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Introduction to 3D Printing

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INTRODUCTION

The aim of this Report is to produce an introduction to 3D printing, what it is, the opportunities and potential for its use, the impact on society, the prospects for employment, how to introduce 3D printing in training establishments, including the type of hardware and software required, and a few general 'tips/tricks'.

This Report complements two further training programmes to be developed by THREE-D-PRINT project Partners in 2021:

TEACHING MATERIALS FOR TRAINERS:

THREE-D-PRINT will create a training programme on 3D printing for trainers, to provide them with the knowledge and tools to develop a teaching programme on 3D printing in adult education.

THREE-D-PRINT will develop a teaching pack to enable educators to learn how to teach the 3D printing programme and provide course materials for their students e.g., assignments, quizzes, general learning materials.

***NOTE**: These 2 outputs will be freely available to download from 1st August 2021 at https://www.3dprint-training.com/*

Worldwide pandemic multiplies the problems in supply chains, especially in sectors such as manufacturing and logistics. The spread of coronavirus has caused disruptions in many plants, disrupted supply chains and prevented production at many industrial factories. This time of global crisis forces most companies to review their current working methods and consider implementing new tools and technologies: such as 3D printing (Additive Manufacturing (AM)).

Since its beginning, the 3D printing industry has experienced significant growth, evident in Wohlers Associates' yearly reports (Wohlers Report 2019 ISBN 978-0-9913332-5-7). Behind this growth is a talented workforce. But, as with most disruptive technologies, the sector growth happens much quicker than the pace of learning, leading to a talented workforce.

This lag has created what is commonly known as the 'Additive Manufacturing (AM) Skills Gap'; the notion that there are simply not enough talented people to fill jobs and thus meet the needs and demand from the AM employers.

"For educators, having an understanding of 3D modelling and 3D printing techniques will be invaluable, as the culture of fab labs is starting to gain support as an important aspect of education. Teachers with 3D modelling and fabrication experience have a range of opportunities open to them within educational programs looking to incorporate this new technology," (Erol Gunduz, a professor at New York University's School of Continuing and Professional Studies (NYU-SCPS)).

Regarding the skills that will be needed by workers in new age technology fields, there are four basic skill fields.

First, there are **cognitive skills**, which include digital literacy, as well as advanced problem-solving and creative and critical thinking skills.

Second, there are **social and behavioural skills** like conscientiousness, grit, and openness to experience.

Third, there are **educational skills** like cooperative learning, peer education, metacognitive attitude, an optimal proximal learning environment developing a group identity and prosocial values attitude.

Fourth, there are job- or occupation-specific **technical skills**, in this case related to robotics systems and 3D printing.

WHAT IS 3D PRINTING?

3D printing refers to the process of additively building a three-dimensional physical object from a digital model data (Computer Aided Design or scanned object) file by depositing and forming successive layers of material under computer control.

A 3D printer is a machine that can turn a blueprint into a physical object by applying material layer by layer without the need to adjust the production tooling. This additive manufacturing process is the reason why 3D printing is also referred to as "**additive manufacturing**", and while technically more accurate, the term 3D printing has been more enthusiastically adopted due to mainstream media diffusion. The analogy with document printing also presents the basic underlying concept of depositing material with a printing head to bring a specified object into existence.

However, there are many underlying additive manufacturing technologies that can be used (e.g. stereolithography, laser sintering, fused deposition modelling), which allow various degrees of precision and sophistication. While in principle the printed objects can be of almost any shape or geometry, their characteristics depend on the underlying printing technology and the materials that can be employed. With advanced 3D printers it is also possible to create assembled objects with internal, movable parts. The time it takes to print a full object however increases with the level of detail and complexity of the object.

The technology is significant because it offers **direct manufacturing**, meaning a design goes directly from designer to physical product through a computer and a 3D printer. It brings a revolutionary approach to manufacturing through three key advantages - shorter lead time, design freedom, and lower costs. It thus enables rapid and low-cost prototyping, manufacturing end-use products (direct digital manufacturing) and producing tooling that allows the manufacture of other components and products using different methods.

3D printed parts allow them to be designed with more complex architectures whereas with little additional costs, for example, the structure with hollowing, holes, atypical shapes or rich interior details. In addition, some pieces that used to be moulded separately and then assembled can now be produced as one piece in a single run, even for some precision components.

In THREE-D-PRINT we see the knowledge and use of 3D printing as a tool that can motivate, enable, and empower. In terms of motivation and inspiration, **it allows the user/learner to experience a rapid and easy materialization of the envisioned objects,** it enables the production of parts that can be used in robotics training and ultimately empowers the user to master the skills that will be relevant and needed in numerous commercial, manufacturing and even healthcare settings.

Finally, it can be used to foster creativity, innovation, experimentation and a DIY "maker mentality" that can be usefully employed in an entrepreneurial as well as an industrial setting.

There are also enabling interconnections between the fields of robotics and 3D printing, for example printing robot parts with 3D printers, without the technology engineers would be unable to construct certain components for (for instance) a soft legged robot that can navigate difficult terrain and could be used in search and rescue operations.

The five stages of 3D Printing

1. The image to be printed in 3D format needs to be designed using relevant software and saved as the STL [1] file format.
2. The STL file becomes the blueprint which is used by the machine to recreate the design in physical form.
3. The STL file is then uploaded into the 3D printer and the computer changes its settings according to the output needed to be extracted.
4. The next stage involves the selection of materials where the layers of the 3D object need to be embedded.
5. Once the print work starts, the 3D printer deposits layer upon layer of material filaments over the print board to get a final 3D product.

[1] STL (an abbreviation of " stereolithography ") is a file format native to the stereolithography CAD software created by 3D Systems. STL has several backronyms such as "Standard Triangle Language" and "Standard Tessellation Language". This file format is supported by many other software packages.

THE WORLD OF 3D PRINTING

Today's 3D printers had their beginnings in the rapid technology development of the 1980s and found their use in many industrial sectors.

The possibilities and opportunities that 3D printing is creating are endless.

For example, 3D printing has been used successfully to make both standard and customized hearing aid shells, dental implants, and prosthetic limbs, sometimes within 24 hours. Previously, implants had to be validated before being used clinically, which is very time-consuming. Today, 99% of hearing aids are 3D printed. 3D printed anatomical models allow surgeons to properly understand organs' internal structure.

In addition, surgical guides with a better visualization assist surgeons to plan detailed surgical procedures. As a result, it increases the clinical efficacy, lowers the surgical risk from errors, and produces better outcomes for patients. More than 70,000 surgical guide units were produced in 2013 using 3D printing.

"…. In 10 years' time, who knows what the printer will look like. It is already capable of self-replication – you can buy a 3D printing machine that can print another 3D printing machine.."
Professor John Bryson, professor in enterprise and competitiveness at the University of Birmingham.

This has also been highlighted in the publication "The disruptive nature of 3D printing" from the Digital Transformation Monitor from the European Commission (2017) [2] which reports that by 2021 the 3D printing market could be worth €9.6 billion. However, whilst the uses of 3D printing are endless in the real world, they are also limitless in the classroom.

Advances in 3D printing are being announced daily. The technology is being used for all kinds of applications, from building human hearts, to building houses! Even NASA has a 3D printer on the International Space Station.

[2] https://ec.europa.eu/growth/tools databases/dem/monitor/sites/default/files/DTM_The%20disruptive%20nature%20of%203D%20printing%20v1.pdf

According to the EU Digital Education Action Plan (DEAP) 2021-2027[3]

'…rapid digitalisation over the past decade has transformed many aspects of work and daily life. Driven by innovation and technological evolution, the digital transformation is reshaping society, the labour market and the future of work. Employers face difficulties in recruiting highly skilled workers across a number of economic sectors, including in the digital sector.

