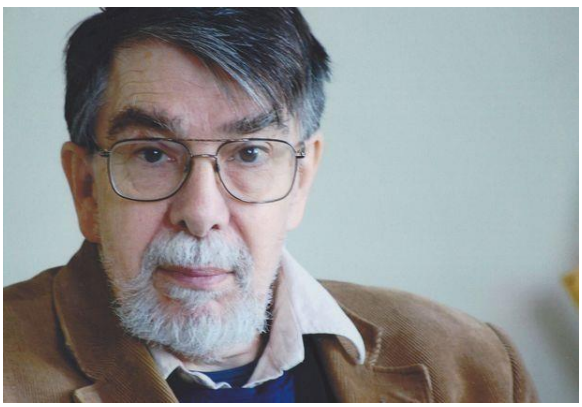
3D Printing and Additive Manufacturing, Words – Menelik Eshetu

Three-dimensional (3D) printing or additive manufacturing is a manufacturing method in which three-dimensional solid objects are made by fusing or depositing materials such as plastic, metal, ceramics, powders, liquids, or even living cells. 3D printing is a process of making an object of virtually any shape and size from a digital model. And most importantly, successive layers of material are laid down in different configurations to construct an object both effectively and efficiently.

The terms 3D printing and additive manufacturing are alternate names for additive technologies - the former being used in popular language by consumer-maker communities and the media, and the latter being used more formally by industrial producers, machine manufacturers and global technical standards organisations. The term additive manufacturing (AM) gained popularity in the 2000s and it was inspired by how materials are added together in several ways to create a three-dimensional object.

There has been a lot of hype in the last decade when referring to the possibilities we can achieve by adopting 3D printing, but it was in 1974 the concept was first introduced by David E.H. Jones. In the 1980s and 1990s it started to gain momentum and 3D printers became a reality. In recent years, 3D printing has developed significantly and can now perform crucial roles in many scenarios, with the most important being - construction, manufacturing, medicine, architecture, custom art and design.



David E.H. Jones

3D models can be created with a computer-aided design (CAD) package, via 3D scanner, or by a plain digital camera and photogrammetry software that can then be transferred to 3D printers. 3D printed models created with CAD result in relatively fewer errors than other methods, plus, it is easy to identify and correct errors before printing itself.

For a long time, the issue with 3D printing was that it demanded high entry costs, which does not allow profitable implementation when compared to standard processes. However, recent market trends have found that this is finally changing. Since the start of the 21st century there has been a large growth in the sale of AM machines (3D printers), and their price has dropped substantially. Even more, for people who are in need of 3D printing but who have difficulty doing it themselves, there are numerous service providers i.e. **ShapeWays** (www.shapeways.com), **Three Ding** (www.threeding.com) and **MyMiniFactory** (www.myminifactory.com).

