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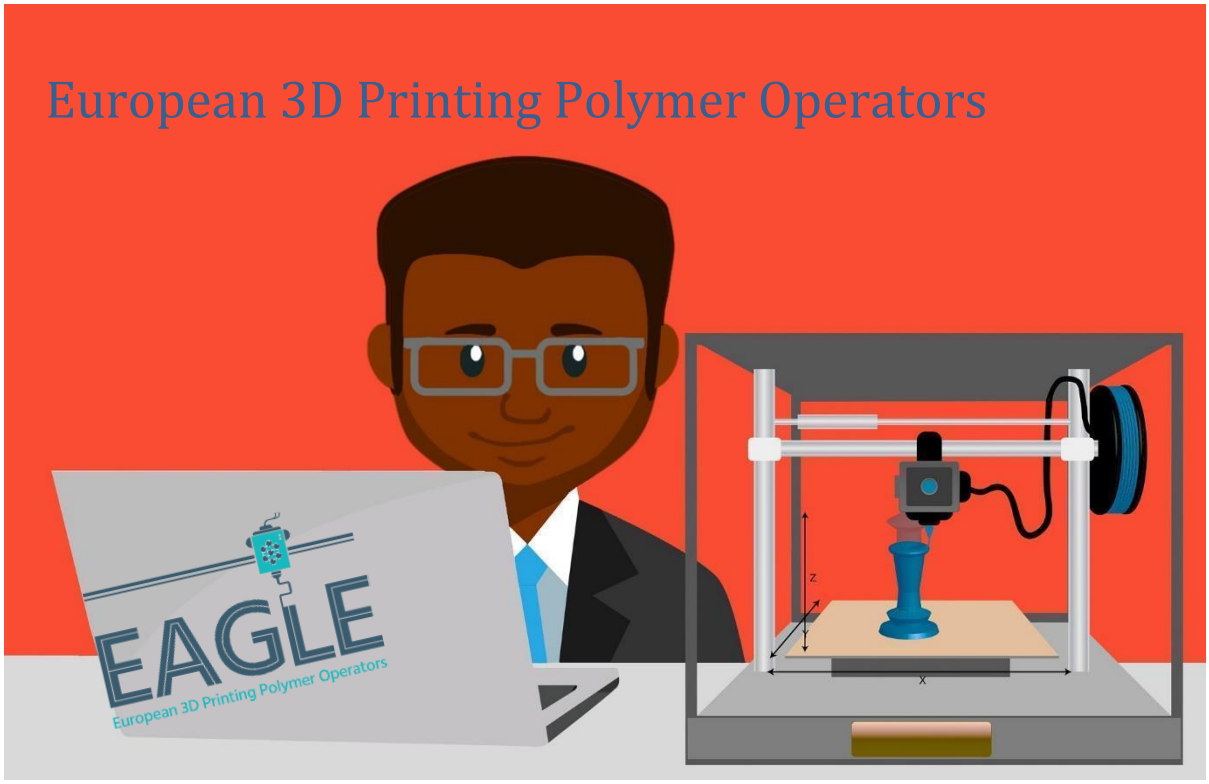
EAGLE
European 3D Printing Polymer Operators



EAGLE

Train the Trainer Guideline

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Train the Trainer Guideline

1. Scope

This project has been carried out with the contribution of the European Union, within the ERASMUS + program. EAGLE project's goal is to create a learning platform for additive manufacturing machine operators, with all the necessary learning materials, exams, qualification system and a guideline for the trainers. This document summarises ideas, principles and guidelines for trainers to help them from planning the training to examining the students.

2. Pedagogical skillset and tools

2.1. Personal tools 3D Monument

2.1.1. Creating conditions for learning

For the training to run smoothly, the trainer must take care of the appropriate conditions.

These conditions are:

- A suitable location for the calm education
- Internet connection
- Possibility to use laptops and 3D printers
- Safety equipment: safety glasses, gloves and mask for SLA printing to prevent exposure to the fumes generated during 3D printing. Because this 3D printing education will be held at different places like universities or companies, enhanced security measures are essential.

2.1.2. What the trainer should must do

The trainer should research the various types of 3D printing technologies and materials available, including the pros and cons of each. Become familiar with

the setup and operation of different 3D printers. Identify and source 3D printing-related software, tools, and resources. Prepare safety guidelines and protocols for the students.

Create a list of 3D printing projects and activities that trainees could complete. Prepare materials for the class, such as 3D printing raw material, models, and other supplies. Become familiar with 3D printing industry trends and news.

The trainer should have the ability to model and/or scan things to create 3D printable files.

At the beginning of the training, the trainer should ask about the trainees, what background, education, competences and abilities they have. In this way a trainer can easily assess where the students are in terms of knowledge, what their strengths are and what their weaknesses are that still need to be worked on. One of the easiest ways to get to know the trainees is when each of them introduces themself in a few sentences. So the students get to know each other too. At the beginning of the course the trainer should clarify to the trainees what they could expect during the courses, and what they will learn.

During the education of 3D printing, the most important is safety. The trainer has to know that the 3D printing process presents a variety of potential safety concerns, such as the potential for hazardous fumes, the risk of heat or fire, and the general safety of the user. When using 3D printers, it is important to be aware of the potential hazards associated with the process. The primary concern is the potential for hazardous fumes, which can be emitted from the heated plastic or metal used in the printing process. Inhaling these fumes can cause irritation to the eyes, nose, and throat, as well as potentially more serious health risks. To minimise the risk of hazardous fumes, it is important to ensure that the workspace is well-ventilated and that a respirator or other safety equipment is used when operating the 3D printer like masks, glasses, and gloves. Another potential safety concern with 3D printing is the risk of fire or other heat-related accidents. This is especially true when using materials such as ABS plastic, which is highly flammable.

2.2. Software

These programs are the base of printing a real 3D model. The trainer has to be able to handle two types of programs: slicer and designing/modelling programs.

There are many 3D printing modelling software available, including Autodesk Fusion 360, Blender, TinkerCAD, FreeCAD, SketchUp, and Meshmixer. Each type of software has different features and capabilities, so it's important for teachers to understand the differences between them and choose the best one for their students' needs.

