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TRAINER TOOLKIT



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3DPRISM TRAINER TOOLKIT

Introduction

The purpose of this toolkit is to enable trainers to integrate the learning materials developed by the 3DPRISM project into existing or under-formation VET courses on additive manufacturing (AM). AM represents an inexpensive, accurate and effective alternative to subtractive manufacturing with applications in most industrial and technological sectors. In order for AM techniques to be smoothly integrated in the manufacturing process, workers and technicians should familiarize with 3D printing technologies, acquire specialist skills and increase their overall capacity to design and produce finished products using suitable 3D printing processes. To this end, the toolkit provides: a) guidelines on how to teach with the use of the 3DPRISM learning units, b) assessment materials, c) recommendations on how to develop new units, and d) instructions to launch a MOOC based on the 3D PRISM infrastructure and content already available online.

The learning material is separated into six units and each learning unit corresponds to a broad theme (e.g. materials, technologies). In turn, each learning unit is further separated into distinct sections. This format allows VET instructors to follow a basic structure which they can also adapt to specific training needs. All learning material is developed in the form of OERs (Open Educational Resources) to facilitate instructors to teach the material in class or make it available as a Massive Open Online Course (MOOC) through the Versal platform (<https://versal.com/c/jppgwv/3dprism-mooc>). The material requires approximately 30 hours to cover. Further, the 3DPRISM MOOC features a number of applications, discussed in some detail in this toolkit, that give instructors the means to add or remove material, share the course, or collaborate with other instructors.

Toolkit structure

1. Occupational profiles and training needs
2. The 3DPRISM learning units
3. Lesson plans – assessment materials
4. MOOC
5. Recommendations on how to develop new materials
6. ANNEX I (all learning units)



Learners' occupational profiles

Traditional manufacturing skills include an ability to read technical drawings, an ability to set up and fine-tune the machines, a thorough knowledge of their functioning, a well-developed dexterity, ability to do maintenance etc. Transferrable traditional manufacturing skills *are* relevant; nevertheless, AM is a complex process requiring expert skills similar to those needed in precision mechanics. In order for the fast-growing technology of AM to serve current and future industry needs, technicians in traditional manufacturing are in need of upskilling and updating their competencies with the necessary digital skills for AM. AM quality control and finishing are automated (virtualization and robotization) and production process is remote, minimizing the hazards of working with toxic materials and the functioning of these machines is relatively independent of the operator's profile. However, a different hierarchy of skills is required, depending on the materials used, the selected printing method as well as the expertise of the operator.

In terms of learning outcomes, knowledge and skills, **two occupational profiles have been identified**, differentiated by the level of experience than the type of additive manufacturing technologies used.

The **first** category of learner is the **entry level technician** with reasonable AM manufacturing experience, typically a graduate or an apprentice. The entry level operator should be able to train as AM Machine worker and to perform standard maintenance. For this category of learner, the high priority knowledge to be gained is safe working practices and procedures at all times. Knowledge of materials, processes and CAD design are assigned a medium priority for this category of learners.

The **second** category of learner is the **experienced Level technician**. Emerging manufacturing job profiles relatable to the experienced Level Technician are: AM CAD Worker, AM Powder metallurgist, AM Health & Safety Officer, Machine Optimisation Officer, Quality Control Expert. Pre-production, set-up and post-production skills for both categories of learners are described in TABLE 1 & 2 on pages 5 & 6:



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Occupational Profile	Learning outcomes	Skills/ Competences		
		Pre-production	Set-up Phase	Production
<p>Entry Level Technician</p> <p>Emerging Manufacturing Job Profiles: AM Machine Worker, Maintenance Worker</p>	<p>High priority</p> <ul style="list-style-type: none"> Application of safe working practices and procedures at all times <p>Medium priority</p> <ul style="list-style-type: none"> Understand the different types of Additive Manufacture (AM) processes available as well as their advantages and disadvantages. Understand the different materials, and their properties, used to produce components by the AM process. Understand how problems and defects can occur in components produced by AM processes as well as the preventative measures. Understand the finishing techniques (e.g. Machining, HIP, Coating, Heat Treatment) used for the various AM techniques. Possess CAD Design skills relative to manufacturing/product design. Understand how position and orientation affects the build's properties. 	<p>High priority</p> <ul style="list-style-type: none"> Check all equipment is in a safe and usable working condition. Obtain sufficient quantities of all required materials, correct handling/storage of materials and check the documentation. Obtain all the necessary data, documentation and specifications for the component to be produced. Download the correct build files to produce the components. Check the data files are suitable for the application. Understand the basic principles of the AM equipment being used. Clear communication with co-workers and customers is important to ensure components are fabricated correctly. <p>Medium priority</p> <ul style="list-style-type: none"> Interpret drawings, imperial and metric systems of measurement, workpiece reference points, systems of tolerancing. 	<p>High priority</p> <ul style="list-style-type: none"> Able to start/stop the equipment in normal, completion and emergency situations. Understand the hazards, and how they are minimised, that are associated with operating AM machines. Wear appropriate PPE and keeping the work area safe and tidy. Import appropriate files (e.g. STL) from a data system into AM software. <p>Medium priority</p> <ul style="list-style-type: none"> Able to check/set equipment operating parameter (access program edit facility to make minor adjustments for production). 	<p>High priority</p> <ul style="list-style-type: none"> Know when the component(s) can be unloaded from the machine. Remove part from remaining raw material and supports. Safe storage and disposal of used filters and waste powder material is very important in this process. Leave the machine in a safe condition on completion of AM activity <p>Medium priority</p> <ul style="list-style-type: none"> Monitoring process parameters for quality control. Inspection of the component for dimensional accuracy, visible defects and appearance. Components to be cleaned, packaged and stored with all necessary documentation (e.g. Batch No., CAD file No., date, Operator, etc.). Maintenance skills on AM machine e.g. laser, optical systems, automatization

TABLE 1: ENTRY LEVEL PRIORITY LEARNING OUTCOMES AND SKILLS

Occupational Profile	Learning outcomes	Skills/ Competences		
		Pre-production	Set-up Phase	Production
<p>Experienced Level Technician</p> <p>Emerging Manufacturing Job Profiles: AM CAD worker, AM Powder Metallurgist, AM Health & Safety Officer, Machine Optimization Officer, Quality Control Expert</p>	<ul style="list-style-type: none"> • Application of safe working practices and procedures at all times. • Understand the different types of Additive Manufacture (AM) processes available as well as their advantages and disadvantages. • Understand the different materials, and their properties, used to produce components by the AM process. • Understand how problems and defects can occur in components produced by AM processes as well as the preventative measures. • Understand the finishing techniques (e.g. Machining, HIP, Coating, Heat Treatment) used for the various AM techniques. • Possess CAD Design skills relative to manufacturing/product design • Understand how position and orientation affects the build's properties. 	<ul style="list-style-type: none"> • Check all equipment is in a safe and usable working condition. • Obtain sufficient quantities of all required materials, correct handling/storage of materials and check the documentation. • Obtain all the necessary data, documentation and specifications for the component to be produced. • Download the correct build files to produce the components. • Check the data files are suitable for the application. • Understand the basic principles of the AM equipment being used. • Interpret drawings, imperial and metric systems of measurement, workpiece reference points, and systems of tolerancing. • Clear communication with co-workers and customers is important to ensure components are fabricated correctly. Manufacturing expert technician should interface with designer to provide process guidelines to designer. 	<ul style="list-style-type: none"> • Able to start/stop the equipment in normal, completion and emergency situations. • Understand the hazards, and how they are minimized, that are associated with operating AM machines. • Wear appropriate PPE and keeping the work area safe and tidy. • Import appropriate files (e.g. STL) from a data system into AM software. • Able to check/set equipment operating parameters (access program edit facility to make minor adjustments for production). 	<ul style="list-style-type: none"> • Know when the component(s) can be unloaded from the machine. • Remove part from remaining raw material and supports. Safe storage and disposal of used filters and waste powder material is very important in this process. • Leave the machine in a safe condition on completion of AM activity, e.g. close programs, clean machine, removal and disposal of waste. • Monitoring process parameters for quality control. • Inspection of the component for dimensional accuracy, visible defects and appearance. • Components to be cleaned, packaged and stored with all necessary documentation (e.g. Batch No., CAD file No., date, Operator, etc.). • Maintenance skills on AM machine eg laser, optical systems, automatisisation.

TABLE 2: EXPERIENCED LEVEL PRIORITY LEARNING OUTCOMES AND SKILLS



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3DPRISM Learning Units

The 3D PRISM learning material is divided into the following six Modules (Learning Units):

Module 1: Introduction to Additive Manufacturing

Module 2: AM technologies

Module 3: Materials

Module 4: Process Parameters

Module 5: CAD/CAM for Additive Manufacturing

Module 6: Basic Maintenance

Lesson plans

The aim of all modules (learning units) is to support VET provision to equip technicians & operators with 3D printing skills.

The overall learning objectives of the modules are:

1. Providing learners with the basics of Additive manufacturing (AM)
2. Familiarizing learners with implications to manufacturing industries
3. Introducing learners to advantages, limitations & advances in AM
4. Comparing AM to subtractive manufacturing

The outcomes correspond to six learning units comprising the learning content developed by the project. The learning units are summarized below:

Module 1: Introduction to Additive Manufacturing

Addressing the advantages and challenges of AT: Additive manufacturing (AM) can be defined as a joining solidification process that builds objects using a digital design data file to create a three dimensional object, usually by adding layer-upon-layer of materials, whether the material is plastic, metal, ceramic, concrete or even human tissues using a computer driven-technology. AM is a completely different manufacturing approach compared to traditional subtractive manufacturing (through machining) which involves subtracting materials from a larger workpiece (e.g., grinding, polishing) or conventional forming methods (e.g., pressing, casting, injection moulding). The main concept in AM is to “stack layers” of materials in order to reproduce a tridimensional object.



