BEST PRACTICE GUIDE

How to set-up and operate successful didactic innovation labs in VET

DIOS
Didactic Innovation Labs

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Structure

1. Preface

Digital technologies are our daily companions. Without them our life would look completely different. The pace of their absorption into our daily life is breath-taking. Modern technologies come with a lot of promises. We are the one who decide whether it is for the good or not. To do so, we must understand them and being capable to solve todays' challenges. This applies for our professional and for private lives.

The application of modern technologies like Augmented Reality (AR), Virtual Reality (VR), 360° Video, intelligent sensors (IoT) and 3D printing in vocational education and training (VET) is mainly a terra incognita. Almost squaring the circle solutions include of choosing versatile, no code and tailor-made solutions with a measurable pedagogical impact. This seems impossible but it is not.

In this best practice guide will show how AR, VR, 360° Video, IoT, 3D printing can be applied by doing exactly that. It is enriched with examples from the field of training by doing exactly that. We also will also the path how the gained insights can be transferred and institutionalized within your company or education institution. A suitable format for that is a learning lab.

After reading the guide you will understand the educational possibilities of AR, VR, 360° Video, IoT, 3D printing and can start to apply the knowledge in your class and preparing that before in your learning lab.

2. Why – the importance of educational innovations in VET

The extent to which teachers apply new technologies is correlated to the quality and effectiveness of education. Technological, and social changes follow each other in rapid succession. It is a challenge for education to keep up with this and prepare teachers for this change. The speed at which the changes are occurring will be experienced as a challenge for several teachers and motivates them to work on educational innovation using new technologies. However, for a large group of teachers, the changes are happening so fast that they are concerned.

Our mission: "Supporting educational innovation by teachers and trainers in using ICT to meet educational challenges “.

Educational innovation is by itself not innovative. It is the adaptability to changing demands of the students, society and new technologies options and resources. The access to a network infrastructure, software, and applications are becoming less of an obstacle to educational innovation. With regard the educational innovation with ICT is becomes more important to ask:

- Do I use (self- developed) digital learning materials for teaching?
- Do I help learners to find and access information on the internet?
- Do I have sufficient pedagogical skills to regularly and successfully use new technologies in teaching?
- Do I use digital learning resources regularly?

The framework to apply AR, VR, 360° Video, IoT and 3D printing correctly in practical VET training for the focus industries was to answer the following questions:

CHEMICAL PLANT (AR, 360° Video, IoT):

1. How to apply no-code AR solutions to support self-directed learning as well as increase collaboration during carrying out the work?
2. How to provide insights before carrying out the work about a machine functioning with 360° video?
3. How to use IoT to reduce the number of patrols within a chemical plant to determine pH value, temperature?

CHEMICAL LAB (AR, IoT):

1. How to leverage guided and self-directed learning with AR during lab work (conductometric titration)?
2. How to use IoT to support lab work (conductometric titration) to measure automatically values like temperature?

IT (AR, IoT):

1. How to use AR to support self-directed learning during troubleshooting hard- and software?
2. How to measure environmental condition (temperature, humidity) in automated and easy accessible way by using AR and IoT?

MECHATRONICS (IoT, 3D Printing):

1. How to use 3D printing for supporting group and project work?
2. How to use IoT and 3D printing to automatically measure environmental conditions in the classroom as well as support acquiring professional knowledge and increase collaboration and communication among learners?

ELECTRONICS (VR, IoT, 3D Printing):

1. How to support group work with group work for designing with 3D printing and IoT?
2. How to enhance visualization, collaboration, and real-time feedback by using VR?

3. What educational technology suits for which scenarios

The selection of a suitable educational technologies requires insights about characteristics and whether they support reaching the defined learning goals.

Each new or modern technology surfs the hype cycle[1]. Boosted by high expectations, entering the period of disillusion and in the best case proving to be productive.

