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**3D print training modules for electric-electronic teachers in vocational high schools**

**(2019-1-TR01-KA202-07433)**

**IO1: ECVET based knowledge and skills progression framework**

**Start date: 01-12-2019**
**End date: 30-06-2020**

**Leader: Vienna Association of Education Volunteers**

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## 1. Preface

Professional development of vocational teachers is the key element for ensuring the quality and relevance of the vocational and technical education both in school and work based. Using the new technologies like as 3D print and prototyping in VET high schools will strengthen the links between school education and labour market. There is not a developed curriculum for 3D print training modules for electric-electronic department to implement 3D modelling to engage young minds and increase speed & creativity in school lab. 3D printing technology is important to today's VET students because they will be tomorrow's employees.

3D printing is everywhere, impacting industries such as healthcare, aerospace, manufacturing and practically any other areas. However, adoption of the 3D printing technology is still relatively low for educational purpose. Despite potential benefits, there is not a unique teaching material for the integration of 3D printing technology into the electric-electronic education in vocational high schools.

With the expansion of the applications of 3D printing technology throughout electric-electronic industry, it is important that VET teachers start to increase design and technical skills required to harness this technology.

VET, together with the overall education and training systems, will need to support the competitiveness and innovation of European economies. Development of skills anticipation is necessary by using updating curriculum accordingly for the effective learning according to the electrical-electronic sector demands and new technologies.

Teachers' role is changing as a result of new approaches to learning. With a growing attention to active learning, responsibilities are shifting from the VET teacher to the student, with the teacher becoming a facilitator of learning processes rather than a transmitter of expert knowledge. Self-directed learning is apparently a necessity for an increasing part of the population in changing societies.

"3D print training modules for electric-electronic teachers in vocational high schools" project will develop a unique educational material for the purpose of the professional 3D printing technology implementation in school atmosphere by VET teachers. It will help VET teachers:

– To provide visual materials in classroom,
– To seize engagement of students,
– To enhance hands-on learning with realistic models,

The project will developed the following intellectual outputs for electric-electronic teachers in vocational high schools.

- IO1: ECVET based knowledge and skills progression framework
- IO2: 3D print training module for electric-electronic course in vocational high schools
- IO3: 3D print training module online learning platform

Main aim of the project is to develop ECVET based on unique educational materials for up skilling of electric-electronic teachers in vocational high schools.

Educational materials development process will include four quality design principles for teaching. These are:

1. Competency-based system
2. Active ownership
3. Development of rigorous high level skills
4. Responsiveness

## 2. Introduction

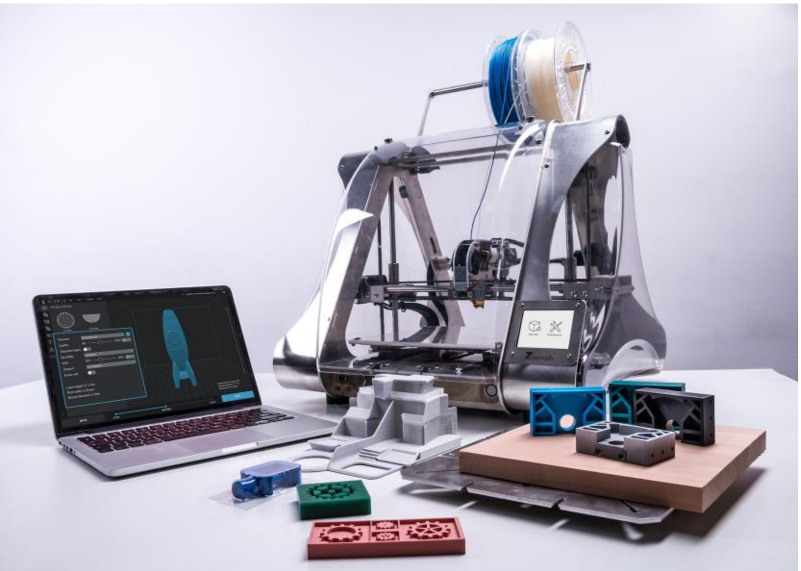
Main aim of this output is to develop ECVET based unique training curriculum for 3D print training modules to use at vocational high schools by electric-electronic teachers.