1.1 What is Additive Manufacturing?

- The AM process

Duration: 60mins (45mins lecture + 15mins evaluation)

Objectives: Learners should be able to:

- understand how AM differs from subtractive manufacturing
 - describe the flow and stages of the AM process
 - relate AM to specific manufacturing needs and sectors of interest
-

1.2 Advantages

- Complexity of Manufacture
- Less waste
- Materials
- Lead time & Design Freedom
- Cost saving

Duration: 120mins (100mins lecture + 20mins evaluation)

Evaluate understanding / assessment Learners should be able to:

- describe how the use of 3D printing will be beneficial and facilitate the production process and increase output
-

1.3 Challenges

- The Staircase Effect and Part Built Orientation
- Duration of Manufacture
- Support Structures
- When are Support Structures Needed?
- Resolution

Duration: 120mins (100mins lecture + 20 mins evaluation)

Evaluate understanding / assessment Learners should be able to:

- understand the limitations of the AM process
 - understand how the 'staircase effect' and part orientation affect surface finish
-

Module 2: AM Technologies

Addressing the different AM technologies (Powder Bed Fusion, Directed Energy Deposition (DED), Vat Polymerisation, Extrusion Based Systems, Material and Binder Jetting, Sheet Lamination Process). The layer-by-layer process involves stacking flat layers of material on top of each other to make a three-dimensional part. This section summarises different technologies that use the process. This section is divided into 5 subsections dedicated to each process and their related technologies.



2.1 Powder Bed Fusion

- Selective Laser Sintering (SLS)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)

Duration: 120mins (100mins lecture + 20mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Understand why certain materials are suitable for each Powder Bed Fusion technique
-------------------------------------	--

2.2 Directed Energy Deposition (DED)

- Laser Metal Deposition (LMD)

Duration: 120mins (100mins lecture + 20mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Recognize the standard uses of LMD
-------------------------------------	--

2.3 Vat Polymerisation

- Stereolithography (SL)
- Mask Projection Technology (DLP)
- Two Photon Approach

Duration: 120mins (100mins lecture + 20mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Understand the three different Vat Polymerization techniques, their limitations and applicability
-------------------------------------	---

2.4 Extrusion Based Systems

- Material Feed System
- Deposition Characteristics
- Support Structures
- Printing Patterns
- System Diagram



Duration: 120mins (100mins lecture + 20mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Understand why extrusion techniques increase anisotropy - Understand how manufacturing inaccuracies occur may occur within extrusion techniques
-------------------------------------	--

2.5 Material & Binder Jetting

- Material Jetting
- Binder Jetting

Duration: 60mins (45mins lecture + 15mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Understand Jetting applications and specificities (allows combinations of different materials, colour, production of casting patterns)
-------------------------------------	--

2.6 Sheet Lamination Processes

- Laminated Object Modeling (LOM)
- Ultrasonic AM (UAM)
- Hybrid Manufacturing

Duration: 60mins (45mins lecture + 15mins evaluation)

Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - recognize the advantages & disadvantages of the different lamination techniques - understand why hybrid manufacturing is indispensable
-------------------------------------	---

Additional resources Video: <https://www.youtube.com/watch?v=GUvnz0borAI>
Video: <https://www.youtube.com/watch?v=zzQrJ3AqZEs>

Module 3: Materials in Additive Manufacturing

Explaining the different base materials used in AM (Metal Feedstock, Polymer Feedstock, Thermoplastic Support Material, Ceramics). While individual systems are limited in the materials that they can print, the range of AM technologies as a whole can manufacture with a large variety of materials. The different forms of base material include powders, filaments, pellets, wires and liquids. AM processes can be classified by the type of base material employed.

3.1 Metal Feedstock

- Metal Powder
- Metal Wire



Duration: **60mins (45mins lecture + 15mins evaluation)**

Evaluate understanding / assessment	Learners should be able to: - understand materials' (Metal Powder/wire) properties: packing density, evaporation losses, contamination, flowability of powders
---	---

3.2 Polymer Feedstock

- Photopolymers
- Thermoplastics
- Acrylonitrile Butadiene Styrene (ABS)
- Polyactide (PLA)
- Polyethylene Terephthalate (PET)
- Polycarbonate (PC)
- Nylon
- Wax

Duration: **180mins (150mins lecture + 15mins evaluation)**

Evaluate understanding / assessment	Learners should be able to: - differentiate between thermoplastics and thermosetting plastics - understand occupational hazards associated with use of photopolymers - understand the applications of and compatible printing techniques to thermoplastic materials - understand how temperature and print speed affect the different feedstock
---	---

3.3 Thermoplastic Support Material

- High Impact Polystyrene (HIPS)
- Polyvinyl Alcohol (PVA)
- Ceramics
- Clay Extrusion Ceramic Printing
- Composites

Duration: **120mins (100mins lecture + 20mins evaluation)**

Evaluate understanding / assessment	Learners should be able to: - know when and why material support is necessary - understand the different properties of HIPS and PVA - know the difference between Particle-reinforced polymer composites and Fibre-reinforced polymer composites
---	---



Module 4: Processing Parameters

Describing the set of processing parameters specific to the different AM technologies (Laser Based Processes, Extrusion Processes, Binder Jetting & Laminated Object Manufacturing). Optimising process parameters in additive manufacturing reduces the chance of defects occurring, such as excessive porosity, delamination, cracking and swelling. This section looks at the sets of processing parameters specific to laser-based, extrusion-based, lamination-based and binder-jetting technologies respectively.

4.1 Process Parameters Laser-Based Processes

- Powder-based Laser AM
- Process Parameters in Wire-based AM

Duration:	60mins (45mins lecture + 15mins evaluation)
Evaluate understanding/assessment	Learners should be able to: <ul style="list-style-type: none"> - understand how controlling for parameters in powder-based AM and wire-based AM influences mechanical properties of parts

4.2 Process Parameters for Photopolymers

- Cure Depth and Width
- Photospeed
- Time Scales
- Weave
- Weave Patterns
- Scanning Strategies

	120mins (100mins lecture + 20mins evaluation)
Evaluate understanding/assessment	Learners should be able to: <ul style="list-style-type: none"> - describe the set of parameters for Photopolymers

4.3 Parameters in Extrusion Processes

- Raster Angle
- Raster Width
- Raster-to-raster Air Gap
- Build Orientation



120mins (100mins lecture + 20mins evaluation)

Learners should be able to:

- Describe how mechanical strength of parts is affected by the above parameters

4.4 Binder Jetting & Laminated Object Manufacturing

- Binder Jetting
- Laminated Object Process Parameters

Duration: 60mins (45mins + 15mins evaluation)

Evaluate
understanding /
assessment

Learners should be able to:

- Describe which parameters affect accuracy and product finish of parts

Module 5: CAD/CAM for Additive Manufacturing

Addressing 3D CAD/CAM transformation techniques into AM format (Converting CAD to STL, Modelling Tools, 3D Scanning, Exporting Machine Language Code). The STL format is the standard file type used by almost all AM systems. Most 3D CAD packages have a 'Save As .STL' or 'Export' option that can be used to export 3D models to STL files. When a model is exported as an STL file, all of the faces that make up the mesh are converted to triangles in a process known as triangulation. The number of triangles used to approximate the original mesh can affect the surface quality of the final part. Too few triangles can result in coarse surfaces but too many triangles results in very large file sizes, slowing down exportation and the build process.

5.1 What is CAD/CAM?

- AM Software
- Before Importing the File to AM program
- Before Exporting an STL File

Duration: 60mins (45mins lecture + 15mins evaluation)

Evaluate
understanding /
assessment

Learners should be able to:

- Describe how and why a CAD file is a necessary component of AM manufacturing

5.2 Converting CAD to STL

- Chord Height
- Angle Tolerance
- Model Manipulation
- Software Environment and Measurements
- Part Positioning
- Part Orientation



120mins (100mins lecture + 20mins evaluation)

Learners should be able to:

- Explain what process the STL file should undergo before it can be functional

5.3 Modelling Tools

- Drawing tools
- Model preparation

Duration: 60mins (45mins lecture + 15mins evaluation)

Evaluate
understanding /
assessment

Learners should be able to:

- Distinguish between the two basic approaches to 3D printing
- Describe the main modelling tools

5.4 3D Scanning

- Optical-based Systems
- Contact-based Scanners
- 3D Scanner Software

Duration: 60mins (45mins lecture: + 15mins evaluation)

Evaluate
understanding /
assessment

Learners should be able to:

- Describe the types of 3D scanning

Resources: <https://www.youtube.com/watch?v=TTCiOoedUco>

5.5 Exporting Machine Language Code

Duration: 60mins (45mins lecture + 15mins evaluation)

Evaluate
understanding /
assessment

Learners should be able to:

- Explain what are the basic steps of converting the digital object into an AM recognizable form (e.g G-Code)

Module 6: Basic Maintenance

Addressing basic maintenance procedures (Cleaning and Lubrication, Health and Safety). This module addresses best practices for performing maintenance on additive manufacturing systems. Some procedures should be carried out every time the printer is used, others need to be done regularly (every fifty hours of use), and some less regularly (every two hundred and fifty hours of use).



