly presents any new risks. After all, it is just a machine that demands relatively little manual involvement. Also, most materials with 3D-printing are known as are their effect on heath by emission of gas, material exposures, material handling and static electricity.

The impact on the well-being of the worker will be strong, however. New risk are posed on job insecurity, working hours, liability, monotony and routine on the job, keeping up with new developments by training and education and finally security riks with the introduction of experimental machinery. It is highly recommended that a response to these changes in the work environment is made on a European rather than a national level, since 3D printing is a global economy. This involvement should manifest at three levels:

<u>1 Monitoring & Verification</u>

What are upcoming innovations? How likely is it that this innovation will be implemented on a large scale? Is this technique patented or otherwise protected? Who is liable in case of malfunctions? Can the used materials be traced? These are just a few of the questions that will emerge. Monitoring changes in 3D printing requires a constant dialogue with the industry. This can be done most easily and cheaply by establishing an online platform where both workers and employers can check in. For contacting and monitoring individuals such as the *prosumer* (self-producing consumer) the vast network of fablabs in Europe can be used.

2 Regulating & Certification

Due to the dynamic, bottom-up, and sometimes experimental nature of 3D printing, there is a lack of regulations. A strong instrument can be certification. Until now this certification has only been done by high-tech companies that are very protective of production techniques developed with large investments. Their secrecy and patenting does not contribute to regulation of 3D printing in general. The regulation of 3D printing in the working environment must be done for the following reasons:

- Quality and Safety control

3D printing is under constant influence from new techniques and materials. This poses risks to safety in relation to the 3D printers as well as the manufactured goods. EU governments can demand the registration of all innovations.

- Liability

The introduction of new techniques and materials can lead to conflicts of intellectual property and creative ownership between employer and worker. Also, with designs being (mostly) freely available online, there are new risks of copyright infringements and liability in case of malfunctioning or inferior products. Governmental bodies can intervene by drawing up standard contracts and offering legal advice.

- Workers‘ wellbeing

The global economy and dynamic start-up atmosphere surrounding 3D printing can be stressful to workers who are faced with higher demands in working hours, flexibility, and responsibility. Since the 3D printing industry consists mostly of start-ups and new types of microfactories, the organization of workers in traditional unions is outdated. New forms of worker organization should be explored.

- Health
  E.g material use, emissions,
- Job insecurity

In an industry that is highly innovative, job insecurity can be high. This can be reduced by mandatory training possibilities to keep workers updated.

- Involvement

Working with automated machinery like 3D printers can be boring and stressful. Training can have a positive influence on workers’ motivation. Workers in 3D printing are usually relatively young. Employers should also take extra measures to keep them motivated by sharing responsibility and offering flexible work conditions.

3 Training & Education

Apart from challenges concerning the individual working environment, 3D printing also offers incredible opportunities for improving equality on the labour market in

general. We are living in a knowledge society based on networking and technology. The division between people who have access to and knowledge of technology is growing. Yet with 3D printing and the underlying maker movement, access to knowledge is cheap and relatively easy via the internet. The most important network in this maker movement are the fablabs. By collaborating with fablabs in offering education and training, the growing ‘tech gap’ can be undermined, which will lead to a more equal labour market. This is especially relevant in the economical context in Europe, where individuality, openness, and innovation are main targets.

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