Too few adults are up- and re-skilling to fill these vacancies, often because training is not available at the right time and in the right place.

The use of digital technologies is also crucial for achievement of the European Green Deal objectives and for reaching climate neutrality by 2050. Digital technologies are powerful enablers for the green economic transition, including for moving to a circular economy and decarbonising energy, transport, construction, agriculture and all other industries and sectors…'

The jobs that are emerging and opening with the development of 3D printing are in the areas of 3D design, 3D computer-aided design (CAD) modelling, research, and development (R&D), biological and scientific modelling, architecture/construction modelling, education, law and legal professions, new business opportunities, 3D-Printing-as-a-Service franchises and operations and administrative positions.

Jobs for designers who can translate a product idea into 3D printed objects will be opening in 3D printing firms, as part of 3D design teams in companies and as freelancers. Such job seekers will be most competitive if they acquire hands-on experience with the latest 3D printing technologies and stay up to date with how 3D printing is used in companies and work processes. Job seekers skilled in 3D CAD modelling will support the work of 3D designers, both for mass 3D printing and for custom designed 3D prototyping and manufacturing.

To help fill the skills gap 3D printing programmes at all grade levels need to be developed and widely offered. This will open jobs for educators who can teach the technical and business aspects of 3D printing.

Training institutions are looking to 3D printing as a point of exposure for students within the Arts as well as scientific areas of study. Teachers will need to have a background in the 3D printing industry. They will also need specific skill sets to teach specialized courses and stay current on the latest trends.

3D printing presents new business opportunities as well as new (including social) entrepreneurial models based on transforming digital data into physical objects in

[3] https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

remote locations, independent of centralized production and industrial areas by using "printing hubs".

In addition to enabling the creation of a greater range of products than would be possible with conventional manufacturing, it presents the possibility to democratize design and empower communities by decentralizing production and promoting innovation and creativity.

In industrial markets, the economics of 3D printing needs to fit into traditional business management models asking questions such as:

- What is the cost to produce components?
- What will be the return on investment?
- How is intellectual property protected?
- What liability does the business face should components fail?
- Can components be delivered in the timeframes needed?

The market has a wide range of 3D printers available, with corresponding variations in price; the Quintessential Universal Building Device is available for less than $200, whereas MakerBot's Replicator Z18 model costs $6,500.

With 3D printers becoming more affordable some libraries are providing 3D printing stations for their visitors. There are also commercial 3D Printing Services such as 3D Quick Printing (UK)- All they need is the CAD data, .stl file or step files and they can 'print' the item.

THE THREE-D-PRINT PROJECT - ORIGINS

In 2018, EU15 Ltd (in association with European Partners based in Portugal, Sweden, Slovenia and Austria) conducted an extensive web-based European survey relating to 3D printing training activities in Europe.[4]

The Survey focused on three key groups of stakeholders:

1. Providers of vocational education and training.
2. SMEs as potential users of 3D printing and employers of individuals with the necessary skills.
3. Individuals who could be interested in pursuing such knowledge, skills, and careers in the future.

The responses clearly showed that skills and knowledge at the intersection of 3D printing will be in future demand.

In terms of education, jobs for educators who can teach such skills, in respect of both 3D printing itself and interdisciplinary connection and intersections with other fields and subject areas, will become another emerging job opportunity. Such educators will be needed in the Arts as well as the Sciences and stay current with the latest trends and technologies that the various industries and fields will adopt. Many legal questions related to intellectual property rights of 3D printed products will emerge with the possibility of copying, modifying, and selling 3D designs that infringe on existing patents, copyrights, and brands.

The results of this THREE-D-PRINT project will provide an answer to the general educational and training challenges related to equipping the future workforce with relevant and needed skills to participate in the 3D printing revolution.

The key focus of the project is on providing entry-level, easily accessible courses that could motivate adults with fewer qualifications.

3D PRINTING EUROPEAN SURVEY

Main Results

- 36% of respondents knew how to use a 3D printer. The answers show that there is a need for additional education and training opportunities in 3D printing that are easily accessible to SMEs.
- 45% of respondents already use 3D printing in their company.
- 82% of SMEs thought that their employees would benefit from more knowledge/training about the use of 3D printing.

[4] Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437

- 67% of SMEs thought that the use of 3D printing would improve their competitiveness and/or reduce costs.
- 86% of respondents thought that schools and educational institutions should provide more 3D printing skills/knowledge training.
- 9% of the institutions who responded said they offer stand-alone 3D printing courses. However, 33% offered some kind of module.

DETAILED REPONSES

SMEs on 3D printing

All respondents said that they had already heard of 3D printing.

Of these, 36% knew how to use a 3D printer, 41% had some knowledge and 23% had no knowledge. The answers show that there is a need for additional education and training opportunities in 3D printing that are easily accessible to SMEs.

Regarding whether their company already uses 3D printing, 45% answered in the affirmative and 55% answered no. While almost half of the surveyed SMEs already use 3D printing, the other half shows there are still many potential companies that could be future users.

Most, 82% would like to know more about the beneficial uses of 3D printing in industry, while 18% would not. As with robotics, the majority interest in more knowledge of 3D printing uses shows the need and opportunity for additional courses and training in 3D printing.

A majority of 82% thought that their employees would benefit from more knowledge/training about the use of 3D printing. The answers indicate that not only future workers, but also existing employees could have an interest in gaining additional training and skills.

76%, also thought that their company will likely make use of 3D printing in the future. The fact that most of the surveyed SMEs think it likely that they will use such technologies in the future shows that demand for 3D printing and related skills will likely increase in the future.

Also 67% thought that the use of 3D printing would improve their competitiveness and/or reduce costs. Such an opinion further strengthens the probability of future demand for 3D printing and related skills.

A majority of 86% thought that schools and educational institutions should provide (more) 3D printing skills/knowledge training. The majority in favour of more such training in schools and educational institutions also confirms the need for online courses and materials that can be used and adapted to suit specific curricula and training.

Individuals on 3D printing

99% of all respondents have heard of 3D printing.

Regarding the use of 3D printing, 22% answered that they knew how to use 3D printing, 52% partially knew how to use it, while 26% did not know how to use it. Given that a majority of the individual respondents had only partial or no knowledge of 3D printing use, this indicates a need and possible demand for additional, easily accessible online courses and training.

Most of the respondents, 94% have not yet taken any course or module about 3D printing. Given this answer, we can again see a need for more freely and easily accessible courses and training on the topic of 3D printing.

More than two thirds, 72% thought that in the future, knowledge of 3D printing could give them a professional advantage in job seeking or their work. Since a majority see a professional advantage in more such knowledge, we can expect a rise in the demand for courses providing such knowledge and skills.

If a course or module about 3D printing were available for free, a majority of 70% would consider taking it. The answer clearly shows a need for more free courses and training on the topic.

A little less than half, 46% thought it likely that their work will involve 3D printing in the future. This further confirms the need and possibly a growing future demand for such training and knowledge.

Most of the individual respondents, 84% thought that schools and educational institutions should provide more 3D printing skills and knowledge training. The majority of affirmative responses further indicate a need and future growing demand for more training and courses on the topic.

Vocational education and training institutions on 3D printing

Regarding 3D printing, we asked the representatives of institutions whether they offer any stand-alone courses about 3D printing. 9% answered that they do, while 91% answered that they do not. We can see an even greater need for additional courses on 3D printing.

We further inquired whether they offer any modules about 3D printing within existing courses, and this time 33% answered that they do, and 67% answered that they do not. Again, there is the indication of a clear need for more easily accessible courses on 3D printing.

Regarding whether they are considering offering such courses or modules in the future, 77% answered that they do have such plans. Future plans for offering such courses indicate a growing demand for adaptable courses.