ECVET based knowledge and skills progression framework will include learning outcomes, curriculums, technical requirement report with equipments and software benchmark.

ECVET based knowledge and skills progression framework will be split into 6 units. These are:

1. Introduction to 3D printing
2. 3D printing process
3. Creation a model to 3D print
4. Developing modelling skills
5. Optimization
6. 3D printing for electric-electronic

Within these three strands, the knowledge and skills framework will be designed into intermediate level to allow its structuring and progression. A series of discrete knowledge and skills will be listed as learning outcomes. These will be used to plan electric-electronic lessons with assessment opportunities for new curriculum.



Elements of innovation:

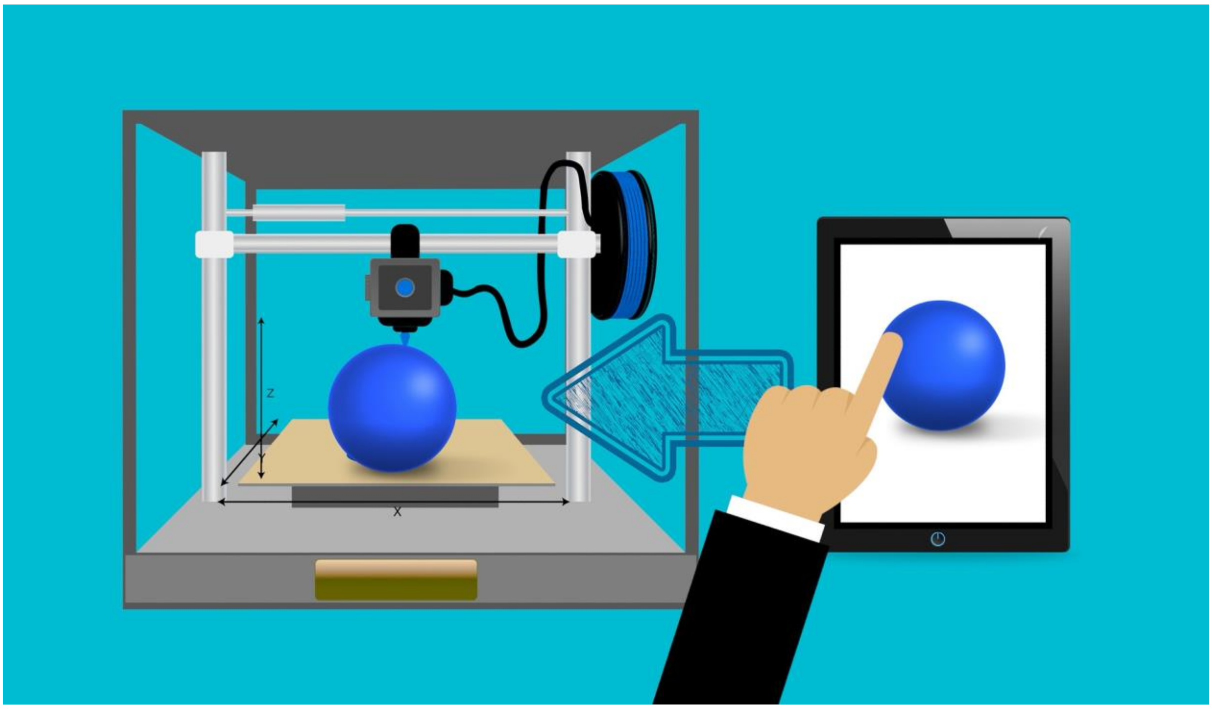
This output will be a unique ECVET based training curriculum for 3D print training modules to use at vocational high schools by electric-electronic teachers to use in 4 countries.