Autodesk Fusion 360 is a cloud-based 3D modelling and design software developed by Autodesk, a leading software company in the field of computer-aided design (CAD) and computer-aided manufacturing (CAM). Blender is a free and open-source 3D creation suite that encompasses a wide range of tools for 3D modelling, animation, rendering, video editing, and more. Tinkercad is a web-based 3D modelling software developed by Autodesk. Tinkercad is a free software, making it accessible to anyone with an internet connection. FreeCAD is a free and open-source parametric 3D modelling software designed for mechanical engineering, product design, and architecture. SketchUp is a 3D modelling software developed by Trimble Inc. It is known for its user-friendly interface and intuitive tools that make it accessible to a wide range of users, including architects, interior designers, and hobbyists. Meshmixer is a free, standalone 3D modelling software developed by Autodesk. It specialises in mesh editing and manipulation, providing powerful tools for modifying, repairing, and optimising 3D mesh models.

Trainers should also be aware of the different 3D printing file formats that are supported by each type of software, such as STL, OBJ, AMF, and 3MF. They should also be familiar with the different steps involved in 3D printing modelling, such as designing the 3D model, creating a 3D printable file, and sending it to a 3D printer.

- Slicer Software
  - With the slicer programs the trainer can see what an STL, an OBJ, or an STP file looks like. In these, they can set the parameters of printing speed, heating, etc, and this is where the g-code file is created. This is the file format that the 3D printer can interpret.
  - Here the trainer should know how the basic file formats describe the 3D model they contain. (STL, OBJ)
  - It is also important to have the right skills in printing settings for different materials, whereas each material must be printed at a different temperature and speed to get the correct final product.
  - Slicer programs: Ultimaker Cura, PrusaSlicer, Simplify3D
- Modelling software
  - It is an advantage if the trainer knows the basics of modelling programs, while 3D printable models can only be created in these programs, but it is not a requirement.
  - The first step to creating a 3D printed model is to make a good printable model in modelling software.
  - This is an opportunity to introduce these programs as well, so that the students can see the whole production process.
  - Modelling software: Autodesk Inventor, Solidworks 3D CAD, Blender, Cinema 4D, ZBrush, Autodesk 3Ds Max, SketchupFree

Before choosing the software to be used for teaching, the trainer must make sure that the students actually have access to the selected software. Many educational institutions order licences for the software of various manufacturers, but if the trainer has to teach in an institution where, for example, no licence is given, free, freely accessible software must be chosen. For this reason, it is advisable for all trainers to have user-level knowledge of both professional and free software in order to provide training.

2.3. Hardware

The trainees can learn easier if the trainer has the right hardware to demonstrate and illustrate the processes. In this way, the course will be more interesting than a traditional educational method. These tools are laptops or computers, fast internet connection, modelling software or designer apps, 3D scanners and most important 3D printers.

- What hardware the trainer at least should have:
  - a powerful computer
  - 3D printer(s), 3D scanners (optional)

- Internet connection

Desktop FDM or SLA 3D printers are the most common type of 3D printer and are used to produce 3D objects from digital files. The course does not necessarily need each student their own 3D printer because that would be expensive, they can even work in small groups with a common 3D printer.

3D scanners are used to capture 3D objects and create digital models. Without a professional 3D scanner the trainees can only model the less complicated parts and objects. But if they have one, then they can make roughly anything a printable 3D model. Nowadays there are a lot of types of scanners available. For example, there are colourful scanners, so if we have a 3D printer which can handle many colours, we can print things as they look in reality. In today's world, we can also scan with our smartphones. There are already tons of apps, and the latest phones have LiDAR for more accurate scanning.

All of these hardware devices can be used to teach students about 3D design, engineering, and manufacturing.

2.4. Routes to the training

The learning courses define the Competence Units (CUs) with the education and training syllabuses, which are intended to be taught in a classroom or laboratory environment, thereby providing for direct interaction with the students on a continuous basis. Whilst some content of the syllabuses may be replicated in a blended learning or other learning methods, some of the attributes mentioned above cannot. It is only through exposure to the individual experts that these benefits may be gained. Therefore, different routes to gaining the qualifications have been developed: the standard route (/traditional way), which is the in-person training or blended learning route by using an online platform like Google Meet, Microsoft Teams, or Zoom. Of the two educational routes, direct education (in school) is preferable in order to obtain a lesson that is much more interactive so the trainees could develop better. On the other hand online courses require less infrastructure, could be presented for students from different regions and also easier to organise.

- Standard Route (or classroom / traditional)
- Blended Learning Route

Both online and traditional teaching methods can be effective for 3D printing training, depending on the specific goals and needs of the learners.

Online 3D printing training can be convenient for learners who may not have access to in-person training, or who prefer to learn at their own pace. Online training can also be more cost-effective, as there are no travel expenses or rental costs associated with a physical location.

The online platform is the greatest form to educate the theoretical parts of 3D printing because it allows for a more personalised approach to learning. Through online platforms, learners can access information on their own time, and can go back and review lessons as much as they need to. It also allows for a more interactive experience, as learners can interact with 3D printing experts and ask questions or share ideas. Finally, online platforms make learning 3D printing more accessible, as learners can access the best resources from around the world.

Online teaching is a good alternative to educate 3D printing next to the traditional form because it offers flexibility and convenience. Online courses allow students to study at their own pace and in their own time, meaning they can fit their studies around their other commitments. They also don't have to waste time and money travelling to and from classes. Plus, online courses provide access to a wide range of resources and learning materials, such as video tutorials, interactive simulations and case studies, which can be extremely helpful when learning complex topics such as 3D printing.

On the other hand, traditional in-person training can provide hands-on experience with 3D printers and other equipment, as well as immediate feedback from instructors. In-person training can also offer opportunities for collaboration and networking with other learners and industry professionals. Another disadvantage of the online form of education is that, due to the flexibility, the attention of younger students in particular can wander more easily, they allocate the time necessary for learning inappropriately, and they often wander off while sitting in front of the computer on the Internet. For this reason, it is important that the trainer maintains regular and preferably close contact with the students during the course, even when choosing the online form of education.

Ultimately, the best option for 3D printing training will depend on the learner's individual needs and preferences, as well as the availability of

resources and instructors in their area. A combination of both online and traditional teaching methods may also be a viable option for some learners.