A majority of 95% believed schools and educational institutions should provide (more) 3D printing skills/knowledge training. Considering the majority agreement with the need for more such training, we can expect that new, adaptable courses will be in greater demand in the future.

IMPACT OF 3D PRINTING ON INDUSTRY, WORK, EDUCATION AND SOCIETAL NEEDS

Looking at the overall picture technology is a key factor in the socio-cultural development of humanity. It serves as a means of expanding the range of human capabilities, and it is also an element in a feedback loop within which technology, humans, and society (and of course, the wider environment) mutually shape and transform each other.

New technologies, as far back as writing and the plough, and all the way forward to smart computational devices and automated production machinery, have brought new opportunities for production, transport, and organization. They have also transformed the ways in which society is organized, including work processes, human interactions, and social stratification. As humans are not born with an innate knowledge of how to operate specific technologies and how to efficiently conduct work processes, this requires the acquisition of specific knowledge, of skills, training, and mastery to be able to occupy a specific job.

In the scope of industry, economy, and the allocation of work, this also means that specific jobs requiring specific capabilities, knowledge and skills will be more sought after and that others will be in much lesser demand. As smart technology is increasingly able to automate at least some tasks, some professions and workplaces will become obsolete.

Technological development over the past two decades has progressed extremely rapidly in several domains, especially in Nanotechnology, Biotechnology, Information-communication technology, and Cognitive science (NBIC). New technologies, especially those that are emerging at the intersections of the NBIC domains, are now permeating practically all levels and spheres of societies in developed countries.

Technological applications thus increasingly condition and mediate how we do things, that is, how we interact, how we think, how we produce, how we learn and how we work. Contemporary societies are generally marked by a trend of acceleration, which means that, in no small part due to scientific and technological advances, things are changing more and more rapidly, whether we are talking about institutions, social interactions, technologies, jobs, employment, job opportunities, grand societal challenges and a score of others.

Another accompanying trend is a general orientation and striving to increase and enhance performance, both at the individual and the collective level, which is especially relevant in terms of job requirements, skills, performance and demands. From an individual viewpoint, since the preconditions for living a fulfilling life in contemporary capitalist societies mostly still entail performing some sort of work that is compensated by a preferably high salary at a stable job, it is extremely important to

have the necessary skills, know-how and experience to be able to compete for and enter such jobs. From a collective, societal perspective it is necessary to ensure that qualified workers are available to fill the demand for jobs that are opening due to new developments and new opportunities, and that relate to addressing societal challenges, needs and wants.

The current social technological context in which modern, technological capitalist societies are currently located, is strongly marked by technological innovations, which, together with rapid sociocultural transformations, are producing rapid shifts and changes in all spheres of society.

For the scope of this report, we will primarily focus on the areas of education, training, employment, and skills that are needed to access new and emerging jobs in the 3D printing sector.

To better understand what is going on, we should first look at the technological side.

Societies, which are increasingly interconnected through globalization and information-communication technologies, are currently being strongly affected by several technological trends, among which are, in a general sense, digitalization, automation and robotization. All these trends are of course mutually interconnected and are enabling and reinforcing each other. Digitalization is visible in terms of the widespread introduction of various digital technologies in the work process, planning and monitoring.

Many workplaces are now becoming digital workplaces.

Automation means that several tasks in the workplaces, and in some instances entire work processes, can be carried out by smart machines, with little or no human supervision and input. This can relate either to industrial manufacturing, to warehouse robots, or to data acquisition, analysis, and management. Robotization refers to physical manipulators, at least partially controlled by some form of information technology, that carry out various work tasks or processes by manipulating objects in the physical environment, either semi-autonomously or completely autonomously. Thus, increasingly smart machines can carry out not just predictable physical activities but also more demanding cognitive activities.

Some experts postulate that we are currently located during a new industrial revolution, what Brynjolfsson and McAfee term as The Second Machine Age or what others have called The Fourth Industrial Revolution or Industry 4.0.

While the First Machine Age was marked by the automation of physical tasks through mechanization, the second is characterized by the automation of cognitive tasks through digital technologies. The progress in the development of the underlying enabling technologies is exponential, the technologies are mostly digital and are driving the digitalization of previously solely physical objects and processes, and they are capable of combinatorial reinforcement, meaning that robots can be directed

through cloud-based algorithms, that tasks and needs can be automatically communicated through networks without human intervention, that digital objects can be printed remotely using 3D printers, and that big-data driven analytics can be used to optimize drug discovery or disease prediction.

Similarly, in Industry 4.0, various technologies are combining and blurring the boundaries between the physical, the digital and the biological. The third industrial revolution made use of electronics and information technology, in the forms of computer and automation, to achieve further automation, while the fourth industrial revolution is based on cyber-physical systems that are increasingly connected and smart.

The distinctive features of the fourth industrial revolution are that the speed of progress is exponential, that the scope is widening, and has the potential to be a 'disruptive technology'. It is having a systemic impact, for example on production (workplaces), on management (organizations, companies) and on public policies (economy, employment, education).

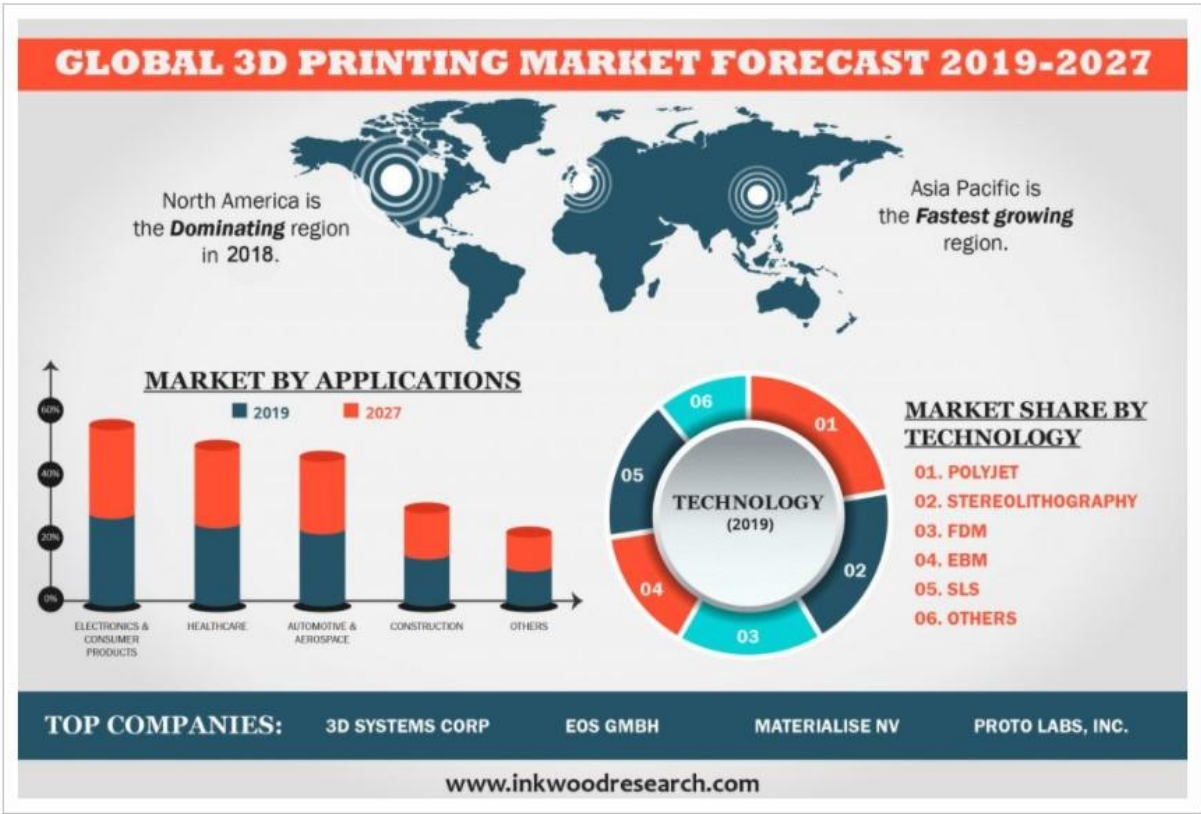
There are numerous technology fields and technological applications that are likely to have disruptive impacts in the coming years and decades. Expert literature and the media are full of speculation on how the internet of things, 3D printing, social robots, artificial intelligence, expert systems, smart personal assistants, self-driving cars, quantum computers, robotic exo-skeletons and other features that were once only in the domain of Science Fiction, will transform our lives and societies.