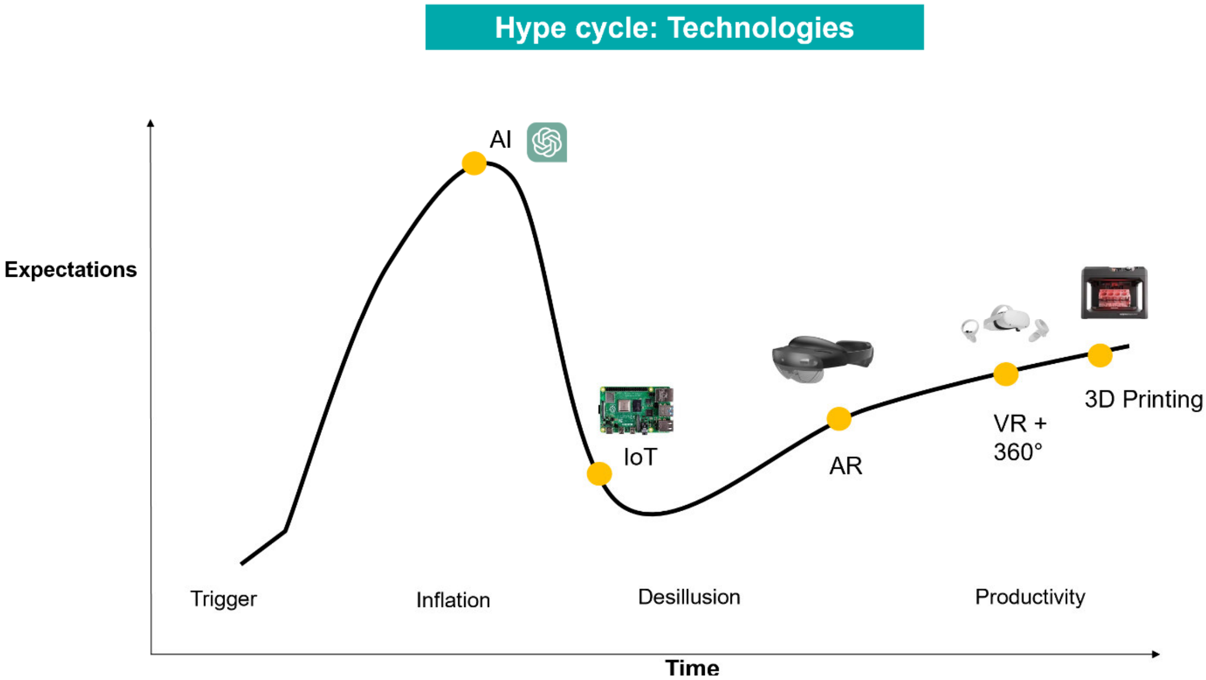


Figure 1: Hype cycle of technologies

Augmented Reality

Decisive factors for the purchase of an AR glass are:

- Price
- Battery duration
- Field of view
- Weight
- Control: gesture or voice
- Available learning content

The Microsoft HoloLens 2 is the best device. We also gave the Meta Quest Pro a try.

[1] https://viraloctopus.com/magazine/strategy/gartner-hype-cycle-technology-adoption-curve/ (19.07.2021)

Microsoft HoloLens 2 (3800 €) Meta Quest Pro (1200 €)

There two basically two types of **no-code AR solutions**:

I. **Remote Assist or Remote Support App**: The learner is guided and viewed in real-time by the remote expert (trainer or experienced learner), who provides audio-visual instructions by word and by integrating simple holograms for a better guidance in the field of view of the learner. This solution is the choice for providing technical and procedural knowledge when learner and expert are not in the same room.

II. **Guides App**: The learner is guided by previously set learning path by an expert. The digital overlay in the field of view provides instruction and insights by text, pictures, and videos clips. Guides is the solution for carrying out rather standardized procedures and to foster self-directed learning when the trainer or expert is not available.

Virtual Reality

Decisive factors for the purchase of an VR glass are:

- Price
- External computer not needed
- Battery duration
- Weight
- Hand tracking and external controllers

The Meta Quest Pro was the best available device for our purposes.

