# The Digi4VET Manual

integrating new technology in VET programmes

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# Contents

# Preface

The idea of a ‘fourth industrial revolution’ or ‘industrie 4.0’ concerns the introduction of interconnected, ‘smart’ digital technologies that are predicted to revolutionise the way that work is organised and performed. Developments such as augmented reality, machine learning, mobile robotics and the ‘internet of things’ are predicted – and beginning – to lead to significant changes to work tasks, with some being eliminated or automated, others augmented by new equipment or software, and new ones created. These changes create demands for new and enhanced skills, while also creating opportunities for new ways of delivering training and supporting learning both in the classroom and the workplace.

The project Digi4VET is designed to aid the introduction of new technology in vocational education and training. It does this in two ways – by looking at the impact of technology on jobs, and therefore new training needs and programme content, and by integrating appropriate technology into the education and training process. Digi4VET focuses on three aspects of new technology for use in teaching and training – augmented reality (AR), virtual reality (VR), and 3-D printing (3DP), but the principles involved are also expected to apply to other emerging technologies.

The project involves partners from three areas – the chemical industry, painting, and floristry – and focuses on occupations at around EQF level 4, as well as supporting teachers and trainers in VET centres and in the workplace.

This manual is designed to take course designers and VET trainers through a rigorous process to create new or enhanced programmes that respond to technological changes and make use of new technology.

# Introduction

The process described in this manual consists of up to eight steps, shown in Figure 1. A one-page summary of each then follows – the 'blue pages' – so please **read these first** if you want an overview of what is covered, or if you just want a 'bite-sized' introduction to any of the topics. The second half of the manual goes into more detail on each of these, and includes references if you want to explore further. The manual is designed so that you **only need look at the relevant sections** – course developers for instance may need to read all the sections, but teachers and trainers may want to focus on sections 5, 6 and 7.

The process begins by looking from an **occupational and learning needs perspective**, to define the occupational area or job that is being looked at, assess the impact of emerging technology, and identify learning needs that are not covered by existing VET or workforce programmes (sections 1-3). This forms the foundation for development of formal content (4), which could be a change or addition to an existing VET programme, or stand-alone courses for instance to upskill the current workforce.

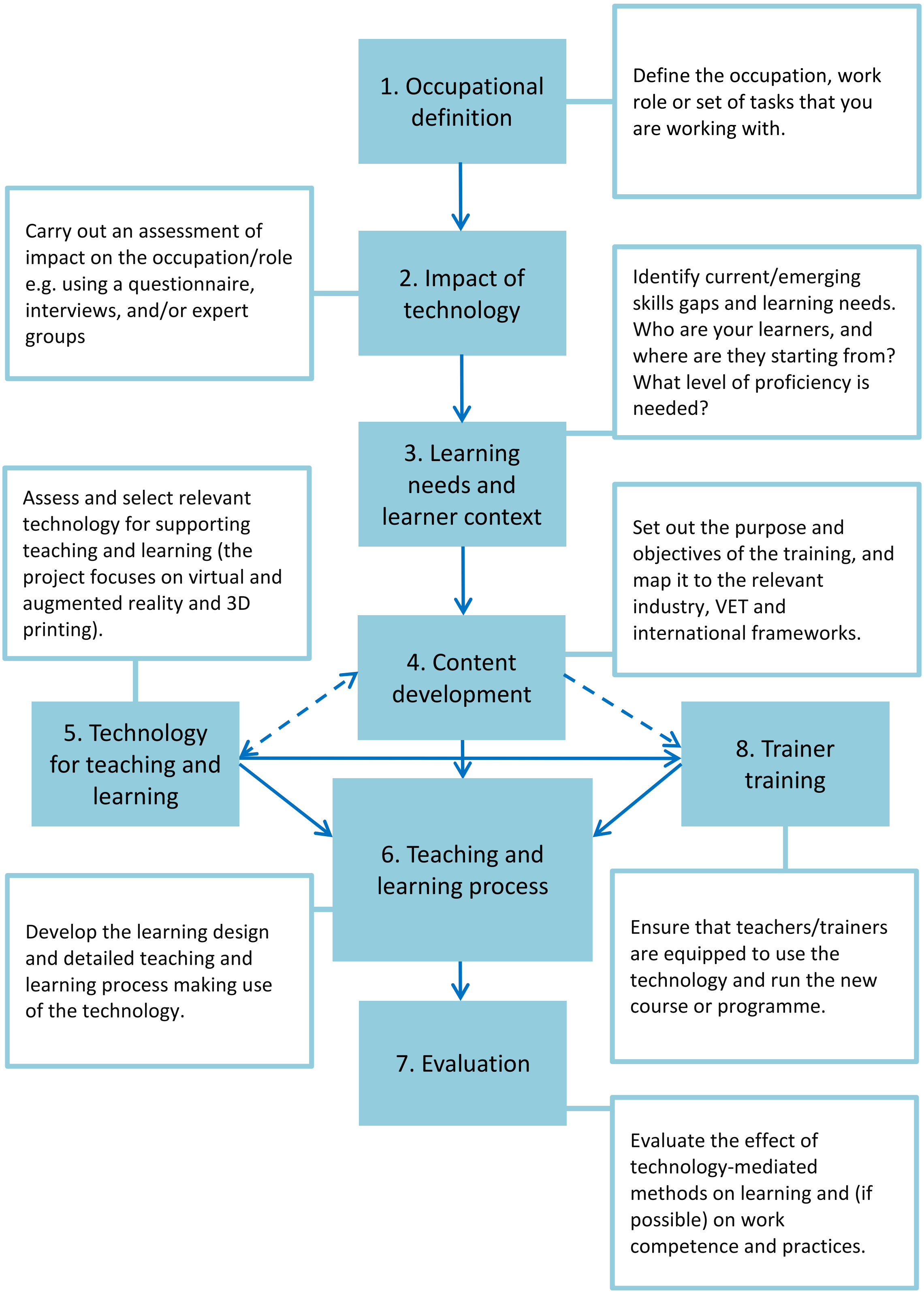
A second line of approach is to **examine and evaluate new technology** to support the learning process (5). This may relate to technology used in the occupation itself (e.g. using virtual reality in construction to provide a 'walk-through' of a proposed building), or technology used to support learning 'non-technological' skills (such as simulating painting to develop hand skills). Digi4VET focuses on three technologies that are currently becoming more affordable and widely available: virtual reality (VR), augmented reality (AR) and three-dimensional printing (3DP). Some of the principles have been borrowed from earlier innovations in technology-aided learning, and they can also be applied to other emerging technologies.

The next step is **incorporating the technology into teaching/training and learning** (6). The result of this step could range from guidelines for using unfamiliar technology, to a detailed set of training plans for delivery of a course or module. Appropriate learning design, learner support and guidance, and feedback are all critical here, particularly because of the potential for embedding them in the technology.

A further important step is **evaluating the learning** (7). When introducing new technologies and methods this generally means doing a comparative evaluation, comparing groups using the technnology and those using current methods.

Finally, introducing new technology will give rise to learning needs for teachers and trainers in VET, which may relate to the technology itself, its use for teaching and training, or its use for the specific applications that have been developed through the above process (8).

*Figure 1. Steps for integrating new technology into VET programmes*




Each step is a section of the manual. Using the 'TPACK' model (technological pedagogical content knowledge) outlined in section 8, steps 1-4 are principally about content (CK, although this may be technological content), step 5 is about the technology in the teaching or training context (TK), steps 6 and 7 about technological pedagogy (TPK), and step 8 about integration (TPCK).

# Topic-by-topic overview

The 'blue pages' give a summary of each of the eight areas covered in the manual.  They can be used as a read-through introduction to the entire process, or as a 'bite-sized' overview of each topic.

## 1. Defining the occupation

This first step involves being clear about the occupation, profession, or area of work that you are examining, in order to assess the impact of new technology on it, and the opportunities for using technology in teaching and training.

All that is needed is a short description – perhaps half a page – of the activities and responsibilities that are typically involved.  These are often available from:

- an existing training specification
- ESCO or the national equivalent (https://ec.europa.eu/esco/portal/occupation)
- the relevant industry, trade or professional body.

Make sure the description is up-to-date and reflects the realities in the industry concerned.

If needed there are various guides to developing or revising occupational descriptions such as the one at http://www.comprocom.eu/products/43-methodological-manual, but you do not need to go into the level of detail that these cover: just enough so that industry practitioners, teachers and trainers are clear about the occupation or area of work that you are working with.

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## 2. Assessing the impact of technology on the job

This step concerns assessing how new technology is affecting the occupation. It leads naturally into training needs analysis (section 3), and both can be covered in the same investigation or survey.

**Effects on jobs**

New technology can have a variety of effects on jobs, including:

- automating work tasks, or making them unnecessary (substitution) – sometimes extending to whole jobs, such as assembly line worker, copy typist or switchboard operator
- making tasks easier to do, more effective, or more efficient
- creating new tasks – for working with the technology, as well as things that were previously not possible or cost-effective
- transforming jobs by creating new responsibilities, possibilities and patterns of working.

**Carrying out an assessment**

Before starting an assessment, think about:

- the starting-point of the occupation – what technology and technological skills are currently widespread?
- the timescale you are looking at – the next year, 2-3 years, 5 years, 10 years?
- how quickly new technology is adopted in different parts of the industry and across firms of different types and sizes.

There are various ways to carry out an assessment, depending on the structure of the industry or occupation, who has up-to-date expert knowledge about it, and how much time and resource you have. It can be helpful to draw on a small group of experts as well as a wider-scale survey. Methods that can be used include:

- documentary/online research – particularly what is being written in industry and trade journals, blogs, online discussion groups etc.
- expert panels, focus or Delphi groups – using the expertise of a small number of people with good, up-to-date inside knowledge
- a questionnaire survey – advantages include a wide reach and ease of analysis, disadvantages low response rates and difficulty in exploring matters in depth
- individual interviews – time consuming, but allow issues to be explored in detail
- visiting workplaces to see and discuss work processes and technology – again time-consuming, but potentially revealing.

In some, particularly traditional, industries, workers and business owners may not be very aware of emerging developments, and the methods used for the assessment will need to take this into account.

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# 3. Learning needs and learner context

As discussed in the previous section, it is likely to be easier to assess learning needs at the same time as the impact of new technology. Technology can create learning needs that relate to:

- using and working with the technology
- using the technology to carry out particular tasks
- new or changed tasks
- adapting to new responsibilities and ways of working.

The technology may also make some existing skills redundant, but for a VET programme (rather than company-specific training), caution is needed before taking them off the curriculum.

In order to design a successful programme some additional context is also needed. This can include:

- the level of proficiency that is needed – a tool such as the Dreyfus novice-to-expert model can be useful here
- the context(s) that learners will be in – e.g. full-time student, apprentice/dual, full-time worker
- learners' existing familiarity with different types of technology, and their levels of digital literacy
- any potential barriers to learning – particularly important for workers who have had little recent training and do relatively unchanging, repetitive work
- where relevant, the range of work environments learners are in, how jobs are organised, the learning opportunities that they provide, and the technology that is actually being used.

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# 4. Developing formal content

The next step from examining learning needs and learner context is to develop the content for the programme or training specification.  This will typically include:

- the overall aim – geared to what learners will be able to do at the end
- who it is intended for, including any assumptions about starting-points
- the objectives to be achieved by learners
- a rough length, and if relevant how it is split between for instance classroom learning, independent study and workplace.

Formal VET programmes are also likely to need:

- a statement of where the course, module or programme fits in relation to existing training and qualifications in the same field
- a level in the national qualifications system and the European Qualifications Framework
- a measure of time or credit
- details of how learning will be assessed.

Sometimes the introduction of new technology in the workplace will raise the level of training needed, so don't be surprised if new or revised courses or modules are at a higher level than the existing programme.

A useful tool to help locate technology-related skills in a wider framework is DigComp 2.1.  This can help with writing learning objectives, identifying the level of technology-related skills, and identifying digital skills that may have been overlooked in the learning needs analysis.

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## 5. Evaluating technology for teaching and learning

Start from considering how technology can support and enhance the teaching and learning process – rather than from the perspective of how the technology works (though it is important to understand that as well). Starting with the technology can mean that training becomes altered to work with it, not necessarily for the better.

A simple model for assessing technology is:

- **Cost** – is it cost-effective compared with existing methods?
- **Learners** – is it accessible and appropriate for the target group?
- **Applicability** – can it provide an effective and engaging way of enabling the required learning goals to be met?
- **Industry relevance** – how does it fit with industry practice?
- **Resilience** – how quickly will it go out-of-date?

Cost needs to be balanced against what the technology is achieving: if it simply substitutes for current methods, a direct comparison can be made, but well-selected and designed technology-based education and training can be used to transform learning processes and achieve more effective results.

New technology normally benefits from **trialling** before committing to introduce it. This typically means developing an application with a pilot group who can evaluate it, refining it, then trialling with a group of real learners.

Digi4VET focuses on three types of technology:

**Virtual reality (VR)** – providing a simulated environment, with wide application in teaching and learning including:

- visualisation – effectively, enhanced video
- scenario or game-based learning – ideal for familiarisation and decision-making
- skill-based training – typically for manual and operator skills, including highly complex ones.