Expected impact:

1. Increased knowledge of VET teachers about 3D print processes, designing for 3D printing and slicing models, 3D modelling.
2. Greater understanding of 3D printing technical requirements with equipment and software benchmark
3. Increased practice level of VET teachers to effective use of learning outcomes and curriculum with assessment opportunities.

Transferability potential:

Developed learning outcomes, curriculums, technical requirement report with equipments and software benchmark can be easily adapted to other VET programs such as mechatronic, machine, automation, engine technologies. Its level can increase to advance level to use in vocational colleges and universities.



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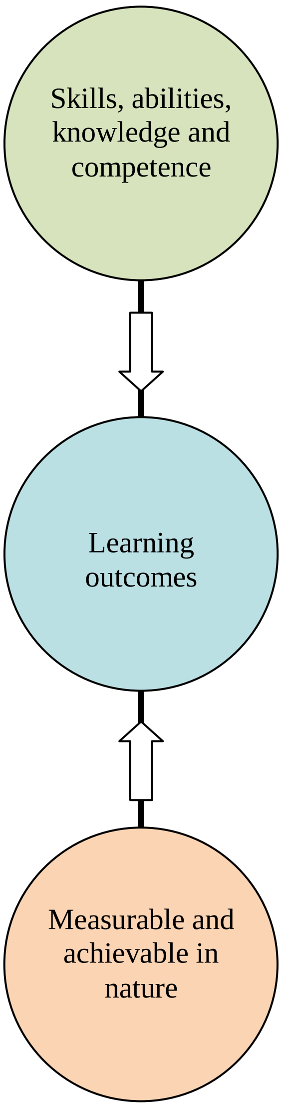
## 3. Learning outcomes

Learning outcomes are statements that describe the knowledge, skills and competence learners should acquire by the end of a particular assignment, class, course, or program, and help learners understand why that knowledge and those skills will be useful to them. They focus on the context and potential applications of knowledge and skills, help learners connect learning in various contexts, and help guide assessment and evaluation.

Those developed learning outcomes are measurable skills, abilities, knowledge or competence that the learners demonstrate as a result of completing a given course or class. The effective learning outcomes are developed through 6 units learner-oriented; they describe what both students have to learn and what the instructor will teach them.



| **Unit 1** | Introduction to 3D printing |
|---|---|
| **Responsible partner** | P4, Vienna Association of Education Volunteers - Austria |
| **Table of content** | 1.1 Overview of 3D printing technology<br>1.2 Materials used in 3D printing<br>1.3 Components of 3D printers<br>1.4 Safety issues in 3D printing<br>1.5 3D printing application fields<br>1.6 3D modelling and printing software<br>1.7 3D printing file formats |
| **Training workload** | Theoretical part (hours): 5, Practical hours:2 |
| **Learning outcomes** | Knowledge:<br>1. Tell the differences between 3D prototyping machines (CNC) and 3D printers<br>2. Describe and list the different 3D printing technologies<br>3. Sequence strengths and weaknesses of 3D printing technology<br>4. Find the right 3D print materials to use in different projects<br>5. List the mechanical and electrical components of 3D printers<br>6. Tell the safety issues and precautions in 3D printing<br><br>Skills:<br>1. Use different 3D print technologies such as FDM and SLA<br>2. Prepare the right materials used in 3D printing such as PLA filament, ABS filament<br>3. Show mechanical and electrical components of 3D printers<br>4. Operate safety instructions in 3D printing<br><br>Competence:<br>1. Be responsible for the 3D printing technologies<br>2. Comply safety instructions in 3D printing<br>3. Ensure the right software and 3D printing materials for own project |
| **Assessment type** | Quiz (10 questions) |