Meta Quest 2 (450 €)

360° Video

Decisive factors for the purchase of 360° video cameras are:

- Price
- Resolution

- Battery duration
- Easy to use
- Post-production time
- Video file compatible with system

Ricoh Theta Z1 (1000 €)

Intelligent Sensors (IoT)

Decisive factors for the purchase of IoT devices were:

- Price
- Computing power
- Power consumption
- External hardware compatibility
- Developer support

Raspberry Pi 4[2] (140 €)

Arduino[3] (25 €)

3D printer

To carry out the additive printing scenario in mechatronics and electronics a suitable 3D printer was selected. This enabled to print 3D designs easily by using different kind of “plastic” like PLA (polylactic acid), ABS (Acrylonitrile butadiene styrene), PETG (Polyethylene terephthalate glycol) and TPU (thermoplastic polyurethane). Decisive factors for buying an 3D printer are:

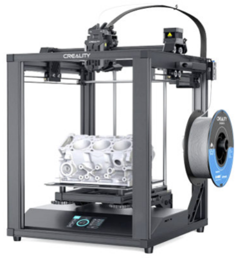
- Price

[2] = Small scale computer, which runs on a full OS (Linux based), capable of reading inputs and running programs.

[3] = Micro controller able to read inputs and execute simple tasks like reading temperature, etc. programmed though an open-source software.

- Materials or filaments available
- Nozzle temperature for printing
- Layer thickness
- Speed of printing
- Available 3D models / learning content

Ultimaker S 2 (2700 €)



Creality Ender-5 S1 (500 €)

	Chemical plant: 360° Video tour	
1. Problem	Chemical operators work with mills for cutting raw materials. They have to understand how the function. Often different cutting mills are in a room. The training (1:1) is time-consuming for the trainer. The provision of tacit knowledge is key, which paper-instruction cannot deliver.	
2. Solution	An interactive 360° video environment for the positioning and functioning of different cutting mills was created. It includes videos, work instructions and knowledge quizzes about operating up to 10 cutting mills in the chemical training plant of SBG Dresden. The apprentices access it on a tablet of laptop to use it for self-directed learning BEFORE they go to training plant.	
3. Outcome	The 360° Video is low threshold and motivating way to support self-directed learning in practical training. It supports the provision of professional, digital, and tacit knowledge. The apprentices can better transfer the experienced knowledge into their training reality. The operation of the cutting mills is carried out more efficient by more motivated apprentices, which made less mistakes.	

SCAN ME

	Chemical plant: AR Guides	
1. Problem	Chemical operators run different cutting mills, like the Retsch SR 300. Teaching the specifics on starting up and operation is time- consuming. In addition, tacit knowledge about mill operation cannot be transferred by paper-instructions.	
2. Solution	In the chemical plant an apprentice wears the AR glass Microsoft HoloLens 2. Before the training session the trainer created a learning path to start and operate the Retsch SR 300. The apprentice opens the “Guides” App in the AR Glass and scans the QR Code on the mill to start the digital guidance. Information like text, pictures and videos are visible in a digital overlay which is projected in the field of view of the apprentices. After finishing each working step, the apprentice can “airtap’” to go to the next step. The digital guidance in front of his/her eyes provides a hands-free option to operate the cutting mill.	
3. Outcome	The provision of operational and technical knowledge works for inexperienced apprentices well as for experienced ones. With the self-directed way of learning the apprentices can choose his/her pace of learning. A higher motivation, efficient work execution and a better knowledge transfer into practical training is the result.	

SCAN ME

	Chemical plant: AR and IoT	
1. Problem	Chemical operators monitor synthesis and technical processes in chemical plants. This has to be done in real-time for parameters like temperature and pH value. A neutralisation process requires the addition of an acid like citric acid to a sodium hydroxide solution. In regular manner citric acid has to be added. The effect is time-consuming (taking a probe) as well as it required a walk through the whole plant.	
2. Solution	In the chemical training plant, the apprentices carry out the neutralisation in one-person groups, instead in a group of two. The combination of the AR glasses Microsoft HoloLens 2, a tailor-made app as well as the combination of an IoT device (Arduino) with the pH sensors allows a real time gathering of temperature and pH values.	
3. Outcome	The technical solutions helped apprentices to save time and to provide a probe-free way to monitor the neutralisation process. The real-time monitoring provides learners with insights on parameters influence in chemical reactions during using AR glasses and an IoT device.	