6.1 Cleaning and Lubrication

- Cleaning Extrusion-based Systems
- Cleaning Powder Bed Systems
- Cleaning SLA Machines

Duration:	60mins (45mins lecture + 15mins evaluation)
Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - To describe the main cleaning steps for each category of AM - Indicate what malfunctions result from improper maintenance
Duration	https://www.youtube.com/watch?v=g8uvh6kvr54 https://www.youtube.com/watch?v=vmlY9_6s8Ss

6.2 Health and Safety

- Machine-related Hazards
- Material Hazards
- General Safety Procedures

Duration:	60mins (45mins lecture + 15mins evaluation)
Evaluate understanding / assessment	Learners should be able to: <ul style="list-style-type: none"> - Indicate what hazards are associated to the functioning of AM machines, to materials used as well as general hazards and precautions



Assessment

Module 1 - INTRODUCTION TO ADDITIVE MANUFACTURING

- 1. What is the main reason why most 3D printed objects do not have a smooth finish after coming out of the printer's tray?**
 - Printing file size and model resolution*
 - The interaction with support material*
 - The material properties*
 - The layer-by-layer fabrication method***
- 2. Overhanging feature requires...**
 - Fast printing speed*
 - Slow printing speed*
 - Pre-heating*
 - Support***
- 3. Part orientation can affect its strength. True or False?**
 - True*
 - False*
- 4. Which of the following is the main purpose of support material in 3D printing?**
 - It increases the durability of the final product*
 - It allows easier assembly and post-processing*
 - It reduces waste*
 - It support layers as they are printed, functioning as scaffoldings***
- 5. Which file format is the most common format for 3D printing?**
 - STM*
 - SLS*
 - STL***
 - SLC*
- 6. What is the term used to describe 3D model printing when it is used to create models for testing a product's design?**
 - Rapid prototype modeling (RPM)*
 - Rapid prototyping (RP)***
 - Fused deposition modeling (FDM)*
 - 3D Printing*
- 7. According to the rule 360 degree, the self -supporting zone is in the range:**
 - 130 to 20 degrees*
 - 150 to 30 degrees***
 - 0 to 70 degrees*
 - 180 to 90 degrees*



8. **The layer thickness in AM is defines as the resolution of the...**
Zero axis
Z-axis
XY- axis
XYZ- axis
9. **Wrong build orientation and slice thickness can give rise to...**
Support structures
Overhang
Material wastage
Staircase effect
10. **A 60 micron layer thickness has a better resolution that 150 micron. True or False?**
True
False

Module 2- ADDITIVE MANUFACTURING TECHNOLOGIES

1. **One 3-D printing technology has the trademark name of SLS. What does SLS stand for?**
Solid laser surfacing
Surface laser sintering
Selective laser sintering
Selective Laser Lithography
2. **Which of the following 3-D printing approaches uses liquid glue added to a fine powder?**
Photopolymerization
Multi-jet modeling (MJM)
Binder- Jet 3-D printing
3. **Which of the following printing approaches applies an ultraviolet light to a liquid polymer to change it into a solid plastic?**
Binder 3-D printing
Fused deposition modeling (FDM)
Photopolymerization
4. **Liquid, powder, or metal sheets are examples of forms of materials used in AM. True or False?**
True
False
5. **Which additive manufacturing technologies do not need support structures?**
Stereolithography (SL)
Selective Laser Sintering (SLS)



Laser Metal Deposition
Fused Deposition Modelling (FDM)

6. Which heat source is used in FDM process?

Electric Discharge
Laser
Open Flame
None of the above

7. What can limit the speed of FDM deposition head?

Melting rate of the feed material
Inertia of the printing head mass
Too many support structures

8. Which one is NOT a drawback of vat Polymerisation processes?

Cost
Speed
Post processing
Material availability

9. Which material deposition order is right in FDM process?

The inner sections are filled first and the outline is deposited next
The outline is deposited first and then the inner sections are filled
It depends on the geometry
The material can be printed in any order

Module 3 – BASE MATERIAL FOR ADDITIVE MANUFACTURING

1. Which material is a thermoplastic?

Polycarbonate (PC)
Nylon
ABS
All of the above

2. Thermoplastic polymers can be re-melted and reused without losing their properties. True or False?

True
False

3. Which polymer is the most flexible?

Nylon
ABS
TPU
Wax



4. **Which solvent should be used for HIPS support material?**
Alcohol
Water
Acetone
D-limonene

5. **It is easy to melt ceramic and use it in FDM. True or False**
True
False

6. **Which reinforcement method results in higher strength?**
Short fibre
Continuous fibre

7. **In powder bed processes pre-heating can be used to limit thermal deformation and porosity of the part. True or False?**
True
False

8. **In metal AM the base material used can be used in the form of:**
Metal powder
Metal laminate/sheet
Metal wire
All of the above

9. **Which of the following is not an important AM metal powder characteristic?**
Reusability
Good particle density and particle size distribution
Spherical powder particle shape
None of the above

10. **Selective laser melting (SLM) can be used in AM for metals, polymers, ceramics, and composites. True or False?**
True
False

11. **In wire AM, scratches on wire surface can bring about...**
Stress in built part
Porosity
Delamination
Poor surface roughness
None of the above



Module 4 – PROCESSING PARAMETERS

- 1. Which of the following is a type of defect associated with layer-by-layer AM processing?**
Delamination
Cracking
Residual stresses and swelling
Porosity
All of the above
- 2. In extrusion based AM parts are generally stronger when the raster angle increases. True or False?**
True
False
- 3. In wire based AM the wire feed rate is limited by the laser in order to avoid partial melting of wire. True or False?**
True
False
- 4. A uniform wire diameter is important in wire based metal AM systems. True or False?**
True
False
- 5. Relative density decreases with pre-heating temperature. True or False?**
True
False
- 6. Selecting the right scan strategy/path can help reduce temperature gradient and residual stresses in part model. True or False?**
True
False
- 7. As the laser beam energy density increases the hardness of part increases and surface roughness increases. True or False?**
True
False
- 8. Delamination of part is due to non-uniform heat and gas distribution during the printing process. True or False?**
True
False



Module 5 - CAD/CAM FOR ADDITIVE MANUFACTURING

- 1. AM software adjust the units for printers automatically upon importation.
True or False?**
True
False
- 2. Why is it better to build the part at the centre of the print bed?**
The printer works faster
The temperature distribution is more uniform at the centre
It is easier to clean the platform later
- 3. What can be done to improve the optical 3D scan quality?**
Scan the object from closer distance
Highlight the object details
Scan more points on the surface of the object
Superimpose more than one scans
- 4. On which of the following parameters the part orientation has significant effect?**
Build time
Support structure
Strength
Surface quality
All the above
- 5. Sweep of an open profile in CAD can be used for 3D printing. True or False?**
True
False
- 6. What is the role of escape holes in parts printed by laser Sintering?**
To let the air circulate and take the hot air out
To let out the excess material caught inside the part during printing process
To be able to wash the part inner surfaces
- 7. Increasing Chord Height in print setting will increase the surface quality.
True or False?**
True
False

Module 6 – BASIC MAINTENANCE

- 1. Best practices in AM requires cleaning the printer after each build. True or False?**
True
False



- 2. Since safety procedures in AM varies from printer to printer as well as the base material used, the best safety practices would be...**
Referring to manufacturers safety guide
Company's safety procedure
A typical manufacturer of another printer safety guide
General AM safety procedures
- 3. Which of the following is an example of particles emitted during AM that poses dangers to the user(s)?**
Gamma particles
Coarse particles
Nanoparticles
- 4. In metal AM, extra precaution should be taken as an example when dealing with titanium due because...**
Titanium is pyrophoric
Titanium is poisonous
Titanium emits radiation
None of the above
- 5. The type of the personal safety protection (PSP) employed in AM does not depend on the printer type and the base material used. True or False?**
True
False
- 6. In AM processes temperature levels can exceed 270 C and may constitute hazards as a result of...**
Skin irritation
Breathing difficulties
Possible fire and burns
Explosion
- 7. Health and safety should be consulted before modification of printers. True or False?**
True
False



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How to access the 3DPRISM MOOC

The Versal platform

The 3DPRISM MOOC is hosted in the Versal platform (<https://versal.com/c/jppgwv/3dprism-mooc>). Versal is an e-learning platform offering free, open, and interactive courses in a wide range of disciplines and subjects. As an open course publishing platform, it is designed to give anyone the ability to offer truly interactive instruction without needing to know how to code. Founded in 2012, it provides course builders and trainers with a library of interactive gadgets to easily incorporate videos, surveys, quizzes, diagrams, and other tools so as to create engaging online learning experiences.

versal
Online learning for everyone.
In the classroom or the office, creating powerful, interactive online learning experiences has never been easier.

for EDUCATION

for BUSINESS

Courses provided by Versal are divided into individual lessons (modules), supported by short video units, textual documents, presentations, images, recommended readings, exercises and automated quizzes to enhance learning process and enable learners assess knowledge and skill acquisition. The platform also enables instructors to create fixed learning paths with interdependency of sequential modules and tasks. Also, Versal offers a discussion forum, a blog and social media connections aiming at enhancing learners' engagement and support interaction with peers and instructors. To support flexible and ubiquitous learning, all MOOCs are compatible with smart phones and tablets.



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Features, functionalities, and tools: self-paced learning, learning activities that can be sequenced, direct access to material, interactive quizzes and exercises, automated and peer assessment, discussion forum, social media connections, interoperability of learning content.

Minimum system requirements

Below are the minimum system requirements for using Versal.

Due to potential programming changes, the minimum system requirements may change over time.



Supported operating systems

Currently, authoring is only available on desktops. Learning is supported on desktop computers and mobile devices running Android and iOS. We suggest using the newest version of any software, when possible.



