IQMET

New Innovative Methods for Quality Capacity
Life Cycle Production Process Training of Inspectors

Welding Simulators, Blended Learning and Greener Fabrication in Vocational Education and Training

IQMET practical guide for VET providers, trainers and industry partners

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About this guide

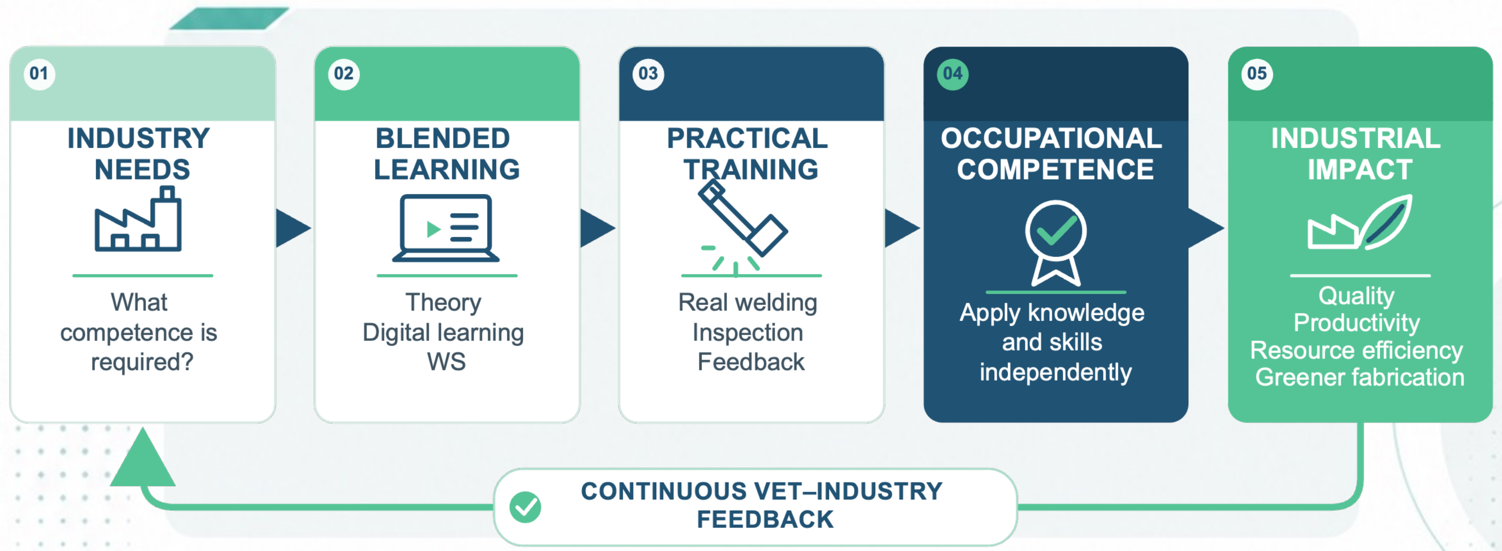
Welding education must develop competence that can be applied in real industrial environments. Learners need more than technical knowledge: they must be able to perform tasks, recognise problems, understand consequences and apply corrective actions.

Welding simulators can support this process by providing controlled practice, repetition and feedback before or between practical workshop activities. Their value depends on how they are integrated with theory, real welding, inspection, industry cases and assessment.

This guide presents the IQMET approach to using **welding simulators, blended learning and work-based learning** in welding education and training. It is based on the implementation framework developed in Deliverable D4.1 and translates its main principles into a practical visual guide for VET/LSP organisations, trainers, instructors and industry partners.

The central idea is simple: **digital learning and welding simulation should strengthen the route towards occupational competence, not replace practical experience.** Simulation, workshop practice, inspection, feedback and industrial application should form one connected learning system.

FROM TRAINING NEEDS TO INDUSTRIAL IMPACT



Digital learning and welding simulation should strengthen the route to occupational competence, not replace practical experience.

PART I

IMPLEMENTING WELDING SIMULATORS IN VET

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Why integrate welding simulators into VET?

Vocational welding training should **connect knowledge directly to practical competence**. Learners need to understand welding processes, but they also need to control technique, interpret results and act correctly in real working situations.

Welding simulators can support selected parts of this progression. They **provide a controlled environment** for **practising movements**, **exploring welding conditions** and **receiving feedback** without requiring every learning attempt to begin with live welding.

Practical workshop training remains essential. Simulation is most valuable when it prepares learners for real welding, identifies specific development needs or supports targeted retraining.

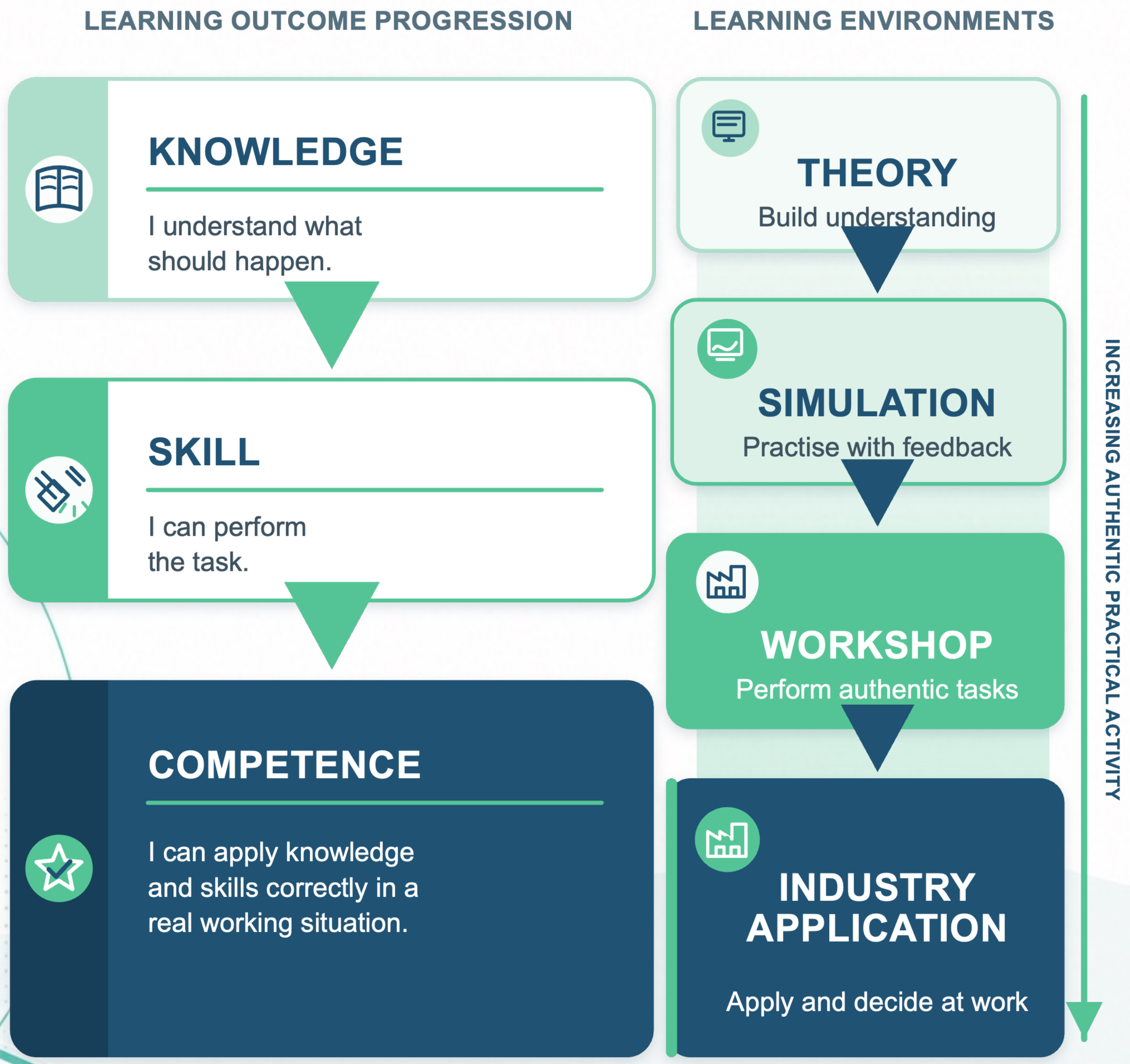
The purpose of using a welding simulator *is therefore not to replace practical welding. Its role* ***is to make the learning process more focused*** *by placing simulation where it provides a clear educational benefit.*

Start with the competence to be developed, then select the most appropriate learning environment.

From knowledge to competence

Knowing how welding parameters, techniques and quality requirements work is only the starting point. **The learner must** also **be able to perform the task** and **apply this knowledge** appropriately in practice.

Simulator training can support the **transition from understanding to controlled performance**. Practical welding then transfers and verifies the developed skills under real conditions.



The objective is not simulator performance.
The objective is workplace competence.

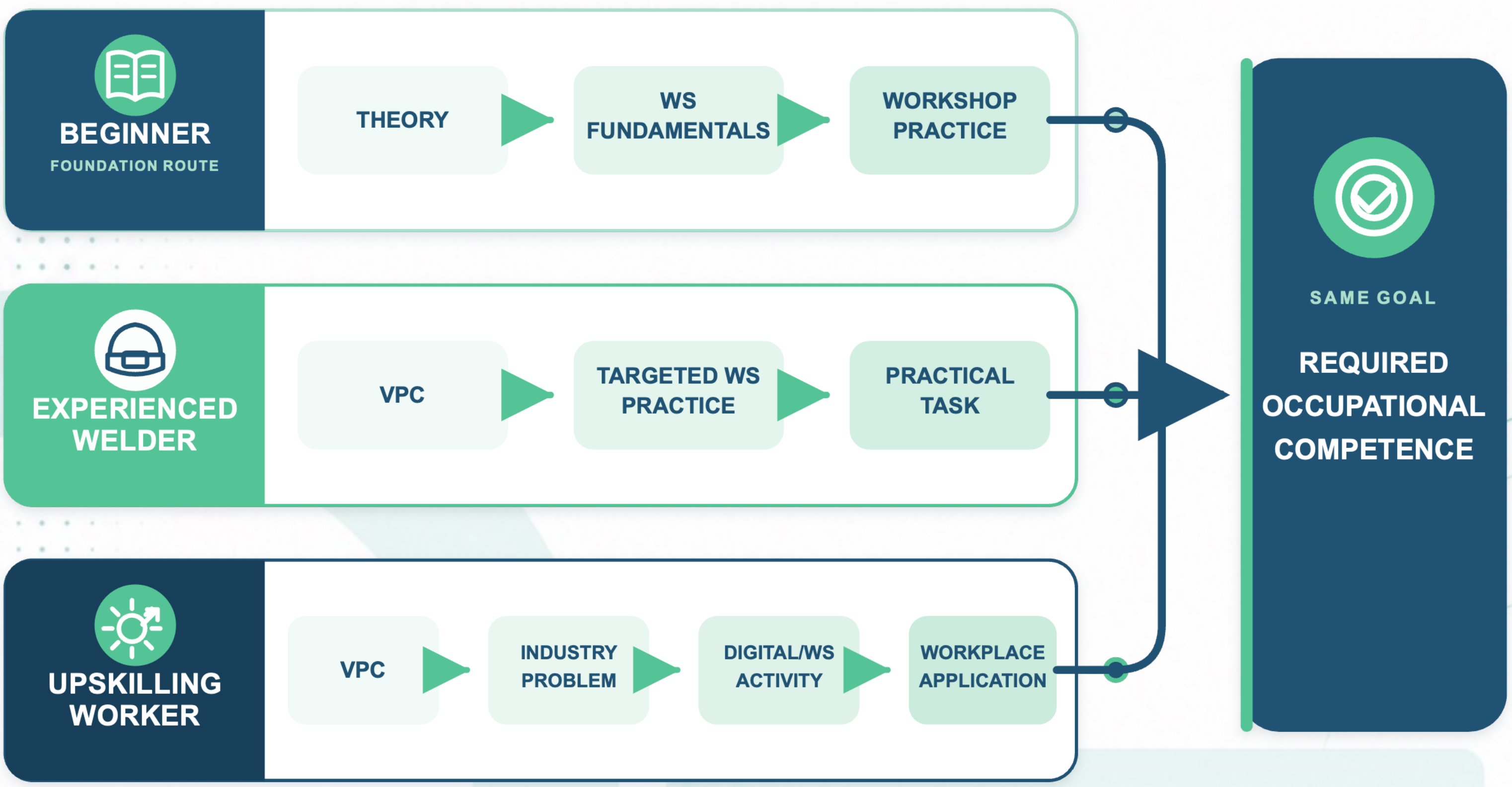
Different learners, different starting points

Simulator training can support the transition from understanding to controlled performance. Practical welding then transfers and verifies the developed skills under real conditions. Learners may enter welding training with very different backgrounds. Some are beginners, while others already have practical experience but need new skills, qualifications or digital competence.

The IQMET approach therefore gives importance to **Validation of Previous Competence (VPC)**. Existing competence can be used to identify what the learner already performs successfully and where additional training is needed.

A modular approach allows learners to follow different routes while working towards the same competence requirements.

Different routes to the same outcome



Training routes may differ. The required competence does not.

A modular approach to welding simulator training

The IQMET D4.1 proposes **several ways to integrate welding simulators into training**, rather than a single fixed simulator course. The appropriate model depends on the learning objective, learner competence, and industrial context.

The five modules range from basic welding practice to non-conformity analysis and industry case learning. They can be combined with theory and workshop activities according to the needs of the course.

This also supports **more efficient use of training resources** by reserving live welding for activities where real equipment, materials, and working conditions are essential.

The right question is not "How much simulator training should we use?" but "Where does simulation add the greatest learning value?"

The goal is not to maximise simulator time, but to use simulation where it adds learning value.

1. **SIMULATE WELDING** — Basic control and guided practice
2. **FILLET WELDING POSITIONS** — Position-specific skill development
3. **BUTT WELDING POSITIONS** — Progress towards more complex tasks
4. **INVESTIGATE NON-CONFORMITY** — Understand cause and effect
5. **INDUSTRY CASES** — Apply knowledge to real problems

LEARNING PROGRESSION

PRACTICE > APPLICATION > ANALYSIS > PROFESSIONAL JUDGEMENT

Five ways to use welding simulators

Module 1 — Simulation and practical skill development

Simulation can be used before practical welding or alternated with workshop training. When a practical task reveals a specific weakness, the learner can return to the simulator for targeted practice before attempting the weld again.

Module 2 — Fillet welding positions

Learners can progress from basic control towards relevant fillet-welding positions and tasks. Simulator practice and practical welding can alternate according to learner performance and industry requirements.

Module 3 — Butt welding positions

The same modular principle can support butt welding, with progression through relevant positions, joint configurations and practical tasks. Real welding remains essential as complexity increases.

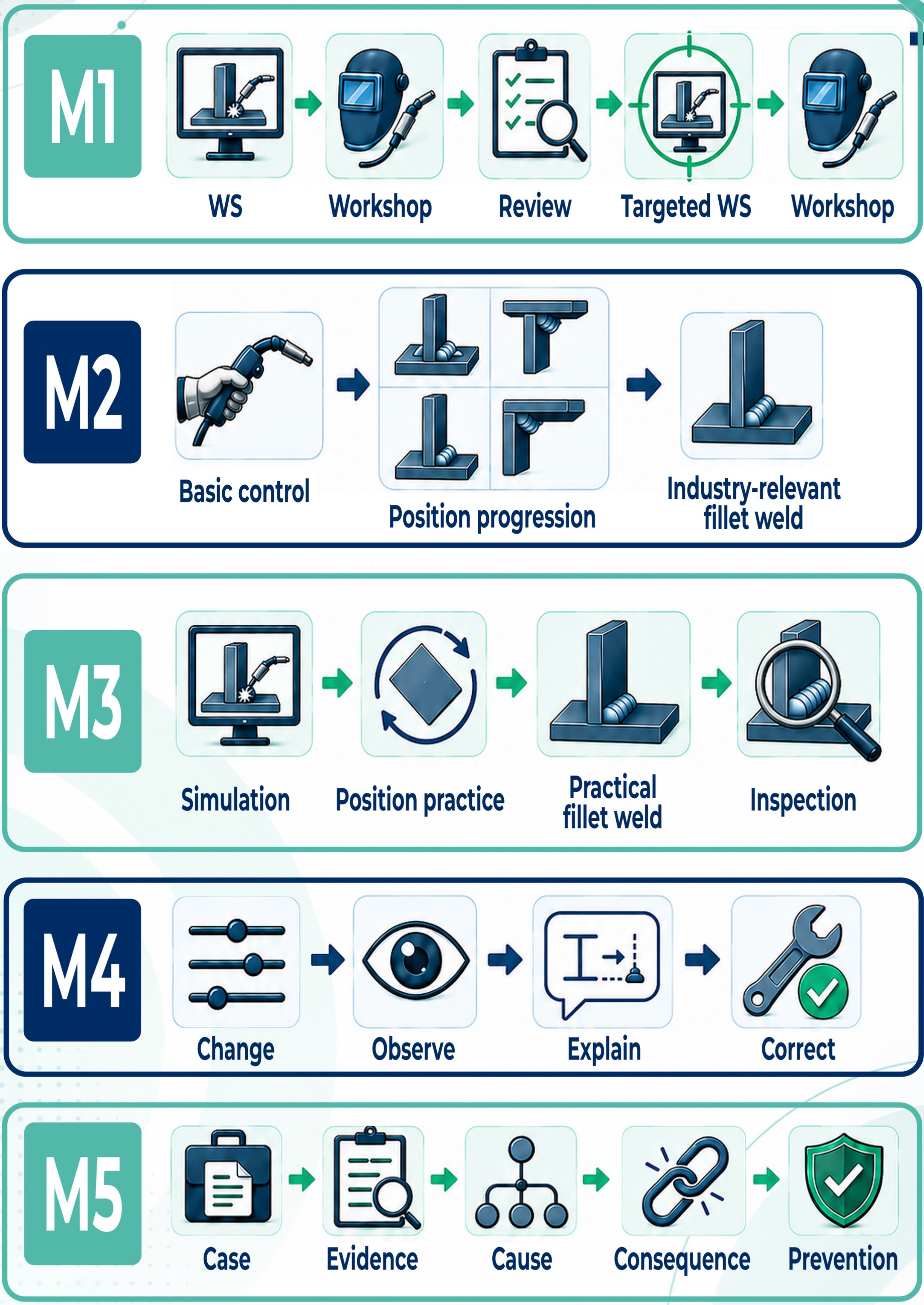
Module 4 — Learning from non-conformity

Simulation can also be used to investigate what happens when welding conditions change. By varying parameters or technique, learners can observe the result, identify the cause and test corrective actions.

Module 5 — Learning from industry cases

Industry cases connect technical training with real production problems, failures and decisions. Learners analyse evidence, identify causes, consider consequences and propose preventive or corrective actions.

WS can support technique, correction, experimentation and professional judgement at different stages of learning.



Finding the right balance

1 THEORY AND DIGITAL LEARNING

Understand

2 WELDING SIMULATION

Practise, experiment and receive feedback

3 WORKSHOP TRAINING

Perform and validate

4 INDUSTRY CASES AND WBL

Apply, analyse and decide

The balance can change. The competence objective remains.

Welding training remains **strongly practical**. Theory, digital learning and simulation should support the learner's ability to perform real welding and inspection tasks.

There is **no single ratio** between simulation, classroom learning and workshop practice that fits every course. The balance depends on the competence objective, previous experience, welding process, qualification route and available resources.

The important principle is continuity: learning in one environment should prepare for, explain or improve performance in another.

Simulation should connect to practical application, not become a separate training goal.

Side Note

Later IQMET pedagogical work reinforced the same integrated approach: simulator activities are most useful when linked with practical welding, inspection, feedback and targeted retraining rather than treated as standalone digital exercises.

PART II

WELDER AND WELDING INSPECTOR PATHWAYS

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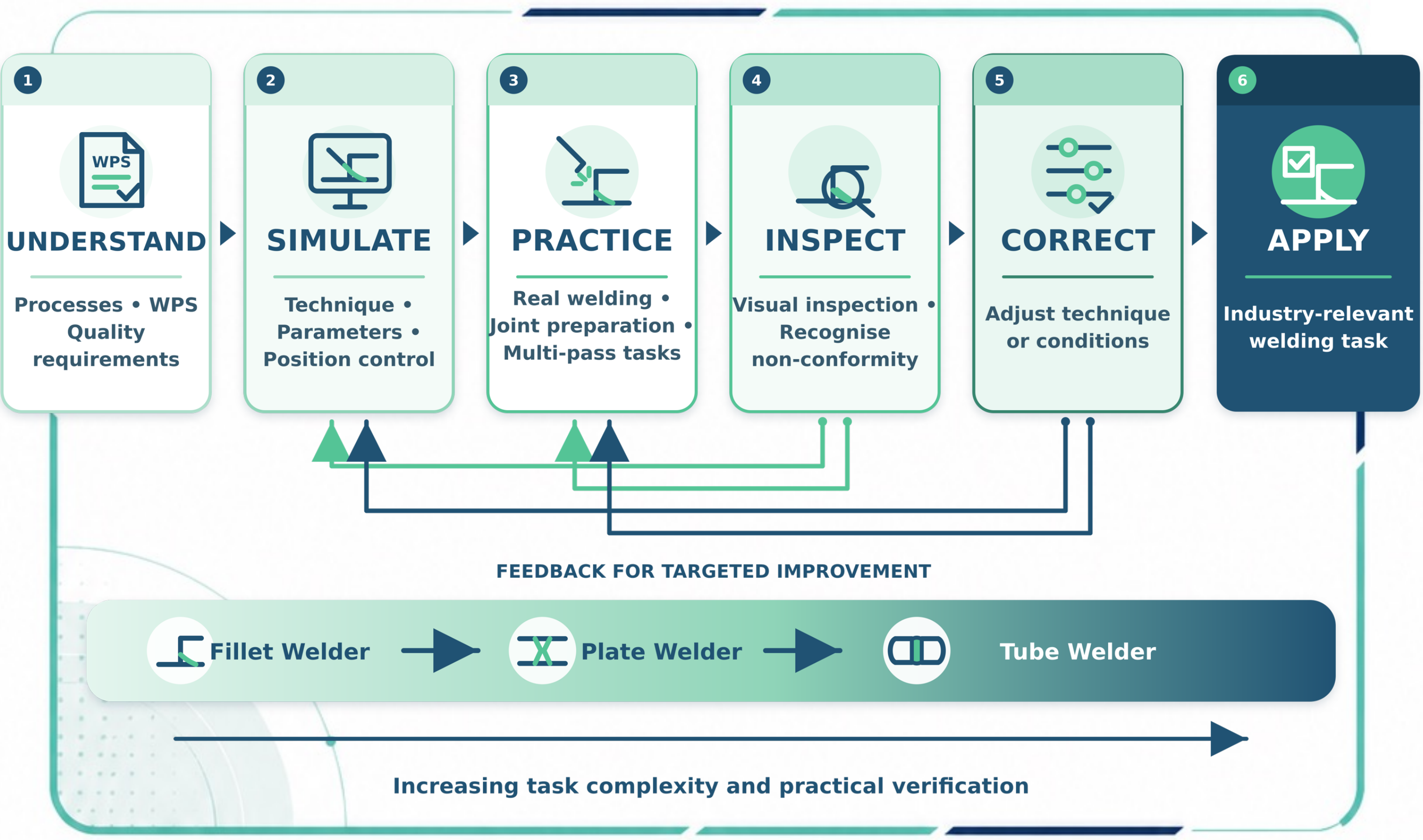
Welder pathway

Welder training should **combine technical understanding**, **simulator-supported practice** and **real welding** so that learners can progress towards reliable workplace performance.

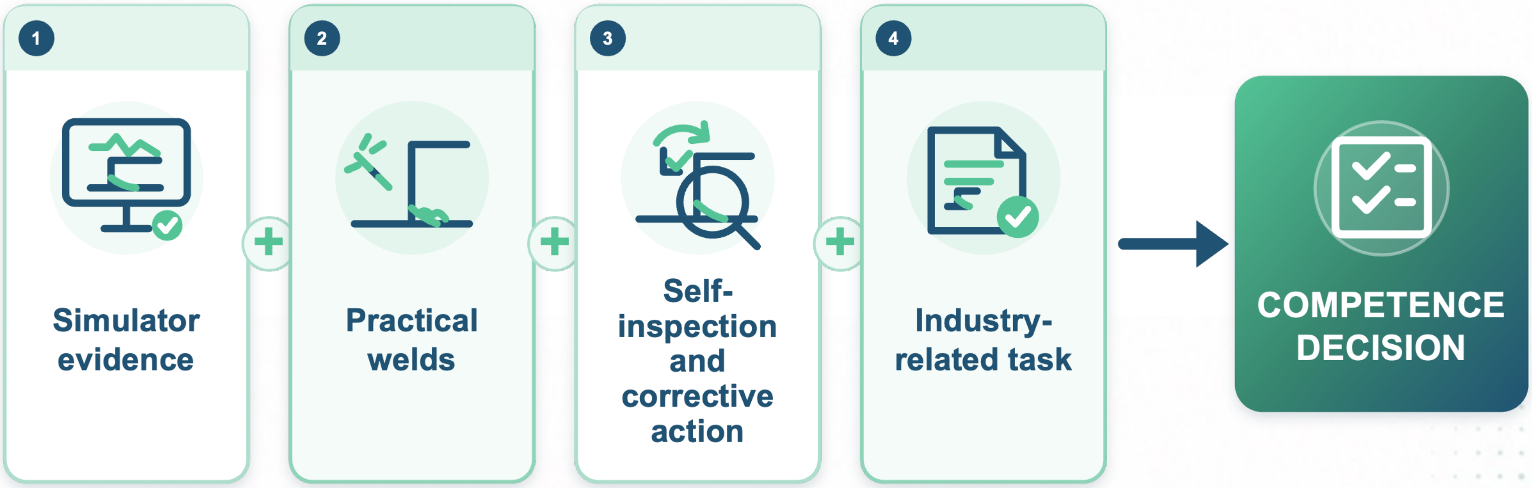
Theory and digital learning provide the basis for understanding welding processes, WPS requirements and weld quality. **Welding simulation** can support technique development, repetition and targeted correction, while **workshop training** transfers these skills to real equipment, materials and working conditions.

Progression should be adapted to the learner's **starting competence** and to the **welding processes**, positions and joint configurations required in practice. A pathway of development can start from fillet welding and move towards more complex plate and tube welding tasks, while maintaining practical verification as the basis of competence.



Practical welding should also include responsibility for the quality of the completed work. Learners should **inspect** their own welds, **recognise visible non-conformities** and consider how technique, parameters or preparation may have influenced the result.

Assessment should therefore combine simulator evidence with practical welding, self-inspection and industry-related tasks. Simulator results can support progression and feedback, but the **final competence decision** must be based on the learner's ability to perform the required welding task under **real conditions.**



Use simulation to prepare, correct and reinforce practical welding — not to replace it.

Side Note

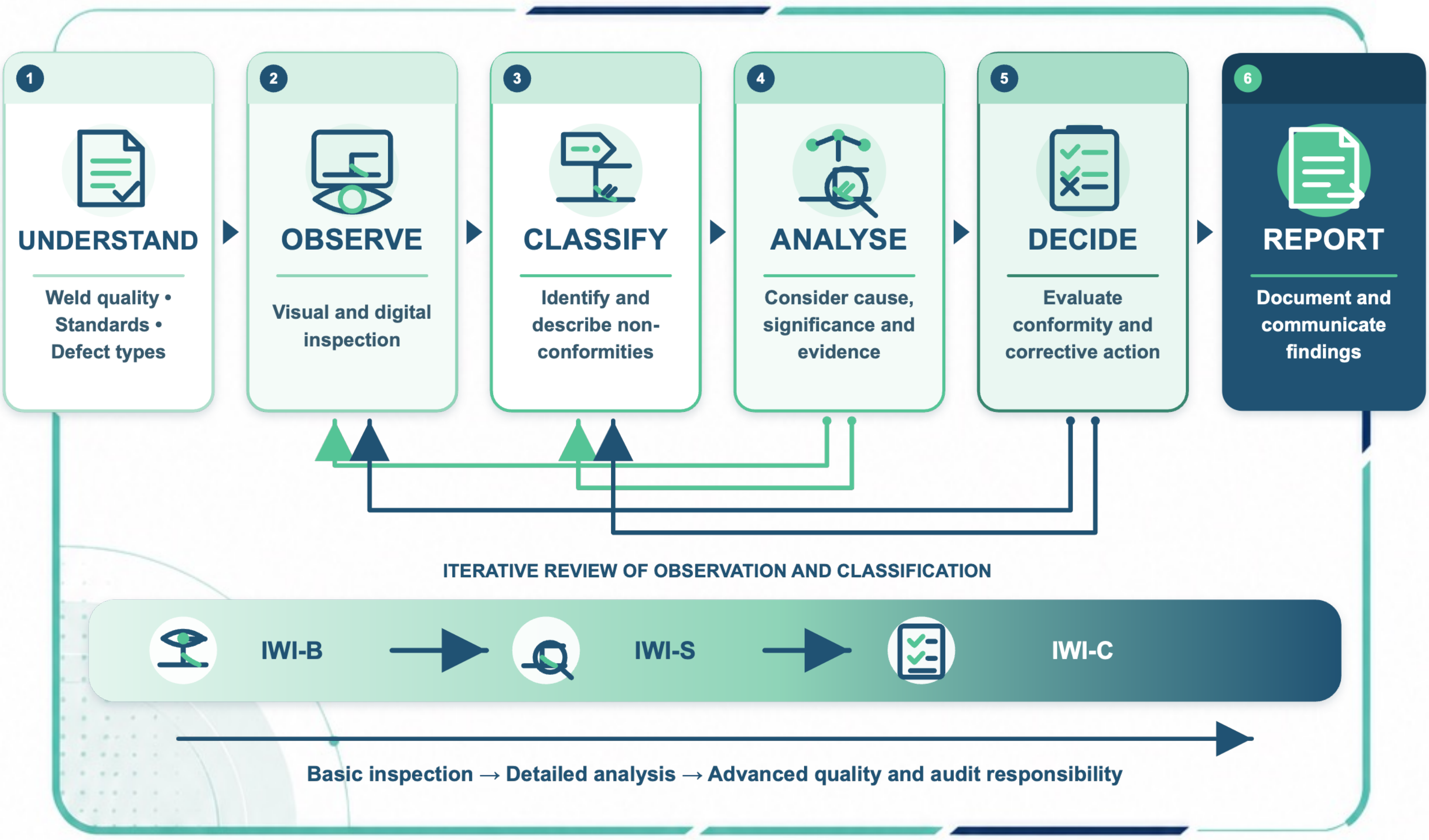
Later IQMET work reinforced the value of moving repeatedly between simulator practice, real welding, inspection and targeted correction. Simulation was most useful when linked to a specific development need and followed by transfer back to the practical task.

Inspector pathway

Welding inspector training requires a different balance of learning activities. The focus is less on performing the weld and more on **understanding welding quality**, recognising **non-conformities**, evaluating **evidence** and making appropriate **inspection decisions.**

The IQMET guideline proposes a **blended route** that combines online and video-based learning, digital and simulation-based activities, hands-on inspection and industry case studies. These elements support **progression from basic** visual inspection towards **more advanced** defect analysis, quality evaluation and inspection planning.

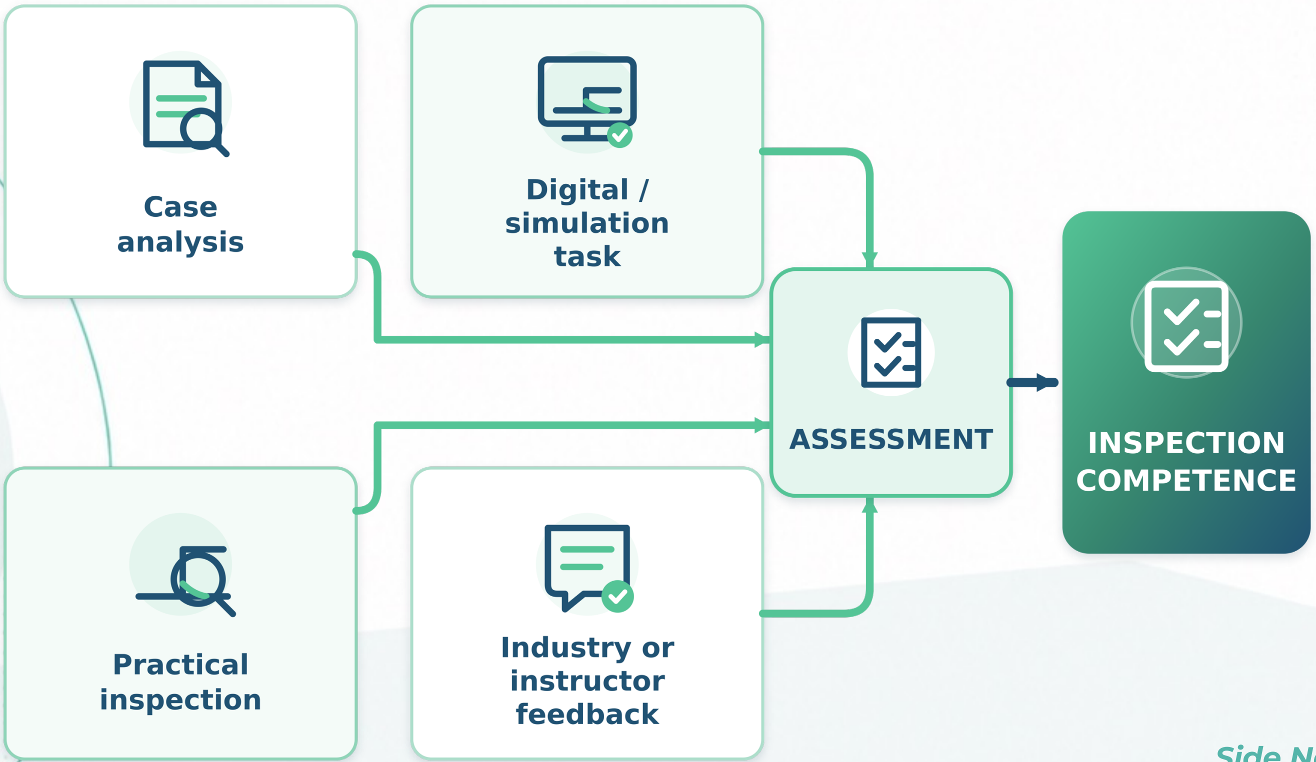
Learning should connect theoretical **understanding** with practical **inspection** tasks. Digital tools and simulation can support defect recognition, process understanding and **analysis,** while hands-on activities allow learners to inspect real welded components and apply relevant **acceptance criteria**.



Industry cases are particularly important because they require the learner to interpret evidence, consider causes and consequences, and make decisions in a realistic context.

Assessment should combine case analysis, practical inspection, digital or simulation-based tasks and, where appropriate, industry feedback. The objective is to demonstrate that **the learner can apply inspection competence consistently** and justify decisions using relevant technical evidence.

Inspection competence develops from recognising what is visible to understanding why it matters and deciding what should happen next.



Side Note

Later IQMET pedagogical scenarios placed additional emphasis on debriefing and structured reflection after practical or simulation-based tasks. This helps learners move from identifying a result to explaining its cause, significance and implications for future work.

PART III

GREENER WELDING AND FABRICATION

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Greening at three levels

Greener welding starts before the welding process itself.

At the training level, welding simulators can reduce unnecessary material and energy consumption during early practice and repeated corrections. At the competence level, welders and inspectors can reduce waste by preventing defects, avoiding unnecessary weld volume and improving first-time quality.

GREENING AT THREE LEVELS

LEVEL 1 GREENER TRAINING

- Targeted simulation
- Less unnecessary trial welding
- Reduced consumables and energy

LEVEL 2 GREENER WELDING COMPETENCE

- Correct parameters
- Appropriate weld size
- Defect prevention
- First-time quality

LEVEL 3 GREENER FABRICATION

- Design
- Process planning
- Production
- Welding engineering
- Inspection
- Welding

PRODUCTION & INSPECTION FEEDBACK

At the fabrication level, sustainability depends on decisions made across the entire production chain—from design and process planning to inspection and welding.

These three levels are connected: **better training supports better technical decisions, and better decisions support more efficient fabrication.**

Sustainability is not a separate topic. It is the result of technical decisions made throughout training and fabrication.

Greening across the fabrication chain

The environmental and economic performance of a welded product is not determined solely by the welder. Important decisions are made before welding begins, and each actor influences the options available to the next stage.

Design determines much of the required material, joint geometry and weld volume. Process planning influences fabrication methods, sequencing and opportunities for mechanisation. Production planning controls fit-up, welding sequence, positioning and handling. The welding engineer defines procedures, equipment and welding conditions. Inspection can prevent deviations from progressing into defects and repair. The welder finally converts these decisions into the completed weld.

Greener fabrication, therefore, depends on **cooperation across the complete production chain**. Design, planning, production, welding engineering, inspection, and welding are interconnected drivers of cost, energy use, and CO_2 emissions.

RESPONSIBILITY FOR GREENER FABRICATION

DESIGN
KEY DECISIONS
material and joint selection;
required weld size and geometry.

→

PROCESS PLANNING
KEY DECISIONS
fabrication route;
process selection and automation opportunities.

→

PRODUCTION
KEY DECISIONS
fit-up and fixtures;
welding sequence, positioning and distortion control.

→

WELDING ENGINEER
KEY DECISIONS
WPS, equipment and parameters;
competence, maintenance and quality monitoring.

→

INSPECTION
KEY DECISIONS
identify deviations before welding;
monitor conformity during and after welding.

→

WELDER
KEY DECISIONS
execute according to WPS;
self-inspect, correct and minimise repair.

CONSEQUENCES INFLUENCED ACROSS ALL STAGES

Material use | Energy | Emissions | Quality | Repair | Cost

A greener weld begins before the arc is struck.

Design it right: avoid unnecessary weld volume

Design decisions can strongly influence the amount of welding required later in production. Material selection, joint type and fillet-weld size affect weld volume, fabrication time and resource consumption.

Let's use a 600 m fillet-weld example. Increasing the specified **a-dimension from 4 mm to 6 mm** increased the calculated cost from **€54,789 to €80,324**, while production time increased from **288 to 488 hours** under the assumptions used in the example.

The lesson is not that weld size should simply be reduced. Weld dimensions must satisfy the applicable design and quality requirements. The point is that **unnecessary over-dimensioning creates additional material, time and energy demand without automatically creating additional value.**

THE COST OF OVERWELDING

COMPARISON Fillet weld example	REQUIRED FILLET WELD a = 4 mm · specified throat size	OVERSIZED FILLET WELD a = 6 mm · excess throat size
Total weld length	600 m	600 m
Calculated cost	€54,789	€80,324
Production time	288 h	488 h

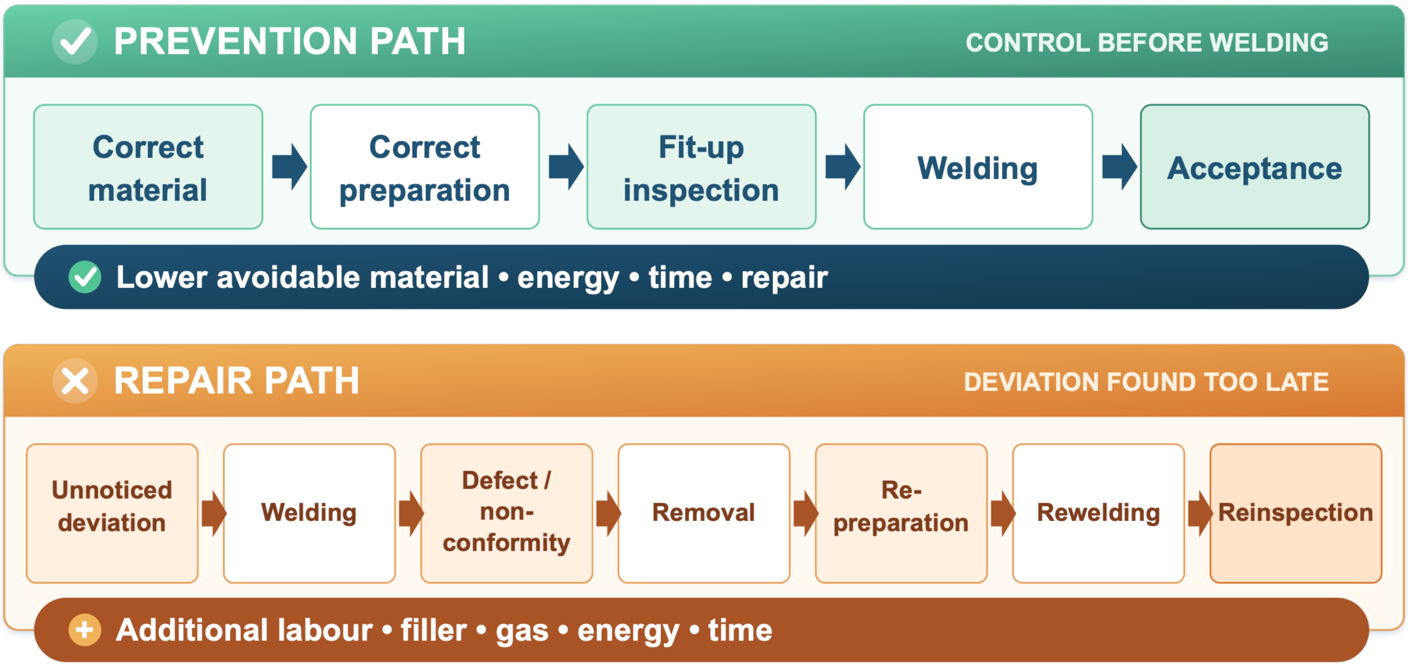
WHY THE PRODUCTION EFFORT INCREASES

1. Larger weld size →
2. More weld metal →
3. More arc time →
4. More heat and consumables →
5. Higher production effort

Example from IQSIM software;
values depend on the calculation assumptions used in the source example.

More weld metal is not automatically better welding. Use the weld size required by the design.

Prevention starts before welding



IQSIM SOFTWARE EXAMPLE

2 mm root opening	4 mm root opening
€157,766 / 1,094 h	**€200,214 / 1,427 h**

Values depend on the calculation assumptions used in the source example.

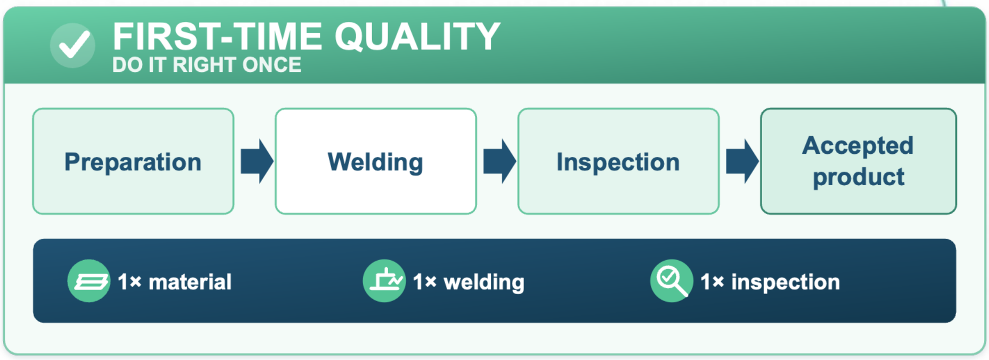
Inspection has its greatest preventive value when deviations are identified **before** they become welded into the product.

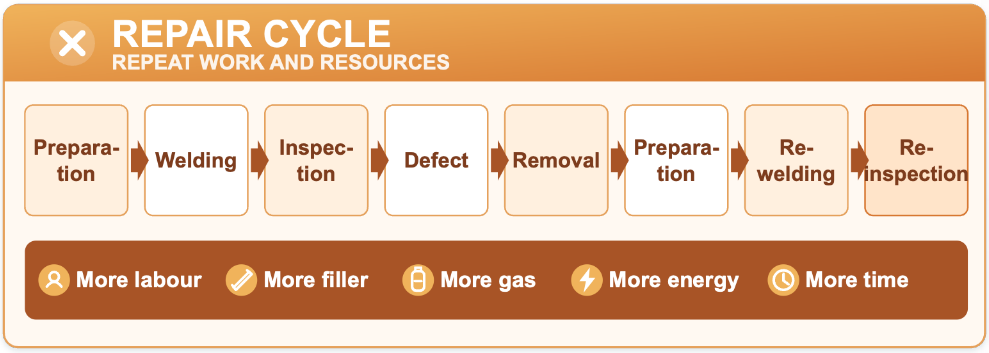
Material condition, joint preparation, alignment and root opening can all affect the amount of welding required and the risk of non-conformity. If deviations are detected before tack welding or production welding begins, corrective action can often be taken with far less resource use than after a completed weld that has to be repaired.

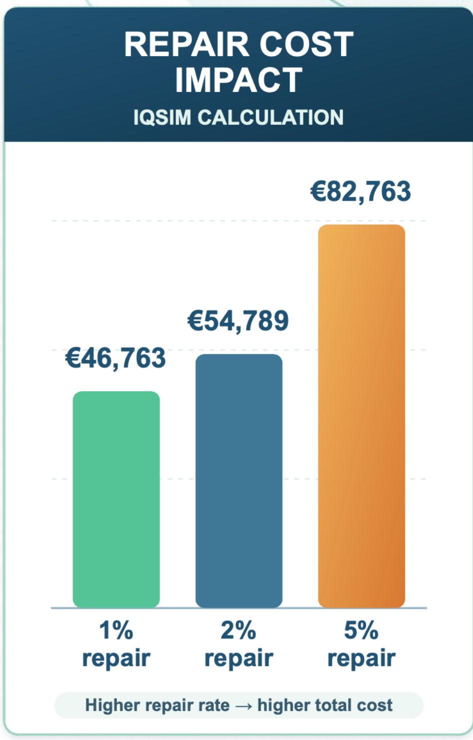
This can be demonstrated with a butt-weld example in which increasing the root opening from **2 mm to 4 mm** increased the calculated production cost from **€157,766 to €200,214** and the production time from **1,094 to 1,427 hours**. The example is used to underline the importance of inspection and fit-up control before welding.

Inspection before welding prevents problems; inspection after welding can only detect what has already happened.

First-time quality: the welder's strongest contribution







Once design, planning and preparation have defined the welding task, the welder's main contribution to greener fabrication is to produce compliant work with the minimum need for repair.

This requires welding in accordance with the WPS, controlling the technique and parameters, visually checking the completed work, and responding to inspection feedback. Avoiding repair reduces the need for repeated labour, filler metal, shielding gas, energy, and inspection.

For example, for 600 m of fillet weld, increasing the repair rate from **2% to 5%** increased the calculated total cost from **€54,789 to €82,763**. The same example shows that reducing the repair rate from **2% to 1%** decreased the calculated cost to **€46,763**.

The training message is clear: **first-time quality is both a quality objective and a resource-efficiency objective.**

The greenest repair is the one that never becomes necessary.

Side Note

Later IQMET best-practice work developed this into a broader sustainability principle: greening should be embedded in technical decisions and assessment by linking material use, energy, emissions, repair, rework and cost with occupational competence. This reinforces the emphasis on first-time quality and distributed responsibility across the fabrication chain.

Quality, productivity and sustainability

The cost of welding is not determined by welding time alone. We should consider the complete fabrication process, including material, preparation, labour, consumables, equipment, energy, inspection and finishing.

Many of these factors are interconnected. A design that requires more weld metal may increase filler consumption, arc time and energy use. Poor fit-up may increase welding effort and the probability of repair. A defect may require removal, rewelding and further inspection.

1 FIRST-TIME QUALITY

Avoid unnecessary repetition

2 CORRECT TECHNICAL DECISIONS

Avoid unnecessary weld volume

3 UNDERSTAND THE COST DRIVERS

Recognise where resources are consumed

4 OPTIMISE THE WHOLE WORKFLOW

Look beyond arc time

COMBINED FABRICATION OUTCOME

QUALITY + PRODUCTIVITY + SUSTAINABILITY

Good fabrication decisions support quality, productivity and sustainability at the same time.

PART IV

WHAT THIS MEANS FOR EDUCATION

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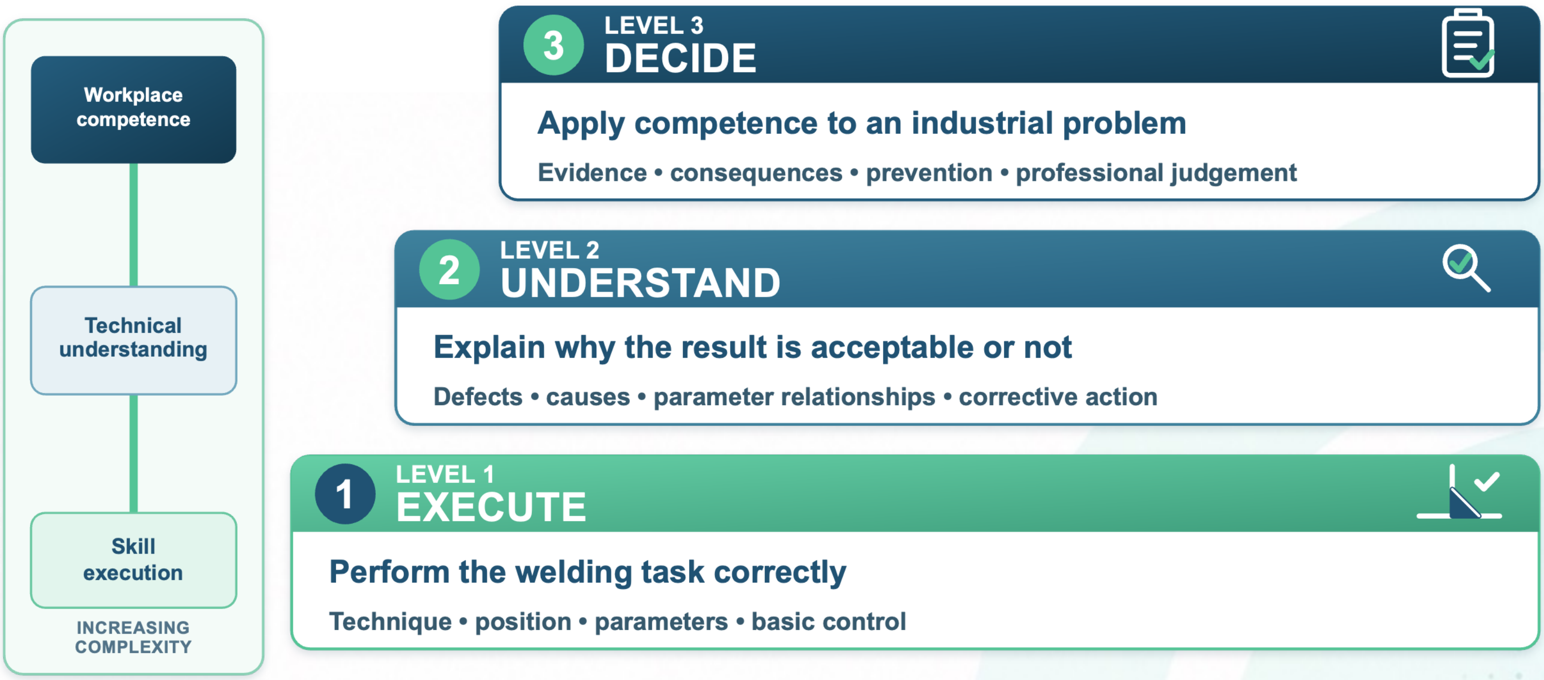
From execution to professional judgement

Welding training should progress beyond reproducing the correct movement or parameter setting. Learners first need to perform the task correctly, then understand why defects occur, and finally apply that understanding to real industrial situations.

We can present this progression through three training scenarios: basic welding skill development, advanced learning focused on defects and their causes, and industry-oriented learning based on practical cases.

This creates a clear competence pathway:



At the first level, the learner develops a reliable technique. At the second stage, the learner interprets cause and effect. At the third stage, the learner applies technical knowledge to workplace problems, quality decisions and prevention.

The goal of training is not only to produce a correct weld, but to understand and control the conditions that lead to it.

Use the right learning environment at each level

Different learning environments contribute differently as competence develops.

At the **Execute** level, welding simulators can support repetition, movement control and immediate feedback, while workshop practice verifies the skill under real conditions.

At the **Understand** level, simulation can be used to vary parameters and explore the causes of non-conformity. Practical welding and inspection then help confirm how these relationships appear in real work.

At the **Decide** level, industry cases become especially important. Learners use evidence, discuss causes and consequences, and consider preventive or corrective actions. Simulation can support selected “what-if” scenarios, but the emphasis shifts towards judgement and application in context.

The result is a learning system in which WS, workshop practice and industry cases are used for different purposes rather than treated as interchangeable methods.

LEARNING ENVIRONMENT	1 LEVEL 1 EXECUTE	2 LEVEL 2 UNDERSTAND	3 LEVEL 3 DECIDE
WS WELDING SIMULATOR	Practise technique	Explore cause and effect	Test selected scenarios
Workshop REAL WELDING	Perform and verify	Observe real outcomes	Apply corrective actions
Industry cases	Limited role	Connect defects to context	Analyse, judge and prevent

LEARNING-ENVIRONMENT PROGRESSION

WS develops control → Workshop verifies performance → Industry cases develop judgement

PART V

IMPLEMENTATION IN VET/LSP ORGANISATIONS

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From industry need to continuous improvement

Successful implementation of welding simulators starts with a training need, not with the simulator itself.

A VET/LSP organisation should **first identify the competence required by industry** and translate this into clear learning outcomes. The **learner's prior competence** can then be taken into account so that training focuses on actual development needs.

Only after these steps should **the role of the welding simulator** be defined. Simulation may support initial practice, targeted correction, non-conformity analysis or industry-based scenarios, but it should form **part of a wider pathway** that also includes theory, practical welding, inspection and assessment.

Implementation also depends on **trainer competence**. Teachers and instructors need sufficient technical, pedagogical, and digital capabilities to connect simulator results to **practical performance and provide meaningful feedback.**

The first implementation should be treated as a **learning process for the organisation** itself. Pilot delivery, learner performance, trainer observations and industry feedback can be used to **refine the course before wider implementation.**

Implement the learning process first. Integrate the technology where it strengthens that process.

IQMET IMPLEMENTATION ROADMAP

1 IDENTIFY INDUSTRY NEEDS
What tasks and competence are required?

2 DEFINE LEARNING OUTCOMES
What should the learner be able to do?

3 IDENTIFY STARTING COMPETENCE
What can the learner already perform?

4 SELECT THE ROLE OF WS
Where can simulation add learning value?

5 DESIGN THE BLENDED PATHWAY
Theory • WS • Workshop • Industry cases

6 PREPARE TRAINERS AND RESOURCES
Technical • Pedagogical Digital • Practical

7 PILOT THE COURSE
Test the pathway with learners

8 ASSESS COMPETENCE
Combine evidence from different learning environments

9 REVIEW AND IMPROVE
Use results and feedback to refine the course

CONTINUOUS REVIEW AND IMPROVEMENT

DECISIONS AT EACH IMPLEMENTATION STAGE

PLAN	Industry needs	Learning outcomes	Learner competence	
DESIGN & DELIVER	WS role	Blended pathway	Trainer preparation	Pilot
VERIFY & IMPROVE	Assessment	Feedback	Course improvement	

REFERENCE POINT THROUGHOUT

Industry relevance remains the reference point throughout.

Side Note

Later IQMET pilot and pedagogical work reinforced the value of treating implementation as an iterative process. Simulator-supported activities become more effective when trainers observe how learners transfer skills between simulation, workshop practice and inspection, and then adapt the learning sequence accordingly.

Implementation checklist

Before introducing or expanding simulator-supported welding training, the organisation should verify that the technology, curriculum, trainers and assessment system support the same competence objectives.

The checklist below can be used during planning, pilot delivery or periodic course review.

ORGANISATION 01

- ☐ Industry competence needs have been identified.
- ☐ The purpose of WS within the course is clearly defined.
- ☐ Suitable simulator, workshop and digital resources are available.
- ☐ Practical training can be connected to relevant industrial tasks.
- ☐ Feedback from learners, trainers and industry can be collected and reviewed.

CURRICULUM 02

- ☐ Learning outcomes describe occupational competence, not only knowledge.
- ☐ Simulator activities are linked to specific learning outcomes.
- ☐ Theory, simulation and practical training form a coherent pathway.
- ☐ Non-conformity analysis and corrective action are included where relevant.
- ☐ Industry cases or work-based activities connect learning with production practice.

TRAINERS 03

- ☐ Trainers have the required welding and quality competence.
- ☐ Trainers can operate and interpret the welding simulator.
- ☐ Trainers can connect simulator feedback with practical welding performance.
- ☐ Feedback and debriefing are planned as part of learning.
- ☐ Trainers can adapt activities to different learner starting points.

ASSESSMENT 04

- ☐ Assessment reflects the required occupational competence.
- ☐ Practical performance is verified under real conditions.
- ☐ Simulator results are used as supporting evidence where appropriate.
- ☐ Inspection, interpretation and corrective action are assessed where relevant.
- ☐ Assessment results are used to improve the learner pathway and the course.

Technology, curriculum, trainers and assessment should point towards the same competence outcome.

Key IQMET principles

The IQMET approach does not define one universal model for simulator-supported welding training. It provides principles that VET/LSP organisations can adapt to their learners, qualifications, equipment and industrial environment.

The following principles summarise the implementation approach presented throughout this guide.

1 START WITH INDUSTRY COMPETENCE

Training should respond to the tasks, quality requirements and decisions learners will meet in practice.

2 RECOGNISE THE LEARNER'S STARTING POINT

Use previous competence to target training where development is needed.

3 USE WS WITH A CLEAR PURPOSE

Simulation should prepare, reinforce, diagnose or extend learning—not become an objective by itself.

4 KEEP PRACTICAL EXPERIENCE CENTRAL

Real welding and inspection remain essential for demonstrating occupational competence.

SMARTER
WELDING TRAINING
REVIEW • ADAPT • IMPROVE

5 LEARN FROM RESULTS AND MISTAKES

Use non-conformity, corrective action and case analysis to develop understanding, not only repetition.

6 CONNECT TRAINING WITH THE FABRICATION PROCESS

Quality, productivity, cost and sustainability are influenced by decisions made before, during and after welding.

7 ASSESS COMPETENCE USING COMBINED EVIDENCE

Simulator data, practical performance, inspection and workplace-related tasks each provide different evidence.

8 REVIEW, ADAPT AND IMPROVE

Use learner results, trainer experience and industry feedback to continuously refine the training.

Smarter welding training combines technology, practical experience and industry knowledge to develop competence that transfers to the workplace.

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FURTHER READING AND REFERENCES

- **D3.1–A. Questions and answers for D3.1–B Industry examples**
- **D3.1–B. Industry examples: 16 industry examples with case analyzes**
- **D3.3–C. Greener fabrication process using welding simulators**
- **D4.1–A. Guideline, implementation of welding simulators in VET/LSP**
- **D4.4–A. Pedagocical scenarios using welding simulators**
- **D5.1. Course design and development**
- **D5.2–A. Best practice guidelines**

These documents, and more, are accessible through the contact page of the website: **www.iqmet.eu**

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Project No: ***2023-1-NO01-KA220-VET-000155256***

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Created based on the final version of deliverable 4.1-A.