3. Lectures

3.1. Online lessons

3.1.1. Pre-made videos

Pre-made videos about the different 3D printing technologies can be valuable teaching resources. It can help to teach in multiple ways. First of all, it is flexible and accessible. Pre-made videos provide flexibility in terms of when and where students can access the content. Students can watch the videos at their own pace and review them as needed. They can access the videos from various devices, allowing for a personalised learning experience. Secondly the visual demonstration. Videos allow you to visually demonstrate the 3D printing process, showing step-by-step instructions, settings, and techniques. Visual demonstrations can enhance understanding and make complex concepts more accessible to students.

By creating pre-made videos, the teacher can ensure consistency in the delivery of his or her content. Each video can be carefully planned, recorded, and edited to maintain a high standard of quality. This helps provide a consistent learning experience for all students. Pre-made videos can serve as supplemental material to complement other teaching resources. They can be used to reinforce concepts taught in live sessions, textbooks, or other instructional materials. Students can refer to the videos to clarify their understanding and reinforce their learning.

Videos provide an opportunity for self-paced learning. Students can pause, rewind, or re-watch sections of the videos as needed. This allows them to learn at their own speed and spend more time on challenging topics or concepts.

Videos can engage students visually and capture their attention. Visual elements, animations, and real-life demonstrations can make the learning experience more engaging and memorable.

These videos can demonstrate hands-on techniques because 3D printing involves a lot of practical skills and techniques. Pre-made videos can showcase hands-on demonstrations of tasks like setting up a 3D printer, calibrating, troubleshooting common issues, or optimising print settings. Students can

observe and learn the techniques visually, enhancing their understanding and ability to apply the knowledge practically.

These pre-made educational videos can be uploaded on different platforms, for example on youtube to a private page. So these videos can only be viewed by persons who have the right to do so. When choosing a platform, consider factors such as accessibility, privacy settings, storage limitations, ease of use, and any institutional or organisational guidelines or restrictions. Ensure that the platform the teacher chooses aligns with their specific needs and the intended audience for the videos.

What should the teacher pay attention to when editing, background, and cutting such a video?

- Background: select a background that is relevant to the content and appropriate for the educational context. A clean, clutter-free environment with minimal distractions is ideal. Consider using a neutral backdrop or a professional-looking setting that enhances the focus on the subject matter. Keep the background visually appealing but not overwhelming, allowing the focus to remain on the presenter or subject being discussed.
- Cutting: Remove unnecessary content and use smooth transitions, and pay attention to the audio quality. Consider the pace and timing of the video. Ensure that the content flows naturally and is presented at an appropriate speed. Avoid rushing through information or speaking too slowly.
- Audio: it is suggested to use microphones for audio recording. The cameras already have a built-in microphone, but their sound quality is not necessarily the best, especially if the camera is fixed on the tripod several meters away from the trainer. If we cut pictures and videos into the educational material, the sound quality of the voice narration is also important, i.e. it should be loud enough and not contain disturbing noises (e.g. hissing).
- Watermarking: It is also recommended to put a watermark on the completed video material. Place the watermark in a place that does not distract attention, does not interfere with the possibly presented materials (images, slides, props), but still prevents unauthorized use of the video material.
- Regular review: before sending the same link to students year after year, make sure the information in the video is still up to date. The task of the trainer is to cut out the outdated parts and replace them with new information, ensuring that the students really have a state-of-the-art knowledge.

3.1.2. Online live session

A key factor in live online training is the quality of the trainer's internet connection. It is recommended to use a cable internet connection instead of Wi-Fi to ensure adequate bandwidth and stability. It is also important to get a good webcam and microphone for the right sound and image quality. It is worth using a headset for the trainer, because the microphone placed close to the face filters out ambient noise better than the laptop's integrated microphone, and the earphones also help the trainer hear the questions asked better. Choose a place for education where you can be quiet and calm (either at home or in the office). Before turning on the webcam, make sure that you have set up a virtual background, and that only things that you really want to show the students are in the camera's field of view (e.g. if you want to show props in the camera, they may not be appear properly due to the filtering of the virtual background, so even if the trainer doesn't want it anyway, it may have to be turned off).

After the technical conditions are provided, the selection of the appropriate platform comes: Select an online platform that suits your teaching needs, video conferencing tools like Zoom or Google Meet, Microsoft Teams, or Go to Meeting. These Online platforms are used regularly in schools. The selection of the most suitable of those platforms depends on the teacher's specific needs and preferences and also the availability of the software in the region and licences.

Zoom: Zoom is a widely popular video conferencing tool known for its ease of use and robust features. It offers features like screen sharing, breakout rooms for group activities, recording sessions, and interactive whiteboarding. Zoom also integrates well with other tools and platforms, and it is often used for online teaching and remote collaboration. Some of those features can be accessed however only for subscribers and also the length of the meeting can be restricted for free users.

Google Meet: Google Meet is part of the Google Workspace (formerly G Suite) suite of tools. It provides video conferencing capabilities with features such as screen sharing, chat, and the ability to collaborate on Google Drive documents in real time. Google Meet integrates well with other Google Workspace tools, making it convenient for users who already utilise Google's ecosystem. Those with a corporate subscription have unlimited access to the benefits of the software, but free users may sometimes experience difficulties, for example the maximum number of participants in a meeting and how many people can turn on the microphone at the same time.

Microsoft Teams: Microsoft Teams is a collaboration platform that offers video conferencing, chat, document sharing, and integration with other Microsoft tools like OneDrive and SharePoint. It is designed for teamwork and communication within organisations and educational institutions. Microsoft Teams provides features like breakout rooms, screen sharing, and real-time document collaboration. If the creator of the meeting has a corporate/institutional license, he can also invite external persons, and external persons can also benefit from the many advantages provided by the platform. However, it is important to emphasize that all files and chat history of already created groups can be accessed by members added later, so if the training is taught to several groups or several grades, it must always be checked that only authorized users enter and stay there.

GoToMeeting: This is a popular video conferencing and online video conferencing and online meeting platform, which is also a perfect online learning platform. While primarily known for its business applications, GoToMeeting offers features that can be beneficial for educators and students in the online learning environment. This online interface contains all the necessary tools for online education, including Video conferencing, screen sharing, and presentations, Interactive whiteboard, that allows recording the sessions, breakout rooms, chat and collaboration features, and of course security and privacy. GoToMeeting easily can be adapted as an effective online learning platform by these features.