- Desktop: Windows, Mac, and Linux
- Mobile devices: Android 4.1, 4.4, 5.0 & iOS 8 and 9

Supported browsers

The Versal platform runs on the following browsers:

Chrome (recommended)

Firefox

Safari version 7.1 and 8+ for authors and learners

Internet Explorer version 10 and newer for learners

Internet Explorer version 11 for authoring

Internet requirements

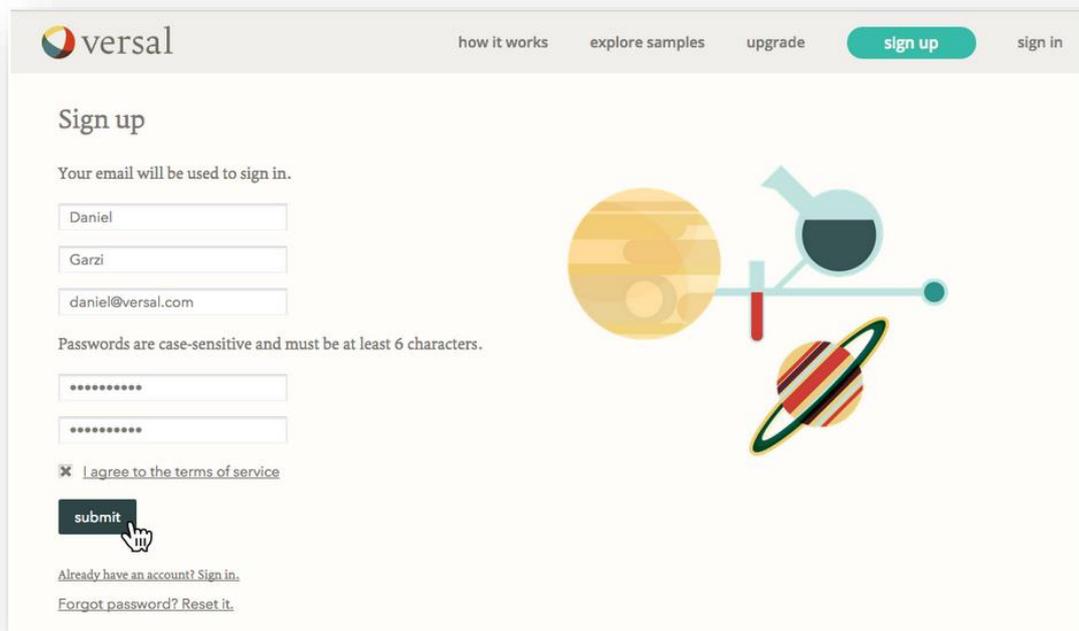
A strong broadband internet connection is necessary for good performance. A minimum download speed of 1.5 Mbps is required for using the Versal platform (basic DSL connection), however faster connections, will further enhance online experience.



Creating an account

All users (trainers and learners) on Versal must create a user profile to get access to available courses and course authoring tools. To create a new profile account, users have to enter their first name, last name, and a valid e-mail address to use as the login. It is important that users check their email address carefully before signing up as they will not be able to change it later.

To sign up, an account join password is also required. It is recommended that users should create a strong password that will include a mix of uppercase letters, lowercase letters, numbers, and symbols to prevent unauthorised access and keep profile secure.



To create a user profile:

8. Go to <https://versal.com> and click on the "Sign up" link next to the "Sign in" button.
9. The sign up form must be filled in.
10. Enter your first name, last name and a valid e-mail address to use as the login for Versal.
11. Create a user password. The user password must contain at least six characters.
12. Re-enter the password to confirm it.
13. Review the terms of service. To continue using Versal, click on "I agree to the terms of service" and submit your form.

Once you click "submit", you will be directed to your dashboard. Since you're just getting started, you will not see the courses you're creating and learning. But once you have courses, you will see them listed on the left.



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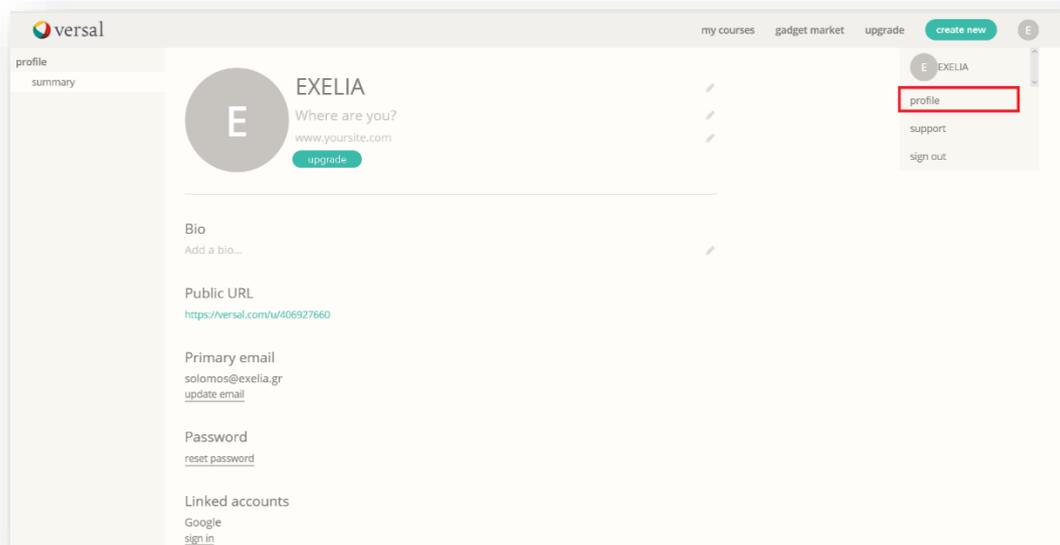


Customising your profile

Users can customise their profile by selecting unique profile images, changing the display name, adding location, website, and biographical information, and by creating connections with other accounts.

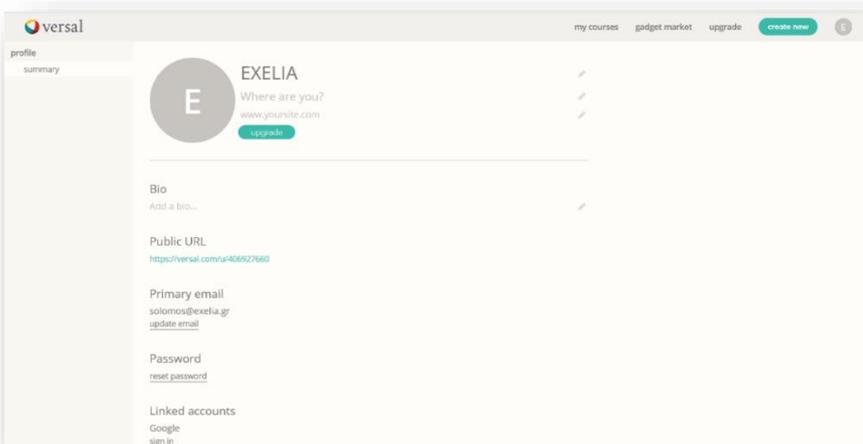
How to edit your profile

- Select profile from the drop down menu to access your profile summary.



- Click the “summary” link in the left navigation and you will be able to edit your profile photo, name, location, website and bio. Click into any of these areas and make your changes. Note that when you create courses, some of your biographical information will automatically display on the course summary page.

Select “account” to see your email address, reset your password, or link your Google account to Versal.





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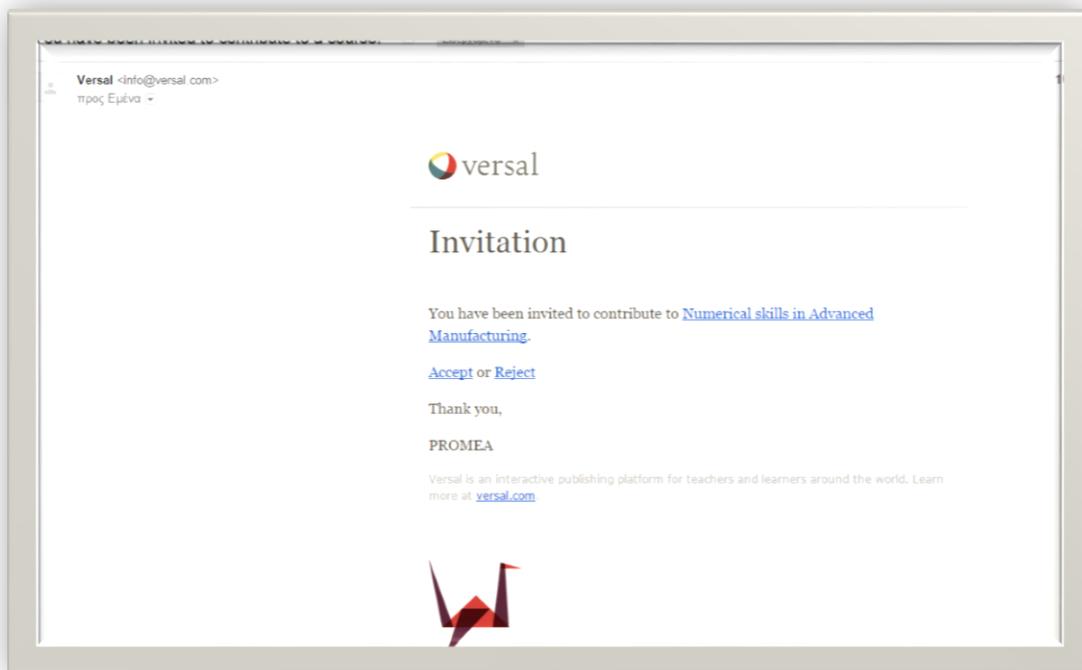
How to modify the 3DPRISM MOOC

Collaborative authoring

Versal allows multiple trainers to collaborate and create content in real-time and comment on each other's work. All Versal courses are collaborative by default. Approved trainers share the possibility to add material and resources by inserting new interactive gadgets. To enhance interactivity and communication, trainers can comment on each other's input and exchange ideas inside the course creator. Keep in mind that course authors can add and edit the gadgets in the 3DPRISM MOOC, however they will not be able to complete the publishing process since the publisher is the only person that can publish the course.