| | |
|---|---|
| **Unit 2** | 3D printing process |
| **Responsible partner** | P2. Kaunas Science and Technology Park – Lithuania |
| **Table of content** | 2.1 Installation and calibration of the machines<br>2.2 Preparations of the machine for printing (material loading, printing bed, environment)<br>2.3 Adjustment of printing process parameters (speed, temperature, etc)<br>2.4 Post processing (part removal from the machine, additional post processing works, etc)<br>2.5 Quality control of 3D printed part (repeatability, accuracy, etc). |
| **Training workload** | Theoretical part (hours): 10, Practical hours:2 |
| **Learning outcomes** | Knowledge:<br>1. 3D printing processes: (software for 3D modelling - Solid Works (student edition), software for 3D slicing - Cura).<br>2. 3D printing materials.<br><br>Skills:<br>1. Operate 3D printing process.<br>2. Operate 3D printing process with different materials.<br><br>Competence:<br>1. Create a three dimensional object.<br>2. Create a three dimensional objects using different materials. |
| **Assessment type** | Quiz (10 questions) |

| | |
|---|---|
| **Unit 3** | Developing modelling skills |
| **Responsible partner** | P1, Yunus Emre Mesleki ve Teknik Anadolu Lisesi - Turkey |
| **Table of content** |  |

| | |
|---|---|
| | 3.5.2 Revolved Cut<br>3.5.3 Swept Cut<br>3.5.4 Lofted Cut<br>3.6. Sketch 3D<br>3.6.1 Filled<br>3.6.2 Pattern<br>3.6.3 Rib<br>3.6.4 Shell<br>3.6.5 Wrap<br>3.6.6 Mirror<br>3.6.7 Reference Geometry<br>3.7 Assembly<br>3.7.1 Insert Component<br>3.7.2 Mate |
| **Training workload** | Theoretical part (hours): 15, Practical hours:15 |
| **Learning outcomes** | Knowledge:<br>1. Draw 2D and 3D Orthographic Projection<br>2. Describe 2D and 3D dimension<br>3. Use 2D and 3D sketch tools on CAD software<br>4. Name 3D objects on CAD software<br>5. Define extruded, revolved, swept, lofted and boundary boss base<br>6. Tell cutting tools<br>7. Describe assembly<br>Skills:<br>1. Practice to draw 2D and 3D Orthographic Projection of objects<br>2. Operate tools of CAD software<br>3. Create assembly and animation on CAD software<br>4. Present extruded, revolved , swept, lofted and boundary boss base<br>5. Show cutting tools<br>Competences:<br>1. Create a three dimensional object<br>2. Use tools of CAD software<br>3. Manage boss |

| | |
|---|---|
| | 4. Negotiate cutting tools |
| **Assessment type** | Quiz (20 questions) |

| | |
|---|---|
| **Unit 4** | Creation a model to 3D print |
| **Responsible partner** | P3, Gheleşian Petru from ”Aurel Vlaicu“ Technological High School Lugoj - Romania |
| **Table of content** | 4.1. Steps of Part: 3D Representation of a single design component<br>4.1.1. Steps of Interface of Solid Workes<br>4.1.2. Steps of Sketch.<br>4.1.2.1. Steps of Line, Steps of Circle.<br>4.1.2.2. Steps of Smart dimension<br>4.1.2.3. Steps of Trim entities<br>4.1.2.4. Steps of Circular sketch pattern<br>4.1.3. Steps of Features.<br>4.1.3.1. Steps of Extruded Boss/Base<br>4.1.3.2. Steps of Revolved Boss/Base<br>4.1.3.3. Steps of Extruded Cut<br>4.1.3.4. Steps of Revolved Cut<br>4.2. Steps of Assembly: A 3D arrangement of parts and/or other assemblies<br>4.2.1. Steps of Mate<br>4.2.2. Steps of Linear/ Steps of Circular Component Pattern<br>4.2.3. Steps of Move/ Steps of Rotate component<br>4.2.4. Steps of Material / Steps of Select view.<br>4.3. Steps of Drawing: A 2D engineering, tipically or a part or assembly.<br>4.3.1. Steps of Sheet/ Steps of Format size<br>4.3.2. Steps of Projected view. |
| **Training workload** | Theoretical part (hours): 10, Practical hours:2 |
| **Learning outcomes** | Knowledge:<br>1. Accessing SolidWorks software as a 3-D design tool Designing objects in SOLIDWORKS software<br>2. Applying Part, Assembly and Drawing in SolidWorks software<br>3. Knowledge of working tools in SolidWorks<br>4. Covers creation, retrieval and modification of 3-D and layout drawings using basic SolidWorks commands.<br>5. Editting materials of parts and assemblies in SolidWorks |