For the purposes of the THREE-D-PRINT project, we have focused on 3D printing which we have identified as having the greatest potential and urgency in terms of new opportunities for work and employment, impacts on industry and entrepreneurship and a societal need for students and workers both interested and skilled in their production and operation.

3D printing or additive manufacturing is a technology that has been in the making since the latter part of the 20th Century but has only now reached a point of technological development where it is becoming accessible to all.

Commercially, these technologies are predominantly used in high value-added industries and applications including those involved with aerospace, automotive, and biomedical (prosthetics and implants) products which require overly complex and customized designs at low volumes. Still, improvements in terms of speed, accuracy, material properties, machine reliability, and development of low-cost machines has widened the accessibility and user base, and thus holds great potential. Currently, just one in a thousand products is fabricated using 3D printing.

Global 3D printing market is estimated to grow with approximately 17.00% during the period 2019-2027 and is expected to gain over $44 billion through to 2027. *(GLOBAL 3D PRINTING MARKET FORECAST 2019-2027 - Inkwood Research Report)*



Low cost, basic 3D printers for universities, schools, laboratories, DIY, and maker communities offer many benefits in terms of promoting research and interest in design, engineering, technology, and manufacturing, as well as in terms of promoting crafts, experimentation, creativity, curiosity, and innovation. While 3D printers are not yet widely diffused and printing complex objects with various materials through moderately priced printers is still at least some years off, sophisticated printers are becoming accessible to smaller businesses and private individuals, where they can be employed to test and develop new products, ideas, or designer items.

The concept and technology of 3D printing also presents new business opportunities as well as new (including social) entrepreneurial models based on transforming digital data into physical objects in remote locations, independent of centralized production and industrial areas by using "printing hubs". In addition to enabling the creation of a greater range of products than would be possible with conventional manufacturing, it presents the possibility to democratize design and empower communities by decentralizing production and promoting innovation and creativity.

Making product conceptualization, creation, and propagation possible in any (relatively speaking) geographical location or community, makes 3D printing businesses and jobs potentially less vulnerable to offshoring. All this of course also raises issues of intellectual property rights and environmental impacts resulting from possibly increased consumption and production in vulnerable, remote locations, etc.

From a sustainability viewpoint, it could reduce environmental impacts through lower waste and reduced need for transportation, as well as enable greater socio-political independence and empowerment through decentralization and inclusivity in production.

It also has the potential to improve sociocultural sustainability (retaining social and cultural diversity) by supporting communal and individual designer-makers. It could increase their economic viability, providing an effective mechanism for craftsmen to compete in a global market utilizing local 3D print manufacturing, increasing geometric and material complexity, and the ability to customize products.

Traditional jobs that require human interaction such as the assembly line mainly now use robotics. Although this technological advancement has displaced many jobs an entire new industry of robotic repair and maintenance people has emerged.

3D printing will impact employment when it eliminates jobs that are undertaken by companies with expertise such as the production of machinery parts, tools, jewellery, and medical devices.

With the growing use of 3D printing there will be an increase in related occupations, and even a few that will have to be created. Repair services, installation technicians, technical support, software, education, and 3D printer custom engineers are just some of the jobs that will be needed to service this new age technology sector.

EMPLOYMENT AND 3D PRINTING

The jobs and opportunities that are emerging with the development of 3D printing are in the areas of 3D design, 3D computer-aided design (CAD) modelling, research, and development (R&D), biological and scientific modelling, architecture/construction modelling, education, law and legal professions, new business opportunities, 3D-Printing-as-a-Service franchises and operations and administrative positions [5]. Jobs for designers who can translate a product idea into 3D printed objects will be opening in 3D printing firms, as part of 3D design teams in companies and as freelancers.

Such job seekers will be most competitive if they acquire hands-on experience with the latest 3D printing technologies and stay up to date with how 3D printing is used in companies and work processes. Job seekers skilled in 3D CAD modelling will support the work of 3D designers, both for mass 3D printing and for custom-designed 3D prototyping and manufacturing.

They will also need to possess modelling skills and be familiar with the constraints of specific materials and technologies. Research and development professionals who understand the intersections, possibilities and constraints between technology and consumer products will also be in demand, for example in fashion, jewellery, and other consumer product areas that will have to keep an eye on lowest costs and efficient production. 3D printing of products in other areas, such as medicine (e.g., prosthetics, replacement parts, tissue printing) will require people with a background in biomedicine and science. Such expertise will be needed in other high-precision industries such as aerospace, military and drone design and construction. 3D printing is also expected to have a disruptive impact in industries such as architecture, construction, and engineering, where it could replace 2D construction blueprints with 3D models.

Skills and knowledge at the intersection of 3D printing will be in future demand.

In terms of education, jobs for educators who can teach such skills, both in respect of 3D printing itself and interdisciplinary connection and intersections with other fields and subject areas, will become another emerging job opportunity. Such teachers will be needed in the Arts as well as the Sciences and stay current with the latest trends and technologies that the various industries and fields will adopt. Many legal questions related to intellectual property rights of 3D printed designs and products will emerge with the possibility of copying, modifying, and selling 3D designs that infringe on existing patents, copyrights, and brands.

A whole new subfield of intellectual property rights issues for 3D printing is thus emerging for legal professionals. Regarding companies, 3D printing is not just creating

[5] http://www.businessnewsdaily.com/5125-3d-printing-jobs.html

new opportunities for design and production, but also for entrepreneurship and new business models. As the price of even the more advanced 3D printers begins to drop, individuals and companies that offer innovative design, process solutions and 3D printing on-site or through remote 3D printing will increasingly be able to utilize innovative opportunities in the emerging 3D printing ecosystem. Vendors that would like to utilize 3D-Printing-as-a-Service franchises could provide 3D printing services to local businesses, entrepreneurs, or individuals in retail stores. Regarding operations and administrative jobs in 3D printing, as new businesses based around 3D printing spring up, they will require other, more common jobs, such as salespersons, administrators, etc. Speaking generally, a 3D printing technician is an emerging profession or career, something that did not exist before, thus any efforts to motivate existing employees and prospective students would help move a greater number of future professionals towards studying and engaging with this emerging field.

Regarding the skills that will be needed by workers in the new age technology fields, there are three basic skill fields [6].

First, there are cognitive skills, which include digital literacy, as well as advanced problem-solving and creative and critical thinking skills.

Second, there are social and Behavioral skills e.g. conscientiousness, grit, and openness to experience.

Third, there are job- or occupation-specific technical skills, in this case related to robotics systems and 3D printing.

In this regard, the World Economic Forum lists three areas that will require systematic changes in education and training due to advances brought about by the Fourth Industrial Revolution.[7]

The first challenge is to connect education and employment, which means that employers need to collaborate with schools and universities on the development of curricula and a shared practical knowledge of the market. The education system also needs to adopt a stronger focus on lifelong learning.