The teacher should examine these factors when they choosing between the platforms:

- Ease of use: is the platform aligned with the teacher's comfort level and technical skills?
- Features: Determine which features are essential for online teaching, for example, screen sharing, breakout rooms, or collaborative document editing.
- Integration: If they already use other platforms that can be integrated well.
- Accessibility: the availability of the software may change either due to local regulations or due to the internal rules of the institute.
- Privacy and security: during the time of COVID, many platforms were found to contain security gaps, so it is recommended to constantly monitor that the chosen platform is still adequate from a data security point of view. For collaboration and shared drives, care must also be taken to ensure that no infectious files or threatening content are included.

Create engaging content: Use a combination of video tutorials, interactive quizzes, and written materials to present the course content. Visuals such as videos, images, diagrams, and 3D models can help illustrate concepts effectively.

Provide hands-on experience: Although teaching 3D printing online can be challenging, it's crucial to provide opportunities for students to practise. Encourage them to access a 3D printer, either through local maker space or by purchasing their own. Offer guidance on operating the printer, troubleshooting common issues, and designing their own 3D models.

Foster interaction and feedback: Encourage student participation through discussion forums, chat groups, or live Q&A sessions. Provide feedback on their assignments or projects to help them improve their skills.

Create quizzes, assignments, or projects to assess students' understanding and progress.

3.1.3. Learning management systems

Besides the online learning platforms, teachers mostly use other additional learning management systems: like Moodle or Canvas. In these systems, they can organise the learning materials like PowerPoint presentations, videos, books, the requirements, and of course the date and nature of audits.

In Moodle, a lot of useable sources here can manage the course, create content, communicate, and collaborate. It is mobile-friendly so students can access their courses and interact with content on smartphones and tablets, allowing for flexible and convenient learning experiences. It supports various communication and collaboration features. It includes discussion forums for asynchronous discussions, private messaging for direct communication between instructors and students, and real-time chat for synchronous interactions. These features foster student engagement and promote peer-to-peer learning. Moodle allows for personalization and customization to meet the specific needs of instructors and learners. Instructors can customise the appearance of their courses, create custom user roles, and define specific access permissions. They can also add plugins and extensions to extend the functionality of Moodle.

Canvas offers a range of tools and features designed to enhance teaching and learning experiences. Canvas allows instructors to organise and manage their

courses effectively. They can create course modules, set up assignments and quizzes, manage grades, and track student progress. The intuitive interface makes it easy to navigate and manage course content. It offers a variety of tools to create and deliver course content. Instructors can upload files, embed multimedia resources, create web pages, and link to external content. The platform also supports the integration of third-party tools and content repositories, allowing for a flexible and dynamic learning experience. Canvas provides numerous communication and collaboration features. It includes discussion forums for asynchronous discussions, direct messaging for one-on-one communication between instructors and students, and announcements to share important updates. Canvas also supports group work and collaboration through tools like group discussions and collaborative documents. Canvas offers a mobile app too, so students can easily access course materials. Besides these functions the canvas offers calendar and notification functions too.

3.2. Classroom ("offline") lessons

Until 2020, the dominant form of education was the classroom, so most educators who have experience before COVID do not find new challenges in this form of education. In the chapters, however, we present what the instructor should pay attention to during the theoretical and practical classroom education, so that the students enjoy and pay attention during the lectures.

3.2.1. Technical aspects

But let's approach the task from the technical side. Before the lesson, make sure that a projector of the right size and image quality is available, bring your laptop with a charging cable, and make sure that you have the slides you want to present. Many institutes have outdated projectors with VGA connectors, while today's laptops have HDMI or displayport. It is therefore worth asking in advance what connectors are available, and if applicable, you should also bring the appropriate adapter/transformer with you. Since the length of the lectures can be several hours, you must definitely bring a charging cable for your laptop, which also requires a power connector. This must also be mapped, because if the nearest socket is far away, an extension cord must also be provided. It can cause very unpleasant moments if the start of the trainer is delayed because the instructor is still running for an extension cord or converter.

In order for the projector's image to be readable, it is advisable that the room has adequate shading, but not too dark, so that the students do not fall asleep during the presentation. It is advantageous if the image projected by the projector is large enough and our presentation is not only visible on a surface of 1 m^2.

The instructor should bring a mouse and a presenter with him. It is worth choosing a presenter that has a built-in laser pointer. Today, in addition to the traditional 2-button versions (forward and backward within the presentation), there are also ones available with a built-in timer, i.e. after a preset time it starts to vibrate to warn the lecturer to start slowly ending the class, and also versions with additional programmable buttons (eg video controls, regulators, etc.). Such devices are available at many educational institutes and companies, but if the instructor often gives a live lecture, it may be worth investing in such a device so that he can always carry his own (even with extra functions) with him.

If the room is too large, or the instructor cannot fill the room sufficiently, it is advisable to provide a microphone and loudspeaker.

In the same way, in today's world we take it for granted that there is internet everywhere, but this is far from the case. Even in a basement classroom or at companies, the problem that the system is shadowed or the Wi-Fi signal is weak can often be encountered. If there is no cable internet or internal network, the unprepared instructor can repeatedly face difficult moments. For this reason, it is worth always making sure what the classroom's facilities are like from this point of view, and always keep with us not only the slides of the presentation, but also the videos, pictures, etc. intended to be presented in offline form as well.

3.2.2. The oretical trainings

The theoretical classroom, i.e. "offline" education is the biggest challenge, because in this case it is the most difficult to maintain the attention of the students (more precisely, it is difficult to maintain attention during online education, but if the students' cameras are turned off, the instructor cannot see the bored or even sleeping faces, or the student playing video games behind the switched-on camera is not as bad a sight as the one pressing his phone under the bench).

The instructor should be sufficiently prepared and practiced to maintain the students' attention and to be able to speak beautifully, audibly and intelligibly.

Hesitating, stuttering, overthinking, and frequent mid-sentence pauses, searching for words are all factors that make students lose focus and start to get bored with the lecture. There is no shame in rehearsing the presentation in advance, or perhaps giving a test run in front of a smaller audience, if you are not sufficiently routine (it is important to point out that many times even people who think they are routine fall into this mistake, because even if you have performed "A" lecture a hundred times, it does not mean , that you will be able to perform "B" with the same ease).

The right breathing technique can help not only to ensure the right volume, but also to keep calm. It is natural for someone to feel feverish during the first

performances, but this can be overcome with proper mental preparation and routine. If the first presentation doesn't go as planned, you shouldn't get discouraged and give up, but keep practising. Because the lecturer, as a profession, requires the same learning and practice as any other profession.