| | |
|---|---|
| | 6. Use the component library in SolidWorks<br>Skills:<br>1. Operate 3D designing software<br>2. Update data to 3D printing and then run it.<br>3. Explore ways to develop and share your design and engineering skills<br>4. Create parametric models of parts and assemblies<br>5. Generate dimensioned layouts<br>Competence:<br>1.Creating a three dimensional object in SolidWorks<br>2. Use common types of 3D printers in SolidWorks<br>3. Creating three-dimensional solid models<br>4. Creating three-dimensional assemblies incorporating multiple solid models |
| **Assessment type** | Quiz (10 questions) |

| | |
|---|---|
| **Unit 5** | Optimization |
| **Responsible partner** | P5, REDVET - Turkey |
| **Table of content** | 5.1 Optimization in the design process<br>5.2 Optimization and quality<br>5.3 Design recommendations<br>5.4 Pre processing parameters<br>5.5 Infill design<br>5.6 Cost optimization |
| **Training workload** | Theoretical part (hours): 10, Practical hours:10 |
| **Learning outcomes** | Knowledge:<br>1. List optimisation techniques applied in 3D printing<br>2. Describe 3D printing optimisation parameters<br>3. Tell quality definition and improvement<br><br>Skills:<br>1. Use geometrical modelling<br>2. Do right materials selection<br>3. Operate 3D printing process improvement<br><br>Competence:<br>1. Be responsible for the optimisation of 3D printing processes. |
| **Assessment type** | Quiz (10 questions) |

| | |
|---|---|
| **Unit 6** | 3D printing for electric-electronic |
| **Responsible partner** | ITIS Polo Tecnico “Fermi-Gadda” |
| **Table of content** | 1. 3D print of electric components<br>STL code of some examples: The plug, electric terminal.<br>2. 3D print of electric projects<br>STL code of some examples: Gearbox, relay.<br>3. 3D print of spare parts for electronics<br>STL code of some examples: Raspberry Pi Case-Box, knob adapter (for potentiometer), breadboard case, battery case, fan grill cover, AA battery holder, easy soldering platform, PWM circuit housing.<br>4. 3D print of electronic projects<br>STL code of some examples: Robot arm, led lamp, resistor storage box, dimmer circuit box, electronics third hand soldering stand, RGB led fidget spinner. |
| **Training workload** | Theoretical part (hours): 4, Practical hours:30 |
| **Learning outcomes** | Knowledge:<br>1. 3D printing materials.<br>2. Slicing techniques & materials.<br><br>Skills:<br>1. Problem-solving.<br>2. Operating 3D printing process with different materials.<br><br>Competence:<br>1. Using common types of 3D printing.<br>2. Creating a 3D object. |
| **Assessment type** | Practical exam |

## 4. Equipments and software benchmarking

### 4.1 Comparison of 3D modelling programs

3D modelling is the process of developing a mathematical representation of any surface of an object (either inanimate or living) in three dimensions via specialized software. The product is called a 3D model.

Used in industries like animation, architecture, manufacturing, product iteration, and industrial design, 3D models are crucial components of digital production. That’s why choosing the right 3D modelling software is essential – it helps you to realize creative ideas with a minimum of fuss.

Finding the best 3D modelling software is not an easy task. To help you choose the right one, we have included suites of 3D modelling programs targeted to every need, starting from 3D modelling beginners to experienced professionals.

| 3D modelling programs | Advantages | Disadvantages |
| --- | --- | --- |
| AutoDESK Fusion 360 | User friendly<br>Price free for students 3 years<br>It has a lot of different free parts (CAM, CAD etc.)<br>Cloud based exchange and storage system<br>Considered industry standard software<br>Useful for basic and easy-to-use simulations | Offers intuitive assembly interface |
| Blender | Free (Open source)<br>Good for small teams or freelancers<br>Has CAD features to repair your meshes | Not easy for beginners. |
| Catia V5 Student Edition | Useful for big project like automation system of factory | Price $110 for each student<br>Modular costs (Mechanical design part, assembly etc.)<br>Complex 3D modelling program for design and assembly<br>High spec PC required such as i5 CPU, 1GB display card etc. |
| PTC Creo Parametric Essentials | It is easy to go back to the design board. Because it is parametric program so when you change a value of your design.<br>It changes automatically the part area.<br>Fast creation<br>Flexible modelling | It is different program for design than others meaning it is unfamiliar and hard to learn.<br>Price $7,699, and it has no student edition option |

| 3D modelling programs | Advantages | Disadvantages |
|---|---|---|
| Sketchup Design | Price free for users<br>User friendly<br>Easy learning curve<br>High quality<br>For large or medium companies | Some limitations with free version |
| Solid Works Student Edition | Useful for big machine design and more<br>Easy and simple smooth transition<br>Offers robust simulation packages | Price $86 for each student per a year<br>Complex 3D modelling program for design<br>High spec PC required such as at least 1GB graphics |
| TinkerCad 123D | Very User friendly, for kids 4 years and over (therefore simplistic functionality)<br>Enjoyable interface for kids<br>Price free for users | Low functionality for design and assembly area so difficult to build specific or complicated parts<br>Will not be updated anymore |

Table-1: Comparison of 3D modelling programs

## 4.2 Comparison of slicing programs

The 3D models must be first sliced into layers since the 3D printer prints out model layer by layer. The slicing algorithm plays a very important role in the 3D printing process. The most common technique for slicing is the produce contour data from STL files. The software then generates the tool path (.gcode) the printer will use for printing. Most slicing software will have a print preview function to help you prevent print failures.

| Slicing Programs | Advantages | Disadvantages |
|---|---|---|
| Cura | User friendly<br>Simple interface<br>Free for users<br>Detailed enough<br>Open source<br>Inspect all the layers to if the slicing is done correctly<br>Intelligent tool path<br>Fast print speed | Poor support quality for printing |
| Craftware | A lot of detailed support<br>Free for users | Complicated |
| Simplyfy3D | A lot of detail<br>Good quality printing | Complicated<br>149$ |
| Slic3r | Simple interface<br>Normal printing quality<br>Free for users | Poor quality support for printing<br>Not as complicated<br>Some errors on thin walled parts |

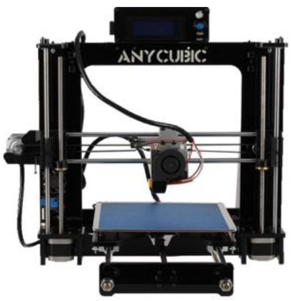
Table-2: Comparison of slicing programs

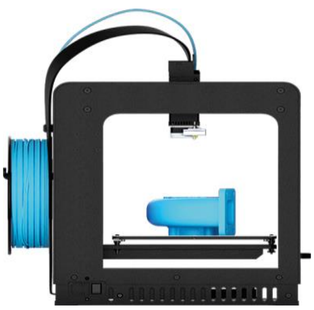
### 4.3. Comparison of 3D printers

3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file. The creation of a 3D printed object is achieved using additive processes. In an additive process an object is created by laying down successive layers of material until the object is created. Each of these layers can be seen as a thinly sliced horizontal cross-section of the eventual object.

