Development and implementation of VR-simulated experiences to train communication skills

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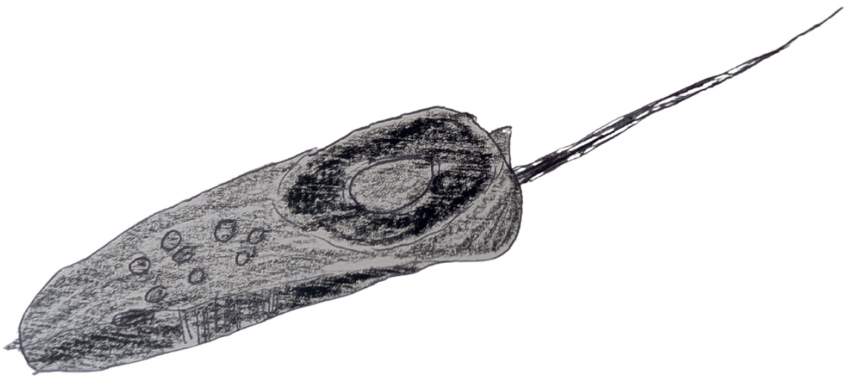
Section V



Discussion and conclusion

V

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SUMMARY PER SECTION

Section II – Communication in High-Stress Situations

This section examined whether and how immersive VR simulation can support the training of communication and teamwork skills in high-stress clinical situations, with a particular focus on CRM in anaesthesiology.

Across Chapters 1 and 2A–C, this section demonstrated that our VR-based simulation is feasible, acceptable, and educationally meaningful for training non-technical skills under pressure. Through a user-centered design process combined with failure modes and effects analysis, an adaptable, multiplayer VR scenario was developed that allowed real-time modulation of clinical parameters. This adaptability proved essential for aligning scenario complexity with cognitive load and learner needs, a limitation of many existing preset VR simulations.

Evaluation studies showed high engagement, perceived realism, and educational relevance, supporting outcomes at Kirkpatrick levels 1 and 2. Participants reported increased awareness of communication patterns, situational awareness, and team coordination during scenarios. However, this section also made clear that evidence for behavioural transfer to clinical practice (levels 3–4) remains limited at this stage. The work therefore positions VR not as a replacement for existing simulation modalities, but as a complementary approach with particular strengths in scalability, accessibility, and controlled exposure to high-stress situations.

Section III – Communication for Patient Comfort

This section focused on therapeutic communication as a mechanism for improving patient comfort and reducing preoperative anxiety, and explored whether patient-embodied VR experiences could enhance clinicians' sensitivity to the effects of language, tone, and non-verbal behaviour.

Across Chapters 3–6, the studies showed that good intentions alone are insufficient: communication subtly shapes patient experience through suggestion, expectation, and emotional framing. Patient-embodied VR enabled clinicians to experience clinical encounters from the patient's perspective, making the emotional impact of routine language and behaviour tangible rather than theoretical.

Qualitative findings consistently demonstrated increased awareness, reflection, and perceived behavioural change among healthcare professionals. Quantitative results showed modest but directionally positive effects on patient anxiety when VR-based experiences were embedded within a broader bundle of non-pharmacological interventions.

Importantly, divergence between qualitative and quantitative findings highlighted the complexity of capturing the impact of communication on patient outcomes.

This section therefore contributes not by claiming definitive clinical effects, but by showing that therapeutic communication is experientially learnable, while also being strongly shaped by context, timing, organisational constraints, and the nature of patient experience.

Section IV – Communication and Team Culture in the Operating Room

This section addressed communication as a social and cultural phenomenon within the operating room, with particular attention to non-verbal rapport, hierarchy, and the hidden curriculum encountered by trainees.

Chapter 7 demonstrated that key elements of rapport—such as gaze, posture, timing, and spatial positioning—are enacted implicitly in routine clinical practice and are rarely made explicit in training. These behaviours contribute to team cohesion, culture, and psychological safety, yet remain difficult to apprehend for novices.

Chapter 8 translated these insights into an educational intervention by developing VR-embodied experiences that externalised elements of the hidden curriculum for medical interns. By allowing learners to observe and reflect on OR dynamics from an embodied perspective, the intervention aimed to support sense-making during the transition into clinical practice.

Together, these studies showed that experiential and observational learning approaches can make team norms visible and discussable. The section acknowledged that such interventions still need further validation in order to study behavioural change, and improved onboarding of novices within hierarchical complex systems.

Bridging the Three Domains

This thesis demonstrates that immersive, embodied simulation can meaningfully strengthen communication training in healthcare by making implicit behaviours visible, enabling perspective-taking, and supporting behavioural change across multiple clinical settings. Across the three domains explored in Sections II, III, and IV we can observe that communication is not a set of isolated techniques but a relational, context-sensitive competence.