How to join the 3DPRISM MOOC as contributing author

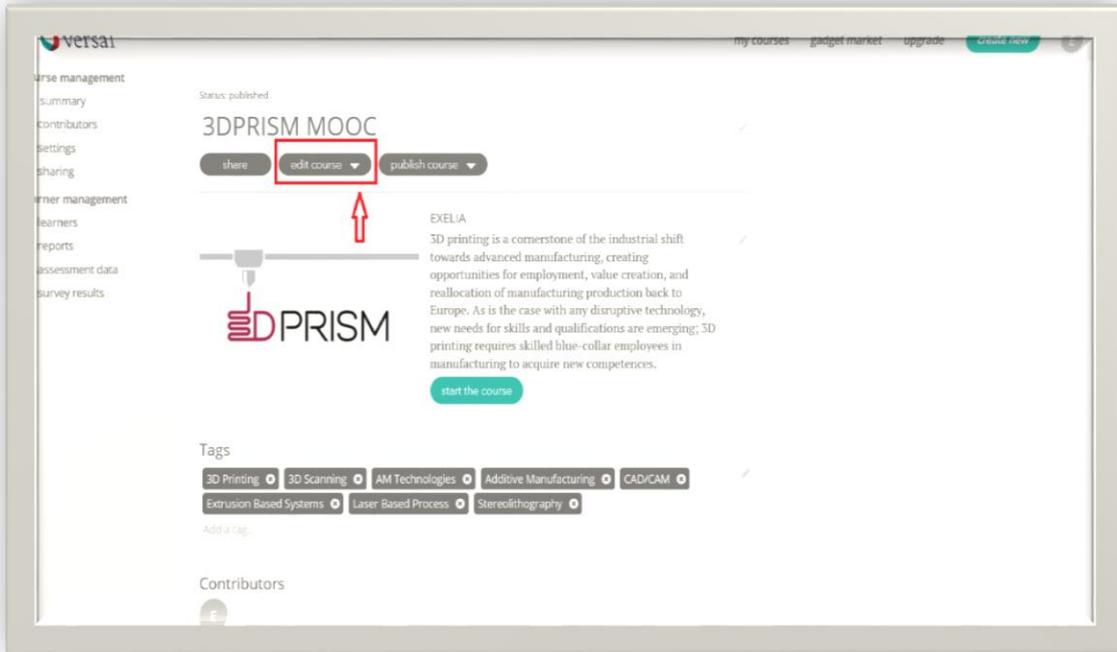
There are two ways to join the 3DPRISM MOOC as contributing author. The first is by receiving an invitation email from EXELIA, which is the publisher of the 3DPRISM MOOC, to collaborate in the development and authoring of the course. Trainers should reply to this invitation by accepting or declining the proposal. Once the trainer wishes to join the 3DPRISM MOOC as contributing author, he/she has to click the "Accept" link.



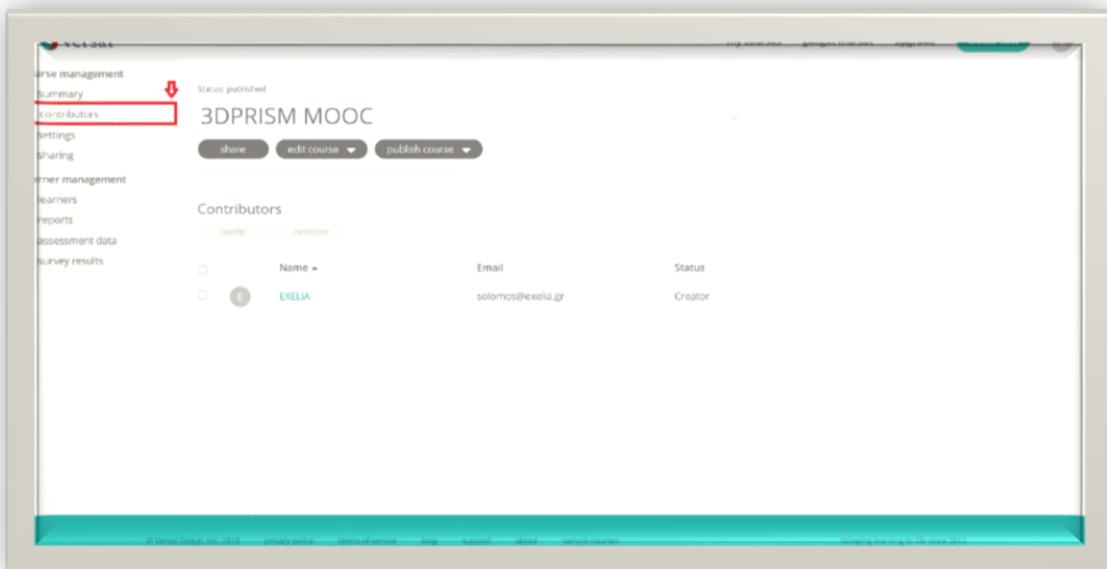
The second way is to visit the overview page of the 3DPRISM MOOC and start the co-authoring process by clicking the tab "Helping create this course".



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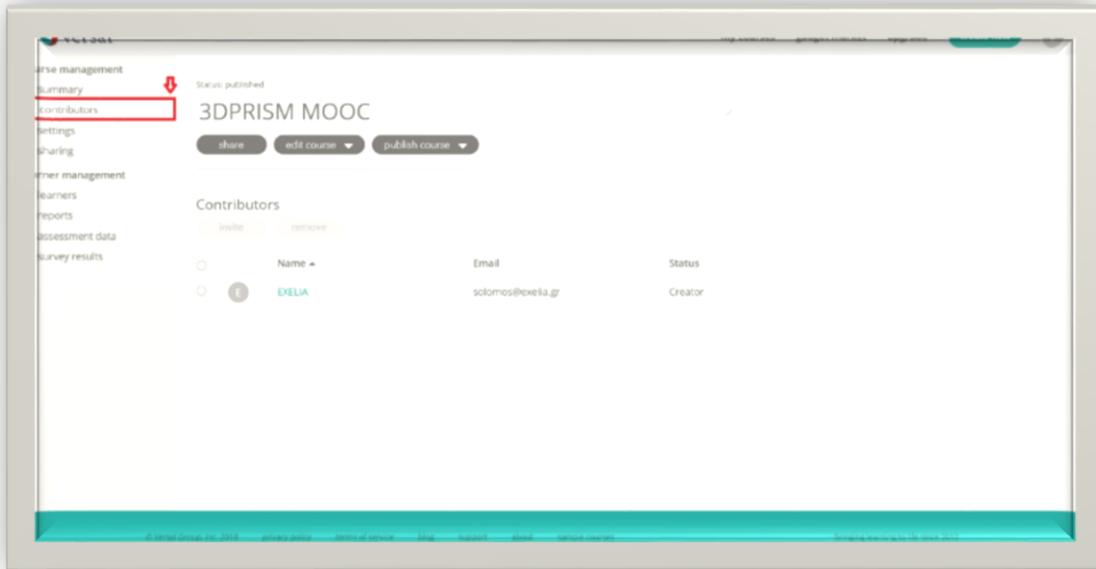


Collaborative authors are shown inside the course creator.

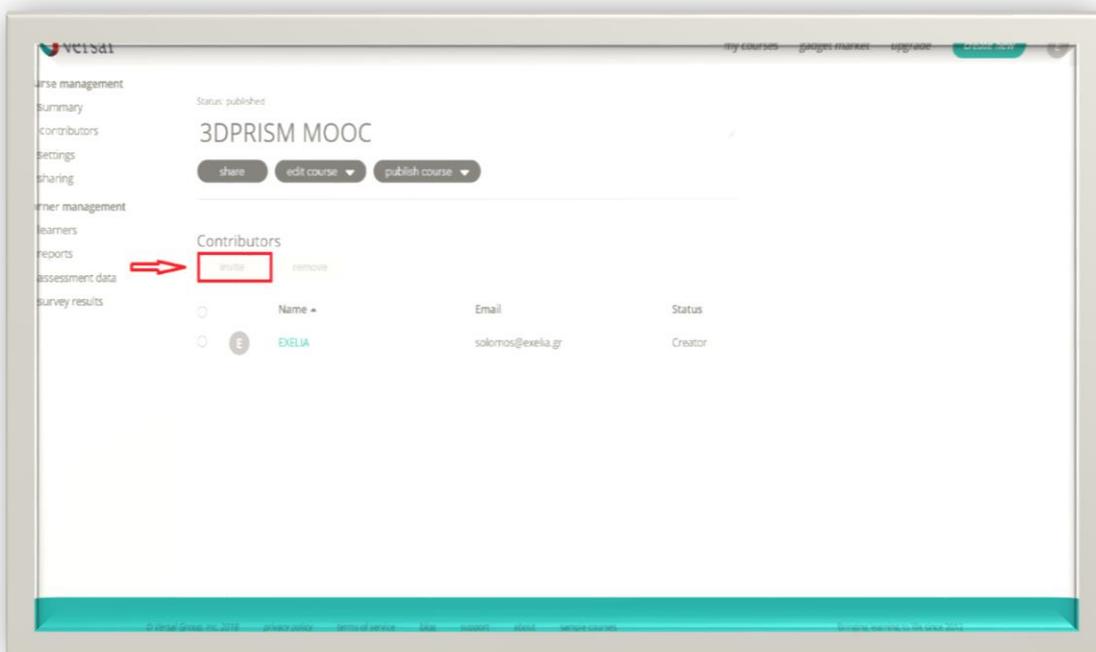


How to add collaborating trainers

1. Visit the course's overview page, and click the "contributors" link in the left navigation.



2. Click the “invite” button



3. In the pop-up window, add the email addresses of trainers you would like to invite to contribute. These trainers will receive an email to join the course as contributing authors.