The second challenge is to improve forecasts regarding industry and the labour market, so that governments, businesses, and individuals are able to react quickly and appropriately.

The third challenge is disrupting education and labour policy, related to improving the quality and relevance of learning, government policies that would ensure the required skills are taught to the national workforce.

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[6] https://www.brookings.edu/blog/future-development/2016/03/01/preparing-for-the-robots-which-skills-for-21st-century-jobs/

[7] https://www.weforum.org/agenda/2016/01/what-is-the-future-of-work/

THREE-D-PRINT AND EDUCATION

A survey in 2019 by EY implies that even product engineers admit that they do not have enough in-house expertise to establish the processes driven by 3D printing. In this sense, education and learning to cover a wider range of the population is more than necessary to drive up the adoption."

The emergence of additive manufacturing and 3D printing technologies is introducing industrial skills deficits and opportunities for new teaching practices in a range of subjects and educational settings. [8]

In terms of motivation and inspiration, it allows the user/learner to experience a rapid and easy materialization of the envisioned objects, it enables the production of parts that can be used in robotics training and ultimately empowers the user to master the skills that will be relevant and needed in the field of New Age Technologies. Finally, it can be used to foster creativity, innovation, experimentation, and a DIY 'maker mentality' that can be usefully employed in an entrepreneurial as well as an industrial setting.

3D printing fits neatly with the current trend for STEAM education (Science, technology, engineering, arts and mathematics). STEM is an interdisciplinary approach to educating children from an early age with knowledge and skills in these four key disciplines which drive much of the economic development and innovation in the modern world.

By enabling students to engage with STEAM concepts from a young age, STEAM education aims to adopt a new learning approach that goes beyond the ability to remember facts and procedures. STEAM encourages people to use their creativity, critical thinking, knowledge, and skills in real-world situations.

This is a unique opportunity to give students the expertise and competencies needed for societal development and individual development.

3D printing technology will undoubtedly shape the future, so it makes sense that it should be a key component in adult education curriculum. With the introduction of more trials across adult education institutions and increased awareness that this technology exists, the education sector will undoubtedly begin to reap the many benefits of 3D printing and inspire artists, architects, and engineers in the years to come.

8 https://www.researchgate.net/publication/320617391_3D_printing_in_teaching_and_education_A_review_of_where_and_how_it_is_used

For instance, the Romanian government considered that the use of 3D Printers is key in technical schools' program and with the initiative of private companies the program 3DUTECH was launched in 2020 and a series of selected institutions will become HUBS for 3D printing.

The main case for 3D printing in educational settings include:

- Teaching students about 3D printing, how 3D printing technology works, and its applications in real-world scenarios.
- Training the trainers in how to teach 3D printing so it can be incorporated into the curriculum.
- Improving student creativity and design skills and the use and value of new age technologies.
- Preparing the students for employment in the 3D printing industry.

3D PRINTING IN SCHOOLS

Teachers should include 3D printing exercises at all school levels, from primary through to secondary schools. 3D printing technologies enable teachers to provide students with low cost and accurate physical prototypes, which provides practical, hands-on knowledge useful for understanding the concepts.

Using 3D-printed objects during classroom presentations can improve students' soft skills, including public-speaking abilities, as this 'skill' is crucial when students enter the world of work. Teachers can also use 3D-printed visualizations to improve spatial education. A study in China from 2014 found that 3D printing significantly improved spatial learning.

Much of the research on 3D printing in education shows how 3D-printed articles provide learning benefits that are not achievable with screen- or paper-based learning. Improved understanding comes through touching and physically observing 3D-printed objects. 3D printing promotes learning through exploration. Schools should access robust printers built for the demands of daily classroom use while also being affordable and user-friendly.

3D PRINTING IN UNIVERSITIES

At Higher Education (HE) there is greater scope to teach students how 3D printing technology works. Many HE and technical colleges incorporate 3D printing modules and projects into engineering, applied sciences, and other courses.

Higher level 3D printing courses focus on building 3D printers in addition to fabricating 3D models using different materials. The need for explicit knowledge of 3D printing is reflected in how dedicated modules have been included in computer graphics courses, industrial engineering, and CAD.

Massachusetts Institute of Technology (MIT) has its own graduate and advanced undergraduate course teaching the fundamentals of 3D printing. The University of Texas and Virginia Tech have their own courses and certificates covering 3D printing and design principles.

3D printing also provides many opportunities to aid visual and practical learning across the sciences. 3D-printed components are often used as test models for scientific experiments across different disciplines, including mechanical engineering, aerospace, and robotics. Other fields, such as design, architecture and biology, can also benefit from such 3D printing opportunities.

TEACHER TRAINING

3D printing cannot be successfully used in education without educators who understand the design principles of additive manufacturing and how to use 3D printers and filaments. Teacher training helps ensure students get the most from 3D printing being used in education.

This THREE-D-PRINT project will provide the necessary training and support by way of two training courses.

TEACHING MATERIALS FOR TRAINERS:

THREE-D-PRINT will create a training programme on 3D printing for trainers, to provide them with the needed knowledge tools to develop a teaching programme on 3D printing in adult education.

PROGRAMME ON 3D PRINTING, PEDAGOGIC GUIDE FOR TRAINERS:

THREE-D-PRINT will develop a teaching pack to enable adult educators to learn more about 3D printing and provide course materials for their adult students e.g. assignments, quizzes, general learning materials.

***NOTE**: These 2 outputs will be freely available to download from 1st August 2021 at https://www.3dprint-training.com/*

STANDALONE INTRODUCTORY 3D PRINTING COURSES

While 3D printing has been the subject of large expectations regarding the impacts on (personal) manufacturing, design, economy, and society in general, it is still a technology that has started to spread only recently, as compared to robotics and automation. Although hobby and limited-range manufacturing 3D printers are now in the range of many consumers, more sophisticated and capable 3D printers still cost upwards of half a million dollars.

We can expect that prices will continue to decline as more businesses and more consumers start to adopt 3D printing technologies, and the technology becomes more developed due to market demands. As 3D printing is not (yet) an established field of science and technology (such as robotics), we can expect that it will probably not be taught in the form of courses by most vocational and higher education institutions (except for some classes on manufacturing technologies), but rather in the form of MOOCs and (fee-based) short introductory courses and workshops. Regarding the potential impact of 3D printing on businesses, Deloite University offered a 2016 online course "3D Opportunity: Additive Manufacturing for Business Leaders".[9]

Perhaps surprisingly, there are no courses on 3D printing on the edX and FutureLearn MOOC platforms, which is probably connected with a lack of university courses on the topic. On the other hand, some of the major companies that sell and produce 3D printing technologies also offer materials and (free) training for 3D printing.[10]

There are very few providers of such courses on 3D printing within Europe. No European universities offer MOOC courses connected with 3D printing on any of the MOOC platforms. A general search provided a few elements of 3D printing in the scope of Master's programs, mostly as part of advanced manufacturing and materials engineering Master's programs, for example the UK University of Sheffield Additive manufacturing and advanced manufacturing technologies.[11] Another interesting example from the UK is the Master's program in Additive Manufacturing [12] at the Anglia Ruskin University, which is described as being the UK's only dedicated Masters program with a focus on 3D printing, funded by the government, in order to increase the number of skilled graduates in this field [13].

Some secondary schools and NGOs organize clubs and workshops for 3D printing, which are mostly the result of individual teacher engagements with occasional collaboration of 3D print companies. For instance, under the EU project "E-DESIGN - European Digital Education for Social Inclusion and Global Neighbourhood" [14] both

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[9] https://www.class-central.com/mooc/2240/novoed-3d-opportunity-additive-manufacturing-for-business-leaders

[10] For example iMakr https://www.imakr.com/en/training-consulting-for-3d-printing/710-introduction-3d-printing-training.html; GoPrint3D https://www.goprint3d.co.uk/3d-printer-training/; RoboSavvy https://robosavvy.com/store/welcome-to-the-world-of-3d-printing-training-course.html; etc.