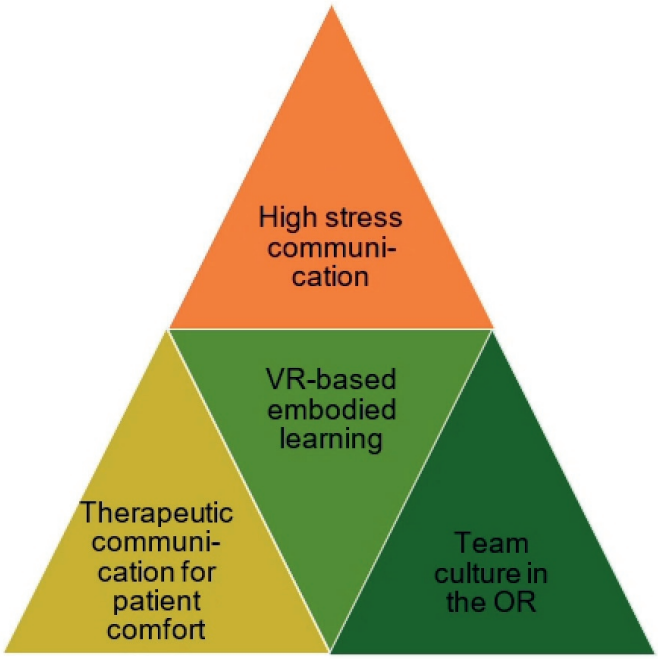

Figure 1. Visual aid with Triangle model outlining this thesis
Upper triangle: High stress communication in section II
Left triangle: TC for patient comfort in section III
Right triangle: Team culture in the OR in section IV
Middle triangle: overlapping theme VR-embodied learning

Figure 1 illustrates this integration through the Triangle Model developed in this thesis. Each vertex represents one communicative domain—high-stress communication (Section II), therapeutic communication for patient comfort (Section III), and team culture in the OR (Section IV)—while the overlapping centre reflects the shared mechanism: embodied VR learning. Together, these findings show that although the clinical settings differ, the educational principle is the same. Learners benefit when they can *feel* the consequences of their communicative choices. VR enabled clinicians to observe their own habits, experience their impact, and adjust behaviour in a controlled, reflective environment.

Thematic Integration of Findings

From design to relevance

Several chapters in this thesis (Chapters 2, 4, and 8) focused on the development of VR-based simulations and experiences. Across these cases, a consistent pattern emerged: end users clinicians, and educators, were actively involved, in the development process, the resulting tools in accordance with actual practice, adapted to learner needs, and more likely to be accepted.

Immersion leading to perspective

Across Chapters 2, 4–8, immersive experiences enabled perspective shifts: from clinician to patient, from actor to observer, from novice to insider. Patient-embodied VR exposed subtle elements such as tone, timing, status, and nonverbal cues that usually remain implicit. The *Proteus effect*, experiential learning theory, and emotional resonance all combined. Indeed, this was not a conceptual learning outcome; it was **felt**. The training sessions that followed, combining VR with clinical teaching, allowed this insight to be taken into practice.

From validation to implementation

The validation chapters provide important evidence that these VR experiences are not only feasible, but also educationally relevant using the Kirkpatrick model as a framework (**Figure 2**).

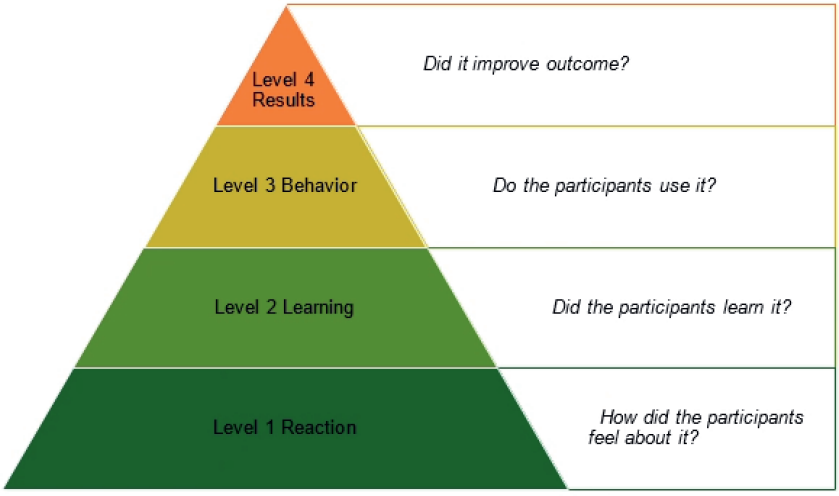

Figure 2. Kirkpatrick four-level training evaluation model

Educational and Clinical Implications

Figure 3 visualises the developmental stage of each tool within the Kirkpatrick framework, highlighting up to what level validation has advanced and where long-term effects remain to be studied. Together, these findings support a layered implementation model in which immersive experience is followed up by further validation and evaluation in clinical settings.