SCAN ME

	Chemical lab: AR Remote Assist	
1. Problem	Chemical lab technicians must be able to carry different analysis in the chemical lab. One is the conductometric titration. The process is for beginners as well as for experienced apprentices challenging especially in the case when an expert is not in the lab.	
2. Solution	In the chemical lab, the apprentice is guides remotely by the trainer. The apprentice wears the AR glass Microsoft HoloLens. Through the Microsoft Remote Assist App the trainer provides audio-visual instruction from his or her laptop by using the Teams app to the apprentice during carrying out the conductometric titration. The trainer can guide by voice and by integrating little holograms (e. g. arrow shape) to emphasise on equipment, chemical or process steps.	
3. Outcome	This setting focussed on the provision of practical knowledge from the trainer to an inexperienced apprentice. This form is useful to learn routines. The trainer instructed and could intervene in real-time. Therefore, error patters could be prevented. These 1:1 learning does not require any software programming and is the choice for the provision of rather technical or process knowledge, in real-time and from the distance. It is expected to affect positively accuracy and speed as well as the motivation of the learner during an unassisted session.	

SCAN ME

	IT: AR Guides	
1. Problem	Hardware and network engineers have to be able to troubleshoot in case of an emergency, especially when an expert is not on-site. The provision of paper-based instruction is time-consuming to provide a practical and on-time solution e. g. in case of network problems.	
2. Solution	At the date centre the apprentice wears the AR glass Microsoft HoloLens 2. Before the training session the trainer created a learning path to troubleshoot network problems with a modem. The apprentice opens the “Guides” App in the AR Glass and scans the QR Code on the modem to start the digital guidance. Information like text, pictures and videos are visible in a digital overlay which is projected in the field of view of the apprentices. After finishing each working step, the apprentice can “airtap’” to go to the next step. The digital guidance in front of his/her eyes provides a hands-free option to troubleshoot. .	
3. Outcome	The provision of operational and technical knowledge works for inexperienced apprentices well as for experienced ones. With the self-directed way of learning the apprentices can choose his/her pace of learning. A higher motivation, efficient work execution and a better knowledge transfer into practical training is the result.	

SCAN ME

	Mechatronics: 3D printing	
1. Problem	Mechatronics must be able to develop, repair and operate technical systems. In case components of the technical systems are missing their redesign can be time-consuming to reduce production down-times.	
2. Solution	Apprentices identify the missing part. In a next step they design, and 3D print the missing plotter part by working collaboratively in group together. Then the assemble the plotter with the 3D printed part successfully.	
3. Outcome	By designing and 3D printing the missing plotter part apprentices were more motivated. The provision of professional knowledge about operating a 3D printer and using the 3D design software let to a time-efficient carrying out of the work.	

SCAN ME

	Electronics: IoT and 3D printing	
1. Problem	Electricians must be able combine different technologies. The use of IoT and 3D printing provides the possibility create tailor-made solutions. This was needed when designing a camera solution for retail recordings of the sales conversations as currently the reflection afterwards on how the customer contact went is not available. The solution has to be solid and neat design and not disturb the view during customer talks.	
2. Solution	Two apprentices designed collaboratively a good looking and wirelessly working camera solutions with an IoT device (Raspberry Pi) and a 3D printed camera design.	
3. Outcome	The group work supported collaborative working as well as complex problem solving by using IoT and 3D printing. The creation of a tailor-made solution of the apprentices to the problem lead a more motivated learning and a better application and transfer of the concepts and knowledge into reality.	

4. How to set-up and operate a learning lab for didactic innovations

A learning lab is aimed at inspiring and guiding teachers, trainers, and apprentices/students to implement ICT-rich education at their own school or training institute.

A “training innovation lab” is not only a physical place where teachers and trainers gain knowledge and experience about technological needs and support, but also a space to test ready-made materials by integrating selected educational technologies like AR, VR, 360° video, IoT, and 3D printing.

Physical and/or virtual

In many cases, a Learning Lab will be a physical location where educators can test hardware and software and receive support in using them in education. A physical Learning Lab will often be combined with a virtual environment such as a website or application. The virtual environment is then to support and supplement the physical lab. A major disadvantage of only a virtual lab is that educational staff are only supported to a limited extent in the actual deployment of what is offered. The possibilities to stimulate teaching staff to work on learning to teach with ICT is considerably less in comparison with a physical Learning Lab. The main advantage is mainly in the cost.