[11] The 1-year program provides knowledge and skills in additive manufacturing (also known as 3D printing) and advanced manufacturing technologies. The course has been developed to meet the demands of industry and expose new graduates and professional engineers to cutting-edge manufacturing techniques and applications.
http://www.sheffield.ac.uk/postgraduate/taught/courses/engineering/mechanical/additive-manufacturing-advanced-manufacturing-technologies-msc-res

[12] The 1-year program covers a range of topics from product design to 3D CAD modelling, from additive manufacturing strategy to engineering management, equipping students with the knowledge required to produce prototypes and products across a range of industries including the biomedical and aviation sectors. The program provides access to advanced computer based analysis and modelling software, together with leading-edge engineering facilities including 3D printers and a metal direct metal laser sintering machine.
http://www.anglia.ac.uk/study/postgraduate/additive-manufacturing

[13] http://www.anglia.ac.uk/news/government-funding-for-new-3d-printing-course

[14] For more information about the Project visit https://www.e-designproject.eu/ - Project number: 604451-EPP-1-2018-1-DE-EPPKA3-IPI-SOC-IN

CEPROF and Citizens In Power have been implementing training sessions whose learning offers, amongst others, are 3D Modelling and 3D Printing. Similar collaborations can be found between various types of maker/DIY communities and companies or research institutions.[15] Practically the only open free online course that we could locate is provided on the ALISON e-learning platform.[16] Short standalone courses are mostly offered as workshops and summer schools, or as part of more extensive CAD courses, but in contrast to at least some courses on robotics, these are offered for a fee and usually require the presence at a physical location where hands-on work with 3D printers is available.

DISCLAIMER

The information contained in this report is for general information purposes only.

The THREE-D-PRINT Project makes no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability, suitability or availability with respect to the information regarding the courses outlined below.

Any reliance placed on such information is therefore strictly at your own risk. In no event will we be liable for any loss or damage including without limitation, indirect or consequential loss or damage, or any loss or damage whatsoever arising from loss of data or profits arising out of, or in connection with, the courses.

We have no control over the nature, content, and availability of the following courses. The inclusion of any links does not necessarily imply a recommendation or endorse the views expressed within them.

The THREE-D-PRINT Project takes no responsibility for and will not be liable for the following courses being temporarily unavailable due to technical issues beyond our control.

Below are some examples of available training courses.

ALISON: LEARN HOW TO USE A 3D PRINTER (2017)

https://alison.com/course/how-to-use-a-3D-printer

Content

The free 2–3-hour online course introduces the hardware and software technology behind 3D printing. You will learn about the different plastic filaments that are used and you will pick up tips on how to feed the plastic filament into the 3D printer for optimal performance. You will learn about the different components of a 3D printer such as the extruder nozzle and contact sensor and their functions. You will then learn how to set up and calibrate a 3D printer so that the object is printed correctly on the

[15] For example in Slovenia

[16] An e-learning provider and academy founded in Galway, Ireland in 2007. Its main objective is to enable people to gain basic education and workplace skill, and a majority of its learners are located in the developing world.

printer base plate. You will learn about different 3D print software that can be used to design 3D objects and the importance of using 3D model repair to eliminate errors in the design that can cause defects in the printed object.

Outcomes

- how to set up and use the Printrbot Simple 3D printer;
- the features of 3D Builder software and how it can be used for 3D printing;
- the importance of 3D model repair;
- the types of 3D objects that can be printed; and
- Certificate of accomplishment (Alison Diploma) (for a fee).

Prerequisites

The course should be of interest to professionals in the areas of engineering, design and manufacturing who would like to learn more about 3D printing and its applications, as well as to all learners who would like to learn more about 3D printing and its future applications.

BLENDER : LEARN 3D MODELING & TEXTURING ONLINE TRAINING COURSE

https://www.reed.co.uk/courses/3d-printing

Learn Blender from a beginner's perspective with this Blender – Learn 3D Modeling; Texturing course. Blender 3D is a free, easy to use tool that will allow you to master 3D modeling with no money out of pocket. So, if you're interested in 3D modeling and texturing for game design, 3D art, 3D animation or architectural design, then this course is for you - Length: 1.5 hrs

Prerequisites

Anyone can take up this course upon interest in anytime you want, anywhere you want, all you need is a smart phone/tablet/computer connected to the internet. Upon completion, you will have a test with multiple choice questions and there is no limit on the number of attempts. No formal requirements, any interested learner can take up this course and get certified.

GETREADY4 3D COMPANY. 3D PRINTING

by Diogo Quental and Nadia Yaakoubi

http://www.sabe-online.com/products/3d-printing

Content

The fee-based 130-minute course enables you to learn everything about the 3D printing process, understand its benefits, and demystify some preconceived ideas. You will also identify the major players within the 3D printing ecosystem and understand that there's a place for new business models waiting for you. With easy-to-follow

segments and plenty of real-world examples, you will learn how to take advantage of this amazing technology.

Outcomes

- understand the fundamentals of 3D printing;
- know the 3D printing process and ecosystem;
- understand the steps of the printing process;
- materialise your idea into a real 3D object;
- distinguish among printers, materials, and techniques;
- understand the business potential of 3D printing technology.

Prerequisites

The course is intended for anyone with an interest in 3D printing, anyone who wants to take advantage of the 3D printing business opportunities, professionals and business leaders who want to understand this new industrial revolution as well as the potential impact on their area of activity, and students.

COURSERA (UNIVERSITY OF ILLINOIS - THE 3D PRINTING REVOLUTION

https://www.coursera.org/learn/3d-printing-revolution

Content

This course will demonstrate how 3D printers work, show what people make with them, and examine the 3D printing ecosystem. It will also explore the future of 3D printing and discuss how this technology will revolutionize our world. The course materials include informative video lectures, on-location interviews with a variety of 3D printing experts and engaging hands-on exercises. Learners who complete this introductory course will have a solid understanding of 3D printing and its revolutionary potential and will be able to print and customize 3D designs.

Outcomes

You will be able to create physical objects using 3D printing design programs, scanners, and printers. The Course is free, but the certificate of accomplishment is only available for a fee.

Prerequisites

Access to lectures and assignments depends on your type of enrolment. If you take a course in audit mode, you will be able to see most course materials for free. To access graded assignments and to earn a Certificate, you will need to purchase the Certificate experience, during or after your audit.

UDEMY: How to Start 3D Printing at Home - Even Without a 3D Printer

by Jason King
https://www.udemy.com/introduction-to-3d-printing-at-home/

Content

The short fee-based course teaches what 3D printers are, how they work, how to purchase one and how to use it to create amazing 3D prints. It demonstrates how to design a simple chess piece using two free design tools, Tinkercad and OpenSCAD. After the course you will be able to start designing your own products. This is not an MOOC course, but an online course consisting of videos, slides and on screen demonstrations.

Outcomes

- learn the fundamentals of 3D printing including the history, methods, kinds of 3D printers, how to design your own models and share them around the world;
- create their own 3D models using CAD software;
- explore new business models that take advantage of 3D printing and the customizability aspect; and
- how to monetize your 3D Designs.

Prerequisites

This course is for complete 3D printing beginners who are curious about what's involved in buying and using a 3D printer for home use.