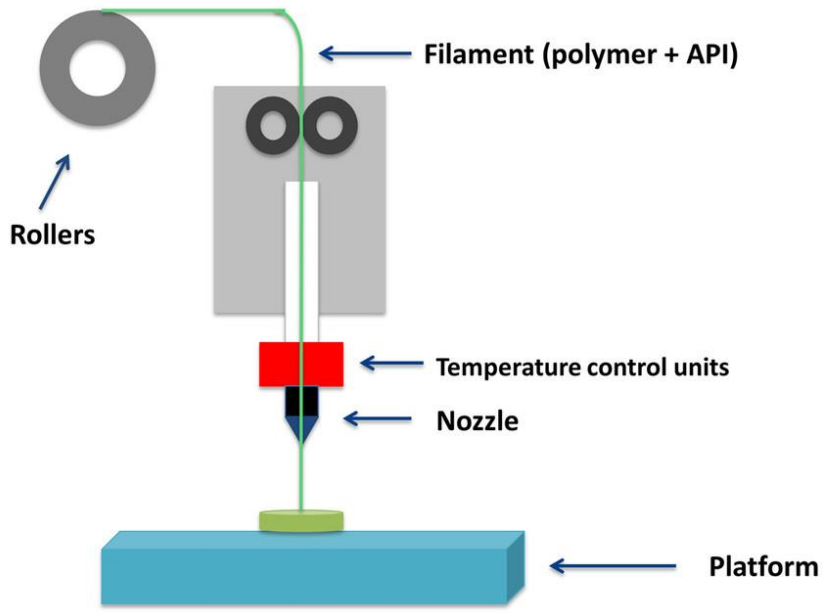
SHAPEWAYS

3D Printing on demand

Types of 3D Printing Technologies

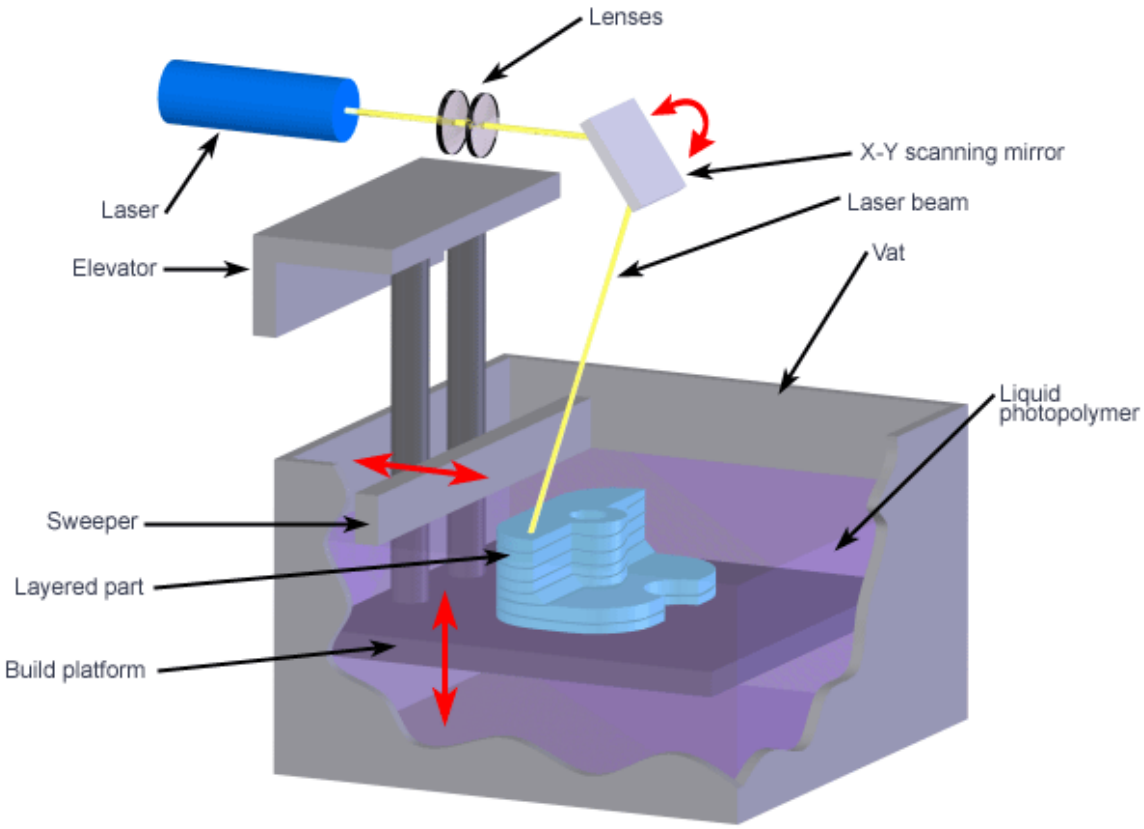
Although new types of 3D printing technologies (3D printers) are being built and updated all the time, common types being used in different industries today include:

Fused deposition modelling (FDM)