Size

A distinction can be made between Learning Labs that are specialized and limited in size and broad-based Learning Labs where a wide range of technological resources are available to reach and support a large group of educational staff. Especially if you start with a Learning Lab, it is good to gain experience with a Learning Lab of a limited size. Make sure that you choose a setup that can be scaled up.

Integration

The result regarding the contribution of a Learning Lab to educational innovation with ICT depends to a large extent on its embedding in the organization. A Learning Lab is not an isolated phenomenon. It is certainly not a goal in itself to have a Learning Lab. The Learning Lab must be included in all actions and measures taken to innovate and improve education. The impact can be enlarged by involving external stakeholders such as innovative start-ups or training companies of different sizes as well as living the open innovation approach inside the educational organisation. This helps to increase the impact on the output and financial side.

Setting Up

The successfully set-up a learning lab the following steps are key:

a) Development plan. This plan should incorporate:
   - a *vision* (“How education can influence the world of tomorrow?”)
   - a *strategy* (“How we will achieve it”?) and
   - a *mission* (“What are your core values?”, “How do we want to deal with learners and employees?”)

Within the DIOS project we define the strategy to set up didactic innovation labs. This involves the following steps:

- Understand (What is known? What does fit in the mission and vision of the planning learning labs? For whom, why, what, and how learning labs are developed? (incl. educational questions)
- Explore (What scenarios and training settings are suitable? Which digital prototypes should be built and tested?)
- Materialize (What the user liked? What did they not like? What should be altered? How to bring the final product or result to more users?)

b) Decision making

Key is to make explicit choices on the professionalisation of teachers/trainers ICT skills by the management. Options are:

- Information meetings,
- Short courses and trainings,
- Coaching and peer review,
- Participation in a network and
- External trainings.

c) Professionalisation of teachers/trainers

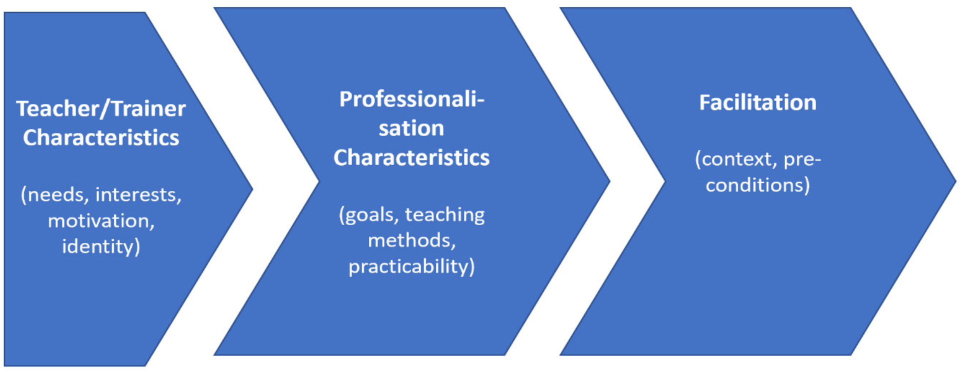


Figure 2: Flow chart professionalisation of teaching personal in 3 steps

d) Content development for trainings

The enrichment of existing trainings with modern digital media is aimed. Key is the description of the specific educational problem or challenge where the new technology can help with. E. g. AR can be used to support self-directed learning or more collaborative learning when providing technical knowledge on how to operate a machine.

5. Do's and Don'ts: Operating a learning lab

1. Educational focus

It is very important to take education as the starting point for setting up a Learning Lab. This sounds logical, but without this focus the Learning Lab becomes a cabinet of curiosities where fun technological games can be played and borrowed without a direct link to education. Of course, getting acquainted with new technology is one of the goals, but the set-up of the Learning Lab must always be aimed at the "possible" applicability in education. This means that an educational question must be formulated when purchasing resources, hardware and/or software. Which educational problem or challenge can be solved efficiently, effectively and motivating with the use of a certain technology?

It will not always be possible to make a direct link with education with new promising technologies. In that case, you ensure that the use and lending always include the assignment to investigate possible use in education.

2. Involvement of educational staff and support

From the start of setting up a Learning Lab, it is important to involve the target groups, such as teachers/trainers and students/apprentices. It is important to listen carefully to the needs of the educational field. It must be clear why investments are made in a Learning Lab. If this does not happen, this is a barrier to implementing the intended educational innovation with ICT and making it successful. Continuity can also only be guaranteed if the organization sees the usefulness of this and makes a budget available for several years.