It is worth starting the lecture with an attention-grabbing story, which can be funny and personal in nature, so that the students bond with the trainer, take an interest in the person and, of course, the topic being taught.

We monitor the audience, and when we notice that they are bored, their attention is waning, ask questions, tell them stories of personal experience relevant to the topic, and relax the atmosphere. Of course, let's not divert too much from the topic, since the purpose of the course is to deliver the pre-compiled educational material. If the trainer does not have enough experience, ask experienced colleagues, collect videos and interesting things from the Internet, which can also add colour to the monotonous education.

If a student has fallen asleep during class or is conspicuously on the phone, gently warn them, but don't make hurtful comments, don't embarrass them by asking them questions that they predictably won't be able to answer.

Adhering to the time frame, take regular breaks and, if possible, thoroughly ventilate the classroom, as fresh air also helps with good concentration. Do not leave the window open during class (unless there is another reason), because due to the noise filtering in from the outside, the trainer would have to speak too loudly, and it would be difficult for the students to understand.

3.2.3. Practical trainings

The previously described technical and theoretical aspects also apply to practical education.

In the case of practical education, however, this is complemented by the fact that, in addition to his own equipment, the instructor is also responsible for the equipment accessible to the students.

Ensure that an adequate amount of equipment is available or, if resources are limited, allow sufficient time to complete the practical tasks so that all students are able to complete the task on their own. Solving tasks in groups is often good, but there are types of students who tend to stay in the background during group tasks and expect the solution from the dominant parties, so they do not have the necessary independence and experience to finish the work. We can help with this by redistributing teams and with several smaller, independent tasks.

In addition to the equipment, we should also pay attention to the raw materials, as it is the trainer's task to ensure that the right quality and quantity of raw materials are available for the beginning of the training. If several types

of equipment and materials are used in the room, make sure that they do not mix.

One of the key points of practical education is accident prevention and safety education. This should be done right away, and it must be ensured that no student who has not participated in it is allowed near the equipment. In addition to equipment and raw materials, it is extremely important to have the right amount of safety equipment. If the room does not have the appropriate amount and quality of safety equipment (e.g. safety glasses, masks, etc.), it is forbidden to start teaching, even at the students' or trainers' own responsibility.

The trainer must be able to use all the equipment, if he is not able to do so, then support staff must be available. The trainer must be able to teach the use of the equipment, so the equipment must be placed in the practical training room in such a way that all the students participating in the training can clearly see how the equipment should be handled properly. It is always necessary to make sure that the students really saw and understood the task and the steps of the work process. Always leave enough time for questions and answers.

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For the details on the exact practical and theoretical knowledge (eg. technology-related requirements) please see the related sections in this document.

4. Planning lessons

Building a course for 3D printing involves careful planning and consideration of various elements.

Start by clearly defining the learning objectives of your course. Determine what knowledge, skills, and competencies you want your students to acquire by the end of the course. Ensure that your objectives are specific, measurable, attainable, relevant, and time-bound. Select the learning resources. These can include textbooks, online articles, tutorials, videos, software, and hands-on activities. Choose resources that align with the learning objectives and cater to the needs of your students.

Organise the course content into modules or units. Break down the topics into manageable sections to facilitate learning and progression. Determine the logical sequence of topics and create a course outline that guides learners through the content.

Develop a variety of learning activities that allow students to apply their knowledge and skills. Include hands-on projects, design challenges, problem-solving tasks, group activities, and discussions. Incorporate opportunities for creativity, critical thinking, and collaboration.

4.1. Key factors of the lesson

When designing a lesson or course on 3D printing, there are several key factors to consider to ensure an effective and engaging learning experience.

Preparation: The preparation and state-of-the-art knowledge of the teacher are crucial factors in delivering an effective and high-quality learning experience. Teachers who possess in-depth knowledge and expertise in the subject matter inspire confidence and credibility among trainees. When trainees perceive their teacher as knowledgeable and well-prepared, they are more likely to engage actively in the learning process and trust the information being shared. A prepared teacher can anticipate common questions and challenges that trainees may encounter and proactively address them. They can provide clear explanations, offer guidance, and facilitate discussions that help learners overcome difficulties. Being up-to-date allows the teacher to offer relevant and accurate information and solutions. Preparing for a lesson involves understanding the trainees' backgrounds, prior knowledge, and learning styles. This knowledge helps the teacher tailor the content, examples, and explanations to suit the specific needs of the learners, ensuring that the instruction is accessible and meaningful.

Structured Curriculum: Organize the course content in a logical and structured manner. Break it down into modules or lessons that flow coherently, building upon previously covered material. This helps learners understand the progression of the course and facilitates better comprehension and retention of information.

Clear Learning Objectives: Begin by clearly defining the learning objectives of the lesson or course. What specific knowledge, skills, or competencies do you want learners to acquire? Having well-defined objectives will guide the content and activities throughout the course.

Visual and Engaging Content: Videos have the advantage of combining visuals, audio, and motion, making them highly engaging for learners. They can present complex concepts, demonstrations, or procedures in a more accessible and understandable manner compared to text-based resources. Visual content can help learners grasp ideas, retain information, and enhance overall comprehension.

Hands-on Activities: Include hands-on activities and exercises that allow learners to apply their knowledge and practice their skills. In the context of 3D printing, this could involve designing and modeling 3D objects, preparing models for printing, operating 3D printers, and troubleshooting common issues. Providing opportunities for active learning enhances retention and skill development.

Demonstrations and Step-by-Step Instructions: Provide clear demonstrations and step-by-step instructions for essential tasks and processes related to 3D printing. This could include software tutorials, printer setup and calibration, file preparation, and post-processing techniques. Visual aids, screenshots, or videos can be effective in illustrating these procedures.

Practical Tips and Troubleshooting: Offer practical tips and insights based on your own experience in 3D printing. Share common challenges or mistakes to avoid, troubleshooting techniques, and best practices. This practical knowledge will be valuable for learners as they engage in hands-on activities and encounter real-world situations.

Interaction and Collaboration: Foster interaction and collaboration among learners. This can be done through discussion forums, online communities, group projects, or live sessions where learners can exchange ideas, ask questions, and learn from one another. Peer-to-peer learning can deepen understanding and provide a supportive learning environment.