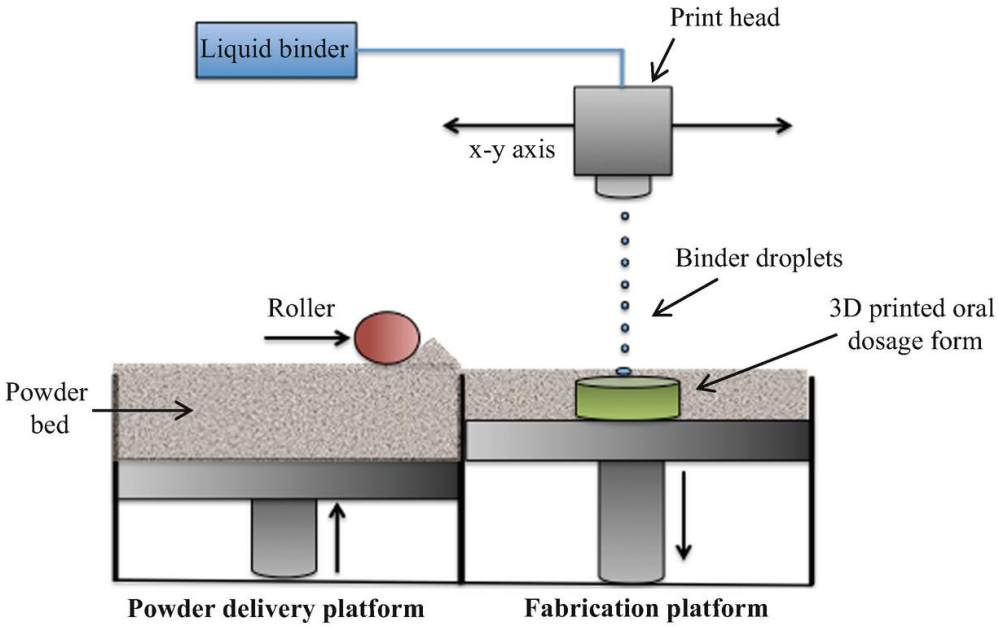
This is one of the most affordable and popular 3D printing technologies. FDM Technology constructs objects layer by layer from the bottom up by heating and extruding thermoplastic filaments. It prints not just operational prototypes, but also ready to use products such as plastic gears. In addition - the fact that it uses high grade thermoplastics means engineers and manufacturers find it very advantageous.

Stereolithography (SLA)



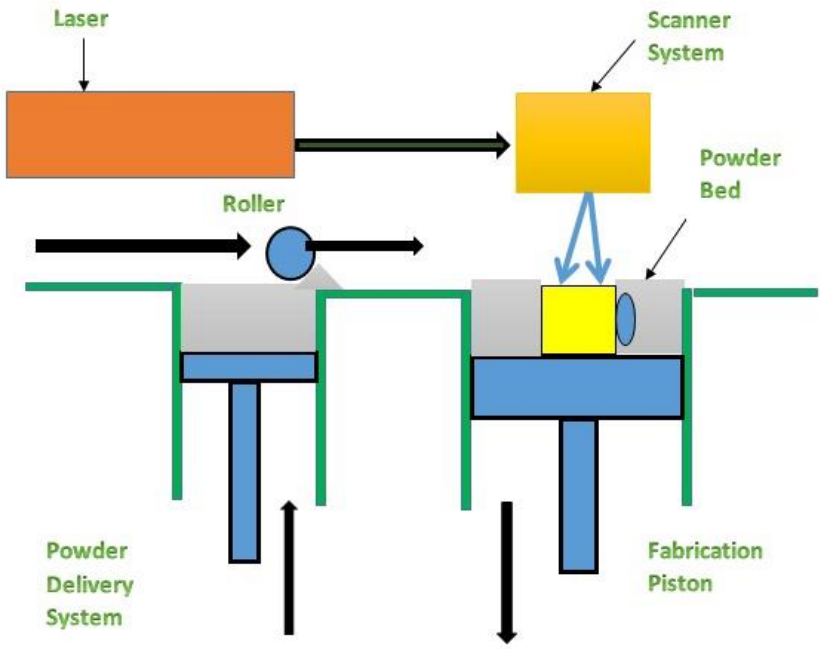
This is ideal technology when accuracy and precision is the goal. SLA 3D printers use liquid plastic to form the desired object. That liquid plastic hardens after a while to form solid objects. The printer constructs layers using an ultraviolet laser, directed by X and Y scanning mirrors and just before each print cycle, a blade moves across the surface to ensure each thin layer of resin spreads evenly. The print cycle continues in this way, building 3D objects from the bottom up. Parts printed by stereolithography usually have smooth surfaces, but unlike FDM, the quality of objects being printed depends on quality of the SLA printer.