3. Top-down or bottom-up

The advantage of bottom-up is that educational innovation arises from the teachers' own enthusiasm and is in line with their priorities. Lecturers also receive tailor-made support through this approach; the support is in line with the teacher's request. The disadvantage is that stimulating individual initiatives takes a lot of time, money, and effort. Achieving sustainable innovation is difficult: early adopters thrive with this approach, but the masses are less likely to move.

The top-down approach has the advantage that movement is created faster and that you can take the next step sooner. Setting up a support infrastructure is easier if you know that almost everyone will be using it. A disadvantage of this approach is that it (also) costs a lot of time, money, and effort, especially to create a culture shift. Teachers may fear that they no longer retain ownership of the education they provide. This could lead to a less inspired result.

The solution could be mix of both approaches. This includes the use of the Learning Lab in development plans (top-down) and the purchasing of new learning materials after feedback with teachers/trainers.

4. Push or pull

Once the Learning Lab has been installed, the balance must be found between the information you bring into the organization and the demand you collect or receive. At the start of a Learning Lab, the emphasis will be on push from the Learning Lab, bringing information to the employees. You want to achieve that people become familiar with what the Learning Lab has to offer. However, the goal should be that the majority of the activities in the Learning Lab are determined by the customers, the educational staff. The emphasis is then on the employee or the teams that involve the Learning Lab in the educational innovation, “pull”.

Retrieving the necessary information from the organisation could be a challenge. It is therefore important to have contacts within the various teams who can collect the question and who can answer questions in the first line. Within larger organisation distinguished ambassadors are a good choice to as they meet regularly to share information about what is going on in the different teams and what experiences have been gained. In this way we can determine the innovation needs with ICT and to have clear understanding which resources should be purchased, what should be created (e. g. instructional videos) and which courses/workshops can be organized. This helps to learn from each other and to bring teachers/trainers into contact with each other to share information and to collaborate on educational innovation.

5. Ownership

Teachers and trainers must remain the owner of the education. If you want to improve education with the help of new technologies, every team will have to be aware of the added value.

This means that teachers must feel ownership of educational changes, that organizations encourage teachers to develop blended education and that education managers feel the need for innovation. Although the lead for a redesign of education lies with the teacher, not everyone is ready to take big steps yet. It is therefore up to the organization how large the 'interference' of the management should be. Do you stimulate educational innovation by supporting initiatives from below, do you impose from above that all programs must deal with a redesign of education, or do you opt for a way in between?

Ensure to create creative solutions for/with teachers and trainers and to innovate with existing technologies to support actively community building within the organisation.

6. Accessibility and visibility

The Learning Lab, the activities and the results must be visible and findable for the target group. It should be easy to visit the Learning Lab. This means that a Learning Lab must be in a central and visible place in the organization. Ensure good accessibility.

The website is an important entry point for employees to stay informed about everything that is happening in the Learning Lab. This includes new materials, software, and publications about educational innovations with ICT. Best practices and reviews should also be available on the website. If employees in the Learning Lab can also borrow resources, then a good overview of resources and a lending system is of great importance.

7. Budget

At the start, a budget must be made of the costs to realize a Learning Lab. Think of the costs of materials and resources, location costs and the costs of deploying people. In this case be realistic and creative. Many resources are often already available within an organization, but they are not optimally used throughout the whole organization. Bundling and making it available throughout the organization can lead to cost savings and increase effectiveness.

There are also often local and international subsidies and incentive projects to support educational innovations with new technologies.

Do not forget about possible partnerships with companies and organisations. Collaboration with other schools, by pooling knowledge, experience, and resources, can contribute to limiting costs and increasing the quality of the Learning Lab.

It is not always necessary for the location to have a space completely dedicated to the Learning Lab. A combination with an innovative classroom that is available for a few hours, or a creative staff room are good alternatives.

In addition to the costs that must be incurred for starting a Learning Lab, it is important for continuity to make a multi-year budget that must consider additional investments, replacement budget, deployment of people, both permanent staff, but also the costs of the investment of teams.

