# Learning Through Hand Demonstrations: Using Augmented Reality to Overlay Hands for Self-Directed Surgical Suturing Training

*Keywords: Augmented Reality; Head-Mounted Displays; Surgical Training; Suturing; Human–Computer Interaction; Skill Acquisition*

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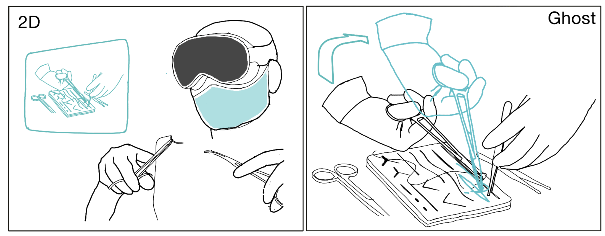
## Context




Surgery is primarily learned through apprenticeship, but a growing number of medical students and a declining surgeon-to-population ratio limit opportunities for hands-on learning in the operating room (Sheldon et al., 2008). Suturing, one of the most fundamental manual skills, is particularly affected: many graduates report insufficient proficiency due to tutor shortages and inconsistent integration of practice into curricula (Peters et al., 2023). Our **hypothesis** is that Augmented Reality (AR) Head-Mounted Displays (HMDs) can address this gap by overlaying interactive instructional content directly onto the learner's workspace (Figure, right side), but that current systems remain too passive or too specialised to effectively support motor skill acquisition (Figure, left side). The **challenges** of designing such a system are twofold: (1) suturing is a bi-manual task that demands the learner's full visual and manual attention, making it difficult to consult external instructions without interrupting practice, and (2) the optimal way to present assistive information during hands-on AR tasks is not well understood. We show in a recent study (Koh et al., 2025) that people dynamically reposition assistive information during bimanual physical tasks based on mobility type and access frequency, yet these insights have not been leveraged for AR surgical training.

**Previous works** in Human–Computer Interaction (HCI) and the medical field have explored HMD-based surgical training in several directions. We have shown in a randomised trial (Favier et al., 2024) that immersive 3D video via HMDs improves students' engagement and sense of preparedness compared to conventional 2D video. Moreover, HMD-based courses yield self-assessed competence comparable to tutor-led instruction (Peters et al., 2023). However, we showed in a systematic review of these approaches (Ferrier-Barbut et al., 2023a) that learning benefits do not yet reliably transfer to clinical settings. Interactive prototypes have begun addressing this limitation: MR MANE (Kojima et al., 2024) displays ghost-hand overlays for microsurgical suturing training, showing skill improvements in novices, but relies on a microscope-tethered setup rather than a standalone wearable device; Javaheri et al. (2025) validate that wearable AR can provide in-situ 3D overlays during real surgery with clinically acceptable accuracy, yet the system targets intraoperative navigation rather than training. Moreover, while pedagogically structured video can complement physical training by explaining the rationale behind expert actions (Ferrier-Barbut et al., 2023b), its linear and static nature limits integration into self-directed practice. Through this thesis, we aim to design and evaluate an interactive, stepwise AR training system on a standalone optical see-through HMD that combines instructional content delivery with hands-on suturing practice, investigating how content presentation and positioning can improve motor skill acquisition.

## Scientific Objectives

This thesis goal is **to design interactive AR systems that bridge the gap between visual learning and motor skill development to support the learning of physical gestures**. We structure this around three research questions:

- **RQ1.** How should assistive information (instructional video, 3D hand overlays, anatomical landmarks) be composed and positioned in an AR HMD during a bi-manual suturing task to support skill acquisition?
- **RQ2.** What is the effect of interactive AR-based suturing instruction—compared to passive video and conventional teaching—on suturing skills as measured by validated clinical instruments (OSATS)?
- **RQ3.** How do individual differences (e.g., visuospatial abilities, prior experience) moderate the effectiveness of different instructional modalities in AR?

## Approach

We will explore these questions through visual overlays leveraging AR HMDs. Conceptually, our approach combines insights from immersive video research (Favier et al., 2024), overlay-based skill acquisition through imitation (Kojima et al., 2024), the spatial positioning of assistive information during bi-manual tasks (Koh et al., 2025), and pedagogical video design (Ferrier-Barbut et al., 2023b) into an integrated training system for surgical suturing.

**We justify the approach** by noting that visual overlays enable learners to observe expert demonstrations and receive feedback in situ while actively practising, bridging the gap between visual learning and motor skill development that passive video alone cannot address. The richness of surgical mentoring communication, including non-verbal cues and gesture demonstration (Lambert et al., 2024a; 2024b), motivates the development of a system that can present expert hand movements alongside the learner's own. Some of the **challenges** in pursuing our goal include: (1) Achieving robust hand tracking and overlay registration, for which we plan to use an Apple Vision Pro see-through ARHMD; and (2) recruiting actual medical students with different levels of skills for controlled evaluations, for which we plan to rely on the medical school at la Pitié-Salpêtrière as we have done for past studies which included 150 students (Jaafar et al., 2024 & Favier et al., 2024) and 450 students (data analysis ongoing).

**Methodology. WP1** — As a first step, we plan to conduct field studies with medical students and surgical educators to understand instructional needs and information positioning during suturing practice, using qualitative methods similar to Koh et al. (2025) and Lambert et al. (2024b). **WP2** — Building on these insights, we will design and implement the AR suturing training system through participatory design workshops, studying how to combine interactive step-by-step videos, hand-tracking overlays, and ghosted expert-hand display. **WP3** — Finally, we plan to evaluate the approach through experiments with medical students, comparing AR conditions with conventional 2D video and tutor-led instruction, using OSATS and visuospatial ability measures similar to Jaafar et al. (2024).

| | M1 – M6 | M7 – M12 | M13 – M18 | M19 – M24 | M25 – M30 | M31 – M36 |
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| WP1: Field studies | | | | | | |
| WP2: Design & impl. | | | | | | |
| WP3: Evaluation | | | | | | |
| Thesis writing | | | | | | |

## Benefits of the IUIS funding & student profile

The IUIS funding pairs a clinician with a computer science supervisor, providing a unique opportunity for the Ph. D. student to develop this research project. From the computer science supervisors, the student will receive mentorship on software development for the ARHMD (WP2) and be integrated into a research lab with permanent engineers who can assist and provide development resources. The student will also receive training in qualitative methods (WP1). From the clinician supervisor, the student will gain access to medical students (WP1 & WP3) and training on quantitative methods for randomized trials (WP3).

We expect the Ph.D. candidate to have a strong academic record, background in software development (particularly in HMD environments), and notions of HCI through their studies. The following skills will be considered a plus: prior exposure to research in the medical domain, experience with statistical analysis, and oral presentation skills. The candidate will integrate a multidisciplinary research environment and should thus be willing to communicate and work in teams. We expect candidates to be motivated to learn new skills, grow personally, and develop a professional network through traveling to present their work. We strive to provide fertile ground for personal and academic growth, and opportunities and guidance to prepare students for future academic or industrial careers.

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