Real-World Applications: Highlight real-world applications of 3D printing across different industries. Showcase case studies, success stories, and examples of how 3D printing is revolutionizing design, manufacturing, medicine, architecture, or other fields. Connecting the learning to practical applications can motivate learners and show the relevance of the skills they are acquiring.

By considering these key factors, you can create a well-rounded and engaging course on 3D printing that effectively supports learners in acquiring the knowledge and skills they need.

4.2. Milestones during lesson

These milestones serve as guideposts for both students and instructors, helping track progress and ensuring that key concepts and skills are adequately covered. Here are some potential milestones that can be included in a 3D printing course.

1. Safety education
2. Basic knowledge of 3D printing, and 3D printing technologies
3. Modelling and slicer software
4. Advanced 3D printing knowledge
5. 3D printer assembly and commissioning
6. Calibration and machine settings
7. Material knowledge
8. Final exams

4.3. Preparing examples

4.3.1. Demo pieces

First of all, you should determine the specific learning objectives you want to achieve through the demo pieces. Are you aiming to teach a particular technique, showcase the capabilities of a specific printer, highlight the use of certain materials, or highlight a common issue? Having clear objectives will guide your selection of demo prints and the way you present them to trainees.

Select demo prints that are relevant to the topics covered in the course. Consider choosing prints that demonstrate different aspects of 3D printing, such as functional prints, artistic models, architectural prototypes, or engineering components. Including a variety of prints can engage trainees and show the versatility of 3D printing technology.

Really important to consider the trainees' skill level. Take into account the skill levels and prior knowledge of your trainees. Choose demo prints that align with their proficiency, starting with simpler prints for beginners and gradually

progressing to more complex prints as trainees advance. This approach helps trainees build confidence and gradually develop their skills.

Make sure you have the necessary design files for each demo print. If you're using pre-existing models, ensure you have the rights or permissions to use them. Additionally, optimize the slicing settings for each print to achieve the desired results. This may involve adjusting parameters such as layer height, infill density, support structures, and print speed.

Before presenting the demo pieces to the trainees, practice the printing process yourself. Familiarize yourself with the specific printer you'll be using, calibrate it if necessary, and test the settings and parameters for each print. This will help you identify any potential issues or challenges and ensure a smoother demonstration during the course.

It is also very important to prepare troubleshooting tips. Anticipate common issues or challenges that trainees may encounter during the printing process, and prepare troubleshooting tips or solutions. This could include addressing adhesion problems, adjusting print settings for optimal quality, or dealing with print failures. Being prepared to troubleshoot and provide guidance will help trainees navigate potential obstacles.

During the course, clearly explain the objectives of each demo print, provide context, and walk trainees through the printing process step-by-step. Explain the design considerations, demonstrate the setup of the printer, and highlight any important details or settings. Encourage trainees to ask questions and engage in discussions about the demo pieces.

4.3.2. Example documents

However operators have a limited responsibility in documentation it is useful to show them how production of parts can be documented. Documentation of manufacturing can vary greatly throughout the industry from barely documented to highly documented according to the demand of customers, standards or laws and directives. Trainers should be familiar with different levels, where they occur and explain to students why there is such a difference between documentation levels. Trainers shall explain to students key factors of documentation like traceability of materials, personnel or machinery. Examples of manufacturing and quality control documents shall be given to students of different specifications.

During courses demo pieces, explained earlier, could be documented on preferably three different levels, for example:

- "close-to-nothing" with minimum data only necessary for pricing
- "total quality management" recording all accessible data of production required to ensure traceability and presenting inspection documents specific to technology and field of application,
- "in between" trainer and trainees could carve down together a TQM documentation within reason to be suited for small companies, that aim to grow

The exercises regarding documentation can be tailored to customer needs, in booth directions.

5. Assessment

5.1. Theoretical knowledge

The theoretical knowledge is measurable with the following questions to be explained:

- Part of a 3D printer:
- What are the main parts of an FDM 3D printer?
    - Extruder: This is the part of the 3D printer that heats and melts the plastic filament, which is then used to build the 3D object.
    - Hot End: This is the part of the 3D printer that controls the temperature of the extruder and shapes the melted filament into the desired shape.
    - Print Bed: This is the platform that the 3D object is printed on.
    - Motors: These are the motors that control the movement of the extruder and the print bed.
    - Electronics: This includes the control board, power supply, and other components that control how the 3D printer works.
    - Filament: The filament is the type of plastic that is extruded through the extruder. It is available in a variety of colors and types.
- What are the main parts of an SLA 3D printer?
    - Resin tank
    - Build platform
    - Laser
    - Mirrors
    - Control board
    - Power supply
    - Resin
    - UV light
    - Cleaning tools

The Resin tank is where the liquid is stored during the printing process.
Build platform is where the object is created. The build platform moves up and down, allowing the object to be printed layer by layer.
The laser is used to harden the resin and create the object that we want. The laser follows a specific pattern to create each layer of the object.
Mirrors are used to direct the laser to the correct location on the resin tank.
Control board is the brain of the printer. It controls the movement of the build platform and the leaser and ensures that the object is printed correctly.
The power supply provides the energy needed to operate the 3D printer.
Resin is the material that is used to create the object. It is stored in the resin tank and hardened by the laser.
UV light is used to cure the resin and harden it into a solid object.
Cleaning tools are used to clean the object, the resin tank, and the build platform after the printing process is complete.

- Describe the AM technologies in a few words!
    - Additive technologies, such as 3D printing, are processes that build up layers of material to produce a three-dimensional object from a digital file. This technology is used to create products from a variety of materials, including plastics, metals, ceramics, and composites. The process begins with the development of a 3D model or blueprint, which is then sent to the 3D printer or machine. The 3D printer then reads the instructions from the model and layers the material in the desired shape. The end result is a finished product that is ready to use.
- What are the necessary values that need to be perfectly adjusted for perfect printing?
    - bed leveling, levels
    - printing speed, extrude speed
    - heating parameters
    - cooling parameters

Material knowledge – What is suitable material and what is good for?

- Basic FDM materials:
    - ABS: ABS is a good material for printing objects that require high strength and temperature resistance, UV resistance, such as tools and engineering parts. For example: car parts, mechanical parts.
    - PLA: PLA is a good material for printing objects that don't require high strength or temperature resistance. It's common

for prototyping and decorative objects, basic parts such as phone cases, jewellery, statues and mockups.