UDEMY: The Fundamentals Of 3D Printing

by Jeffrey Ito
https://www.udemy.com/fundamentals-of-3d-printing/

Content

The short fee-based course teaches the basic terms and definitions of 3D printing along with the history of the technology. One will be able to learn how to use a 3D printer and learn its potential future applications. There are also case studies on successful businesses already using 3D printing for customization. We take you through the creation of your own 3D model and walk you through 3 of the most popular 3D printing services to print, sell and share your design. This is not an MOOC course, but an online course consisting of videos, slides and on screen demonstrations.

Outcomes

- learn the fundamentals of 3D printing including the history, methods, kinds of 3D printers, how to design your own models and share them around the world;
- create their own 3D models using CAD software;

- explore new business models that take advantage of 3D printing and the customizability aspect; and
- how to monetize your 3D Designs.

Prerequisites

The course is suitable for makers, entrepreneurs, inventors, engineers, architects, artists and explorers.

LEARNING 3D PRINTING

https://www.linkedin.com/learning/learning-3d-printing

There's never been a better time to try 3D printing. This course draws a roadmap for getting started with 3D printing (aka additive manufacturing), from choosing a printer to learning about 3D modelling. After surveying a variety of commercial 3D printing technologies (filament-based, laser sintering, and more), author Kacie Hultgren walks you step-by-step through a variety of 3D design tools, including 3D modelling and 3D scanning. You'll also learn how to repair designs so they're ready to print, with netfabb Studio, a 3D printing suite. This is a great course for both 3D printing novices as well as designers with existing modelling skills that want to enter the 3D printing marketplace.

CHOOSING A 3D PRINTER

The 3D printing market offers a multitude of 3D printers, materials, service agreements, and software across a wide price range. Even for those with some 3D printing experience, choosing the right 3D printer can be daunting. Many factors must be considered, including noise level, safety compliance, technical specifications, and production parameters.

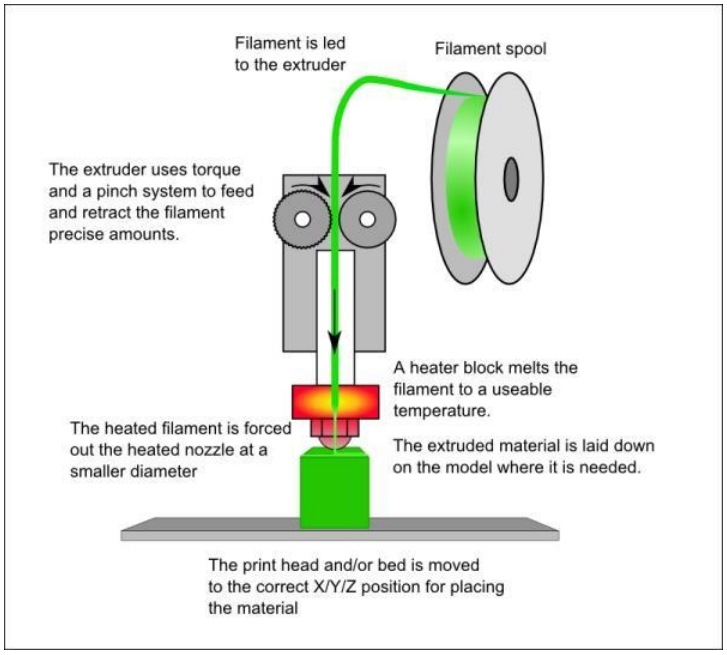
There are several types of 3D printers in the market, some are more expensive than others. Usually, they are known by the printing method. Below is detailed information on the most common types of 3D printers and their main characteristics.

Before you choose a 3D printer define the printing needs.

- 3D print prototypes or models?
- Aesthetics or functionality are the priority?
- Production volumes?

FUSED DEPOSITION MODELING (FDM)

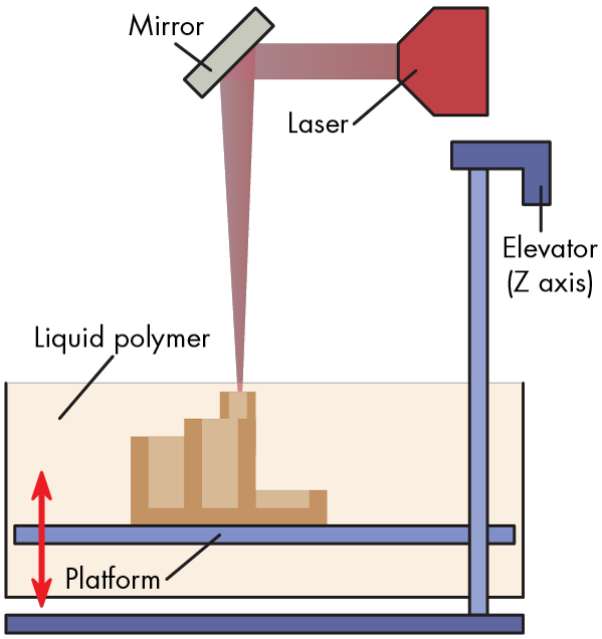
FDM is the most common 3D printing method used in desktop 3D printing. It uses thermoplastic filament that is heated and extruded. The object is printed layer by layer from bottom up. The colour of the printed object is the same as the thermoplastic filament. **It is commonly used for rapid prototyping and for beginners with 3D printing**.



Fused Deposition Modelling 3D Printing Mechanism (Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

STEREOLITHOGRAPHY (SLA)

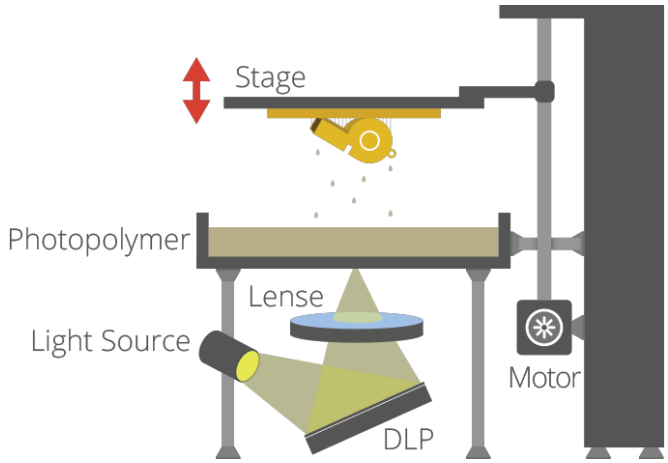
SLA exposes a layer of photosensitive liquid resin to a UV-laser beam so that the resin hardens and becomes solid. The object is printed layer by layer and each layer is built on top of the preceding one. **It is used to print objects with a remarkably high detail, although it takes a while to print an object if it is very detailed.**



Stereolithography 3D Printing Mechanism (Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

DIGITAL LIGHT PROCESSING (DLP)

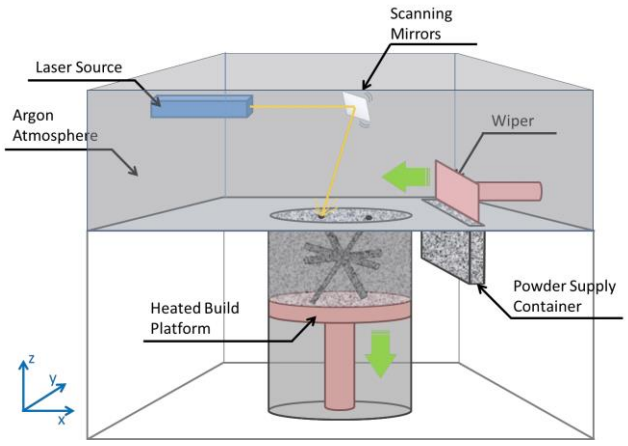
Digital Light Processing (DLP) and Stereolithography have a lot in common. Both use photosensitive liquid resin. The object is printed layer by layer, from top to bottom and with a special light projector. **It is used for rapid prototyping objects that do not require much detail, consequently it can print faster than other types of 3D printer.**