Binder Jetting (BJ) Technology



Also referred to as Powder Bed Printing, Inkjet 3D printing, or Drop-on-powder : Binder Jetting is a 3D printing process that uses two types of materials to build objects. Materials such as ceramic, metal, sand and plastic can be used with a bonding agent. Although it is not possible to get super high-resolution 3D objects with BJ printing, it can be implemented for rapid prototyping. The tech is mainly for aerospace, automotive, and medical industries.

Selective Laser Sintering (SLS)



This technique uses high-power lasers to fuse particles together to form strong 3D printed objects. SLS is rather expensive as compared to other techniques making it popular only among manufactures. And because of the fact that a large selection of materials may be used - the technology is quite popular in customized 3D printing.

Applications

There are many applications for 3D printing technologies, including architecture, construction, automotive, aerospace, military, engineering, dental and medical industries, fashion and jewellery. It has been found to be a fast and cost-effective solution in whichever field of use. The applications of 3D printing are ever increasing, and it is proving to be an exciting technology to look out for…

In the medical industry

Medical applications for 3D printing are expanding rapidly and are expected to revolutionize healthcare soon. 3D printing has the potential to significantly improve research knowledge, skills of surgeons, relationship between patient and doctor, understanding of disease, patient-specific implant designs, surgical tools, optimization of surgical processes and cost-cutting. 3D printing is offering more and more applications in the medical field helping to save and improve lives in ways never imagined before! In fact, 3D printing has been used in a wide range of healthcare settings including cardiology, neurosurgery, ophthalmology, plastic surgery, transplant surgery, vascular surgery + more.

In the medical world, CT scanning and MRI imaging are used to achieve cross-sectional images of bones and tissue and are now a necessary part of the industry. Modern software can turn medical images into complete models that can be used for 3D printing. Also, devices that were once purely theoretical can now be produced quickly, cheaply, and effectively thanks to advancements in 3D printing.

There are several reasons why 3D printing (additive manufacturing) works perfectly for medical applications. One is that surgical implants are complex and require organic structures that must be accepted by a host's body - and these structures are absurdly

expensive to manufacture through traditional methods. Thankfully, 3D printers can create them at a significantly lower cost.

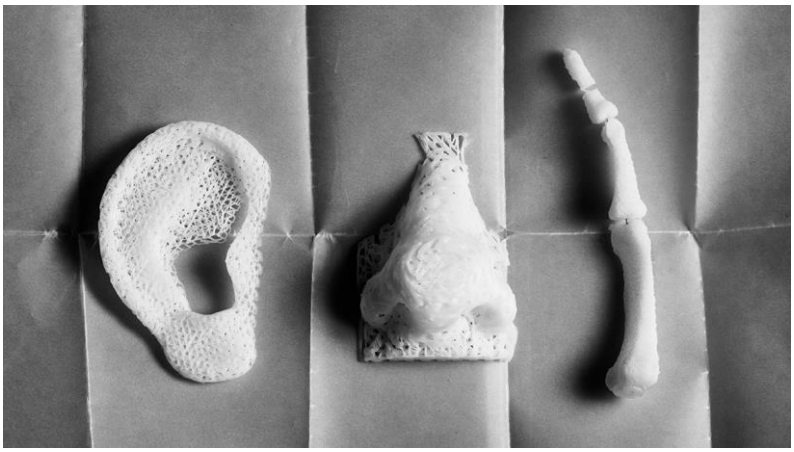
Medical devices are often sterilized; therefore, the materials used to create them must also be immune to sterilization processes. Most of the materials used for FDM printing or 3D metal printing can be sterilized by steam autoclave or gamma radiation.