- PETG: PETG is a good material for printing objects that require strength, flexibility, and water, UV, chemical, temperature resistance, such as medical, food containers, water-based parts, UV resistant parts.
- TPU: TPU is a durable material that can withstand high temperatures, wear, and tear. It is also resistant to most chemicals, UV radiation, and abrasion. TPU has excellent flexibility, allowing it to bend and twist without cracking. It is also resistant to stretching and shrinking, making it a great material for creating complex shapes and parts. TPU is resistant to most chemicals, making it suitable for a wide range of applications. This material is good for elastic parts, Water-based and so on.
- ASA: ASA is a durable thermoplastic filament that can be used for a wide range of applications. It is a strong and UV-resistant material that is highly resistant to the elements, making it a great choice for outdoor projects. It is easy to print with and has a smooth finish, making it perfect for detailed and intricate designs. It is also a low-cost material, making it ideal for prototyping and small-scale production.
- Nylon: Nylon is a type of thermoplastic filament used for 3D printing. Nylon is a good material for printing objects that require strength, flexibility and durability, such as outdoor wear and automotive parts.

- Basic SLA materials:
  - SLA 3D printing resin is a type of photopolymer material that is used in stereolithography 3D printing. This material is made up of liquid resin which is cured and solidified when exposed to ultraviolet (UV) light. It is an acrylic-based plastic that can be used to create highly detailed, accurate, and durable 3D prints. SLA 3D printing resin is available in a wide range of colors, allowing for unique, colorful 3D prints. This material is easy to post-process, making it a great choice for any 3D printing project. It is also highly resistant to heat and chemicals, making it a great option for functional parts. SLA 3D printing resin is a great choice for any 3D printing project and comes in a variety of colors and finishes. SLA 3D printing resin materials feature a wide range of properties, such as flexibility,

transparency, and hardness, allowing them to be used for a variety of applications.

- Rigid Resin: This type of resin is often used for creating functional components and end-use parts that require strength and durability.
- Flexible Resin: This type of resin is ideal for producing parts that need flexibility, such as gaskets, seals, and other components that require flexibility.
- High Temperature Resin: This type of resin is designed to withstand high temperatures and is often used for producing parts that will be exposed to extreme heat.
- Castable Resin: This type of resin is designed to be used for casting, such as for jewelry and dental components.
- Transparent Resin: This type of resin is designed to produce parts that are transparent, such as for optical lenses or lighting applications.

SLS (Selective Laser Sintering)

What are the main parts of an SLS 3D printer?

The main parts of an SLS 3D printer include the build platform, powder bed, laser, scanning system, powder delivery system, chamber, cooling system, and control system.

- Build platform: The build platform is the base on which the 3D object is built layer by layer. It is typically made of a metal plate and can be heated to ensure that the material adheres to the platform.
- Powder bed: The powder bed is a layer of powdered material, which can be made of various materials such as nylon, polyamide, or metal powders. The powder bed is spread across the build platform, and the laser selectively fuses the particles to create the 3D object.
- Laser: The laser is the primary tool used in the SLS process to selectively melt and fuse the powdered material. The laser is typically a high-powered CO2 laser, which can be adjusted to control the temperature and speed of the fusing process.
- Scanning system: The scanning system is responsible for directing the laser across the surface of the powder bed to selectively melt and fuse the particles together. It typically consists of mirrors or galvanometers that move the laser beam precisely across the powder bed.
- Powder delivery system: The powder delivery system is responsible for spreading a new layer of powdered material across the build platform after

each layer is fused. It typically consists of a roller or blade that evenly distributes the powder across the surface.

- Chamber: The chamber is an enclosed space that houses the powder bed and the laser system. It is designed to maintain a controlled environment to prevent contamination of the powder and ensure consistent printing conditions.
- Cooling system: The cooling system is used to rapidly cool the 3D object after it has been printed to prevent warping or deformation.
- Control system: The control system is responsible for controlling the various components of the SLS printer, such as the laser power, scanning system, and powder delivery system. It typically consists of software that allows the user to create and modify 3D models, set printing parameters, and monitor the printing process.

Common SLS materials:

SLS is a versatile 3D printing technology that can print a wide range of materials, including plastics, metals, and ceramics. The choice of material depends on the requirements of the application, such as strength, durability, and temperature resistance. SLS parts printed using these materials have excellent mechanical properties and are used in a variety of industrial applications.

- Nylon: Nylon is one of the most common materials used in SLS printing. It is a strong and durable thermoplastic that can be easily recycled, making it an eco-friendly option. Nylon parts printed with SLS technology have excellent mechanical properties, including high strength and stiffness.
- Polycarbonate (PC): Polycarbonate is another popular material for SLS printing. It is a transparent thermoplastic that is known for its high impact resistance and toughness. PC parts printed using SLS technology are strong, durable, and resistant to temperature extremes.
- Polypropylene (PP): Polypropylene is a lightweight and flexible thermoplastic that is used in a variety of applications, including packaging, automotive parts, and medical devices. SLS-printed PP parts have good mechanical properties, including high strength and stiffness.
- Metal powders: SLS can also print with various metal powders, including aluminum, titanium, and stainless steel. Metal parts printed using SLS technology have excellent mechanical properties, including high strength and stiffness, and are often used in aerospace, automotive, and medical applications.

- Ceramic powders: SLS can also print with ceramic powders, such as alumina and zirconia. Ceramic parts printed with SLS technology are strong, durable, and have high resistance to wear and corrosion, making them ideal for use in high-temperature and harsh environments.
- TPU (Thermoplastic Polyurethane): TPU is a flexible thermoplastic that is used in applications where flexibility and elasticity are required. TPU parts printed with SLS technology are strong, durable, and have high abrasion resistance, making them ideal for use in medical and consumer goods.

PolyJet

What are the main parts of a PolyJet 3D printer?

The main parts of a PolyJet 3D printer include the build platform, printhead, material cartridges, UV lamps, print head carriage, and control system. These components work together to create highly detailed and accurate 3D objects by depositing and curing liquid photopolymer materials layer by layer.