You can use 3D printers to create everything, from toys to prototypes. These days, some people are even using 3D printers to churn out protective gear related to the coronavirus pandemic. And with that kind of flexibility, it's no surprise that 3D printers have found a place in classrooms, design shops and even homes of hobbyists and makers.

But with a wide range of users comes an even wider range of printers. 3D printers come in all shapes and sizes, with prices ranging from a couple hundred Euros to four-figure price tags.

| Printers | Advantages | Disadvantages |
|---|---|---|
| Anycubic Prusa i3<br> | Build volume: 200x200x200mm<br>Minimal assembly<br>100-600 micron layer resolution<br>Works with all filaments<br>SD-Card and computer connectivity<br>All spare parts are cheap and very common<br>$500<br>Fast and responsive user interface | Single extrusion<br>Normal printing quality<br>Somewhat noisy<br>Not very upgrade-friendly |

| Printers | Advantages | Disadvantages |
| --- | --- | --- |
| Makerbot Replicator<br> | Flexible connectivity (WiFi, Ethernet, USB)<br>Build volume: 52.8x44.1x41.0<br>100micron layer resolution<br>Good printing quality<br>Box body<br>Fast print speed<br>Simple to use | Only use Makerbot filament (expensive)<br>Only use Makerbot slicing firmware<br>Not easy to reach spare parts<br>$800 |
| Robox Dual<br> | Dual extrusion<br>Box body (low noise)<br>Good printing quality<br>Min. layer resolution 20 micron<br>Supports open source hardware and software | 210x150x100mm (small plate for printing)<br>Not easy to reach spare parts<br>Limited resolution<br>£1000<br>Basic interface<br>Open frame design |
| Ultimaker 2+<br> | Build volume: 22.3x22.3x20.5<br>Good Printing quality<br>Layer resolution 20-600 micron<br>Works all slicing programs<br>No limitation on modifying a device and the use of any slicer wanted<br>Open source | Single extrusion<br>Not easy to reach spare parts (expensive)<br>SD-Card connectivity<br>£2750 |
| Zortrax M200<br> | Build volume:20x20x18cm<br>90-400 micron layer resolution<br>Good printing quality<br>Box body<br>For professional applications<br>Infallible<br>Convenient maintenance | Single extrusion<br>Only use own filament<br>Only use own slicing firmware<br>SD-Card connectivity<br>Not easy to reach spare parts<br>1000$<br>Any modifications are very limited<br>Not open-source |

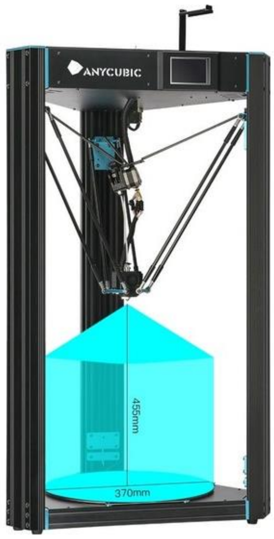
| Printers | Advantages | Disadvantages |
|---|---|---|
| ELegoo Mars UV SLA<br><br> | Great budget resin 3D Printer<br>Excellent print quality<br>Minimal setup<br>Simple but effective<br>Build volume:12x6.8x15.5mm<br>2560 x 1440 pixels, 10 microns resolution | Basic connectivity (USB) in an awkward location<br>The fan is quite loud<br>Prolonged use can trip the firmware up |
| Anycubic Predator Delta<br><br> | Heavy duty DELTA structure, Minimum shaking during printing<br>Easy levelling, save your much time and effort on print bed levelling<br>Build volume:37x45.5cm<br>Layer Resolution: 0.05-0.3 mm<br>High-precision and stability | Some issues with the controller |

Table-3: Comparison of 3D printers