Steam Autoclave

The other benefit that comes with this technology is that 3D printed parts can be shaped to fit perfectly with a patient's anatomy and customised for the purposes of their profession or habits. Dental implants, cosmetic prosthetics, and other models are all created within exact required specifications. This flexible nature of 3D printing has greatly benefited patients and reduced the cost of custom medical devices. Traditional manufacturing methods remain less expensive for large-scale production; however, 3D printing is becoming more and more competitive for small scale productions. This is especially true for smaller-sized standard implants or prosthetics : such as those used for spinal and dental disorders. It is especially advantageous for parts or products that are overly complex or require frequent modification. It benefits kids as they can quickly outgrow their prosthetics.

In the business of saving lives, medical procedures rely heavily on the availability of required materials in the least amount of time. 3D manufacturing lets hospitals source necessary parts within a short time-period. It is common for amputees to wait weeks or months to receive prosthetics through traditional routes; however, 3D printing significantly speeds up that process. Both dental and medical surgeries require extreme precision. A 3D printed guide can help a surgeon line up holes and incisions far more easily. Thanks to additive manufacturing, guides can be produced quickly and with exact specifications.

3D printers can produce fine mesh structures necessary for surgical implants. These organic structures have a reduced risk of rejection after surgery is completed. Customisable implants can be manufactured with results that are strong, sterile, and perfectly suited to a patient's needs.



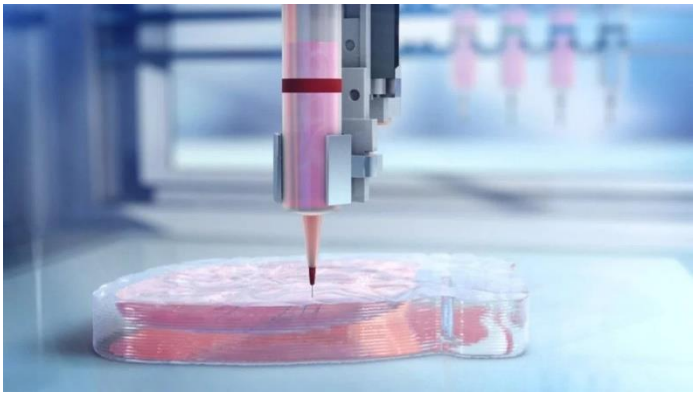
Fine mesh structures from 3D printing

A 3D printers' capability to produce perfect scale models of patient-specific anatomy and structures allows doctors and nurses to study a subject from multiple angles and hopefully find solutions to problems. Additive manufacturing is an affordable way to produce anatomical models; both medical students and experienced professionals can take this advantage from the technology.

Sterile surgical instruments, such as forceps, haemostats, scalpel handles, and clamps can be produced using 3D printers. Not only does 3D printing produce sterile tools, but it can also produce very small tools used to operate on tiny areas so as to prevent causing unnecessary damage to a patient.

Organ failure due to aging, diseases, accidents, and birth defects is a critical medical problem. Current treatment for organ failure relies mostly on organ transplants from living or deceased donors. This is where 3D printing comes in to play. A process called **Bioprinting** allows the modelling of implantable tissue. Rather than printing using plastic or metal, bioprinters use a computer-guided pipette to layer living cells, referred to as bio-ink, on top of one another which creates artificial living tissues. Some examples are the 3D printing of synthetic skin for patients who have suffered burn injuries. Another is the replicating of heart valves using a combination of cells and biomaterials. Or, the replicating of human ears using bovine cartilage cells. Bioprinting may represent an opportunity to save lives and reduce the waiting list of transplant patients. Bioprinted organs may also be used in the future by pharmaceutical industries to replace animal testing for analysing the toxicity of new drugs.