- Build platform: The build platform is the base on which the 3D object is built layer by layer. It can be made of various materials such as glass or metal, and it can be moved up and down during the printing process to create each layer.
- Printhead: The printhead is the component that deposits the liquid photopolymer material onto the build platform. It typically contains multiple nozzles that can eject small droplets of material onto the build platform with high precision.
- Material cartridges: The material cartridges are containers that hold the liquid photopolymer materials used in the printing process. They are typically located on the top or side of the printer and can be easily replaced when they run out.
- UV lamps: The UV lamps are responsible for curing the liquid photopolymer materials as they are deposited onto the build platform. They emit intense ultraviolet light that hardens the material, creating a solid 3D object.
- Print head carriage: The print head carriage is the component that moves the printhead and material cartridges back and forth over the build platform. It is typically driven by a motor and a series of belts or rails.
- Control system: The control system is responsible for controlling the various components of the PolyJet 3D printer, such as the printhead, UV lamps, and print head carriage. It typically consists of software that allows the user to create and modify 3D models, set printing parameters, and monitor the printing process.

What are the common PolyJet materials?

- Acrylonitrile Butadiene Styrene (ABS): ABS is a commonly used thermoplastic that is known for its high strength, durability, and heat resistance. PolyJet printed ABS parts have excellent mechanical properties, including high strength and stiffness.
- Polypropylene (PP): Polypropylene is a lightweight and flexible thermoplastic that is used in a variety of applications, including packaging, automotive parts, and medical devices. PolyJet-printed PP parts have good mechanical properties, including high strength and stiffness.
- Polycarbonate (PC): Polycarbonate is a transparent thermoplastic that is known for its high impact resistance and toughness. PolyJet printed PC parts are strong, durable, and resistant to temperature extremes.
- Rubber-like materials: PolyJet technology can also print flexible, rubber-like materials, such as TPU (thermoplastic polyurethane) or TPE (thermoplastic elastomer), which are ideal for applications requiring flexibility or cushioning.
- Clear materials: PolyJet technology can print clear materials, such as transparent acrylic or polycarbonate-like materials, which are ideal for creating light guides, lenses, and other optical parts.
- Multi-material parts: PolyJet technology can print parts with varying durometers or colors in a single print run. This is achieved by printing multiple photopolymer materials simultaneously, which are then cured to form a single part with multiple characteristics.

MJF (Multi Jet Fusion)

What are the main parts of an MJF 3D printer?

- Powder bed: The powder bed is the base on which the 3D object is built layer by layer. It is typically made of a material such as nylon and is contained within the build chamber of the printer.
- Printhead array: The printhead array consists of multiple inkjet printheads that deposit the fusing agent and detailing agent onto the powder bed. The printhead array moves back and forth over the bed during the printing process, depositing the agents in precise patterns.

- Fusing lamps: Fusing lamps are located above the powder bed and emit intense light energy to selectively fuse the powder material. The fusing lamps are responsible for melting and bonding the powder material together to create the final 3D object.
- Detailing lamps: Detailing lamps are also located above the powder bed and are responsible for heating the detailing agent to promote bonding with the powder material.
- Build platform: The build platform is the component that moves the powder bed up and down during the printing process. It is typically driven by a motor and a series of belts or rails.
- Control system: The control system is responsible for controlling the various components of the MJF 3D printer, such as the printhead array, fusing lamps, detailing lamps, and build platform. It typically consists of software that allows the user to create and modify 3D models, set printing parameters, and monitor the printing process

MJF basic materials:

- Nylon: Nylon is a popular material for MJF printing because of its strength, flexibility, and durability. It can be printed in various grades, including PA12 (polyamide 12), which is widely used in automotive and industrial applications.
- TPU (Thermoplastic Polyurethane): TPU is a flexible material that is commonly used in applications requiring cushioning or flexibility, such as phone cases or shoe soles.
- PP (Polypropylene): PP is a lightweight and flexible thermoplastic that is used in a variety of applications, including packaging, automotive parts, and medical devices.
- PA11 (Polyamide 11): PA11 is a bio-based nylon that is produced from renewable sources such as castor oil. It has excellent mechanical properties and is commonly used in automotive and aerospace applications.
- PA12GB (Polyamide 12 Glass Beads): PA12GB is a nylon material that is reinforced with glass beads, providing increased stiffness and strength.
- PA12MB (Polyamide 12 Mineral Beads): PA12MB is a nylon material that is reinforced with mineral beads, providing increased stiffness and heat resistance.
- MJF TPE (Thermoplastic Elastomer): MJF TPE is a rubber-like material that is commonly used in applications requiring flexibility or cushioning.

In conclusion, MJF technology can print with a variety of materials, including nylon, TPU, PP, PA11, PA12GB, PA12MB, and MJF TPE. The choice of material

depends on the requirements of the application-. MJF-printed parts using these materials have excellent mechanical properties and are used in a variety of industrial, medical, and consumer applications.

5.2. Practical knowledge

The practical knowledge is measurable by these practices:

- Build a 3D printer from parts or just a sub-unit of a 3D printer, or set up a 3D printer
- Found the error on the wrong 3D printer and solve it
- Modelling and 3D printing a perfect workpiece
- Printing with 3 (basic) 3D printing material
- A final 3D printed workpiece with a self-assembled machine
- Choose the right technology and material for a specific workpiece
- Determine from a defective workpiece what could have caused the defective result. It is caused by the machine setup or the wrong material setup?
- Go through a basic machine maintenance process
- Change material in the 3D printer and start a new print

These exercises help us to ensure that the student has mastered the necessary theoretical material, and to make sure of his or her practical knowledge as well.

Students have to learn how to control a 3D printer. And the best way is to discover the machine yourself so let the students handle the 3D Printers.

6. Qualification of trainers

6.1. Required experience on this field

To assure the relevance of the qualification, it must be closely related to industrial practice, and it is essential for teaching staff to have continuing contact with industry. In this sense, teaching staff need to combine:

- Teaching ability - evidence of training in lecturing, public speaking or verbal communication.
- Competence in the subjects being taught.
- Knowledge and experience of current industrial practice in the subjects being taught.

- Practical skills relevant to the course being taught.

The training centre must provide an appropriate complement of teaching staff which has, collectively, the knowledge and skills necessary to deliver the course for which approval is being sought in an effective manner. The number of such staff shall be sufficient to ensure that the essential specialist knowledge and industrial experience to cover the syllabus is adequately represented in the team of teachers and visiting lecturers. It must also provide a resource which is adequate for updating and monitoring of the training programme.

Teaching staff must maintain contact with current industrial practice and, for example, the involvement of teachers in consultancy work is one way of achieving this link; short-term secondments are another. The use of outside speakers from industry is recommended to introduce a strong industrial element into the course.