

Beyond Device Recognition: Defining Foundational Device Fluency in Interventional Radiology

The Educational Gap: From Device Exposure to Device Understanding

Contemporary interventional radiology curricula already introduce learners to core devices and materials, including catheters, guidewires, needles, drains, stents, and embolic agents.^{1,2} Yet undergraduate exposure to IR remains inconsistent; in the ELIXIR study, 64% of final-year medical students rated their IR knowledge as inadequate.³ Existing curricula identify devices learners should encounter and describe their characteristics and uses, but exposure alone does not define the organized understanding a novice should develop. The unresolved educational question is therefore not simply which devices learners should see, but what foundational understanding of device function, characteristics, and procedural role should result from those encounters.

Professional training standards describe progression from basic catheter and wire skills toward advanced device use and, ultimately, device selection and utilization.^{4,5} Between initial device exposure and that level of clinical competence lies an educational stage that is not explicitly defined by these standards. We propose foundational device fluency as a distinct intermediate competency within this space: the organized understanding of devices needed to support supervised procedural learning before responsibility for device selection and use. Such understanding may help a novice follow device transitions, connect unfamiliar equipment to the problem being addressed, ask more informed questions, and recognize when a distinction exceeds current knowledge. These abilities may make subsequent case-based learning more interpretable without implying selection competence. Defining this intermediate stage therefore makes an otherwise implicit phase of device learning explicit and creates a construct that can be examined empirically.

Defining Foundational Device Fluency

Foundational device fluency comprises six related domains: device-family recognition, interpretation of salient visual and labeled characteristics, functional understanding, procedural contextualization, discrimination between plausible alternatives, and recognition of when compatibility, sizing, selection, or use requires escalation. Recognition extends beyond naming to identifying the device family; label literacy requires understanding the dimensions, interfaces, working characteristics, and manufacturer information relevant to interpretation. Functional understanding addresses the problem the device addresses, while procedural contextualization places that function within the case sequence and broader device system. Meaningful discrimination requires distinguishing devices on the basis of consequential differences rather than superficial resemblance alone. Boundary awareness completes the construct by requiring the learner to recognize where interpretation ends and operator-level decision-making begins.

Together, these domains describe an organized understanding of what a device is, what it does, how it fits within a procedure, how it differs from alternatives, and where the learner's knowledge ends. This construct is therefore a cognitive educational competency, not a claim of procedural competence.

A Function-First Framework for Developing Device Fluency

How foundational device fluency should be taught is distinct from how the competency itself is defined. We propose a function-first instructional framework that organizes device encounters around procedural purpose rather than surface features alone. Expertise research suggests that novices are more likely to organize unfamiliar information according to visible or literal characteristics, whereas experts more readily recognize underlying principles and relationships.⁶ This may be particularly relevant in IR, where the same device family can appear across procedures, manufacturers, packaging, and local terminology, while similar-looking devices may serve different roles. Beginning with procedural function gives the learner an organizing question that can persist despite this variation: What problem is the team trying to solve at this point in the procedure? The framework then prompts the learner to ask: What function is being accomplished? What device family serves that function? Which visual and labeled characteristics establish what it is? Where does it fit within the procedural workflow and device system? What meaningful distinction separates it from a plausible alternative? Which decisions require escalation? Other device-intensive procedural fields provide precedent for explicitly organizing fundamental device knowledge into a standardized curriculum and competency assessment.⁷ Function is therefore an entry point for inquiry, not an algorithm for choosing a device; the same function may be served by different devices depending on clinical and procedural context.

The function-first framework could be applied across several educational settings, including supervised case exposure, structured orientation, simulation, and dedicated device instruction. During a procedure, for example, an educator might identify one or two relevant device functions before the case, ask the learner during appropriate noncritical moments to identify the function being served and the device family involved, and afterward compare the device used with a plausible alternative. Discussion could emphasize the features that establish device identity, the clinically meaningful distinctions between alternatives, and the decisions that remain the operator's responsibility. This represents one application of the framework rather than a prescribed curriculum; foundational device fluency could be taught through multiple educational formats whose effectiveness should be evaluated separately.

Preserving the Boundary Between Familiarity and Competence

Any framework for device learning must preserve the contextual nature of IR device selection. Appropriate device choice may depend on anatomy, procedural objective, compatibility, dimensions,

local practice, operator judgment, and patient-specific considerations; a function-first framework therefore cannot imply that a given function maps to a single correct device. Recognition and familiarity likewise should not be mistaken for selection competence. Repeated exposure may make a device recognizable without establishing whether the learner understands the characteristics that determine its suitability, compatibility, or limitations in a particular case. A learner may therefore know what a device is and why it is being used while remaining unqualified to determine whether a particular size, configuration, or compatibility profile is appropriate. A useful foundational competency should make that distinction explicit rather than allow familiarity to serve as a proxy for competence. For this reason, boundary awareness is part of foundational device fluency itself: learners should be able to identify not only what they understand, but also which conclusions they cannot yet make independently. The framework is intended not to replace apprenticeship or clinical judgment, but to make supervised apprenticeship more interpretable while preserving clear limits on learner autonomy.

Toward Validation and Future Study

Foundational device fluency should first be evaluated as a proposed competency before any instructional method is judged by its ability to develop it. Expert content review could assess whether the six domains are clinically meaningful, sufficiently distinct, and appropriately bounded for early learners, while cognitive interviews could determine whether learners interpret the domains and assessment tasks as intended. Objective measures could then examine device-family recognition, interpretation of labeled characteristics, function matching, procedural contextualization, discrimination between plausible alternatives, and confidence calibration. Subsequent studies should distinguish immediate recognition from deeper understanding, self-confidence from demonstrated competence, and performance on familiar devices from transfer to unfamiliar examples. Only after the construct and its measurement are adequately established should the function-first framework be evaluated prospectively as one strategy for developing that competency, including its effects on retention and transfer. The validity of foundational device fluency should not depend on the effectiveness of any single teaching method. Explicitly naming this competency creates a shared language for educators and learners to describe an otherwise implicit stage of procedural development. This shared framework may allow institutions to identify curricular gaps, design targeted assessments, and study how learners progress from device exposure toward more advanced procedural reasoning. IR educators should consider organized device understanding a deliberate educational target rather than assume that it will emerge through procedural exposure alone. Whether foundational device fluency represents a valid and measurable competency, and whether specific educational approaches improve its development, remain empirical questions that should now be tested.

References

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