**Augmented and mixed reality (AR)** – where information or representations are superimposed on base reality. Uses have mainly been operational, but AR is now increasingly being used in training, from providing simple instructions in real time to superimposing complex representations and models that aid learning. AR equipment is generally more expensive than that for VR, but the cost of AR glasses is gradually falling, and phone/tablet or laptop-based AR can be very accessible.

**3-dimensional printing (3DP)** – any method of producing an object (from a small model or component to part of a prefabricated building) directly from digital instructions. Again uses have mainly been operational, but 3DP is increasingly being used for design education and to produce instructional models.

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# 6. Developing the teaching and learning process

Incorporating new technology requires particular attention to pedagogic principles, as it is easy to allow the technology to lead the process – sometimes at the expense of learners and learning goals.  For instance, traditional computer-based training can be allowed to impose too much structure, while internet-based technology is easy to use in a way that assumes a high level of engagement, self-direction and information literacy.

Some things to think about include:

**Preliminaries**

Be clear about:

- The characteristics of the learners and how this will affect their use of the technology.
- The goal and objectives of the learning, including the level of proficiency to be achieved.
- How much the design (or the teacher/trainer) controls both the content and the learning process, v. how much these are decided by the learner (and whether this needs to change as the learner's level of understanding and proficiency increases).
- Where the technology fits in the process – whether for instance it sits in the background as a teaching/learning tool, or needs to be fully understood by the learner because they will be using it as a work tool.

**Learning design**

- Be clear about what the technology can do, and how this can be exploited for an effective learning design.
- Develop a sequence of activities that enable learners achieve the learning objectives – moving from simple concepts or skills to complexity, and from beginner to more proficient.
- Make sure the level of challenge and complexity is appropriate and maintains 'flow' – keeping learners' attention without baffling them – perhaps increasing as learners become more proficient.
- A flow diagram, written from the perspective of the learner, is a good aid to developing an effective design.

**Guidance and feedback**

- Provide enough guidance to stop learners from floundering, but also allow them to figure things out for themselves. This often means adapting the level of guidance to how they are coping – this can sometimes be built into the application.
- Distinguish feedback to support 'reflection-in-action', i.e. to modify actions during the learning process, from 'reflection-on-action', i.e. post-activity discussion or 'take a break' review.
- VR and AR technology can record actions and provide an opportunity to review afterwards.  This can sometimes also be used to contribute to formal assessment.

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# 7. Evaluation

The purpose of evaluation is to answer the questions 'how effective is this, and what is the value of doing it?'. Comparative evaluation also compares the effectiveness of one approach or training design with another (e.g. 'traditional' and technology-mediated).

**Basics**

A four-stage evaluation model is fairly widely used in vocational and commercial training. This looks at:

- Feedback – learners' comments on the training (typically uses evaluation forms)
- Learning – increase in knowledge, skills etc. (observation, assessment)
- Application – change in practice in the workplace (feedback, assessment/evidence of practice)
- Impact – effect on the learner's organisation (quality, sales, productivity etc.).

The last stage can be difficult to do in a VET context.

**Comparative evaluation**

This can compare between two or more parallel groups (e.g. one using AR and a 'control' group with existing training methods), or 'before and after' programmes.

- Parallel groups make it easier to get comparable data.
- The groups should be set up so that the only significant difference is the use of technology, and obvious sources of bias are eliminated (e.g. not allowing all the tech-enthusiast learners to be in the new technology group).
- Objective comparison is strengthened if a 'blind' assessment can be included – e.g. by someone who hasn't taught the learners and doesn't know which groups they are in.

Previous studies have generally found significant learning benefits from technologies such as AR and VR, as well as some drawbacks and limitations.

**Methods and analysis**

A comparative evaluation of skills-oriented training is likely to use:

- Short evaluation forms, with carefully-constructed questions and a response scale, plus a space for free text comments
- Observation of learner activity, e.g. number of questions asked, number of errors, speed to complete tasks
- Assessment, e.g. level of proficiency reached, possibly both immediate and longer-term.
- Workplace feedback if feasible, e.g. work-based assessment or a supervisor feedback form.

Quantitative information makes comparison more accurate and it can be analysed statistically and represented graphically. Qualitative information is less useful for comparison, but it can be at least as helpful for improving the quality of training.

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## 8. Trainer training

Introducing new technology in a VET or workplace training context often creates training needs for teachers and trainers.

This can involve:

- Understanding and using the technology. This includes being able to apply it productively, to recognise when it can assist or obstruct achieving a learning goal, and keeping up-to-date with changes.
- Understanding how the technology can be used in the relevant field, both for work tasks and for teaching particular content.
- Understanding how the technology can be used for effective teaching and learning, and how teaching and learning can change – or need to be approached differently – when the technology is used.
- Pulling this knowledge together to be able to teach specific content, using the technology appropriately and effectively.

The 'TPACK' model covers each of these areas and shows how the existing knowledge and skills of teachers and trainers needs to be added to when introducing new technology.

There are also several standards or competence models for trainers and educators, including:

- DigComp Edu – a European model based on DigComp 2.1.
- The Digital Teaching Professional Framework, a British adaptation of DigComp Edu specifically for VET.
- The DiMBA framework, developed in a project in Germany.

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# 1. Defining the occupation

The first stage for considering both the impact of new technology on an occupation and the scope for using it as an aid to learning is to establish a good working definition of the occupation itself. In most cases this will already exist in the form of an existing VET specification, an occupational profile, or the standards set by an industry or professional body. If these are available and are reasonably up-to-date there is no need to duplicate them, although they may need summarising for use in the next step of assessing the impact of technology (the examples in boxes 1-4 are likely to be about the right length and level of detail).

One useful source of information is ESCO[1], the European standard classification of occupations. ESCO provides summary descriptions of a wide range of occupations, although it may not offer the best description for use in every context and some emerging occupations don't feature on ESCO.

Otherwise, the first step is to put together a working description of the occupation. There are several detailed guides available for doing this, including:

- The ComProCom (Communicating Professional Competence) manual (2017), at http://www.comprocom.eu/products/43-methodological-manual (DE, EN, GR & PL) or http://devmts.org.uk/methodologicalguide.pdf (EN); see Figure 2 overleaf.

- Becker & Spöttl's occupational science research approach (Berufswissenschaftliche Forschung), available in book form published by Peter Lang (2008/2015); there is a summary at http://www.forschungsnetzwerk.at/downloadpub/BerufswissenschaftlicheForschung%20_becker2008.pdf (both DE).

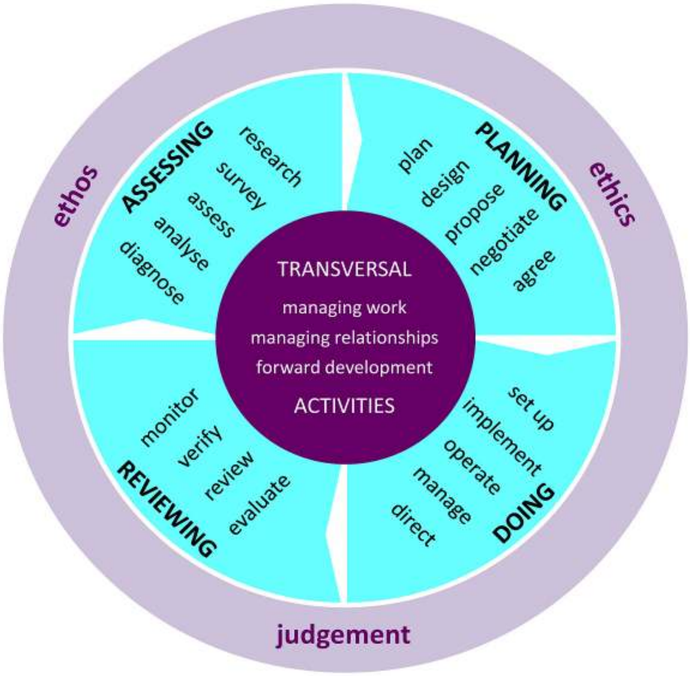
- Mansfield & Schmidt's manual on VET standards, from the European Training Foundation (2001). This is now out of print but it can be downloaded from https://eric.ed.gov/?id=ED457320 (EN). This approach was in the past advocated by the European Training Foundation, but the methodology discussed in the ComProCom manual is more up-to-date.

The methods and the respective outcomes that are described are each slightly different; ComProCom for instance focuses on work activities, while Becker & Spöttl's approach is more geared to developing a specification of knowledge and skills. For the purposes of the process used here, the exact method used is less important than having a description that is easily understood in industry.

To implement any of these approaches thoroughly is a major task. However, unless you need to develop a comprehensive definition and set of training standards for an occupation (e.g. because it is an emerging field that doesn't have VET or professional standards, or the existing definition is out-of-date), it should only be necessary to produce a summary of what someone in the occupation needs to be able to do, as in boxes 1-4.

[1] https://ec.europa.eu/esco/portal/occupation

*Figure 2. The ComProCom model for describing an area of work.*




A note: Many occupational descriptions are '**technology-neutral**', that is they don't describe specific technologies (or even processes) for achieving the work of the occupation. This is not a problem at this stage, and because it doesn't include assumptions that can go out-of-date quickly it can actually be a benefit when assessing the impact of emerging technology.

Box 1: **Example of an outline occupational description**

## Heritage conservation technician

A conservation technician usually works under the overall direction of a conservator to carry out basic conservation tasks and undertake installation and similar activities to support conservation work. A conservation technician is involved in:

**Conservation activities** such as

- cleaning, treating and repairing objects
- monitoring the condition of objects and the environment that they are in
- monitoring equipment and setting and adjusting environmental controls
- installing and maintaining protective measures and structures.

**Measures to support conservation** such as

- making physical, photographic or digital representations of objects
- packing, transporting and unpacking objects
- making and setting up protective components, installations and displays
- keeping environmental and conservation records
- responding to emergencies to prevent or minimise damage.

**Management and development activities** such as

- organising and managing own work, and that of assistants and trainees where applicable
- working effectively with colleagues, clients and the public
- maintaining own knowledge and level of competence
- explaining conservation and technical processes to colleagues, trainees and the public.

The training for this occupation can be at EQF levels 4 or 5, depending on the complexity of the work to be undertaken.

Box 2: **Example of an outline occupational description**

## Chemical operator

Chemical operators work in the chemical industry, e.g. in a manufacturing or processing plant, normally under the supervision of a qualified specialist (*Chemiemeister* or similar). The training for the role is at EQF level 4.

**Main fields of work**

- machine operation
- machine maintenance and cleaning
- repairing machines
- quality control.

**Main tasks**

- operation of production machinery in the chemical industry
- set-up of equipment and machinery
- testing and measuring the products
- quality control
- maintaining, cleaning and repairing machinery and equipment.

Chemical operators will typically be involved in responsible care, measurement and control, predictive maintenance, optimization of synthesis processes, mechanical operations (e.g. drying, extraction), working in virtual teams, use of digital media (AR, VR), etc.

Box 3: **Example of an outline occupational description**

## Floristry – Qualified skilled worker at EQF level 4

The manager/entrepreneur or the specialist in floristry can work in the flower retail business, in a garden centre or in interior planting. S/he also can work alongside other activities engaged in shaping, decorating and styling with living, fragile material.

The job requires professional independent skills including taking responsibility for tactical and strategic actions, and devising new procedures.

**The most important duties of a florist manager are:**

Core task 1: Makes flower and plant arrangements
- 1.1 Puts together flower and plant arrangements
- 1.2 Calculates commercial price

Core task 2: Carries out retail activities
- 2.1 Prepares shop for opening
- 2.2 Takes care of the shop
- 2.3 Takes care of shop presentations
- 2.4 Takes care of products
- 2.5 Receives and processes products
- 2.6 Monitors stock
- 2.7 Determines the range of products
- 2.8 Purchases stock
- 2.9 Draws up maintenance and presentation plans

Core task 3: Retails and provides service
- 3.1 Receives and approaches customers
- 3.2 Carries out sales talk
- 3.3 Takes orders
- 3.4 Indicates and handles complaints
- 3.5 Conclude the sale

Core task 4: Organises and supervises activities
- 4.1 Plans and divides the tasks
- 4.2 Technically supervises staff
- 4.3 Directs staff

Core task 5: Undertakes business activities
- 5.1 Determines location of business
- 5.2 Examines business plan
- 5.3 Draws up marketing plan
- 5.4 Innovates the business
- 5.5 Takes care of financial administration
- 5.6 Analyses the financial situation
- 5.7 Determines staffing requirement
- 5.8 Determines policy regarding quality, safety, the environment, and working conditions
- 5.9 Raises profile of and promotes the business
- 5.10 Determines retail price.

Box 4: **Example of an outline occupational description**

## Painter/decorator

Painters are involved in finishing works on construction of new buildings, in existing buildings, and in some cases in renovation and restoration. The job requires a good visual knowledge of what the result should be, and good hand skills.

Main tasks:

- set up a safe working place
- selecting the right products and materials
- set-up of equipment and machinery needed for the job
- painting walls and ceilings
- wall papering
- quality control.

Main areas of work include:

- Outside and inside buildings
- Painting walls and ceilings
- Wall papering
- Floorcoverings.

# 2. Assessing the impact of technology on the job

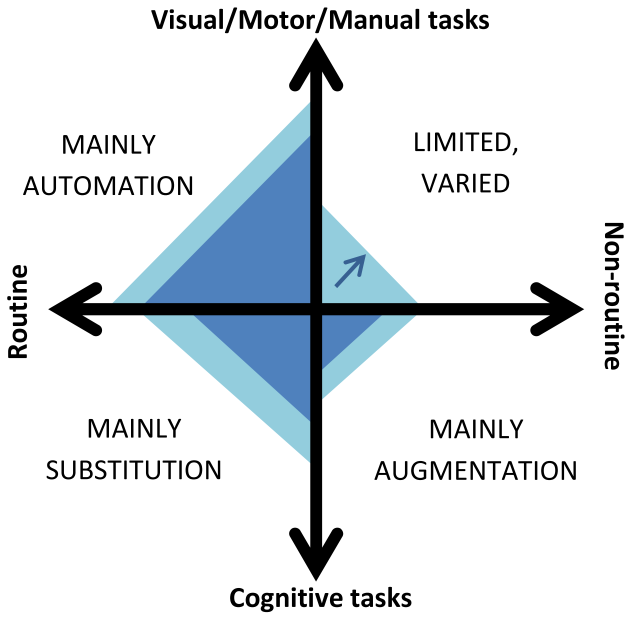
The second step is to carry out an assessment of how new and emerging technology is affecting, or is likely to affect, the occupation or job.

## 2.1 The impact of technology on jobs

A widely-used model developed in the early 2000s by Autor and colleagues[2] identifies that technology can have three types of impact on work:

- **Automation**: the task is carried out by a machine or by software (e.g. production line assembly)
- **Substitution**: a change of technology makes the task no longer necessary (e.g. copy typing, switchboard operator)
- **Augmentation** (or complementarity): the task is enhanced, made easier or more efficient by technology (e.g. design, medical diagnosis, documentary research, photo editing …).

*Figure 3. The impact of technology on different types of job: after Autor et al (2003).*




In the original research it was thought that only routine, codifiable jobs would be susceptible to automation and substitution, but more recent developments have indicated that advancing technology can automate some non-routine manual tasks (e.g. driving) as well as at least partly some complex cognitive ones (e.g. medical diagnosis and legal drafting)[3]. Limits to technological substitution appear

[2] Autor, Levy & Murnane (2003). This model has been used quite widely in predictions of the effect of technology on jobs.

[3] One of the best-known studies is that of Frey & Osborne (2013), which looks at whole jobs and predicts that nearly half of jobs are under threat. Many studies carried out since are more fine-grained and look at tasks within jobs, predicting some substantial changes and skills needs but a much lower level of job losses, along with new jobs created by the technology itself and the possibilities it creates. On balance both upskilling and deskilling are predicted, continuing the trend of a 'hollowed-out middle' with less mid-skilled workers. Some examples include Arntz et al (2016), Hislop et al (2017), McKinsey (2017) and Fischer & Pöhler (2018).

to be present in areas involving creativity, contextual interpretation, social interaction, and ethical and moral considerations[4].

To the above can be added[5]:

- **Creation**: new tasks are created, either relating to the technology itself (e.g. programming, web design), or because tasks can be done that were previously not possible or cost-effective (e.g. exhaust emissions testing, MRI scanning, collecting and analysing mass data).

- **Job transformation**: the tasks within a job change enough to create new responsibilities and patterns of working, either as a direct result of changes above, or because less time is spent on the 'original' job and the role is expanded to take on additional tasks.

## 2.2 Assessing the impact of technology

Things to take into account include:

**Starting-point**. The assessment needs to start from the lowest common denominator for the occupation concerned. For instance, most office jobs can assume at least basic computer and internet use, but some manual and personal service work may currently make little use of digital technology so even the introduction of basic computerised systems or mobile technology can have an impact.

**Timescale**. Depending on the industry or profession, the rate of technological change, and the scope to update courses regularly, VET developments will be looking a year, two years, maybe five years ahead, possibly with an eye on the next ten years.

**Differences in the pace of adoption**. In most industries and professions there will be a mix of innovators, pacesetters, followers, and slow adopters in relation to new technologies. The assessment needs to take into account what the most advanced firms and workers are doing, as well as the lowest common denominator for the industry.

## 2.3 Methods

Methods for assessment can include documentary review; surveys and interviews; and workplace research. The second two of these can also be used for assessing learning needs, so unless a large-scale, formal exercise is being undertaken it is more efficient to do the two things together.

**Documentary review** can be useful to get an overview of developments and issues in the industry or profession, and possibly identify some specific pointers where there are changes and learning needs. However, it is likely to produce uneven and possibly out-of-date information, and on its own it will be unreliable.

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[4] See for instance Nokelainen et al (2018), who have adapted Autor et al's model to reflect this.
[5] e.g. Autor (2015), Hislop et al (2017), Frontier Economics (2018).

- 'Documents' may include a few academic papers and research reports, but also look for information produced by industry bodies, blog posts, online discussion groups, and articles in trade or professional web sites and journals. These may be less systematic but more up-to-date.

**Surveys, interviews and similar methods** can be the most effective means of getting an even picture of trends, issues and needs in the industry or profession. A combination of methods often works best, in particular combining a small-scale, in-depth qualitative approach with a larger-scale survey.

- Expert panels or focus groups are useful for setting the scene and providing a qualitative picture of current and emerging changes. They can also be used to help make sense of survey responses. Select experts for their current knowledge and insights, and to give a range of perspectives from across the industry or profession; this might include different roles, sizes of organisation, and sub-sectors of the industry. Panels can be face-to-face, synchronous online, or asynchronous. A Delphi approach[6], often done by email, is useful to ensure that each participant's views are heard and 'groupthink' is avoided, but it is less good for exchanging views and building on ideas.

- Questionnaire surveys aim to capture a larger number and range of responses, and can be useful for getting to people across the industry. Careful crafting and structuring of questions is needed to ensure that survey results are useful, to encourage potential respondents to fill them in (length is also a factor here), and to aid analysis. Tick-box responses will not provide enough information unless you just want to test out an existing analysis (e.g. by an expert group), so open questions with room for free-text answers are normally needed. Consider who the target respondents are, and how to get representation from across the industry or profession (e.g. different roles, length of experience, types and sizes of firm, subsector, perhaps geographical spread). Is an online survey likely to be more effective, or will it exclude a significant number of potential respondents? Don't expect large response rates (5% or less is not unusual) unless potential respondents have a strong interest in the topic of the survey, or they are a 'tame' audience such as association members or former students. Consider how to increase response rates, such as alerting potential respondents beforehand; setting a short but realistic deadline; sending out a reminder with a short extension; and keeping the questionnaire short and relevant. An alternative to a questionnaire survey is to use structured interviews, asking the same questions verbally.

- Qualitative interviews can provide a deeper level of information and be more revealing, but they are time-consuming and require good research interview skills. A small number of interviews can be used to explore matters that have been identified in a survey or by an expert group in more depth. Consider who will make good informants, and select from a cross-section of the profession or industry without aiming to be statistically representative. Some structure is needed to keep the interview in focus, but there should also be room for participants to discuss the things they see as most important. Consider how to record the interview: audio recordings are least distracting but are very time-consuming to analyse, so a written record – possibly pre-organised around key topics – is often preferred.

[6] A guide is provided by Linstone & Turoff (1975): http://www.is.njit.edu/pubs/delphibook/

Appendix A has a set of points that can be used as the basis both for survey questions and for prompts for group discussions and interviews.

**Workplace research** involves visiting the workplace and typically examining the technology that is in use, interviewing workers and possibly their managers, and depending on the type of job observing tasks being carried out (which can be both using the technology and where there is scope for its introduction). It can provide better insights into how technology is actually used than survey and interview methods, along with direct evidence of training needs. Depending on how many workplaces are included it may not provide a representative coverage, and it is likely to focus on the present and the immediate future.

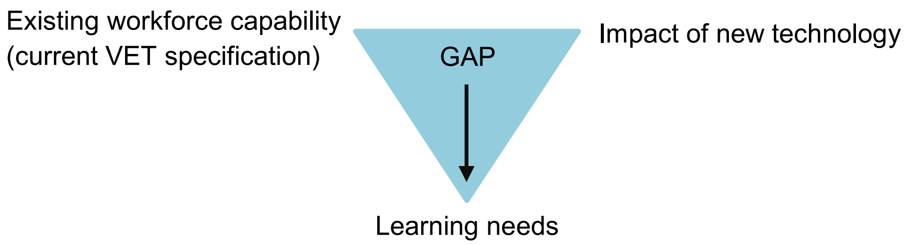
- As with interviewing, workplace research is time-consuming. Consider how to include a cross-section of working environments, and make sure that the people, equipment and activities will be available at the time of the visit. Workplace visits are usually best conducted by someone with good insight into the jobs being observed and discussed.

**Finally**, in some occupations, particularly those made up of small, traditional firms, many people working in the industry may be unaware of recent technological developments that could help them or that they may need to respond to in the near future. In this type of situation, one-to-one and group discussions are likely to produce better results than a simple survey-type approach.

# 3. Learning needs and learner context

## 3.1 Learning needs

Learning needs typically arise when the demands of a job require knowledge, skills and approaches that are lacking in (some of) the existing workforce, or in new entrants. As indicated in the previous section, new technology can give rise to learning needs relating to changing tasks, new tasks (related to the technology itself or to job redefinition), and to differences in the way jobs are organised (for instance leading to more autonomy, decision-making and self-management). At the level of a whole occupation this can be represented as:




Formal learning needs are not exactly the same as task changes, as some changes can be responded to quickly within the workplace. One useful way of grouping learning needs is to consider abilities needed to:

- Use, learn and work with new technology
- Use the technology to carry out specific tasks
- Carry out new tasks that have been created as a result of the technology (this could be for instance to move from an ‘operating’ role to one concerned with setting-up and quality assurance)
- Adapt to new ways of working (for instance the need to be more self-organising and take responsibility for day-to-day work, or where the role has broadened due to less time being spent on routine tasks). There are some fairly common trends here (so-called ‘21st-century skills’), but caution is needed in assuming that a generic set of skills are appropriate across occupations and contexts.

Learning needs can be assessed at the same time as looking at the impact of technology on work, i.e. using the same expert groups or questionnaire survey. This is included in the prompts in Appendix A.

## 3.2 Skill redundancy

Assessment of the impact of technology can also point to areas where existing skills are no longer needed, for instance moving from manual to CNC lathe operation. The implications of this do however need to be treated with caution, particularly if it is intended to remove particular skills from a vocational programme. Questions include:

- Will workers be able to cope with emergencies and contingencies if they lose the relevant manual skills, insights into processes, and tacit knowledge? This can have expensive or even disastrous consequences in case of breakdown or hacking[7].
- Does changing the programme limit bespoke applications or future developments? For instance revivals in hand-made furniture and craft beer made it necessary to reintroduce skills that had dropped out of the mainstream vocational curriculum.

### 3.3 Level of proficiency

An aspect that is not always given enough attention in relation to both learning needs and training design is the level of proficiency, both of learners currently and the level that needs to be achieved through training. This is very relevant later on for training design and the selection of relevant technology.

A well-tested scale for levels of proficiency is the Dreyfus skills acquisition model[8]. This uses five levels, as below. These relate to increasing proficiency within a given task, area of skill, or set of activities, rather than to the complexity of the task itself: so it is possible for instance to progress from novice to expert in a relatively straightforward task (as might be associated with EQF level 3) or a highly complex one (say level 7). The model needs to be used realistically: for instance for broad and fairly complex tasks, the 'expert' level is likely to need several years of varied practice.

'Fully qualified' level is typically competent or proficient, depending on how critical the work is or whether the person is going into employment with some oversight available, or being licensed to practise independently. The 'expert' stage is sometimes thought of as a final level of achievement, but 'experts' still need to keep their knowledge up-to-date, adapt to new ways of doing things, and unlearn practices that are no longer helpful.

Box 5. **A summary of the five stages in the Dreyfus skills acquisition model**

***Novice*** Has an incomplete understanding, approaches tasks mechanistically and needs supervision to complete them.

***Advanced Beginner*** Has a working understanding, tends to see actions as a series of steps, can complete simpler tasks without supervision.

***Competent*** Has a good working and background understanding, sees actions at least partly in context, able to complete work independently to a standard that is acceptable though it may lack refinement.

***Proficient*** Has a deep understanding, sees actions holistically, can achieve a high standard routinely.

***Expert*** Has an authoritative or deep holistic understanding, deals with routine matters intuitively, able to go beyond existing interpretations, achieves excellence with ease.

[7] Billett (2018) provides a good example of this.
[8] Dreyfus & Dreyfus (1986). Examples are also provided at http://devmts.org.uk/dreyfus.pdf

## 3.4 Learners' starting-points and contexts

Before developing a course or training programme, it is also essential to consider who it is for. Some key factors to take into account are:

- Level of experience and proficiency in the relevant **operational** activities. There is a large difference for instance in training an experienced designer to use a CAD package, compared with training a novice to design through CAD; or using virtual reality to help an experienced manager to refine their recruitment interviewing technique (and perhaps overcome poor practice), compared with training a new or prospective manager in interviewing. The way that the technology is used as a training tool may need to be quite different between the two scenarios.

- Learning context. Even if a 'novice' starting-point is assumed, a vocational training programme needs to be constructed differently depending on whether the learner is in full-time work, on a 'dual' (on and off job) programme, or a full-time student. This also has an impact on the level of proficiency that can be achieved and in some cases the type of technology that is appropriate for training. As an example, augmented reality may be a good option for use in the workplace but less so in the classroom, where virtual reality might work better.

- Familiarity with technology. Individual learners will differ in their exposure to different kinds of technology. With experienced workers, a good starting-point is not to assume digital literacy beyond what is already required in the job. On the other hand, research suggests that the common assumption that digital technology is a young person's medium isn't necessarily right: in one study workers in the 30-50 age range were more adept at using technology for information search and learning than their younger counterparts, and another found that while young learners were very comfortable with digital media, their information and media literacy was generally poor[9].

- Capability as a learner. Various factors influence how easy people find it to learn new concepts and skills. Positive achievement at school, recent significant learning activity, and a work environment that involves exposure to new ideas and concepts, or requires frequent updating, favour effective learning. Workers who haven't been involved in any significant learning activity for a long time and do stable, routine jobs may find it more difficult to learn new things quickly.

- Work context. The 'same' job in different organisations can be organised differently, have different responsibilities, allow different degrees of discretion for self-directedness and learning, and have different levels of exposure to technology. In some industries some organisations will be innovators and early users of technology, while others will be slow adopters.

- Time availability. Particularly for learners in work, finding time away from operational activities (and domestic responsibilities) can be a problem. Assumptions that this can be overcome by e-learning have proven overoptimistic. More potential is indicated where learning is integrated with work tasks, provided that this is done properly with an appropriate level of guidance and support.

[9] Härtel et al (2018).

# 4. Developing formal content

## 4.1 Developing formal content

Building from learning needs to formal content typically needs training to be specified in a predefined style to form a package, module or course.

This will typically include:

- The overall aim of the course or module, geared to what learners will be able to do at the end.
- A description of whom the course or module is intended for, including any entry requirements or expectations for previous learning (for instance is it part of an initial training programme, or a one-off course for updating or advanced practice?; and if it is part of a larger course, are there any modules that need to be taken first, or alongside it?).
- The objectives that learners will need to achieve for successful completion, sometimes with associated assessment criteria. Learning objectives (or outcomes) are central to effective learning design, and as discussed in section 6 they are important to ensure that technology is used effectively to aid learning. There is plenty of literature on writing learning objectives, from straightforward guides to research papers and comparative studies[10].
- In formal VET systems, a level in the national qualifications system (and equivalent in the European Qualifications Framework[11]), and a measure of volume (normally time or credits[12]).
- Where the module fits in terms of existing programmes or qualifications, if relevant.

In some VET or professional development systems this 'content-only' specification is all that is needed to specify a module. Technology tends to be referred to only if it is part of the content, for instance the aim is to be able to use a particular software package or to use augmented reality equipment in carrying out a task.

Other systems need more about the teaching and learning process, including things such as:

- Teaching and learning methods, sometimes including the proportion of time spent on different activities, or sample training plans
- Any requirements for using technology as a learning tool
- Assessment methods, including sometimes assessment plans or marking schedules.

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[10] 'Objectives' and 'outcomes' are often used interchangeably in VET, while industry training tends to refer to 'objectives'; strictly speaking an objective is what it is intended that the learner should achieve, an outcome is what is actually achieved. For (quite detailed) practical guidance, see CEDEFOP (2017), http://www.cedefop.europa.eu/files/4156_en.pdf, and for a comparative European study see CEDEFOP (2010), https://www.cedefop.europa.eu/files/5506_en.pdf.

[11] The EQF is a common system of levels for qualifications across Europe: there is a formal system for referencing national qualification levels to it, but it can also be used informally as a tool for positioning qualifications or modules. The full document is here http://ecompetences.eu/wp-content/uploads/2013/11/EQF_broch_2008_en.pdf, with an updated table of levels here https://ec.europa.eu/ploteus/en/content/descriptors-page.

[12] See ECVET, http://www.ecvet-toolkit.eu/

This second part will draw on matters discussed in sections 5 on technology and 6 on teaching and learning.

## 4.2 Using DigComp 2.1

The European framework DigComp 2.1[13] provides a means of referencing technology-related skills against a framework that links into most VET systems. The framework has 21 areas, grouped under five fields, with each area described at eight levels (corresponding roughly to the levels in the European Qualifications Framework). The framework can be used in a number of ways, including:

- Helping to write objectives for technology-related learning. This doesn't mean copying the DigComp statements as they are, but using them to reflect the right level of learning.

- Helping to identify the level that new skills are at. In some occupations new technology is driving up the level of skill needed. For instance, in an area where the 'base' training level is EQF level 4, introducing new technology may start requiring skills some of which are at level 5.

- Identifying digital skills that are needed, but are often missed out from a skills or learning needs analysis. This can include important things such as data protection, privacy, health and safety, and managing online identity.

## 4.3 Generic skills

The idea of generic skills for learning and working in the current century or 'digital age' is becoming increasingly common. A tool such as the 'Framework for 21st Century Learning'[14] can be useful in the context of designing whole VET programmes, but like the DigComp framework it can also identify skills that are essential to being able to learn or operate effectively with new technology.

To give two examples:

- 'Open-content' e-learning, where learners use the internet as a source of information and for research, requires considerably more advanced information and media literacy skills than e-learning where content is under the control of the tutor or is curated as part of a package[15].

- In the workplace, some types of technology present workers with a wider range of options to choose from and more responsibility for how to carry out tasks. This requires judgement and decision-making skills that may not have previously been part of the job.

On the other hand, there are studies that indicate that these types of skill are often less generic or transferrable than commonly thought: they need to be related into the relevant context to be effective, and what seems to be the same skill or area of competence can be quite different between one profession, industry or context and another.

[13] Carretero Gomez et al (2017) *The Digital Competence Framework for Citizens*, http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106281/web-digcomp2.1pdf_(online).pdf
[14] Partnership for 21st Century Learning (2015), see http://www.p21.org/about-us/p21-framework
[15] This links back to 'Familiarity with technology' in section 2.4.

# 5. Evaluating technology for teaching and learning

There is plenty of experience and research available about how technology has been adopted, used (and misused) in teaching and learning. This section starts with some general points to consider when introducing new technologies, and a new model for evaluating technology for use in VET. It then looks in more detail at the three specific technologies that Digi4VET focuses on.

## 5.1 Some issues in introducing technology

- A consistent problem across the introduction of ICT in learning (e.g. computer-based training, interactive videos, e-learning platforms, gamification) has been letting the technology drive the process[16]. The results can be a tendency to over-structure learning processes; to emphasise social and fun elements while losing sight of learning outcomes; or (particularly with more recent technology) to assume learners are always motivated and self-directed, or presume higher levels of information literacy and research skills than the students actually have. This is often more a problem with how learning activities are designed rather that with the technology itself, but it is also relevant to assessing what technology is most effective at supporting specified learning goals. There is more on this in section 6.

- Related to the above point, the release of new technology can drive uptake, regardless of how useful it is. This is often linked to the desire to introduce the latest devices or software, or fear of being left behind, and suggests the need for trialling before adopting wholesale.

- A different limitation is where teachers and trainers use new technology without redesigning their teaching methods to make best use of it, e.g. just repackaging lectures into videos or notes that are downloaded online[17]. This illustrates that it is not sufficient just to introduce the technology, without introducing the training and support to use it.

- Technology may be adopted before its effectiveness and return on investment have been properly assessed, both in terms of initial costs and the development of content. This can leave state-of-the-art equipment poorly used because it doesn't meet trainers' expectations, trainers themselves don't have the time or training to use it properly, or the cost of developing content is too prohibitive[18].

- As more complex technology is adopted in the workplace, this requires higher levels of learning and similarly complex technology for teaching and training[19]. Failure to keep up can create a large technological skills gap between finishing VET and starting work.

- On the other hand, the uptake of technology can vary across different firms within the same industry, and assuming use of the most advanced technology can also create skills gaps when trainees and students have to work with older systems in the workplace. Technology gaps of this

[16] e.g. Piskurich & Sanders (1998), Bedwell & Salas (2010), Brennan (2015), Ang et al (2018).
[17] See Cochrane et al (2014).
[18] Bell et al (2008), Green (2017).
[19] Hamalainen et al (2018).

type are most likely to occur in industries where there is a mix of large and small organisations, or different approaches to production or service provision[20].

## 5.2 Evaluating technology for use in VET

The following is a simple model for assessing technology for use in VET and workplace training. It has five aspects: cost, learners, applicability, industry relevance, and resilience (CLAIR). The model builds on and simplifies Bates' 'ACTIONS' framework for applying technology[21].

**Cost**. Are the initial investment and ongoing costs (e.g. updating software, licence fee, content development and updating, user training) justifiable in terms of what will be achieved? The cost equation is continually changing: for instance while virtual reality was out of reach for many applications a decade ago, it can now provide considerable savings over conventional training, and augmented reality is becoming more accessible as well.

**Learners**. Is the technology accessible to learners? Is it likely to be sufficiently engaging and interactive? What does it assume about existing knowledge, abilities, device familiarity or connectivity – and if there are barriers, can these be overcome? Are any non-technological skills being assumed – for instance the ability to research and evaluate information effectively?

**Applicability**. How effective is the technology for enabling the relevant learning goals to be met? This includes content, skills development, task-relevance, pace and control of learning, facilitation and guidance, feedback and evaluation, and if relevant assessment – i.e. everything covered in the teaching and learning section. The SAMR model, examined in the teaching and learning section, may also be relevant here, as it helps identify where technology is simply providing a different way of doing the same thing, and where it enhances the learning process and makes new things possible.

**Industry relevance**. How does the technology fit with current and emergent practice in the industry? This is particularly critical when the objective is to train people in use of current and new equipment and systems, or to simulate live situations accurately.

**Resilience**. Can the technology be updated and new content easily developed? How quickly is it likely to be superseded, and how does this affect its cost-effectiveness? Is it the industry standard, and which way is the industry moving?

## 5.3 Trialling new technology

The process below is a more general version of one developed by Pantelidis[22] for trialling and developing simulations and virtual reality in education and training. The aim is to first ensure that the technology is the most suitable for supporting the relevant learning, and to develop a well-tested learning environment.

1. Define the learning objectives.

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[20] Lehner & Sundby (2018).
[21] Bates (2005).
[22] Pantelidis (2009).

2. Select objectives that can be supported by technology-based learning.
3. For each objective or learning activity, determine what the technology needs to do, e.g.
    - the level of realism
    - the type of immersion and presence
    - the type of interaction and sensory output
    - the type of feedback.
4. Select the software and hardware most capable of fulfilling these needs.
5. Develop the learning environment.
6. Evaluate the environment with a pilot group (not a 'live' learning situation), modifying it until satisfactory.
7. Evaluate the environment with the client group, modifying it until satisfactory.

There is more about comparative evaluation – e.g. for comparing existing training methods and technology-mediated ones – in section 7.

## 5.4 Specific technologies

Digi4VET focuses on three specific technologies, although the principles discussed are applicable to other emerging technologies. These are all well-established, but in the past their costs have limited their application – for instance virtual reality is widely used for training pilots, surgeons and the military, but reducing costs mean that it is now well within reach for craft and trade applications.

Virtual reality is currently mainly a training tool, although it has a few industry applications; augmented reality has both industry and training applications; while 3-D printing is mainly a practical tool, with a few applications that are geared specifically to training.

### **Virtual reality** (VR)

VR involves the simulation of an environment that may be an accurate representation of a real-life situation (e.g. an aircraft cockpit or part of the human body), a generic representation (e.g. a construction site or a social environment), or an artificial world (e.g. for game- or scenario-based learning). What makes it particularly exciting is that learners are able to experience things directly that they would normally learn about by instruction or reading, or they can practise skills more extensively and in-depth (and safely) than in real life.

VR can be two-dimensional (on a screen), three-dimensional (e.g. using VR glasses or an enclosed space such as a flight simulator), or in addition involve sensory perception other than sight and sound. VR experience can be purely individual (all 'objects' encountered are presented by the software), interactive through the VR environment (as in multi-player games), and/or interactive in the real world (as with a pilot/co-pilot in a flight simulator). VR can attempt to reproduce the real world as accurately as possible ('physical fidelity', for instance building a wall using representations of real bricks and mortar), or use representations that show the essential cognitive elements only ('cognitive fidelity', for instance a wiring diagram that shows how electricity flows through it in response to different actions). A feature of good VR environments is that they have a consistent logic for responding to actions by the learner, so that learning can take place (as in the real world) through seeing or experiencing the results. Evidence suggests that in general the more immersive and interactive the environment is, the more effective the learning; on the other hand the cost increases rapidly the more technically complex the VR environment becomes[23].

VR has been used for three main types of training application:

***Visualisation***. This uses 3-D video or virtual objects, actions, or phenomena (such as electricity, forces, or gases) for information and learning. Applications include:

- showing how designs would look when finished (e.g. a new colour scheme; a fashion, household or industrial product; a new building; an urban environment).
- bringing to life an invisible or intangible phenomenon (e.g. to show how electricity works; which components are live when a switch is in different positions; the stresses on a mechanical structure[24]).
- bringing an external environment into a classroom situation for instructional purposes[25]
- providing precise feedback on virtual or actual actions (e.g. manual dexterity; movement in sport, drama or dance[26]).

Visualisation may be the simplest use of VR (and does not require particularly sophisticated equipment), but it can still be a powerful learning tool by showing the effects of actions that can be difficult to see in any other way. It can allow students to experience (or revisit) environments that may be too difficult, expensive or time-consuming to visit directly; or make abstract concepts and two-dimensional representations come alive. Concepts can be experienced directly, helping learners to develop mental models for things that are non-tangible or counterintuitive. While other uses of VR tend to focus on skill development and application, visualisation can be used for teaching basic principles and concepts in a way that can be more involving and effective than traditional techniques[27].

***Scenarios and games***. For training purposes scenario-based or game-based VR can be used to develop straightforward awareness (e.g. safety hazards on a construction site[28]), develop skills and decision-making in more complex situations (e.g. sales, fundraising, project management[29]), or provide an immersive environment to train for demanding, high-stakes roles (e.g. military and rescue operations). There are some straightforward advantages from using VR here, including:

- the safety of working in a virtual environment
- ability to create scenarios that couldn't be engineered or predicted in reality
- giving learners more control than would be safe in real life
- allowing them to see the results of mistakes that could be catastrophic
- providing immediate feedback where appropriate

[23] See Gavish et al (2011), Gibbs, L. (2017), Kikkawa & Mavin (2018).
[24] Billett (2018)
[25] Several basic examples of this are illustrated by Maltby (2018), see https://www.teachingwithvirtualreality.com/
[26] Chan et al (2011)
[27] Pantelidis (2009), Billett (above)
[28] Sacks et al (2013)
[29] Goulding et al (2011)

- and recording actions for later discussion and feedback[30].

Well-designed VR scenarios appear to be at least as effective as traditional training methods, and more so for some aspects of learning[31].

***Operational skill development***. VR is fairly well-developed as a tool for teaching complex or critical manual and operator skills, including those involving substantial decision-making; these include surgery[32], dentistry[33] and welding[34], as well as one of the most well-established uses, pilot training[35]. Some of these applications require a sense of feel as well as sight (haptic VR), for instance using computer controls that simulate a welding torch and rod or a dental instrument and provide precise feedback from 'touching' the metals to be joined or probing for tooth decay. Advantages can be similar to those for scenario-based learning, and indications are that well-designed VR skills training reduces risk, is cheaper, and can result in more rapid mastery. For instance, many pilots now go directly from a flight simulator to acting as co-pilot on a passenger flight, and welders need less practice on real materials before reaching a proficient level.

Box 5. **VR headsets**

The following are some currently available VR headsets, from the most expensive models (500-1200€ in 2019) that link to a computer, to simple headsets for use with smartphones.

- HTC Vive Pro – connects to a PC, has positional tracking (Vive Cosmos new in 2019)
- Oculus Rift – connects to a PC, has positional tracking
- Oculus Quest – new in 2019, self-contained, has positional tracking
- Oculus Go – self-contained, no positional tracking
- Samsung Gear VR – uses an Android phone, no positional tracking
- Google Cardboard – a simple, inexpensive (under 10€) head mount for Android or iPhone.

Developer software ranges from SketchUp (a Google application with good user support) to fully-featured packages such as Unity and Unreal Engine.

## **Augmented reality** (AR)

Augmented and mixed reality involves the overlay of additional information on the real world. This may be provided by viewing through a transparent screen (as with AR glasses or a vehicle screen with a head-up display), on a portable device (such as a phone or tablet which may be prompted by a QR code or other visual cue, or a GPS location), or via a fully digital projection (for instance electronic viewfinders in cameras, or use of a live feed to a computer screen). 'Mixed reality' generally refers to VR-type displays that are projected over the real world using real-time 3D scanning, for instance interactive graphics, representation of a complete object for assembly, or a historic or fantasy projection on a real site.

[30] Kikkawa & Mavin (2018)
[31] Sacks et al above.
[32] Gallagher et al 2005, Visser et al 2010
[33] Luciano (2006)
[34] Porter et al 2006, Stone et al 2011
[35] Kikkawa & Mavin (2018)

AR can provide information that is pre-programmed (such as instructions that appear as relevant assemblies are viewed, or interpretive displays at a tourist site) or dynamic (things like real-time settings, analysis and control system information). It can provide interpretive information and visual effects, virtual reality overlays, provide information to aid decision-making and physical actions, or also allow electronic interaction (such as performing electronic control operations).

AR is used both in operational situations, for instance to allow real-time analysis, updates and control information to be projected as an operator looks at physical objects, and for training, for instance to project 'how-to' information or guide actions while the learner manipulates objects. It can be used to provide more fundamental information, for instance to show forces, stresses or electricity, or to provide background information and overlays as is becoming common at tourist and heritage sites[36]. As a training tool, AR has advantages over VR in two types of situation. The first is for low-risk physical tasks such as assembly and maintenance operations, as it allows the trainee to handle the physical object or learn in the real-life environment rather than work with a representation of it;[37] and the second is to refine skills that have been developed in a virtual or simulated environment for transfer into a real one.

Classroom applications of AR include variants of the above, where for instance an AR display works in conjunction with real components, and where digital information is used to augment physical media (such as drawings becoming 3D models when viewed with AR glasses or when a code is scanned). On the other hand, for some applications AR can have limitations outside of the workplace because it is too difficult or expensive to recreate the physical environment that the AR is designed to work with.

Box 6. **AR headsets**

There are plenty of AR applications that use phones and tablets, but dedicated AR/mixed reality headsets include:

- Microsoft HoloLens – self-contained, Windows-based (Hololens 2 available early 2019)
- Vuzix – self-contained, Android/iOS-based
- DAQRI – self-contained (with processor module), links to Windows PC.

Prices are generally higher than VR headsets, currently from 1000€ to over 3000€ for the Hololens and DAQRI models. Developer packages include (as with VR) Unity and Unreal Engine, plus applications by Google, Apple and many more.

### 3-D printing

Three-dimensional printing (3DP) is associated with creating objects through building up layers of material sprayed from a print nozzle, but the same principles apply to other automated methods of producing physical objects directly from a digitised representation or design. The basic principle is that an object, or a component of an object, is created directly from a digital image or specification with the human intervention being limited to adjusting settings on screen and initiating the 'print'

[36] Lee (2012)
[37] Boud et al (1999), Gavish et al (2011).

operation. 3DP can be used in conjunction with VR (or AR), so that rather than making a 3-D scan or CAD drawing first, the design is created or modified by physical movements in VR/AR space.

3DP has a high level of utility as an operational tool, with applications ranging from manufacturing models and small, bespoke components through to creating sections of prefabricated buildings. In training, it can be used to enable learners to see the results of operations (such as, but not limited to, CAD) in real form, to produce prototypes of designs rather than relying on 2-D representations, and to create models with different properties for practising various skills (as varied as sculpture, painting and surgery).

Box 7. **3DP hardware**

A wide range of 3D printers are currently available, from industrial scale to mini desktop machines. Desktop versions suitable for teaching and demonstration purposes include Lulzbot Mini and MakerBot Replicator+.

Costs currently range from around 300€ for the cheapest machines to 1000-2000€ for the ones above. The cost of raw materials (filament spools) and replacement printer heads also has to be factored in.

# 6. Developing the teaching and learning process

Learning theorists and teacher-trainers are slightly divided on whether technological learning is creating new principles of learning, or whether existing theories and models (such as cognitive and constructivist paradigms, the learning cycle, and andragogy) are still applicable. On balance, there is some consensus that the principles of learning do not need to be rethought, though the methods may change radically.

In section 5 it was mentioned that the technology is sometimes allowed to dictate the learning process. For instance traditional computer-based training is highly structured and sequential, while new technology may be exciting, fresh and interactive but it can demand a high level of learner engagement, self-direction and information literacy or evaluative skills in order to lead to useful learning outcomes. This points to a need for learning goals and processes (and learner capabilities) to be considered from the outset, rather than following the easiest path for using the technology. The 'spider web' model developed by the SLO (the Netherlands institute for curriculum development)[38] provides a useful framework or set of prompts for ensuring that the technology is considered in relation to the overall teaching and learning context.

This section presents conceptual models that have been found useful in technology-based learning, then discusses three aspects of design and delivery: objective-setting, design and methods, and learner guidance, feedback and assessment. The latter section is not intended to be a teaching and training manual, but aims to apply principles to training on or using technology.

## 6.1 Fundamental models

In their report on technology and learning at work, the UK personnel and training institute CIPD[39] distinguish three primary approaches to teaching and learning:

- Pedagogy[40] – teacher-led methods based on the education of children
- Andragogy[41] – methods that treat learners as adults – goal-oriented, self-motivated and self-directed
- Heutagogy[42] – methods that support self-determined learning, i.e. the learner determines goals as well as methods.

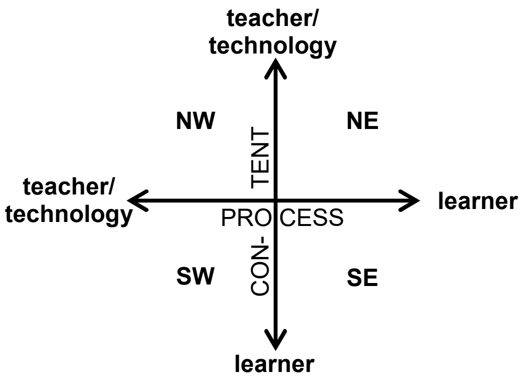
They suggest that more advanced technology is favouring learning that is towards to the self-directed, self-determined end. This makes it more compatible with learning theories such as constructivism, situated learning and those of adult and negotiated learning theorists[43]. However, this model can also be used to consider how approaches might need to change depending on learners' experience of the

[38] http://international.slo.nl/intcoop/
[39] Green (2017).
[40] Although 'pedagogy' is often used generically for the science of teaching and learning, the CIPD (Green, above) along with many adult learning theorists argues that it should not be used to describe adult learning because of its origins and assumptions based in the education of children.
[41] Associated with Knowles (1980).
[42] A more recent concept originating from work-based higher education: see Hase & Kenyon (2000).
[43] e.g. see Knowles above, Kolb (1984), Schön (1987), Boud (1988), Lave & Wenger (1991), Billett (1996), Stephenson (1998) and Gibbs, P. (2017).

tasks or topics being learned. For instance, a novice may initially require a high degree of structure, moving on to more self-directed tasks as experience is gained, and finally self-determined learning (e.g. in response to workplace needs).

A widely-used model that builds on this is the TLP (Coomey & Stephenson's teaching and learning paradigm), originally developed in the context of e-learning[44]. This simple model divides teaching and learning approaches into four quadrants depending on whether the teacher (or the technology) or the learner determines the content and the process.

*Figure 4. Coomey & Stephenson's 'TLP' model*




- The NW quadrant includes traditional classroom teaching (and much basic CBT).
- The NE quadrant represents learners working independently on predefined content, e.g. in many online courses or where classroom learning or an instruction manual is being applied in the workplace.
- The SW quadrant represents learner-defined content that is subjected to a teacher- or system-defined process, as in a project or dissertation.
- In the SE quadrant, learning is more open and exploratory, and may or may not involve any form of structured support.

As with the pedagogy-andragogy-heutagogy model, learning can move from NW to NE to SW or directly to SE as learners develop from novice to expert, with corresponding development of the overall learning environment to support greater autonomy and self-direction[45].

The TLP model has normally been used to consider learning as an individual process, but a social or community dimension can also be added. While the SE quadrant can lend itself to social or group learning, the SW and to an extent NE quadrants are usually best for generating social learning[46].

[44] Coomey & Stephenson (2001).
[45] Weyers (2014)
[46] Layne & Ice (2014).

## 6.2 Purpose and objectives

A familiar starting-point for any education or training process is to set out the overall purpose of the activity, module, course or programme, and define the specific objectives that it sets out to enable learners to achieve. The principles are no different for technology-based learning.

Some points to consider:

- What level should the objectives be set at, in terms of the level of complexity, depth of knowledge etc. – and for formal VET programmes, does this reflect the qualification level? (See section 4 on formal content).

- What level of practical proficiency is required? The Dreyfus model (in the section on learning needs) is useful for this, while the Bloom taxonomy or one of its later developments[47] can be useful for developing appropriate learning objectives. How the training is constructed is likely to differ if the objective is to give learners an awareness of how a job can be done, skills to get started, or bring them to a proficient level.

- What are the objectives in relation to the technology? For instance, to appreciate how it can be used; learn to use the technology effectively; to use it to carry out a particular task or range of tasks; or is it simply a tool for learning? This needs to be looked at carefully in relation to what learners know and can do already. For instance, is the technology the main focus (e.g. for experienced learners who are already proficient in the relevant work but need to know how to use new technology to help them) or is the focus on the task, using the technology? Where the technology is the tool for learning, do learners first need to learn how to use it? This last point is important where the technology could otherwise become a barrier for some learners, or get in the way of learning.

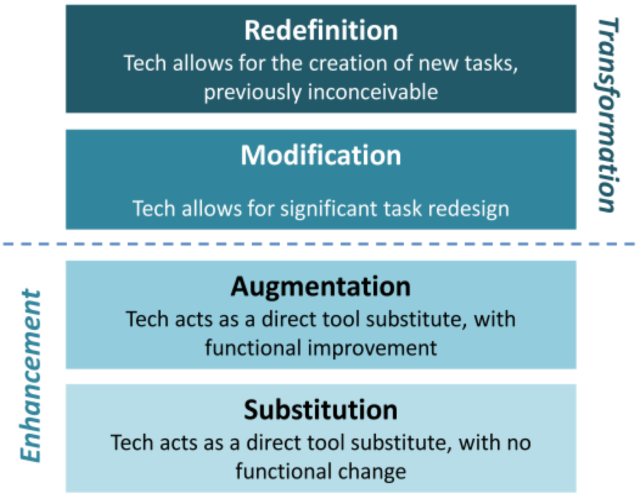
## 6.3 Design

Learning design is used here in the sense of the process that learners are expected to follow in order to achieve the purpose of the activity or programme, and the inputs and interventions provided by the technology or the teacher/trainer at each stage. The idea of 'instructional alignment' is useful here, where the objectives, design, and teaching and assessment methods co-ordinate to produce an integrated and engaging learning experience[48].

A key to using technology in learning design is to be thoroughly familiar with what the technology can do before firming up on the design – not to be driven by the technology, but to make best use of what it offers. The SAMR model[49] (Figure 5 below), developed for curriculum redesign, illustrates this. As an example, VR radically alters the way that students can learn about safety hazards on a construction site, so that rather than just discussing examples and what might go wrong, they can see the results for themselves and work out what to do to avoid them. A design that uses VR would be quite different from one that is 'technology-neutral'.

[47] e.g. Romiszowski (1999), Anderson & Krathwohl (2001).
[48] Cohen (1987)
[49] Puentedura (2009)

*Figure 5. SAMR: the effect of technology on training design*




*from Puentedura, 2009.*

The objective of the design should be to move learners from their current state of knowledge, skill and efficacy to the one represented by the purpose and objectives. The aim should be to maintain 'flow', where learners are engaged without experiencing either boredom (tasks are too straightforward and lack challenge) or stress (loss of control and inability to cope), as both of these can reduce learning significantly [50]. This will normally involve sequences of progression such as:

- From simple concepts and tasks to more complex ones
- From acquiring knowledge to developing mental models to being able to use them to make judgements in real-world situations
- From step-by-step skills to integrated performance
- From dependent to independent learning (e.g. the NW quadrant in the TLP model to one or all of the others).

Various progression models can be used as an aid to this, including the Dreyfus novice-to-expert model outlined in section 3, Bloom's taxonomy or its later developments[51], or Fitts' progression model (in summary, from individual procedures and properties to discrete sequences to smooth performance)[52]. In addition, particularly with longer programmes, more subtle aspects of learning can be considered such as the development of self-efficacy (confidence to act effectively)[53] and movement towards goal-driven motivation[54].

Box 8 summarises a learning design sequence for using VR to teach skills[55], while Box 9 outlines some more specific points developed for game- and simulation-based learning, but which are at least partly relevant to other aspects of technology-based learning.

[50] The original source is Czikszentmihalyi (1990)
[51] e.g. Romiszowski (1999), Anderson & Krathwohl (2001)
[52] Fitts (1954)
[53] Bandura (1995)
[54] Ryan & Deci (2000).
[55] Gallagher et al (2005), Pantelidis (2009)

Box 8. **A sequence for VR skills learning design**

*Before engaging with the VR environment*

- What is the objective to be achieved from learning in VR? For skills learning it is important to set a performance standard.
- Ensure that learners have sufficient knowledge to maximise their VR learning. This includes sufficient theoretical or background knowledge, knowing what to expect and have to do in the VR environment, and being able to recognise common errors. Some or all of this can be taught and tested in VR.

*The VR environment*

- How will learners interact with and use the VR environment? This includes making sure that the level of realism and immersion is appropriate, and the environment provides effective and appropriately-timed feedback.

*Designing the VR tasks*

- Are there any preliminary skills that need to be learned first, such as learning the controls of relevant (virtual) equipment before using it to do something?
- What sequence of tasks does the learner need to master in order to achieve the overall objective? How can these be introduced so that one task is mastered to a sufficient level before the next one is introduced? Also think about maintaining 'flow' here to prevent boredom or excessive stress.
- How can the VR sequencing be designed to build up performance and integration of skills, and help learners develop their overall level of competence?
- How much variation is acceptable in the way things are done before an error is flagged up? Should a distinction be made between major and minor errors, and how the environment reacts to them?

*In the VR environment*

- Provide enough time and guidance to allow learners to develop their skills. This typically means tapered support to build confidence and self-direction, but without leaving learners unsupported if they are struggling.
- Make sure that learners receive timely feedback on errors. This can be different for acceptable variation (e.g. see the consequences, maybe do it differently next time), minor errors (e.g. hints), and major errors (e.g. stop, review, start again).

*Afterwards*

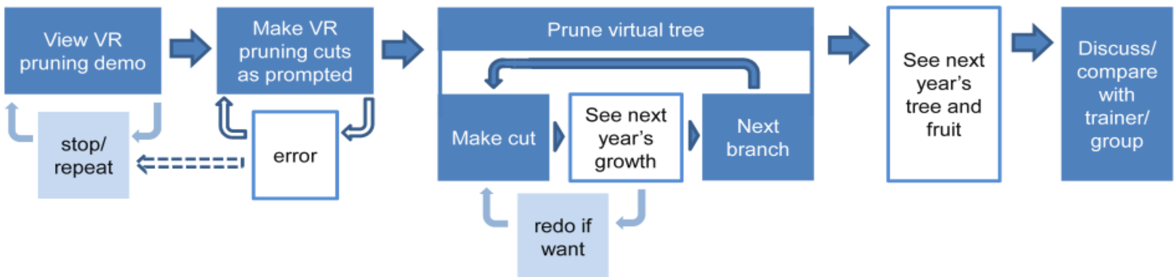
- Provide summative feedback and opportunity for discussion.
- Repeat the process until proficiency or mastery are reached – typically with less guidance and less detailed feedback each time.

Box 9. **Some principles for simulation and game-based learning**[56]

- Clear or emergent goals (emergent goals become clear as the learner progresses through the sequence)
- Balanced level of challenge – stretching but achievable
- There is a coherent theme throughout
- Problems and tasks are relevant to the learner
- The learner has a choice of actions which are relevant within the learning environment
- Actions are relevant to the domain/scenario and have a direct effect on the environment
- The virtual world responds to learners' actions in an appropriate and coherent way
- The environment is suitably novel – not bafflingly complex, but not so predictable that it loses the learner's attention.

Developing a learning design includes considering how the sequence of activities both keep the learner engaged, and maximise learning. Activities can be fully technology-based, or 'blended' i.e. a mix of using technology and interaction with the tutor and/or other learners. In Web 2.0, complex games and VR, interaction can also be incorporated that is both technology-mediated and direct. This can allow for differentiation, e.g. interventions and discussion through the technology within the learning scenario (reflection in action), and wider review (reflection on action) following it (see later in this section). A flow diagram, looking from the learner's perspective of experiencing the process, is a useful aid to setting this out before the individual components and interventions are designed. This can also help with decisions about whether and how the learning environment needs to change as the learner progresses, for instance from instructional to VR to AR, or from individual to group to workplace.

*Figure 6. A simple flow diagram for using VR to learn to prune a fruit tree.*




## 6.4 Guidance, feedback and assessment

A fairly common criticism in technology-based or -enhanced learning is that learner guidance, either provided within the technology or provided by teachers and trainers in real time, is not always a good match with what is needed to facilitate effective learning. Mirroring poor learning design, there can either be too much detailed guidance and direction throughout, or not enough guidance is given to get learners started and enable them to focus on useful tasks[57].

[56] adapted from Quinn (2014)
[57] e.g. Bell & Kozlowski (2002), Green (2017), Ang *et al* (2018)

Two ideas that can be used here are adaptive guidance and soft scaffolding. Adaptive guidance[58] or 'fading'[59] aims to guide learners on what to focus on in terms of both content and the sequence of actions. As they become more adept at using the learning environment, or they master the tasks within it, it changes emphasis from basic processes to more strategic aspects of learning. The aim is to support increasing self-directedness and self-efficacy, but also to provide more structure where needed. This can be done by the tutor, but there are also opportunities to build in intelligent guidance directly into the content.

Scaffolding[60] is a metacognitive approach to supporting problem-solving. The basic model focuses on ensuring that learners are aware of:

- the key stages of the overall process
- the knowledge and skills that they need to draw on
- and the specific processes that they need to use.

Soft scaffolding responds in real time to how learners are behaving on the task, so that guidance can switch from being detailed and step-by-step at the outset to more strategic as learners progress, and temporarily back to being more detailed if they are struggling.

In principle, technology-assisted learning improves opportunities for learner monitoring and providing feedback. Basic CBT typically relies on short tests which can be intrusive and distract from learning, but more advanced technology can allow real-time feedback which, particularly with gamification, VR/simulation and 3DP, becomes a natural part of the learning process based on seeing the results of different actions or decisions. If necessary additional pointers can be included for the learner to step back and consider what they are doing in more detail. The idea of reflection *in* and *on* action[61] is useful here. Reflection in action, or 'hot' reflection, is done while an action is taking place and allows the worker or learner to modify it and affect its results. It is informal, quick, and often fairly intuitive. Reflection on action, or 'cold' reflection, takes place after the event and is more deliberate and evaluative, and allows discussion and theorising. Technology-based learning environments can aid both. Reflection in action can for instance be helped by real-time prompts, while reflection on action can be made more effective if the technology can record actions and allow them to be revisited afterwards; this can avoid having to break up learning sequences for feedback and discussion[62].

Technology also provides opportunities to change assessment processes, both for formative (feedback) purposes and for examination and qualifications. Where learner actions can be monitored, this can enable immediate feedback, as well as sequencing so that the learner masters earlier stages or activities before progressing to more advanced ones. For formal assessment, ongoing evidence can be built up, sometimes from multiple interactions, that contributes to the learner meeting whatever criteria are needed for award of credits or a qualification. Assessment design is not covered here in any depth (there is more on assessment in section 7.3), but in general this more naturalistic use of technology favours criterion-based rather than normative assessment processes, where learners need to meet clearly-defined criteria rather than perform against a norm or gain a particular

[58] Bell & Kozlowski (2002)
[59] Gallagher et al (2005)
[60] An (2014)
[61] Schön (1987)
[62] Kikkawa & Mavin (2018) discuss this in relation to flight simulator training.

percentage mark[63]. In turn this requires a statement of what is expected in terms of competence or mastery. For specific assessment tasks, VR-type technology can provide opportunities to make off-job assessment more realistic and natural, while also enabling more information to be captured than through a typical workplace assessment.

[63] Härtel et al (2018)

# 7. Evaluation

Evaluating education and training involves asking the questions 'how effective is this, and what is the value of doing it?'. Its value is when it is used to improve learning design and teaching/training methods, or to compare the effectiveness of one approach compared with another (as when introducing new technology).

Much 'evaluation' focuses only on effectiveness, and sometimes doesn't even answer that very well (e.g. it only uses subjective methods such as learner feedback sheets). This doesn't mean that learner feedback isn't important, but as the only evidence for the effectiveness of a programme or training session it is usually too limited.

## 7.1 The four-stage evaluation model

A widely-used training evaluation model is the Katzell/Kirkpatrick one[64], which uses four stages or levels. This was developed in the 1950s in an industrial training context, and there are now several criticisms of it as well as newer (and often more complex) models[65]. It is however still useful as a starting-point for thinking about evaluating learning episodes or sequences. One point to note is that the stages are independent of each other from a learning perspective, e.g. positive feedback does not necessarily translate to effective learning, which in turn does not always lead to improved practice in the work setting.

1. *Feedback*: learner (and trainer) reactions to the course or session, what went well, what could have been improved. A common method for collecting this information is an end-of-session questionnaire, but other qualitative methods can be used such as one-to-one or group discussions.

2. *Learning*: the changes observed to skills, knowledge and actions. This is typically identified through some form of assessment (formal or informal), indicating whether the objectives identified for the training have been met. Other sources of evidence can also be used, such as observation of the time taken to reach proficiency in a task, and learner self-reports on what they have learned (this is likely to be more subjective, but it could reveal learning that goes beyond the original objectives). Ideally, short- and longer-term evidence is useful to indicate how much learning is retained over time.

3. *Application*: how the learning is being applied in the work setting. Evidence of this can be obtained for instance by workplace observation or assessment; learner, colleague and manager reports; and direct evidence such as customer feedback, work quality, reduced waste, improved speed, etc.

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[64] The model was developed by Raymond Katzell (see Kirkpatrick 1956 for Katzell's original version), and modified and promoted by Kirkpatrick in several books (e.g. Kirkpatrick 1994).

[65] e.g. Holton (1996), Sutton (2006), Thalheimer (2018). Thalheimer's 8-tier LTEM model is a development of the 4-stage model which is well explained and fairly easy to use. An evaluation model specifically for augmented reality has been developed by Bond *et al* (2019), but it is designed for large-scale programmes and it is too complex for typical VET applications.

4. *Impact*: the effect of the changes, e.g. on productivity and profitability, sales, business expansion, staff morale, attendance and retention, etc. This is an important step for organisations particularly when they have invested in training to solve a problem, improve effectiveness or create new business opportunities. However it is often difficult to do from a provider (e.g. college or training organisation) perspective, and other impact measures – such as learner destinations or progression in work – can be more appropriate[66].

## 7.2 Comparative evaluation

Introducing new technology in teaching and training requires some form of comparative evaluation if its effectiveness and value is to be assessed. As with the introduction of computer-based training and e-learning, the 'wow' factor of the technology sometimes masks things that don't work as well, or are less cost-effective (see section 5 of this manual). On balance, evaluations[67] have generally supported using VR and (more strongly) AR, and shown benefits such as increased learning gain, engagement, and motivation which far outweigh issues and drawbacks. Some of the issues and limitations that have been found include:

- Dealing with technical problems, such as maintaining AR tracking, can get in the way of learning.
- The technology, and the time taken to become familiar with it, can take time away from learning topics and skills (something that is likely to decrease as the technology becomes more commonplace).
- Even allowing for the above, technology-mediated learning is not always quicker or more effective than conventional methods; this may be a particular factor for faster or more intellectually-oriented learners.
- VR can reduce interaction between learners, making sessions unintentionally more directive as well as reducing natural opportunities for peer feedback.
- There can be a skill gap between learning with VR and then applying the learning in the real world.
- In one study, manual dexterity was poorer when using AR than without it.

Ideally, comparative evaluation should use two or more groups of learners in parallel, one using existing methods (the 'control group') and the other technology-mediated. Any other differences between the two groups should be kept to a minimum, e.g. the same objectives, comparable tasks and learning design, ideally the same trainer. If this isn't possible, one group can follow the other, provided that there are no other major changes. Sometimes both approaches are relevant, e.g. parallel groups are used to compare individual sessions or short (e.g. one-day) courses, while sequential evaluation is done to compare programmes for instance between one year and the next.

If it is possible to select learners for the groups, either use a random allocation or be careful that there is a balance of learners in each group – e.g. one group does not have a disproportionate number of low- or high-achieving, or tech-savvy, learners, or those with more experience in the task or topic area

[66] Evaluations of technology-based learning have rarely included this stage, e.g. Jin *et al* (2018).
[67] Bacca *et al* (2014), Sirakaya & Alsancak Sirakaya (2018), Silva *et al* (2018) and Garzón & Acevedo (2019) give summaries or meta-analyses, while Gavish *et al* (2015) provides an evaluation of VR and AR for assembly tasks, and Kaul & Smith (2018) in the context of railway safety.

being covered. Where learners come from different organisations, it can also help to spread learners from the same organisation between the groups.

Evaluation methods (see section 7.3) are likely to produce some quantitative and some qualitative data. Where quantitative data is being compared between two groups, an unpaired, two-tailed T-test can be used to determine whether the difference between them is statistically significant (there are several online calculators into which data can be fed[68]). The group sizes do not need to be the same to produce valid results. Alternatively, use the interquartile range for a quick visual comparison. This is found by putting the results (e.g. time to complete a task, number of errors, etc.) from each group in order and ignoring the top and bottom 25%, so that the comparison is not affected by particularly high- or low-performing learners.

## 7.3 Comparative evaluation methods

Some example schedules for feedback, observation and supervisor reports are provided in Appendix B.

**Feedback** (stage 1)

End-of-session / end-of-programme questionnaires are a common way of collecting feedback, but as indicated earlier they only collect subjective 'stage 1' information. Feedback is more useful for improving the learning design and training input than for comparative purposes, although it can highlight things that are more prominent for one group than the other. Questions need to be written carefully to produce meaningful answers. Examples, based on previous comparative evaluations, are provided in Appendix B.

It can be useful to collect additional information from the technology-using group, specifically about ease of using the technology and how learners think it has helped (or hindered) their learning. This is fine provided that the other questions are the same between the two groups.

An alternative or additional method is to run a feedback session with the learners. The main advantage is that it allows discussion and provides more information for improving the training. Careful management is needed to avoid giving more attention to confident or outspoken participants. The disadvantage for comparative purposes is that it is difficult to compare information between groups, so the session is usually better as an additional method to obtain qualitative feedback.

**Observation** (stage 2)

Observation can provide objective data that is comparable between groups, without needing to conduct formal assessments. An observation schedule, with relevant criteria, needs to be drawn up in advance. If different trainers are doing the observations, it should be discussed between them both before running the sessions, and afterwards to compare how they have applied the criteria. Observation can cover things such as[69]:

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[68] For instance https://www.graphpad.com/quickcalcs/ttest1/, https://www.socscistatistics.com/tests/studentttest/default.aspx

[69] after Rios *et al* (2011).

- What level of proficiency does each learner reach by the end of the session or course? This requires some clear criteria for each level.
- How long do learners take to complete each task, or reach a proficient level? Again, criteria for completion or proficiency need to be identified in advance.
- How many errors does each learner make?
- How many questions does each learner ask? Questions about uncertainty need to be distinguished from questions seeking knowledge beyond that needed to complete the task.

**Assessment** (stage 2).

An assessment (formal or informal) provides a good way of indicating the point reached by the end of the session, course or programme. Formal assessments (i.e. contributing to certification) will often already have measures built in for quality and comparability, but the following points are relevant to any comparative assessment[70]:

- The assessment should reflect the objectives of the session – e.g. if the aim is to develop a practical skill (simple or complex), then it should test that rather than for instance just knowledge acquisition.
- Clear criteria for passing (or achieving different grades or levels within) the assessment. A graded assessment – typically with 3 to 5 grades or levels – is generally more useful for comparative purposes, provided that the grades have well-defined criteria. Alternatively, if the assessment is simply to test knowledge acquisition, the measure can be the number of questions answered correctly.
- Common interpretation between the groups. The most objective assessment will be by using a person who has not been involved in the training to assess all the learners, without knowing which group each learner was in. Alternatives include using the same trainer (who has taught both groups), or having a third person ('moderator') to compare the assessments.

The timing of assessment also needs to be considered, as there may be differences in performance over time, e.g. one method gives good results for immediate recall and performance, but the other results in better retention. If the length of programme allows, an immediate assessment (which can be used formatively to provide feedback on learning) can be followed by a later summative one.

**Application** (stage 3).

Ideally, application needs to be gauged by some form of work-based assessment, after learners have had an opportunity to consolidate and apply their learning. Where relevant and feasible this can be a formal assessment of competence or practice, carried out in the workplace or using evidence from work activity[71]. As above care is needed to ensure comparability.

Where this is not practicable, an alternative is to use feedback from learners' supervisors and to an extent from learners themselves. This should be captured using carefully-designed questions,

[70] Lester (2011) provides a manual for work-based, criterion-referenced assessment from the TRAVORS2 project: http://devmts.org.uk/assmt.pdf.
[71] As above.

otherwise it will tend to be subjective, inconsistent, and difficult to compare between learners. An example is given in Appendix B.

# 8. Trainer training

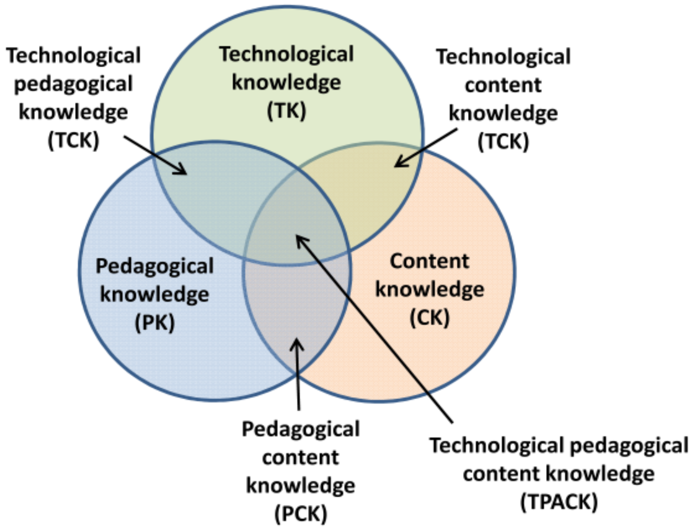
Introducing new technology into the teaching and learning process will often create trainer training needs. This does not mean revisiting the principles of teaching and training, but it can cover using the technology, understanding how to use it both for training in general and for covering specific content or learning objectives, and modifying learning design and teaching methods to make best use of it. In the TPACK model discussed below, the focus is on the upper green circle, and particularly the areas where it overlaps with the other two circles.

## 8.1 TPACK

A useful framework for considering what teachers and trainers need to cover in order to use technology effectively is provided by the 'TPACK' model ('technological pedagogical content knowledge') developed by Koehler & Mishra[72].

This proposes that teaching with technology requires knowledge of what is to be taught (content), teaching approaches and methods (pedagogy), and the technology itself. A common theme in education is that in order to teach a topic, it is not only necessary to have knowledge of the topic and knowledge of how to teach, but to organise and interpret topic knowledge in a way that makes sense for teaching and anticipates where learners may experience difficulties and make mistakes ('pedagogical content knowledge' in the diagram below).

*Figure 7. The 'TPACK' model (after Koehler & Mishra 2009).*




Introducing technology adds a further dimension to this, in that it is necessary to know how the technology works (TK); how the technology affects the field and therefore the knowledge needed to work in it (TCK); how the technology can be used most effectively for teaching (TPK); and how the technology can be used for teaching in the specific field (TP[A]CK). The following notes enlarge on each of these areas in the context of trainer training, and refer back to earlier parts of the manual.

[72] Mishra & Koehler 2006, Koehler & Mishra 2009

- Technological knowledge (TK) needs to go beyond 'computer literacy' or the equivalent to being able to apply the relevant technology productively, to recognise when it can assist or obstruct achieving a goal, and to keep up-to-date with changes. Section 5 introduces TK relating to VR, AR and 3DP.

- Technological content knowledge (TCK) concerns how technology is used in the relevant field. This includes emerging uses, as well as the impact of technology on the field and how the work is carried out. Technological and field-specific knowledge often interact in ways that are more complex than simply applying technology to work tasks; Koehler & Mishra give the example of X-rays in medicine, where the field itself changed as a result of introducing X-ray technology. Section 2 discusses assessing the effects of technology on occupational fields.

- Technological pedagogical knowledge (TPK) is concerned with how technology can be used for effective teaching and learning, and how teaching and learning can change – or need to be approached differently – when technology is used. Section 6 discusses teaching and learning in the context of new technology.

- Technological pedagogical content knowledge (TPCK or TPACK) involves integrating content, teaching and learning principles and technology so that the most effective methods are used for the particular field and type of content concerned. An additional dimension can be added to this, that of context as discussed in the learning needs section (3). Koehler & Mishra comment that working effectively in the TPACK 'space' requires fluency with content, pedagogy and technology.

## 8.2 The DiMBA project

DiMBA[73] was a German project that examined the use of digital media in occupational training. It borrowed an established model from schools[74] and adapted it into a vocational context, as well as reporting training needs of in-company trainers. This model can easily be related to TPACK.

The DiMBA model includes a number of prerequisites for working with digital media (the TK), that can be summarised as being able to:

- operate relevant devices and software
- design and create relevant digital media
- assess digital systems (as in section 5)
- reflect critically on digital media and associated matters.

The main part of the model is concerned with an overall pedagogy of digital media, divided into three parts (the TPK; the last part TPCK). This can be summarised as follows:

[73] Härtel et al (2018)
[74] Blömeke (2000)

**Digital media instructional competence**

- select, develop and use digital media to enhance the quality and effectiveness of learning, taking learners' contexts into account

**Digital media educational competence**

- take a critically reflective approach to education using digital media, including contextual and consequential matters such as cyberbullying, data protection, security and privacy

**Digital media integrative competence**

- integrate digital media into teaching and learning in the occupational context and the organisational/work environment.

Specific trainer-training and resource needs identified in the project include:

- Occupation-specific examples of good practice, case-studies and curated content
- Intellectual property, data protection and data security
- Support for dealing with cyberbullying
- (Certified) training to develop media pedagogic competence
- Resources to develop digital materials and resources and aid the design of digital learning environments
- Information and tools to support competence-based assessment.

## 8.3 Standards for teaching with technology

Standards for teaching with technology are useful both to position trainer training programmes into an external, possibly accredited, framework, and as a reminder of the range and breadth of competencies at different levels for teaching with digital technology and resources.

The **European Framework for the Digital Competence of Educators** (DigComp Edu)[75] is a development of the DigComp framework specifically for teachers and trainers. It covers a wide range of areas and uses a progression scale with six levels from newcomer to pioneer.

In the UK, a model has been developed specifically for teaching in VET. The **Digital Teaching Professional Framework**[76] draws on DigComp Edu and the standards of the organisations for VET staff development (ETF) and information services in higher education (JISC) to produce a framework more specific to VET. This uses a single set of standards, but provides examples of application at three levels.

A summary of these models is given in Appendix D.

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[75] Available from the EU Science Hub, https://ec.europa.eu/jrc/en/digcompedu

[76] Published by the Education and Training Foundation in the UK (EN): links to summaries and the full manual are at https://www.et-foundation.co.uk/supporting/support-practitioners/edtech-support/digital-skills-competency-framework/

## 8.4 Learning design, assessment and evaluation

Many of the points made in sections 6 and 7 apply equally to trainer training. If the training is being carried out by the teachers' or trainers' own organisation, there is often more opportunity to integrate between the course and trainers' own practice, so that some of the 'coursework' can be to design, run and evaluate technology-mediated sessions. Some key points to note are:

- Make sure that trainers are thoroughly familiar with the technology and how to use it in their subject areas before they start designing and running sessions. This embraces the TK, TCK and TPK, and to some extent TPCK, in the TPACK model – i.e. sections 5, 6 and 7 of this manual. It suggests having several sessions to allow trainers to learn and experiment before they start taking the principles back into their classrooms/workplaces. This doesn't rule out learning from practice, but trainers who are not basically competent in these aspects run a risk of introducing the technology poorly, affecting learning and perhaps building up resistance.

- A structured process is useful to help trainers to introduce technology to their sessions, for instance based around a small number of learning scenarios where everything is planned in advance (including any technological content development that is needed). The trainer-training process can help trainers develop each scenario so that it makes appropriate use of technology (section 5), is well-designed, incorporates feedback and guidance as relevant to the learners and the learning design (section 6), and includes evaluation and assessment (section 7). It is particularly useful if trainers can carry out a comparative evaluation between teaching the same topic with and without the technology.

- Trainer training also needs to be assessed and evaluated. The sessions/scenarios referred to above, and the evaluations of them, are a good source of evidence for both.

# Appendix A: Prompts for assessing the effect of technology on an occupation

These prompts are designed both for designing a questionnaire and for discussion in expert groups. It is expected that they will be adapted for the particular occupation and industry.

Definition

The occupation needs to be defined at the start of the session or questionnaire. If there isn't a common definition that everyone will understand – for instance a national VET programme that is familiar to all, or a widely-understood job title – provide either a short definition as in section 1, or a web link.

Context

For a questionnaire, start by getting a picture of the respondent's context. In a discussion group, participants can be asked to say what type of organisation they are from and the perspective from which they are contributing. Contextual questions include:

- Role type – e.g. practitioner (in the occupation being discussed), trainee, manager (of the occupation), industry trainer, VET teacher/trainer, industry expert, researcher/academic.

- Type of organisation or sector of industry – if there are different sectors e.g. production, retail, servicing, or public, private, voluntary. External commentators (the last 3 categories above) can be asked if they are commenting on specific categories.

- Size of organisation – Eurostat categories are $<10$ people, 10-49, 50-249, and 250+. In some industries it may also be useful to distinguish 1-2s and e.g. 1000+, 5000+. External commentators can be asked if they are mostly involved with a particular category or categories.

- This is more subjective, but it can be useful to ask respondents to assess whether they think their organisations are innovators, early adopters, part of the middle majority, or slow adopters in relation to technology.

Technologies

This question is about 'new' technologies that participants or respondents are using or seeing used. Where technologies are identified, ask what they are being used for. The question can also be split into 'using now' and 'exploring/expected within the next five years'. In a questionnaire it can be useful to pick out technologies relevant to the industry, e.g.:

- virtual reality/simulation
- augmented reality
- 3-D printing
- 3-D scanning
- mobile robotics
- networked machinery e.g. 'internet of things'
- intelligent control systems

- intelligent diagnostic/analysis systems.

A related question can be asked about whether the technology is being used to its full potential, and if not whether this is due to (a) limitations with the technology itself, (b) lack of skills, knowledge or confidence in any part of the organisation, (c) lack of investment e.g. in updated software, or for other reasons.

<u>Tasks</u>

This concerns the effect of the technology on tasks and activities. In a questionnaire, space is needed to allow respondents to reply for multiple technologies if relevant. For each category that is selected, ask the respondent how this is happening; this may involve multiple tasks for one type of technology. Also ask if this is likely to change over the next five years.

- Tasks that are, or are becoming, automated
- Tasks that are partly automated
- Tasks that are no longer needed because ways of working have changed
- Tasks that are made easier or made more effective or efficient
- New tasks that are being created related to the technology
- New tasks that are being created related to changed ways of working.

<u>Skills needs</u>

This question is closely related to the two above, but it is not the same – as some new or changed tasks, and operation of technology, can be learned quickly on the job. Ask what new skills are needed to:

- Use and work with new technology
- Use the technology to carry out specific tasks
- Carry out new tasks that have been created as a result of the technology (this could be for instance to move from an ‘operating’ role to one concerned with setting-up and quality assurance)
- Adapt to new ways of working (for instance the need to be more self-organising and take responsibility for day-to-day work, or where the role has broadened due to less time being spent on routine tasks).

Where new skills are identified, it is also useful to identify the level of ability needed – possibly split by newly-qualified entrants and experienced workers. A simple scale (such as novice to expert or a simple three-point scale) can be useful for this.

Where are the most pressing skills gaps – now and predicted over the next five years – for (a) existing workers and (b) new entrants (coming in from VET programmes or similar)?

Skills redundancy

This question asks whether any skills currently associated with the occupation/taught on VET programmes are no longer needed. Ask for the implications of losing the skills: could they still be needed for bespoke applications, or for contingencies and breakdowns?

Barriers to learning

This question is particularly relevant to upskilling the existing workforce.

In the occupation/industry, are there any particular barriers to being able to acquire new skills? Some pointers can be provided, e.g. factors concerning time at work or to get away from work, the way work tasks are organised, knowledge of where to get help, workers' attitudes to training/learning, managers' attitudes to supporting training/learning or to releasing staff, etc.

# Appendix B:  Tools for conducting a comparative evaluation

These are some outline templates for conducting a simple comparative evaluation as described in section 7 of this manual.  They are intended to be adapted according to context and need.

LEARNER FEEDBACK

**Scaled questions** (suggest 5-point scale).  Blue questions additional for technology group only.

| Question | Yes/Very much/ A lot | | | | No/ Not at all |
|---|---|---|---|---|---|
| Did you find the session/course well organised and structured? | | | | | |
| Did you find the process straightforward to follow? | | | | | |
| Do you feel that your understanding of the topic has increased? | | | | | |
| How satisfied are you with your performance of the tasks? | | | | | |
| How confident are you that you can use what you have learned at work/in an independent project? | | | | | |
| Did you find it easy to recover from mistakes or misunderstandings? | | | | | |
| Did you find it easy to get answers to any questions you had? | | | | | |
| Was the technology (AR, VR or 3DP) comfortable to use? | | | | | |
| Was it easy to find your way around the technology? | | | | | |
| Was it easy to move from one step to the next using the technology? | | | | | |
| Did you feel that the technology helped you learn? | | | | | |
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| | | | | | |

Open-ended question:
Please add any comments you have about the session that would help improve it for next time.
Please add any comments about the technology or how it was used in the session.

OBSERVATION (in training session)

This template is for multiple learners for one major activity or task.

| Activity | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Observer | | | | | | | | | | | | | | |
| Name | **Qs** | **Help** | **Step 1** | | **Step 2** | | **Step 3** | | **Step 4** | | **Total** | | **Level** |
| | | | Time | Err | Time | Err | Time | Err | Time | Err | Time | Err | |
| | | | | | | | | | | | | | |
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Note on columns:

- Questions – these are questions seeking to clarify process, get feedback etc. Ignore 'interest' questions e.g. asking for more advanced knowledge.
- Help – where the learner is stuck and needs the trainer's help to move on.
- Time – to complete the step.
- Errors – number of obvious errors at end of step.
- (If there are no clear breaks in the process, ignore the intermediate steps).
- Level – decide on a scale e.g. 1-5 each with clear criteria (e.g. novice-to-expert definitions, see end of document).

Comments:

Add your comments e.g. about learners' engagement and 'flow', and for technology-mediated groups their ease of use of the technology.

ASSESSMENT

This is a rough outline as there may be other requirements e.g. if it is contributing to certification. These are minima to aid comparison of achievements between the two groups – hence the inclusion of a grade level.

Learner:

Assessor:

Date of assessment (and how long after training):

Description of task or activity:

EQF/national level if relevant:

Success criteria (these will normally be, or be an expansion of, the learning objectives):

| Criterion | Achieved | Comments |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

For the task overall, what level of proficiency did the learner reach? (Use a scale with clear description – see the example at the end).

WORKPLACE OBSERVATION.

Provide a clear description of the task, and a <u>short</u> set of success criteria. These could be the same as the assessment criteria, or they may be 'scaled up' for proficiency in the workplace.

Questions for supervisor:

Are there any criteria that the learner has difficulty meeting?

How well does the learner perform the task/activity <u>as a whole</u>? (Suggest using a 5-point scale such as novice to expert, with a short description of each level – see end of document).

How confident is the learner in doing this task unsupervised? (scale)

How confident are you that the learner can do this task unsupervised? (scale)

Any additional comments? Is there anything else that we could have done in the training to improve the learner's level of proficiency?

‘GRADE’ CRITERIA

This is an example from the Dreyfus novice-to-expert scale introduced in section 3 of this manual. other scales could be substituted – it is more  important is that they fit with the type of activity and are applied consistently.

Advice for applying – use a ‘best fit’, e.g. if someone’s theoretical understanding is good but they are struggling to apply it or make frequent mistakes, they will be towards the less advanced end of the scale.

***Novice***

Applied understanding is limited
Approaches tasks by following instructions
Needs supervision to complete the whole task.

***Advanced Beginner***

Has a working understanding
Approaches tasks as a series of separate steps
Can complete simpler tasks without supervision.

***Competent***

Has a good working and background understanding
Approaches tasks as a whole and has at least a partial appreciation of context
Can complete work independently to an acceptable standard.

***Proficient***

Has a thorough understanding
Approaches tasks fluently and in context
Can achieve a high standard routinely.

***Expert***

Has an authoritative understanding
Deals with routine matters intuitively
Can create novel solutions appropriate to context
Achieves excellence with ease.

# Appendix C: The DigComp 2.1 framework

These are the 21 areas covered in the DigComp 2.1 framework. Each area has a short statement at each of eight levels (corresponding approximately to the EQF levels) explaining, in very generic terms, what is involved for the area.

**1: Information and data literacy**

1.1 Browsing, searching, filtering data, information and digital content
1.2 Evaluating data, information and digital content
1.3 Managing data, information and digital content

**2: Communication and collaboration**

2.1 Interacting through digital technologies
2.2 Sharing through digital technologies
2.3 Engaging in citizenship through digital technologies
2.4 Collaborating through digital technologies
2.5 Netiquette
2.6 Managing digital identity

**3: Digital content creation**

3.1 Developing digital content
3.2 Integrating and re-elaborating digital content
3.3 Copyright and licences
3.4 Programming

**4: Safety**

4.1 Protecting devices
4.2 Protecting personal data and privacy
4.3 Protecting health and well-being
4.4 Protecting the environment

**5: Problem solving**

5.1 Solving technical problems
5.2 Identifying needs and technological responses
5.3 Creatively using digital technologies
5.4 Identifying digital competence gaps

The full framework is available at:
http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106281/web-digcomp2.1pdf_(online).pdf

# Appendix D: Frameworks for teaching and training with technology

## DigComp Edu

This framework was developed for educators generally. Each of the areas below is has a more detailed description. There are also six levels of engagement (novice to pioneer), with examples of activities appropriate to each described for each area of the framework.

**1. Professional Engagement**
1.1 Organisational communication
1.2 Professional collaboration
1.3 Reflective practice
1.4 Digital continuous professional development

**2. Digital Resources**
2.1 Selecting digital resources
2.2 Creating and modifying digital resources
2.3 Managing, protecting and sharing digital resources0

**3. Teaching and Learning**
3.1 Teaching
3.2 Guidance
3.3 Collaborative learning
3.4 Self-regulated learning

**4. Assessment**
4.1 Assessment strategies
4.2 Analysing evidence
4.3 Feedback and planning

**5. Empowering Learners**
5.1 Accessibility and inclusion
5.2 Differentiation and personalisation
5.3 Actively engaging learners

**6. Facilitating Learners' Digital Competence**
6.1 Information and media literacy
6.2 Digital communication and collaboration
6.3 Digital content creation
6.4 Responsible use
6.5 Digital problem-solving

The full framework is available at https://ec.europa.eu/jrc/en/digcompedu

## Digital Teaching Professional Framework (DTPF)

This is a UK framework developed specifically for teachers and trainers in VET. Each of the areas below is described at three levels (exploring, developing and leading).

**A Planning your teaching**

A1 Planning and looking for information
A2 Designing and adapting activities
A3 Empowering learners through technology
A4 Communication and collaboration

**B Approaches to teaching**

B1 Teaching and learning resources
B2 Teaching – face-to-face
B3 Teaching – blended
B4 Teaching – online

**C Supporting learners to develop employability skills**

C1 Supporting digital capabilities
C2 Supporting study skills
C3 Communication and collaboration

**D Subject-specific and industry-specific teaching**

D1 Teaching – subject- and industry-specific
D2 Raising learners' digital employability and self-employability skills

**E Assessment**

E1 Assessment and feedback

**F Accessibility and inclusion**

F1 Accessibility
F2 Equality and diversity

**G Self-development**

G1 Self-assessment and reflection
G2 Progression and CPD
G3 Well-being
G4 Managing identity

The full framework and associated resources are available from https://www.et-foundation.co.uk/supporting/support-practitioners/edtech-support/digital-skills-competency-framework/

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