Now dentists can use a 3D dental scanner to capture 3D images of a mouth which can then be used to print perfect fitting crowns, bridges or implants. It saves time, reduces errors, and cuts cost.



Bioprinting

These applications clearly demonstrate that 3D printing is one of the most disruptive technologies with potential to significantly change clinical fields. It improves healthcare by making it affordable, accessible, and personalised. However, it must be accompanied by updated and current legislation in order to guarantee correct and safe use.

In the aerospace industry

This industry was very early to embrace 3D printing and contribute to its development. In the aerospace industry the application of 3D printing starts from the very first design stage all the way to manufacturing. Often, concept models showcasing a component of an aircraft are produced with the use of this technology for the purposes of aerodynamic testing. Accurate models allow designers to clearly communicate the concepts they had in mind to other designers and manufacturers. In addition, parts can be tailored to a specific aircraft or for different types of aircrafts - such as passenger, cargo or even helicopters. 3D printing is also used to manufacture aerospace components that rely on aesthetics over function, such as door handles and dashboards. The technology can produce intricate parts that are more resilient and lightweight compared to those made using traditional techniques.

3D printing in aerospace

Another benefit is that 3D printing processes allow the consolidation of multiple parts into a single component. This leads to weight savings, cost reduction, and reduction in the amount of inventory kept at any time. Current satellites are made from premium and lightweight materials, thus, by using 3D printing technology the amount of waste and time can be kept to a minimum. Also, higher performance designs are not subject to traditional constraints.

Furthermore, 3D printing can produce hundreds of thousands of parts without relying on expensive tooling changes involved with traditional manufacturing processes. It also requires less energy, since modified parts or upgrades can be produced as needed - alleviating the need for costly storage. By cutting fuel and limiting emissions, 3D printing can subsequently help to minimise environmental impact. In the age of heightened environmental awareness, this could not be more on-point with various company CSR strategies and consumer desires.

In the automotive industry

One of the biggest beneficiaries of 3D printing is the automotive industry. Car manufacturers are using 3D printing to prototype components, create spare parts, customised parts and even put together end-use parts for roadworthy vehicles.

In2014, Local Motors introduced its first 3D printed electric car to the world. It was named “Strati” and could be printed in less than a day using a giant BAAM (Big Area Additive Manufacturing) machine. Furthermore, several automotive companies use additive manufacturing to prototype new components - often to see what works and what doesn’t.

Another important use of this technology is the ability to quickly fabricate replacement parts for complex systems. This is usually either to fix or update a desired system. By 3D printing these replacement parts on demand rather than keeping a large inventory of spare parts, manufacturers can save huge amounts of money. 3D printing spare parts for classic cars is an additional benefit. Porsche supplies parts for its vintage and out-of-production models using 3D printers.

3D printing is now playing a huge role in the development and maintenance of consumer vehicles. It has also become more prominent in Formula 1 and British racing team McLaren, for example, uses 3D printing in several ways.

3D printing - Formula 1

With growing demand for customised products and personalised experiences, automakers are increasingly offering their customers the ability to customise vehicles. One way to make this customisation economically viable is through 3D printing. BMW's brand, MINI, is one of the companies that is personalising car parts in this manner. Since early 2018, MINI's customers have been able to customise various parts like dash, LED door sills and puddle-light projections. They can also choose colours and textures. As this technology advances - possibilities for car customisation with 3D printing look set to expand at a much greater speed.