By making a multi-year budget of at least 3 years and having this approved by the management, you increase the chance of success in setting up a meaningful Learning Lab. As previously mentioned, a Learning Lab can be limited and grand in scope. This depends on the ambition and the goal you want to achieve with the Learning Lab.

6. Summary

The low-threshold use of modern digital media like Augmented Reality (AR), Virtual Reality (VR), 360° Video, intelligent sensors (IoT), and 3D printing is inevitable, when fostering digital transformation of the teaching and learning process. The initialization and institutionalisation of the learnings within learning labs is recommended way to innovate existing settings and anticipate developments for teaching and learning in VET.

DIOS tapped into new grounds by integrating elements of traditional and digital pedagogy in training as well as for setting up distinct spaces for working with educational technologies. The starting point is always: What is the pedagogical problem, which shall be solved with technology X? The educational technologies applied are accessible and affordable. An enabling pedagogy should strengthen its use towards content selection, creation, and application.

The use of no-code solutions like AR remote assist for collaborative real-time and indirect learning as well as with AR Guides for self-directed asynchronous learning is the key for a better transfer of professional knowledge into working and learning processes. Higher motivated apprentices and more time-efficient learning fosters the transition of the role of trainers from an instructor to a moderator. Value to teaching personnel and learners also provided group and project work for the use of IoT and 3D printing. The learning station approach was key to encourage learners to come up with own solutions by using available hard- and software options.

The implement a continuous way of working with modern technologies learning labs were successfully founded at the five partner organizations from DE, NL, SI, CY, and CZ. Important learnings are:

a) Education is always the starting point when setting up a learning lab to purchase resources, hard- and software. Without that focus, the learning lab becomes a cabinet of curiosities.
b) The learning lab shall be in the best case the result of top-down (organisation development plan) and bottom-up (teachers/trainers' needs) approach.
c) Teachers/trainers must be involved to get to know their current and future needs.
d) Teachers/trainers must be the owners of the education process, so that they feel the need for educational changes. Ensure the creation of innovative solutions with teachers/trainers and with existing technologies.
e) Once the learning lab is installed, it must bring information to the employees ("push"). However, the goal is the teaching personal approaches the lab with their needs ("pull"). To ensure that on regular base, it is important to have contacts within various teams who can collect and answer questions. Within larger organisation distinguished ambassadors are a god choice.
f) The location and the offers of the learning lab must easily visible and accessible for the target group(s).
g) When starting a learning lab, the costs of materials, location and employees must be calculated realistically. Some resources might be available within an organisation but not accessible to the whole organisation. Bundling and making it available throughout the organisation can lead to cost savings and increase effectiveness. It is important for continuity reasons to make a multi-year budget (e. g. 3 years) to support organisation management in the decision making- process. For that budget consider additional investments, replacement budget, deployment of permanent staff and costs for investment in teams.

The learning labs are "the places to be" for qualifying "experts for digitization in VET".

7. Contact Learning labs

8. Appendices

LEARNER: SELF-EVALUATION FORM

AR Remote Assist App use for Scenario X

Please tick relevant answers.

Ask	Very much	Yes	Rather Yes	Probably not	Not
Do you already have previous knowledge of handling the mill?					
Have you ever used AR glasses?					
Was the operation of the AR glasses easy?					
Was it easy to use the Remote Assist app?					
Was it easy to follow the audio-visual instructions (voice and visualization) of the expert?					
Did you find it easy to overcome mistakes and misunderstandings?					
Did you find it easy to get answers to your questions?					
Did you find it comfortable to wear AR glasses?					
How satisfied are you with the accomplishment of the work carried out?					
Do you feel that your understanding of the operation of the mill has improved?					
How confident are you that you will be able to apply what you have learned in your training?					

Further comments:

Trainer/Expert: EVALUTION FORM

AR Remote Assist App use for Scenario X

Please tick relevant answers.

Ask	Very much	Yes	Rather Yes	Probably not	Not
Have you ever used AR glasses?					
Was it easy to use the Remote Assist app?					
Was it easy to create visualizations (simple holograms) and quickly fade them into the trainee's field of vision?					
Is your impression that the trainee has implemented the instructions quickly and correctly?					
Did you find that the trainee asked good questions?					
Has your understanding of the mill improved?					
How satisfied are you with the trainee's guidance?					

Further comments: