

Competence and Training Controls for Photopolymer Manufacturing Personnel: Roles, Process Skills, Safety and Demonstration

A role-based framework for training content, workplace evidence and bounded competence claims

Juan Seguro

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Correspondence: info@3Dresyns.com · www.3Dresyns.com

ER-480 · Engineering Review · Version 0.1 · 12 October 2026

Abstract

Industrial additive manufacturing depends on personnel who can connect design intent, process selection, machine operation, material state, post-processing, quality evidence and safety. A training record alone does not prove workplace competence, and a generic additive-manufacturing curriculum does not automatically establish proficiency in a specific photopolymer process. This review defines a role-based control framework that separates training content, practical demonstration and local authorization.

The Spanish Real Decreto 280/2021 provides an official competency and curriculum framework for additive manufacturing that explicitly includes vat polymerization, SLA, photopolymer resins, curing/post-processing, machine operation, quality and occupational safety. Stavropoulos et al. propose an industrial AM training framework organized by professional profiles and modular learning areas. NIOSH identifies technology-, material- and environment-dependent additive-manufacturing hazards, including dermal exposure to hazardous liquids and hazards associated with machine support and material handling. Together these sources support structured competence governance, but they do not establish a universal certification scheme, recertification interval, examination instrument or pass/fail threshold. A bounded task demonstration and explicit authorisation denominators illustrate how competence claims can be tied to observable work and process changes.

Keywords: additive manufacturing; photopolymerization; personnel competence; training; safety; roles; demonstration; vat polymerization; manufacturing governance

1. Significance and scope

Competence in photopolymer manufacturing is not a single attribute. A designer, process engineer, operator, maintenance technician, quality specialist and manager interact with different failure modes and therefore require different combinations of knowledge and demonstrated capability. The control problem is to show that each person is authorized for the work they actually perform without inflating course attendance into evidence of competence.

Real Decreto 280/2021 is particularly useful because its official curriculum explicitly names vat polymerization, photopolymer resins and SLA, while also covering process stages, machine operation, post-processing, quality, safety and environmental protection [1]. Stavropoulos et al. provide an industrial training architecture organized around professional profiles and modular content [2]. NIOSH provides the occupational-safety boundary, emphasizing that additive-manufacturing hazards depend on technology, material and environment [3].

1.1 Corpus boundary

ER-479 owns technology transfer to contract manufacturers, including knowledge packages, transfer training, capability evidence and change control. ER-480 owns internal personnel competence: roles, required knowledge, process skills, safety awareness, practical demonstration and local authorization. It does not establish a generic personnel-certification programme and does not prescribe a recertification interval.

2. Role architecture

A competence system should begin with role definition rather than a universal course. The industrial training framework of Stavropoulos et al. distinguishes the needs of engineers, designers, operators and managers and organizes AM knowledge into modules [2]. The Spanish curriculum likewise connects technical learning outcomes with production, maintenance, safety, quality and documentation functions [1].

For photopolymer manufacturing, a practical role matrix may include process/design engineering; formulation or material handling where applicable; printer setup and operation; washing and post-cure; inspection and quality disposition; maintenance; and supervisory or release roles. One person may hold several roles in a small organization, but the evidence requirements for those roles should remain explicit.

3. Core process knowledge for photopolymer work

The official Spanish curriculum identifies vat polymerization with photopolymer resins and SLA as a process family, and includes material selection, slicing/orientation, post-processing and curing, equipment maintenance, calibration and quality controls [1]. That breadth is important: competence cannot be reduced to knowing how to start a print.

At minimum, personnel whose decisions can affect product state should understand the distinction between digital settings and measured process state; material identification and storage controls; exposure and build-state dependencies; orientation and support implications; washing and drying; post-cure or other stabilization; inspection; deviation handling; and the local change-control rules that invalidate a prior setup. The depth required depends on role.

4. Safety competence

NIOSH states that additive-manufacturing hazards vary with technology, material and environment and identifies potential dermal exposure to hazardous liquid materials, volatile emissions, fire/explosion hazards in applicable systems, and mechanical or ergonomic

hazards associated with machines, material handling and products [3]. The Spanish curriculum also embeds prevention, PPE, chemical handling, waste segregation and safety in post-processing and maintenance activities [1].

A competence record should therefore connect each role to its actual hazards and controls. Generic safety induction is insufficient where a role handles uncured resin, solvents, contaminated waste, UV equipment, heated post-cure equipment or maintenance tasks. Conversely, this review does not infer that every listed hazard applies to every photopolymer installation.

5. Training is an input, demonstration is evidence

The training framework of Stavropoulos et al. emphasizes modular learning and active, hands-on participation [2]. ER-480 adopts a strict interpretation: training provides knowledge and practice opportunities; demonstration records whether a person can perform a defined local task under the required controls. These are different records.

“Demonstration” in the title is intentionally bounded. This review does not prescribe an examination method, a scoring instrument or a passing threshold. A local organization may use supervised execution, witnessed setup, traceable inspection, deviation response or another appropriate method. Whatever method is chosen, the record should identify the task, conditions, observer or approving authority, date and scope of authorization.

State	Meaning	Not equivalent to
Trained	Required knowledge or instruction has been completed.	Demonstrated local task competence.
Demonstrated	A defined task has been performed under specified conditions with retained evidence.	Universal certification or permanent authorization.
Authorized	The organization permits the person to perform a bounded role in a controlled process state.	Unlimited transfer to different equipment, materials or changed processes.

Table 1. Separation of personnel-control states in ER-480.

6. Local authorization and change control

Competence is configuration-dependent. New printer hardware, software, resin families, post-processing equipment, revised safety controls or materially changed acceptance methods can alter the skills required for a role. A competence system should therefore link authorization to the controlled process state and define which changes require updated training, renewed demonstration or both.

This does not require a universal periodic recertification interval. Time alone is not the only source of competence drift; process change, infrequent task performance, repeated deviations or a new hazard can be stronger triggers. The appropriate re-evaluation rule remains an organizational decision supported by risk and change history.

7. Minimum competence record

A concise competence record should contain the role; authorized task scope; required prerequisite knowledge; completed training modules; practical exposure or supervised practice where relevant; demonstration evidence; safety requirements; process/equipment/material scope; limitations; authorizing person; date; and change triggers. It should also separate “trained,” “demonstrated” and “authorized” states so that they cannot be used interchangeably.

For quality-sensitive work, the record should be auditable against the manufacturing genealogy. A released part should be traceable to personnel who were authorized for the controlled operations they performed at that time.

8. Competence failure modes

Competence systems fail when role boundaries are implicit. A person may be trained on printer operation but not authorized to release a build, trained on resin handling but not on maintenance, or competent on one post-cure unit but not on another. If the record contains only a course title, those distinctions disappear and later deviations cannot be traced to the actual authorization state.

A second failure mode is permanence by assumption. Additive-manufacturing software, equipment, materials and safety controls evolve. Demonstration evidence should therefore be reviewed when the controlled task changes materially, when repeated deviations reveal a skill gap, or when long inactivity makes prior evidence no longer representative. This is a trigger-based review, not a universal recertification clock.

A third failure mode is treating safety as a separate annual module with no connection to the task. NIOSH and the Spanish curriculum both support task-linked safety content. For photopolymer operations, the relevant training should travel with the role that handles uncured liquid, washing/post-processing, maintenance, waste or exposure-control tasks.

9. Governance metrics without false precision

Competence governance needs indicators, but a single competence score can hide more than it reveals. More defensible measures include the fraction of controlled roles with current authorization, the fraction of changed processes reviewed for training impact, deviation recurrence by task, completion of required demonstrations, and the number of authorizations operating beyond their declared equipment or material scope.

These indicators are management signals rather than universal acceptance criteria. A low deviation count can coexist with poor detection, and a high training-completion rate can coexist with weak practical performance. The useful question is whether the organization can reconstruct who was authorized to do what, under which process state, and what evidence supported that authorization at the time of manufacture.

10. An observable demonstration for a bounded task

The proposed competence exercise begins with one task and its controlled conditions. For example, a washing and post-cure role could require the operator to identify the applicable work instruction, confirm the part and material identity, recognise the authorised equipment configuration, preserve the process record and escalate a defined discrepancy. The example describes evidence to observe, not a universal operating procedure or a prescribed safety limit.

The assessment should distinguish task execution from verbal knowledge. A person may correctly explain a rule yet fail to recognise when it applies during work. Conversely, completing a routine sequence once does not show an ability to detect a relevant deviation. The record could therefore include both a normal execution and a bounded scenario requiring interruption or escalation. Any scenario would need to be designed so that it does not expose people or products to an uncontrolled hazard.

The observer would record the action, conditions and evidence rather than only a global pass label. Where assistance was given, it would be retained because assisted performance supports a different conclusion from independent performance.

11. Authorisation follows the demonstrated scope

A proposed authorisation would identify the task, equipment or process family, relevant limitations and triggers for reassessment. The scope could expand only when the organisation has evidence for the additional task or state. If a new post-cure unit changes an operator's responsibilities, the prior record should be examined for what remains representative rather than accepted or discarded solely by date.

Governance measures can be computed with explicit denominators. For example, current task authorisations divided by required task authorisations describes coverage under a declared roster. It does not measure the probability of an error or establish that training caused improved quality. If one person holds three task roles, counting people and counting authorisations produce different indicators and should not be mixed.

An informative evaluation would examine whether gaps in demonstration or authorisation are detected before affected work, and whether changes trigger appropriate review. Repeated assessment failures should lead to investigation of the task, training and evaluation method, not automatic attribution to the individual. This turns the role-based framework into a usable evidence process while leaving professional certification and universal examination standards outside its claim.

12. Evidence of competence at the work station

Competence is a role- and task-specific state supported by observed performance, not a certificate inferred from classroom attendance. A training matrix should separate material receiving, formulation, printing, washing, curing, inspection, maintenance and deviation handling. For each authorized task it should specify prerequisite knowledge, critical errors, observable actions, evaluator independence and re-assessment triggers.

A practical demonstration could present a nonconforming build record containing inconsistent exposure settings, an uncertain resin lot and incomplete post-cure evidence. The candidate should identify why product release is blocked, quarantine the affected material where required, preserve the data trail, and escalate according to a controlled procedure. This tests interpretation and safe response rather than memorization. The scenario itself remains a proposed assessment, not evidence that operators have achieved competence.

Skill decay and procedural change justify periodic reassessment focused on rare but consequential tasks. Records should distinguish supervised performance from independent authorization and temporary deviation permissions. For processes involving chemical exposure, the assessment scope must also include appropriate local occupational protections and emergency procedures without treating a generic AM course as comprehensive site-specific safety certification.

Competence metrics require denominators: completion percentage does not measure defect prevention; recorded deviations may initially increase when reporting improves. A balanced program uses observed task proficiency, audit findings, repeat errors and follow-up checks, while avoiding unsupported causal claims that training alone reduces failures.

Competence must be demonstrated at the process step

Training attendance records do not establish skill at resin handling or evidence evaluation. A role-based qualification should specify observable decisions and tasks: identifying a suspect raw-material lot, recognising an exposure-calibration deviation, deciding when a washed part is fit for post-cure, interpreting an inspection result and isolating nonconforming work. Each demonstration should have a controlled scenario, an explicit acceptance criterion and a record of the evaluator and equipment state. Competence is therefore an observable capability maintained over time, not a certificate automatically granted by watching instruction material.

Human performance and engineered controls

The possibility of error should be managed by process design as well as instruction. Prompts, physical separation of accepted and rejected material, barcode checks, accessible spill procedures and machine interlocks reduce reliance on memory. However, the effectiveness of each control is empirical: an interface improvement should be evaluated under realistic throughput and disturbance rather than assumed effective from its presence. Safety training must distinguish inhalation, skin contact, fire and waste pathways, and should refer to the actual formulation and operations at the site. The occupational evidence base cannot be replaced by a generic statement that cured polymers are inert.

Requalification and change triggers

Operator authorisation should be reviewed after material substitution, software changes, new post-cure equipment, repeated deviations or prolonged absence from a critical task. A practical matrix links task, observed proficiency, retraining trigger, authoriser and evidence-retention period. Some errors originate in ambiguous work instructions rather than worker failure; corrective analysis should address both. The scientific boundary is clear: broad studies of workforce capability and occupational exposure motivate these controls, while their numerical effectiveness in a specific photopolymer facility remains to be tested.

Competence evidence and qualification of personnel

Training attendance, a completed course and proven task competence are different evidence types. A role-based qualification programme should define the risk-bearing decisions an operator can make: material receipt and storage, resin handling, exposure calibration, washing, post-curing, dimensional inspection, nonconformance disposition and escalation of deviations. Each role requires observable tasks, assessor criteria, a record of competence and a retraining trigger following material, machine, software or process change. A generic AM curriculum does not automatically establish capability on a specific photopolymer production system.

Environmental, health and safety competence is likewise distinct from manufacturing proficiency. Personnel can demonstrate correct print preparation while still requiring separate evidence of adequate chemical handling and exposure control. A training effectiveness study should compare baseline and post-training task performance under specified conditions, not infer effectiveness from participant satisfaction. The cited training and occupational-safety sources provide a basis for selecting competencies, whereas the particular demonstration matrix is a proposed engineering tool awaiting site-specific validation.

Observable competence and bounded authorisation

Classroom attendance and correct recall of a procedure are weak proxies for process competence where decisions depend on handling state, equipment condition or anomalous print response. A better evaluation combines observation of actual task execution with a documented challenge scenario, predefined pass criteria and an explicit authorisation scope for the role.

The training architecture should distinguish operators who execute approved procedures, personnel authorised to disposition nonconforming materials, and engineers permitted to alter validated settings. A trainee may demonstrate routine print setup without being authorised to change post-cure conditions or approve an alternate resin. Requalification should be triggered by process changes, observed errors or prolonged inactivity according to a documented risk rationale.

When human errors recur, retraining should not be the only corrective action. The review should consider whether interface design, interlocks, machine state visibility and procedural ambiguity contributed to the event. The proposed competency controls require site validation and cannot be inferred as universally effective solely from general human-factors literature.

13. Limitations

Real Decreto 280/2021 is an educational and competence curriculum, not an employer-specific certification or recertification rule. Stavropoulos et al. provide an AM-general industrial training framework rather than a photopolymer-only competence standard. The NIOSH page is occupational-safety guidance and does not define personnel certification. ER-480 therefore proposes no universal training duration, assessment method, passing score or recertification interval.

14. Conclusions

A defensible photopolymer competence system separates role, training, demonstration and authorization. Official curriculum evidence shows that vat polymerization, photopolymer post-processing, machine operation, quality and safety are legitimate competence domains. Industrial training research supports modular, role-sensitive learning, and NIOSH reinforces the need to bind safety to technology and material. The resulting control system is local and auditable: people are authorized for defined tasks in a defined process state, and material changes trigger review of the competence evidence rather than assumptions of permanent transferability.

Competing interests

The author is Founder, CEO and CTO of 3Dresyns by Resyner Technologies S.L. The company develops and supplies photoresins and related process materials. No proprietary formulation, manufacturing sequence, process window or comparative product recommendation is disclosed.

Data availability

No new experimental datasets were generated for this review.

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