Even though there are no commercially available 3D-printed bikes on the road yet, companies like BigRep (German manufacturer) is using FDM 3D printers to create unique motorbikes. The company's NERA motorcycle, a fully functional prototype, was designed to demonstrate the capabilities of 3D printing.

While the automotive applications mentioned above are vital, it only scratches the surface of possibilities. As automakers recognise the potential of this technology and start investing in it the space will surely expand.

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In the fashion industry

In recent years, the use of 3D printing in the fashion industry has increased. Fashion designers are experimenting with 3D printing as well as companies like Nike and Adidas. 3D printed clothes such as dresses or jackets, accessories and jewellery are becoming fascinating to some designers. 3D printing footwear addresses the specific needs of each customer by printing each sole according to their foot. 3D printing can significantly expand creative possibilities for fashion design. It makes it possible to create shapes without moulds, and thus easy-to-produce elements of an extreme intricacy that once could not be reached otherwise.

Whether for printing the entire product or just part of it, 3D printing is particularly suitable for fashion accessories and especially glasses or umbrellas. It is also widely used for jewellery. Similarly, in the watch industry, 3D printing can also be used for prototyping.

Without a doubt, 3D printing is essential for the optimisation of production processes, customization possibilities, cost optimisation and creation of complex shapes. 3D printing opens new creative fields for the fashion industry and allows the use of cutting-edge technology instead of traditional techniques.

In the construction industry

Construction 3D printing has been in development since the 1990s. It is a faster and less expensive way of constructing buildings and other structures. Large-scale 3D printers designed specifically for printing concrete can pour foundations and build walls onsite. They can also be used for printing modular concrete sections that are later assembled on-site. The world's largest 3D-printed building was recently completed in Dubai proving the potential of this technology is immense. The building offers 640 square meters of space and is 9.5 meters tall (two floors). The building was created on site using a special 3D printer designed by Apis Cor.

The World's largest 3D printed building in Dubai

Complex structures that were not possible to create before with traditional methods are now becoming a reality. Even in harsh environments, 3D printers can now be utilised. It can also help make housing more affordable to those in need. The buildings are time and cost-effective compared to conventional structures and are also environmentally sustainable.

There are plenty of benefits to using 3D printing in the construction industry and companies using it are profiting from them. 3D technologies help to manage the whole production process, from the early design stages of a project to actual construction. Structures are being 3D printed at a fraction of the regular cost/time and are much more eco-friendly thanks to minimum material wastage.

In education

Every day, more schools are incorporating 3D printing into their curriculums. By closing the gap between an image and the three-dimensional world, it helps better prepare students for their future. Students can create prototypes without the need for expensive tooling. They learn about 3D printing applications by designing and producing models that can be held in their hands.

Students are learning about design, engineering, and architectural principles by exploring and experimenting with 3D printing. They can duplicate precious and historical artifacts to study in the classroom without the possibility of damaging original collections. They are also able to gain a new perspective on topographic maps. Students of medicine for instance can create and study cross-sections of organs in the human body. 3D printing offers students the ability to experience their projects from the modelling stage to actual creation. This creates both excitement and a better understanding of design processes. They gain hands-on experience from concept to creation. It also helps them to understand teachers better. The use of 3D printing technology should be encouraged in schools as it provides new learning opportunities to experiment with ideas which expands and grows creativity.

Final thought

Despite the many advantages and potential that 3D printing may provide, expectations of the technology are often exaggerated - especially regarding how soon some of the more exciting possibilities will become a reality. Although progress is being made towards these goals, 3D printing will require vision, money, and time for the technology to evolve into the anticipated applications.

It is important to appreciate what has already been achieved and how it has affected our future. It is also worth mentioning that despite the many advantages, 3D printing has also given rise to safety and security concerns. 3D printers have been employed for criminal purposes, such as printing guns, master keys, and ATM skimmers. 3D printing is also subject to patent, copyright and trademark law. There is limited experience regarding how these laws should be applied. Therefore, regulation regarding the use of 3D printers and who uses them require serious attention.