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Navigating through learning units in Versal

In Versal, users can navigate between learning units in a course with two different ways. They can either click the title of a particular learning unit in the left sidebar or click the “next” button at the bottom of the course.



In the left sidebar, we can find the table of contents, where trainers can edit the course title, add and edit learning units, move learning units around, and easily navigate between different sections of the 3DPRISM MOOC. Once you click the title of a particular learning unit, you will be automatically directed to the respective section. To navigate within a learning unit, users can click on one of the section headers in the left sidebar to jump to that part of the lesson.

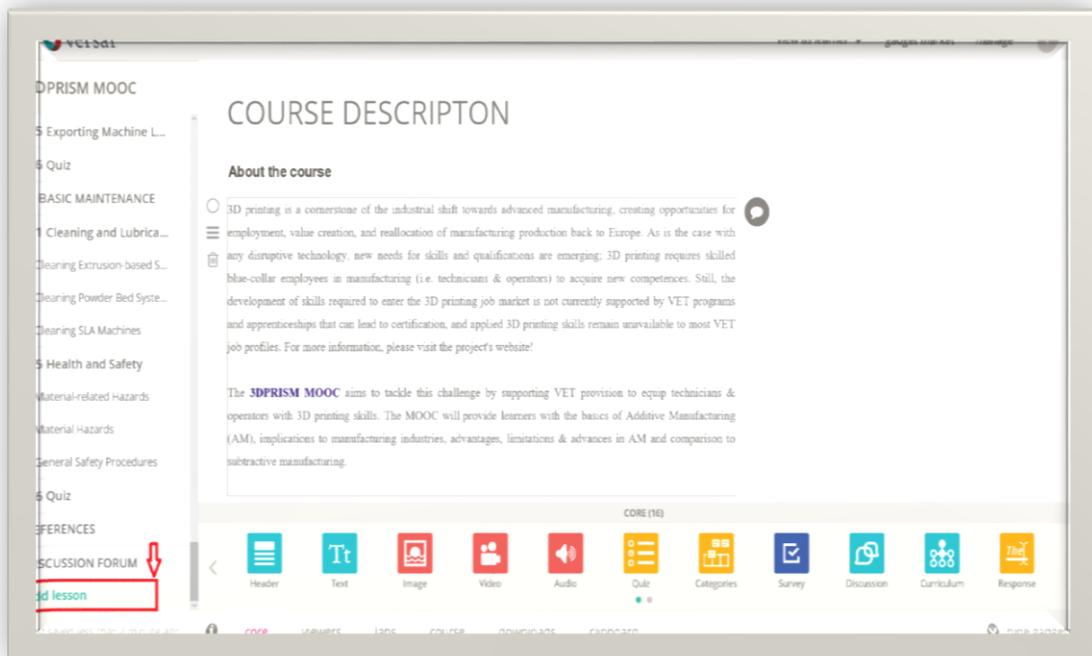


Adding, moving, and deleting learning units (lessons)

Learning units enable trainers to define a structured path for progressing through content within a course, and allow learners to view content in an intuitive, self-paced style. They constitute organised collections of learning material and resources that learners can move through. Moreover, learning units can be viewed in sequential order or in a modular way if learners decide to follow a personal learning path so as to accommodate individual needs. This section will provide guidelines on how to add, move, and delete sections in the 3DPRISM MOOC.

How to add, move, and delete learning units

To add new learning units, click "add a lesson", which is located at the bottom of the left sidebar (table of contents). Each lesson can consist of multiple sections, defined by Section headers. To add a section to your lesson, simply drag the Section header gadget onto the canvas.





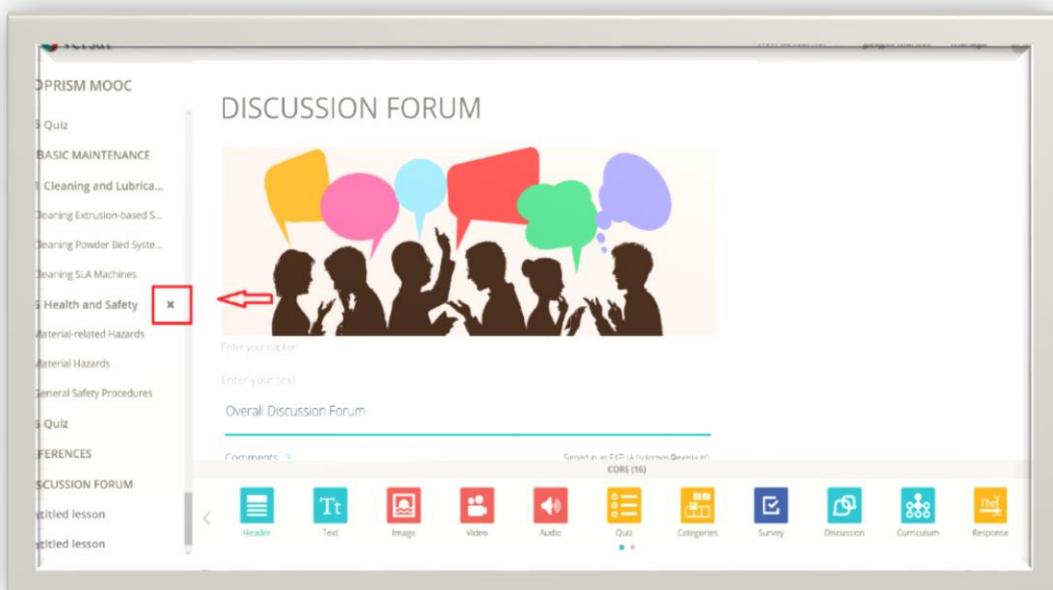
1. To move a learning unit (lesson), hover over the lesson title. Three lines will appear. Then "grab" the hamburger (cross) icon to the left of the lesson, and drag the lesson to its new location in the Table of Contents (move the lesson up and down).



- 2 To delete a lesson, hover over the lesson title. The delete icon will appear. Click on the icon:

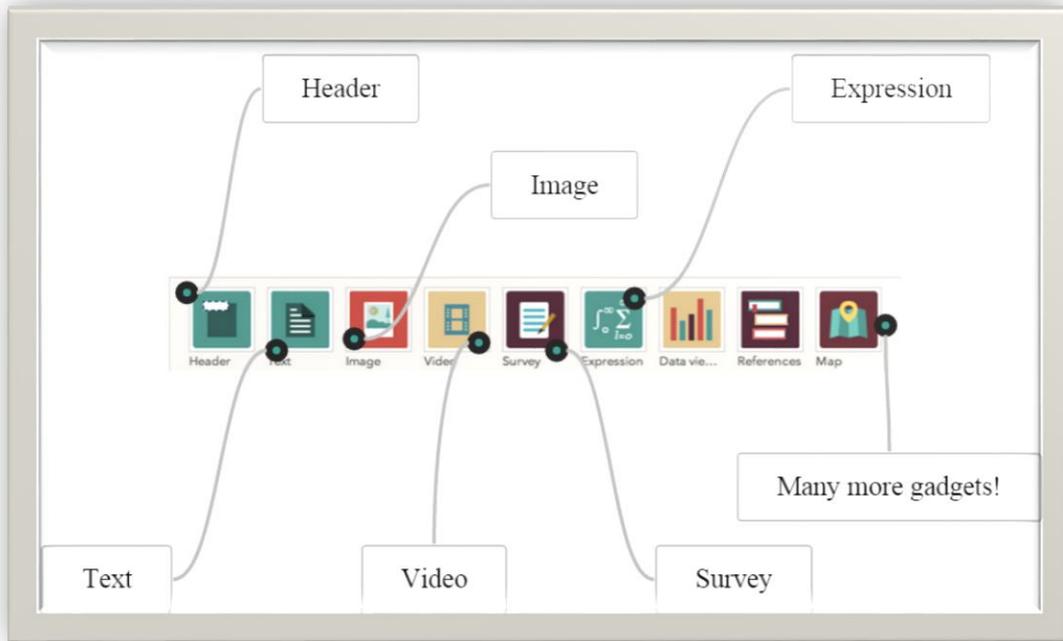
Using gadgets

In Versal, trainers have to use gadgets to build lessons and sections. Gadgets are mini JavaScript applications that enable trainers to create content, import existing educational materials (documents, presentations, images, etc.), and create interactive exercises (e.g.

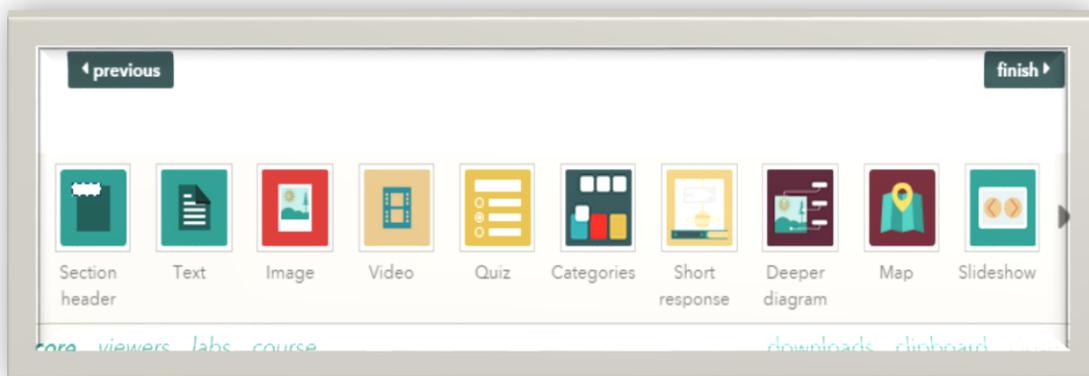




online quizzes). Each gadget has a particular function, such as adding text and videos, importing resources, or creating interactive elements. The following diagram explains gadgets' functionality and usability.