Digital Light Processing 3D Printing Mechanism (Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

SLM (SELECTIVE LASER MELTING)

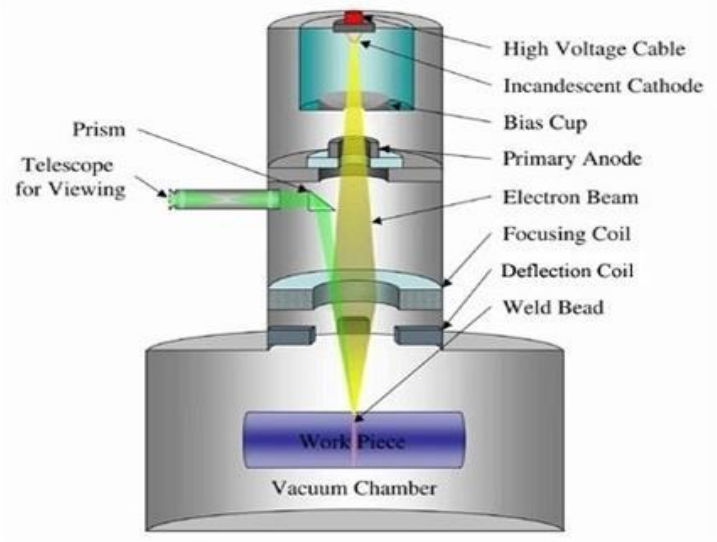
SLM uses a high-powered laser beam to fully melt metallic powders into solid three-dimensional objects. The object is printed layer by layer. Typical materials used are stainless steel, aluminum, titanium, and cobalt chrome. **It is used for rapid prototyping but with metallic materials.**



Selective Laser Melting 3D Printing Mechanism (Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

ELECTRON BEAM MELTING (EBM)

EBM uses an electron beam under high vacuum to fully melt the metallic powder at high temperatures up to 1000 °C. The object is printed layer by layer. This type of 3D printer can use metals like pure titanium, Inconel718 and Inconel625. This type of technology is slower and more expensive than the previous ones. **It is used to fabricate aerospace parts and medical implants, as it can have a high precision.**



Electron Beam 3D Printing Mechanism (Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

CHOOSING 3D PRINTING SOFTWARE

Before moving to actual physical 3D printing, it is necessary to have a file with a 3D Model (the drawing in 3D format). The most common files are STL and OBJ. Afterwards, it is necessary to convert the file into a special code (G-code) that allows the 3D printer to read it.

This type of coding is done by a slicer software and the process is called slicing.

At the end of the slicing process, the user can send the file directly to a 3D printer or have it saved on an SD card or flash drive for example. The user has many options to choose from, since there are several slicing software packages to 3D print. Below are some examples of FREE software to download:

cura.

https://ultimaker.com/software/ultimaker-cura

Slic3r
G-code generator for 3D printers

https://slic3r.org

SIMPLIFY3D

https://all3dp.com

Repetier

https://www.repetier.com

TYPES OF THERMOPLASTIC FILAMENTS

To print, it is necessary to have a thermoplastic filament. There are numerous types of thermoplastic filaments.

You will find a comprehensive filament guide at https://rigid.ink/pages/filament-comparison-guide. The website explains, in some detail, 17 of the most useful 3D filaments. You will learn what they are used for, printing advice, approx. costs and links to troubleshooting information.

TIPS FOR SUCCESSFUL PRINTING

From printer to printer, maximum quality can change.

PLA Filament Rolls

Bending PLA Filament

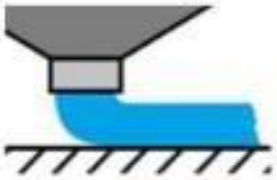
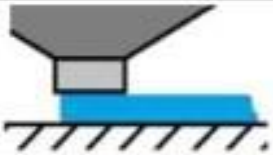
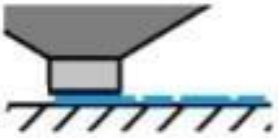
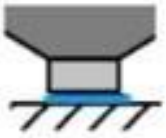
Check your filament.

See if it breaks too easily by bending the filament. It does not need to bend as much as in the following image, but if it does then it is probably in good condition.

See if it has humidity. You will confirm the humidity if the filament releases vapor while passing the nozzle. These two factors can make the prints go from good to bad quickly. If your filament has too much humidity try covering it with silica gel bags or use a food dehydrator.

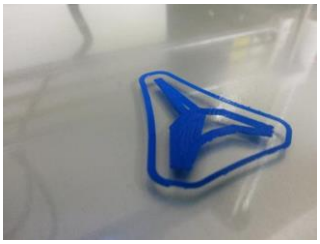
Make sure the Build Plate is level.

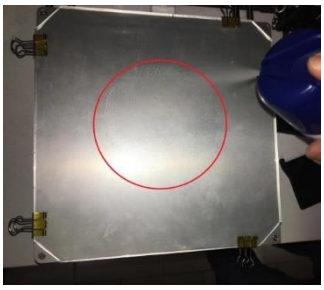
This is very important, because it will help the user have a good first layer. The filament should exit the nozzle as in the table below.

Status	Side View	End View	Comment
✗			Nozzle is too high Not enough pressure on the filament into the bed. Therefore is a small contact area between filament and the bed. Could cause the print to detach.
✓			OK The filament is pushed into the bed slightly to maximise the surface area contact with the bed, but still maintains the extrusion flow.
✗			Nozzle is too low There is not enought clearance for the filament to be extruded, damaging either the nozzle or the bed.

(Robotics – Training for the New Age (ROTENA) Reference: 2016-1-UK01-KA202-024437)

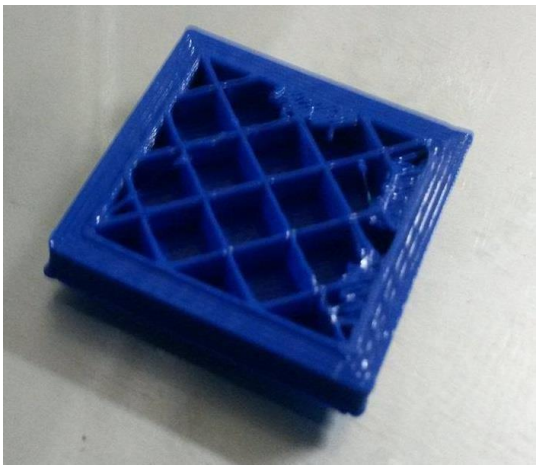
Improve the build plate Adherence.





To have a good first layer a good build plate adherence is needed. A common problem with 3D printing is not having a good build plate adherence. Parts can snap the build plate.

To prevent this, you can put a glass on top of the build plate and use hairspray. When hairspray is heated, it gives a super strong adherence to glass, but when the build plate cools down it loses part of the adherence, which allows the removal of the part/ object easily. It is not necessary to spray the whole glass, but it is necessary to spray the area where the part/ object will be printed.



Wall thickness

Wall thickness is the distance between the limit of the print and the start of the infill. You can change this setting if you want stronger and stiff parts or more flexible parts. The higher the stiffer, the more material will be used. 2 mm wall thickness is a high value and makes your parts very stiff and strong. Lowering too much to be more flexible can cause the part/ object to break more easily. Minimum values are 0.8 mm for example.

CONCLUSION

The objective of this Report has been to give an understanding of 3D printing, its origins and opportunities and its potential for use.

Although there are many benefits of using 3D printing, it is important to recognise its limitations to make the most of the technology.

Having a significant understanding of the potential of what printers can and cannot do is important and result in better-informed choices and decisions and what challenges they can reliably solve.

--ooOOoo--