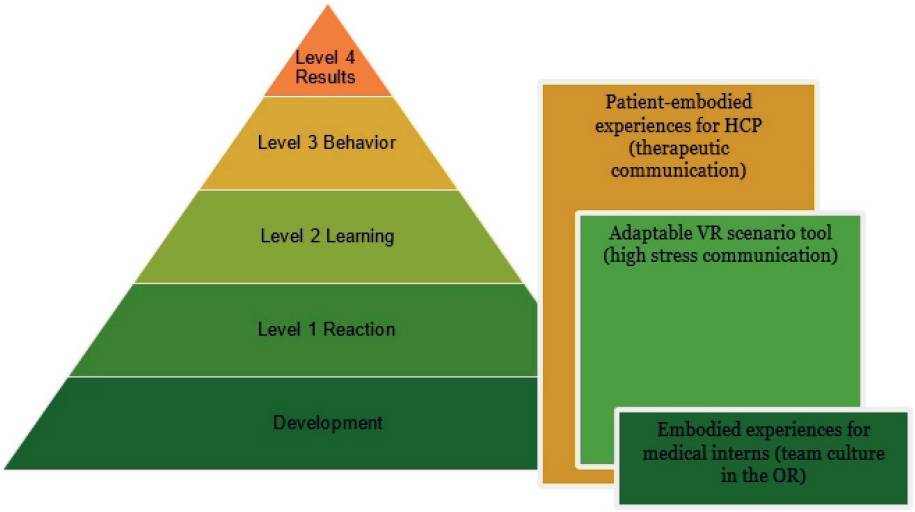

Figure 3. Progress of VR training tools across Kirkpatrick's levels within this

- **Level 1 (Reaction):** High engagement and perceived relevance in Chapter 2 (CRM training) and Chapter 4 (embodied TC experience).
- **Level 2 (Learning):** Increased awareness of communicative style in Chapter 4, perceived knowledge gains in Chapters 5 and 6.
- **Level 3 (Behaviour):** Observable changes in daily practice in acute admission settings (Chapter 5) and behavioural adjustments within a broader TC intervention bundle (Chapter 6).
- **Level 4 (Results):** Modest changes in patient anxiety (Chapter 6), indicating promising but not yet conclusive clinical impact.

Limitations

Limits of Embodied VR

While embodied VR proved effective in making implicit communicative processes visible and experientially accessible, this thesis also highlights important limits to what immersive simulation can represent and achieve. VR environments necessarily offer selective representations of clinical reality. They can evoke perspective-taking, emotional engagement, and heightened awareness, yet they only partially capture the complexity of real-world clinical practice and can never provide a complete picture. As a result, immersive experiences may foreground certain dimensions of communication while attenuating others. This selectivity should be acknowledged explicitly, as it constitutes an inherent limitation of any simulation-based approach.

Transfer, Hierarchy, and Context

Across the studies included in this thesis, increased awareness and perceived learning did not consistently translate into sustained behavioural change or demonstrable clinical outcomes. This limitation cannot be attributed solely to study design or evaluation level, but reflects broader structural characteristics of healthcare practice. Communication is enacted within existing hierarchical systems, time-pressured environments, and organisational cultures that may constrain the application of newly acquired insights.

In such contexts, heightened sensitivity to communication dynamics does not necessarily lead to behavioural change, particularly for learners or junior staff with limited positional power. Without organisational support long term, communicative awareness may remain latent or be selectively applied. These findings suggest that transfer should not be conceptualised as an individual learning outcome alone, but as a context-dependent process shaped by team culture, and implementation conditions. Consequently, the impact of immersive communication training is likely to depend as much on its integration within organisational structures as on the quality of the educational intervention itself.

FUTURE DIRECTIONS

Section II: Communication in High-Stress Situations

Building on the feasibility and early educational relevance demonstrated in this thesis, the next step for VR-based high-stress communication training is to clarify where VR adds value relative to the current gold standard of manikin-based simulation, and where it does not. Comparative work in other acute scenarios has already used randomized or quasi-experimental designs to contrast VR with high-fidelity manikin simulation, often finding feasibility and sometimes comparable performance, but also highlighting that equivalence cannot be assumed and may depend on the targeted outcome (1). In this

context, future studies should move from a general "does it work?" question to a more actionable one: which elements of CRM communication and teamwork are best developed in VR, and which require manikin-based or in-situ team training?

A particularly useful strategy is to map these outcomes onto Entrustable Professional Activities (EPAs) and evaluate whether specific EPAs (or EPA-components such as recognising deterioration, initiating escalation, closed-loop communication, leadership, and task prioritisation) show differential learning curves or transfer patterns across modalities (2). Early work using VR for EPA-aligned formative assessment and serious-game platforms with scoring algorithms suggests this is feasible, but also underscores the need for careful validity evidence if such scores are used beyond formative feedback.

For implementation, elements of faculty training need further development into VR-specific competencies: onboarding learners into immersive environments, managing cognitive load and simulator discomfort, using scenario adaptability deliberately, and conducting debriefings that connect in-VR actions to clinical reasoning and team behaviour. Recent work focusing specifically on immersive VR debriefing practice reinforces that these VR-specific teaching skills are a distinct requirement.

Finally, sustainable curricular integration will require an infrastructure layer that links VR sessions to competency-based education and supports longitudinal evaluation. This includes (1) alignment with EPA frameworks and local assessment systems, (2) mechanisms to store and retrieve performance for follow-up coaching, and (3) the responsible use of learning analytics. Emerging literature on "metaverse"/immersive simulation notes the growing availability of automated metrics and dashboards that can support formative feedback, but also emphasises that integration into high-stakes decisions remains limited and that human interpretation during debriefing is still essential. The most defensible near-term direction is therefore a hybrid assessment approach: a "virtual score" or performance trace that supports structured debriefing and progress tracking, combined with facilitator judgement and team-based reflection (1, 3, 4). Newer systems aimed at automated assessment of communication behaviours (e.g., closed-loop communication) show promise, but they strengthen—rather than replace—the case for rigorous validation, transparency about what is being measured, and clear boundaries around use (formative vs summative).

Section III: Communication for Patient Comfort

The findings in Section III suggest that patient-embodied VR is effective in increasing clinicians' awareness of the experiential impact of communication. Future research should therefore focus less on whether such awareness can be generated, and more on how it can be sustained and translated into routine clinical practice.

Future work should more explicitly address the contextual embedding of therapeutic communication. The modest and variable effects on patient anxiety observed in this thesis indicate that communication is strongly shaped by organisational routines, and the broader care environment. Studying patient-embodied VR as part of longitudinal or bundled interventions may therefore offer a more realistic basis for evaluating its impact.

From an educational perspective, patient-embodied VR may be best positioned as a tool for early sensitisation and reflective learning, rather than as a means of standardising behaviour. Future curricula should explore how such experiences can be integrated within competency-based training trajectories while acknowledging the relational and context-dependent nature of patient comfort and anxiety (5).

Section IV: Communication and Team Culture in the Operating Room

The findings in Section IV indicate that non-verbal rapport, hierarchy, and the hidden curriculum shape how team culture is learned and enacted in the operating room. Future research should therefore move from making these dynamics visible towards determining **whether and how immersive interventions can influence day-to-day team behaviours**, particularly those related to teamwork, speaking up, and psychological safety. Recent work suggests immersive training may affect observable teamwork or safety behaviours in OR settings, but generalisability and mechanisms remain to be clarified.

A key direction is to evaluate VR-embodied experiences as part of structured **onboarding and transition support**, where the educational goal is orientation and sense-making rather than immediate behavioural standardisation. This includes studying whether early exposure to implicit norms reduces uncertainty and improves participation during the first period of OR entry, and whether effects persist beyond the immediate training context.

Finally, implementation-focused research is needed to understand how such interventions can be integrated into existing educational and organisational structures. Also here, this includes faculty development for facilitation and debriefing, and evaluation approaches that can capture cultural change over time rather than only immediate learner reactions.

Closing Statement

This thesis demonstrates that immersive, embodied simulation can be meaningful for communication training by making what is usually implicit visible, experiential, and open to reflection. It also shows that two constraints must be taken seriously: higher fidelity does not automatically lead to better learning, and transfer into clinical practice remains difficult within the sociotechnical reality of healthcare.

Within this thesis, substantial progress has been made in establishing feasibility and in understanding how these experiences are perceived and used as learning catalysts. At the same time, answering these questions has led to new ones. Some of these arise within the broader "why simulation works" paradigm, concerning which elements of embodied training matter most and under which conditions learning persists, and how can implementation be shaped to support real-world uptake? These questions now define the work that lies ahead if immersive communication training is to realise its promise beyond the training setting.

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