Gadgets to be used in Versal are grouped into three categories (core, viewers, and labs groups), which are listed at the bottom left of the gadget tray.



Below you can find an indicative list of gadgets supported by the VERSAL platform and which are relevant to the topic and content of 3DPRISM's course. Trainers are strongly encouraged to use gadgets to create new educational content (presentations, exercises, and assignment) and import interactive elements that will increase learners' retention and engagement.



Gadget	Function
Google Docs	Web-based document management application for creating and editing private and public, word processing and spreadsheet documents.
Microsoft One Drive	Web-based document management application for creating and editing private and public, word processing and spreadsheet documents.
Disqus	Discussion Forum
Sketchfab	Sketchfab is the leading platform to publish and find the best 3D content. You can upload files in almost any 3D format directly on sketchfab.com
Quizlet	Platform that allows registered users to create flashcards and simple study tools.
Prezi	Presentation software that uses motion, zoom, and spatial relationships to bring your ideas to life.
Desmos	Graphing calculator
Educreations	Educreations is a unique interactive whiteboard and screen casting tool that's simple, powerful, and fun to use. Annotate, animate, and narrate nearly any type of content as you explain any concept.
Geogebra	Dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one easy-to-use package.
ThingLink	Interactive media platform that empowers publishers, educators, brands, and bloggers to create more engaging content by adding rich media links to photos and videos.

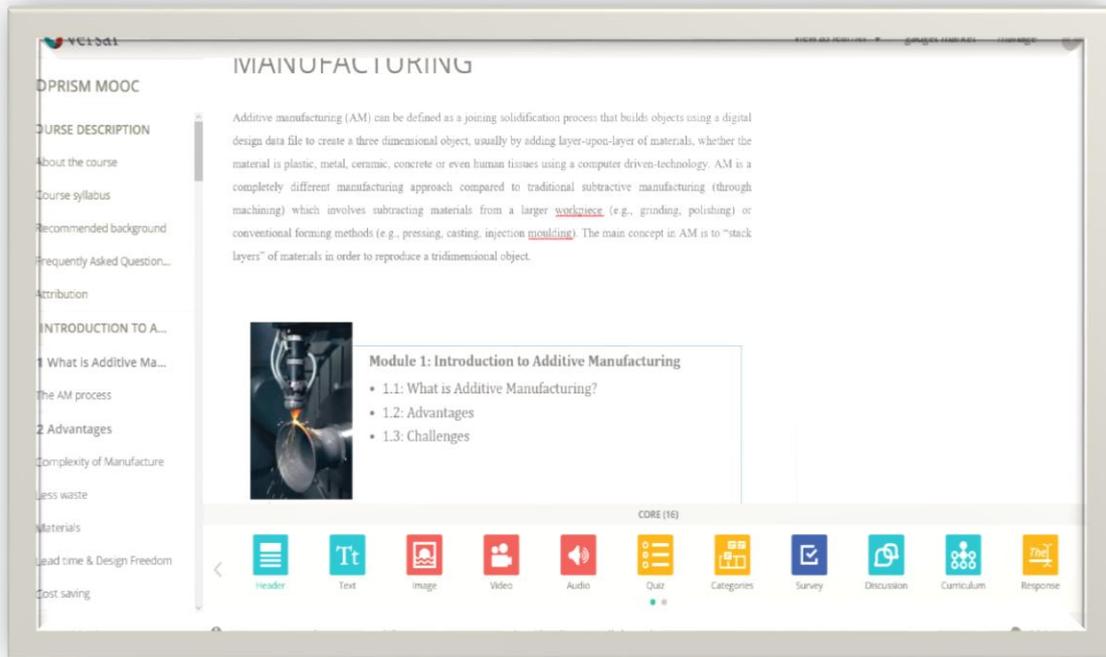


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How to add gadgets to 3DPRISM MOOC

Gadgets are located in the gadget tray at the bottom of the browser. Clicking the arrows in the gadget tray, you will scroll through the gadgets in the tray. Clicking the buttons below the tray takes you to a new gadget category. To add any gadget to the course, drag it from the tray and drop it onto the canvas. You can also move gadgets around within a learning unit.

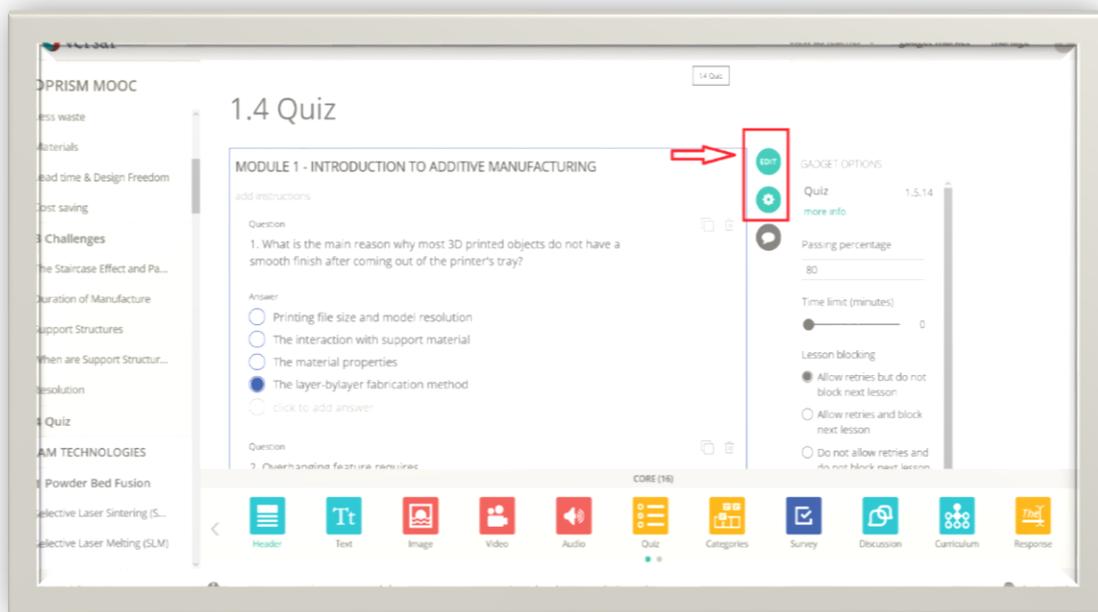




How to customise gadgets used in the 3DPRISM MOOC

Gadgets are designed to be flexible and customisable. The gadget properties box next to each gadget shows how to customise options for each specific gadget. You can access the properties by clicking on the gear icon to the left of each gadget. The box with the properties and settings will appear over the table of contents.

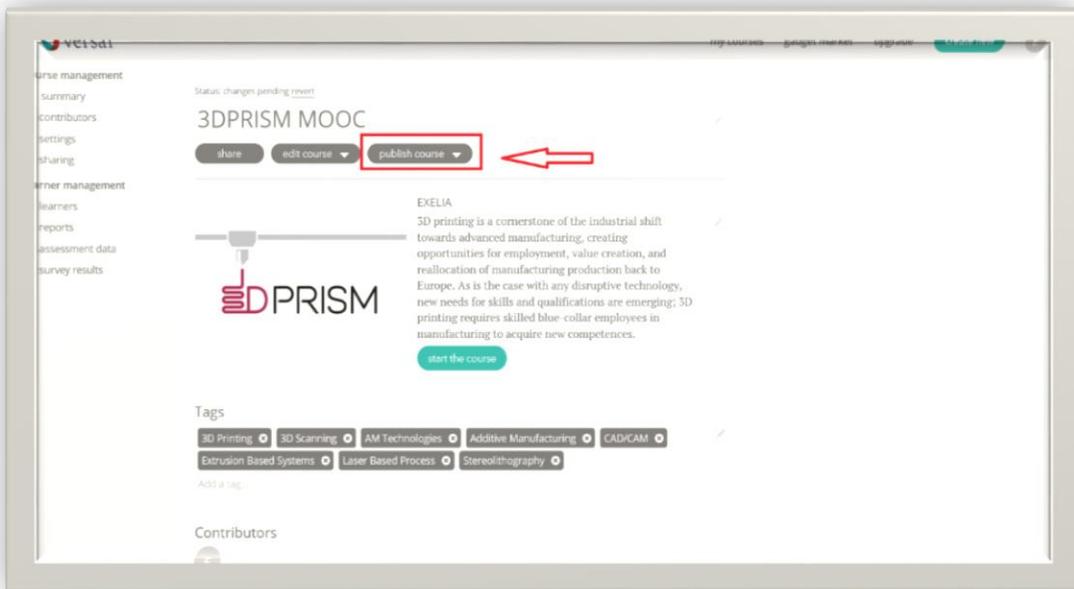
To get an insight, see the “Quiz” gadget. You can easily define a specific passing score for any quiz you intend to integrate into the 3DPRISM MOOC. Setting a passing percentage implies that the next lesson is blocked unless the learners pass successfully the quiz.





Publishing the updated version of the MOOC

Once you have finished making your changes in the content and have proofread the entire course, it is time to publish the updated version of the 3DPRISM MOOC. Note that learners will not be able to see the updated course until you publish it. To publish the course, trainers (under the publisher status) should either navigate to the course overview page and click the "publish" button located under the title of the course, or click the "finish course" button located in the lower right hand corner of the canvas.



Three important publishing notes:

1. Even after you publish a course, you may always edit it at any time. Still, you will need to publish the course again for learners to see your updates.
2. Also, do not forget that your work is automatically saved as you go, so you will not lose anything by leaving the course creator or even signing out of Versal.
3. If you click "Status: changes pending revert", you will lose any changes made since the last time you published the course. So use this carefully!



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How to use the 3DPRISM MOOC

Facilitating the 3DPRISM MOOC

The 3DPRISM MOOC employs a learner-centered and personalised learning approach that places the learner at the heart of learning activities and educational process. The rationale is that learner-centeredness is an educational approach that leads to high motivation and personal commitment to learn, deeper immersion in learning activities, and greater knowledge acquisition. In this context, learners can determine their own learning path, formulate individual goals, and select educational material and resources that address their distinct needs, preferences and expectations.

As concerns teaching with the use of a MOOC, trainers have to abandon their traditional role, which is to be the main source of information, and become a facilitator and motivator of learning. By contrast, trainers need to be more focused on the development of skills and attributes and on comprehensive feedback, rather than on the dissemination of content. In MOOCs, the responsibilities of trainers include: a) encouraging critical thinking, b) fostering self-directed learning and curiosity, and c) motivating learners to engage in learning activities and collaborative mechanisms. Moreover, trainers should concentrate on creating a learning environment that stimulates all participants in the virtual classroom, generates deep understanding, and promotes collaborative learning throughout the course.

Correspondingly, the trainer in 3DPRISM MOOC has to assume the role of facilitator providing regular and consistent feedback on tasks and exercises delivered by MOOC participants, encouraging learners to participate in learning activities, pinpointing learners' weaknesses and misconceptions, and responding to learners' questions and requests.

Guidelines on how to facilitate the 3DPRISM MOOC

1. Introduce yourself to the class

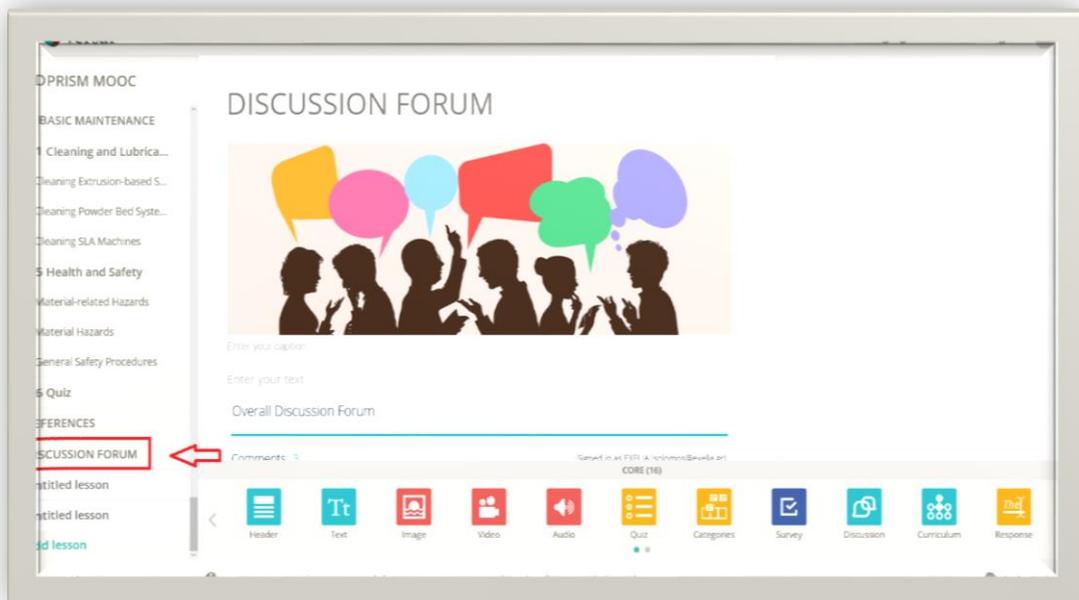
Trainers are encouraged to introduce themselves to the class presenting a short personal bio that will demonstrate their educational background and area of expertise. From the very beginning, trainers should set the tone for the course and describe their expectations in the virtual classroom.



An attractive introduction will effectively increase participants' willingness to experience new learning opportunities and develop a sense of connection between trainer and learners. It is recommended that trainers should prepare a welcome video to introduce the course and help learners get used to the format of the 3DPRISM MOOC. This is the reason why introductory videos should answer initial questions and concerns, and set the course expectations while assisting in creating a positive first impression.

2. Promote online discussions and collaborative learning

The 3DPRISM MOOC stresses the value of peer assistance and collaborative learning through the incorporation of discussion boards and social media links. The 3DPRISM discussion forum (NESTOR) is the place where learners can share knowledge and information with other participants, discuss key concepts and problems associated with the course, exchange views and opinions with trainers, and cooperate with peers to complete tasks and exercises.



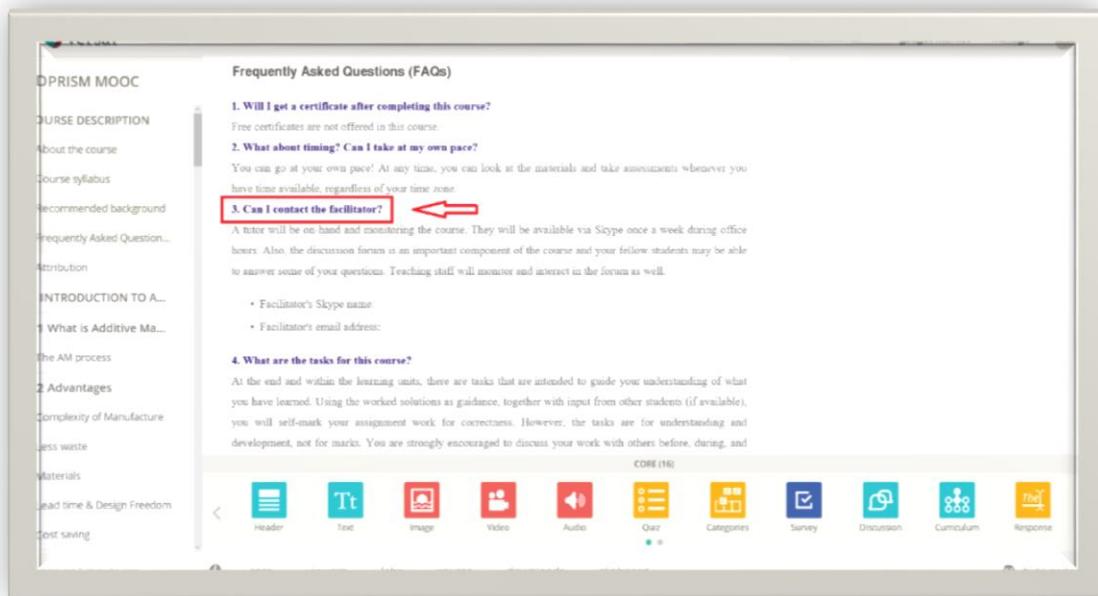
Trainers should encourage learners to participate in the discussion forum by providing incentives for active participation in group discussions (e.g. provision of access to additional learning materials and pedagogical resources). Also, trainers need to scaffold learners' motivation by being explicit about expectations and ground rules for the online discussion forum, setting the framework for interaction, peer collaboration and dialogue (Xia et al.



2013)¹. As regards forum moderation, the trainer should become a facilitator and review the discussions without controlling or intervening to the dialogues. When it comes to questions, sometimes it is better to leave time for other participants to answer so as to leverage interaction among participants.

3. Establish a communication scheme

Trainers should establish a well defined communication scheme to facilitate interaction with learners and support learning throughout the course. Trainers should schedule online office hours for learners once a week through Skype (for a minimum of one hour a week). Facilitators should also add their contact details (Skype name and email address) to the FAQ section of the 3DPRISM MOOC.



Strategic structured communication through regular emails and messages, including weekly feedback, announcements, and reminders will assist to maintain the engagement and focus of learners on the course experience and enhance the perception of “teaching presence” by participants. Another channel to interact and communicate with learners is through the 3DPRISM discussion forum. Trainers and facilitators need to monitor and interact in the forum as well.

¹ Xia J., Fielder J., and Siragusa L., “Achieving better peer interaction in online discussion forums: A reflective practitioner case study”, *Educational Research*, 23(1), 2013.



Responsibilities of trainers (At a glance)

1. Facilitate the course and help learners achieve their personal learning objectives.
2. Login daily to interact with participants or/and monitor course activity.
3. Moderate learners' interaction in the 3DPRISM discussion forum.
4. Respond to learners' emails, messages and discussion postings within a day.
5. Prior to 3DPRISM MOOC release date, the trainer should proofread the entire course, review all educational material, post an introductory announcement (or a welcome video), provide contact details, and set online office hours.
6. Schedule online office hours for learners that will take place once a week through Skype.
7. Provide regular feedback on tasks and exercises submitted by learners and grade assignments (if relevant. Personalised feedback must be provided within forty-eight (48) hours after the submission of tasks due date.

Sharing the course

To disseminate the 3DPRISM MOOC, trainers should either navigate to the course overview page and click the "share" button located under the title of the course, or click the "sharing" sub-section of the course management page.

There are five options for sharing a course:

1. You can post a link to your social media accounts (FaceBook, Twitter, and LinkedIn).
2. You can email the link of the course.
3. You can embed the 3DPRISM MOOC into your own blog or website.
4. You can add the course to Schoology, which is an innovative learning management system (LMS) for sharing educational content and material.
5. You can submit it to the Versal catalog by emailing the course URL to catalog@versal.com

