



Thesis Report.
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UMEÅ INSTITUTE OF DESIGN
UMEÅ UNIVERSITY

Tactile XR Surgical Training

Surgical Training Kit for Extended Reality

Master Thesis
2025

MFA Advanced Product Design
Degree Project

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Collaboration Partner



Topic: Rethinking Input systems in Extended Reality (XR) surgical training for enhanced immersion and greater accessibility.

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Jenna Fizel, IDEO
Thomas Müller, hapticlabs.io

2025

GLOSSARY

AR	- Augmented Reality
VR	- Virtual Reality
MR	- Mixed Reality
XR	- Extended Reality
HCP	- Healthcare Professionals
ELO	- Expected Learning Outcomes
CAGR	- Compound Annual Growth Rate

"How might we design **Extended Reality (XR) surgical training** to become **more immersive and accessible?**"

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Abstract.

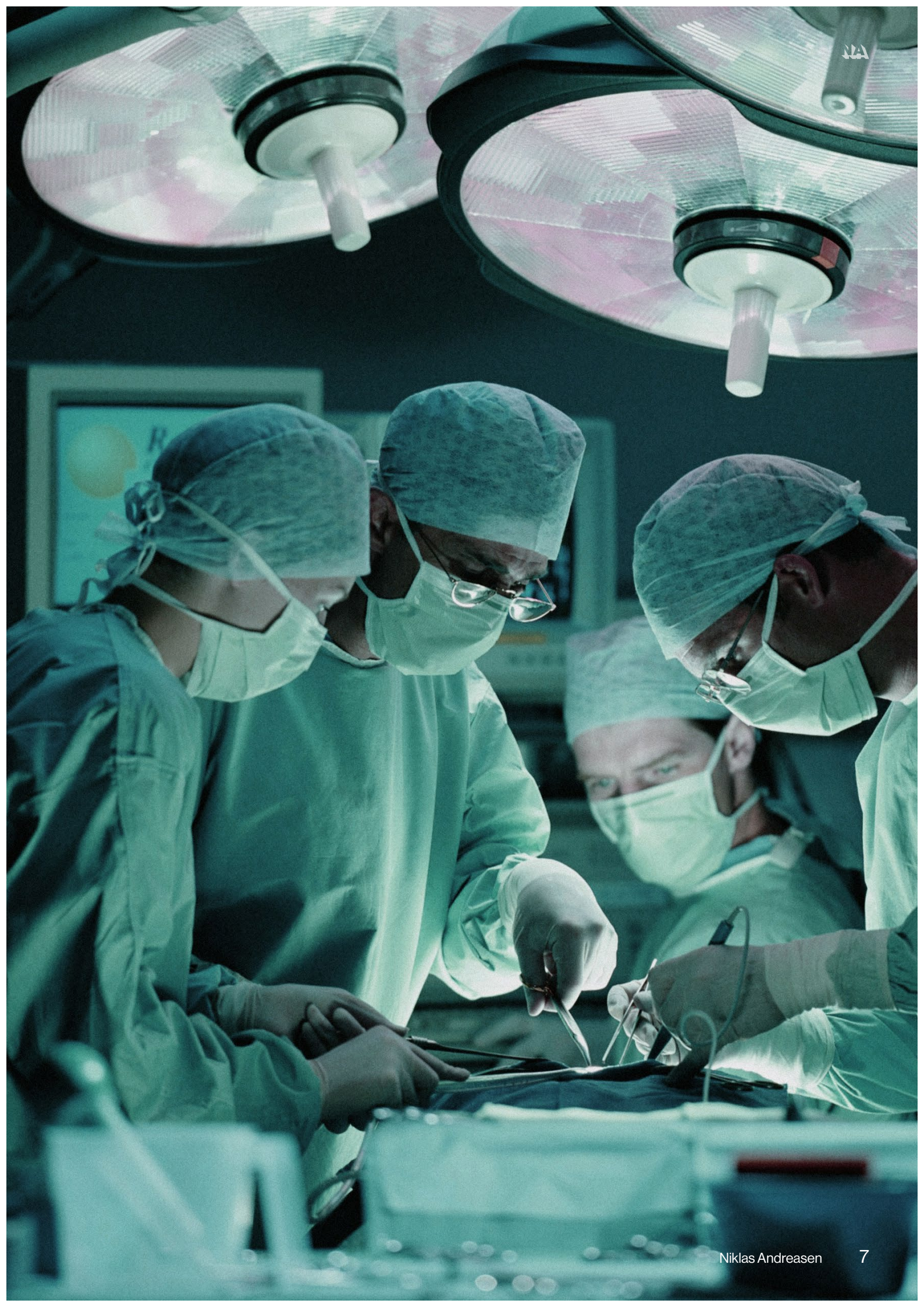
Design Brief.

Topic: Rethinking Input systems in Extended Reality (XR) surgical training for enhanced immersion and greater accessibility.

Surgical education is facing increasing challenges as the demand for high-quality training grows. With rising procedural demands, increasing workloads and a shortage of experienced professionals, there is an urgent need for more effective learning methods. Traditional surgical training often provides limited hands-on experience before trainees perform real procedures, raising concerns about patient safety, skill acquisition, and overall preparedness.

XR technology has emerged as a promising tool in medical education, offering immersive and interactive training experiences. However, current systems lack realism, accessibility, and effectiveness, making skill transfer from simulation to real-world surgery less effective. Existing training stations are limited in availability, and conventional controllers fail to replicate the tactile and mechanical properties of real surgical instruments.

This project explores how XR can be leveraged to improve surgical training by creating a more realistic, accessible, and high-fidelity learning environment. By combining digital simulation with hands-on skill development, it aims to bridge the gap between theory and practice. A tailored set of XR tools would allow trainees to refine their motor skills, build confidence, and gain experience in a controlled, risk-free setting. By rethinking how surgical training is delivered, this project seeks to enhance learning outcomes, better prepare future surgeons, and ultimately improve patient care.



1 Introduction.

Collaboration Partners.

Relevant Insights.

Pioneering Next-Gen Interaction: Logitech's Commitment to XR.

Logitech is a global leader in designing and manufacturing professional input devices, computer peripherals, and innovative interaction solutions. With a strong focus on human-centered design, technological advancement, ergonomics, and precision, the company has been at the forefront of elevating digital interactions across various fields, including emerging XR technologies. Their expertise in developing intuitive and high-performance input solutions makes them a key innovator in human-computer interaction.

Logitech's experience in crafting responsive and specialized interfaces makes them an ideal collaboration partner. The company is already expanding XR applications beyond general controllers, exemplified by the MX Ink stylus, designed specifically for the Meta Quest VR ecosystem. It signals a commitment to advancing precision input in immersive environments. By leveraging their expertise in hardware design, sensor integration, and user experience, this collaboration seeks to bridge the gap between virtual surgical training and real-world procedures—enhancing accuracy, realism, and usability in medical education.



ID/UX & XR

Nick Jinkinson, Global Head of ID.
Andreas Connellan, Head of Design AR/VR.
Aidan Kehoe, Distinguished Designer HCI.

Additional Mentoring

by

INTUITIVE

Dogan Sekercioglu.

ID Design Lead

Surgical MedTech.
 Intuitive Surgical.

IDEO

Jenna Fizel.

Global Head of ET

Emerging Technologies.
 IDEO.

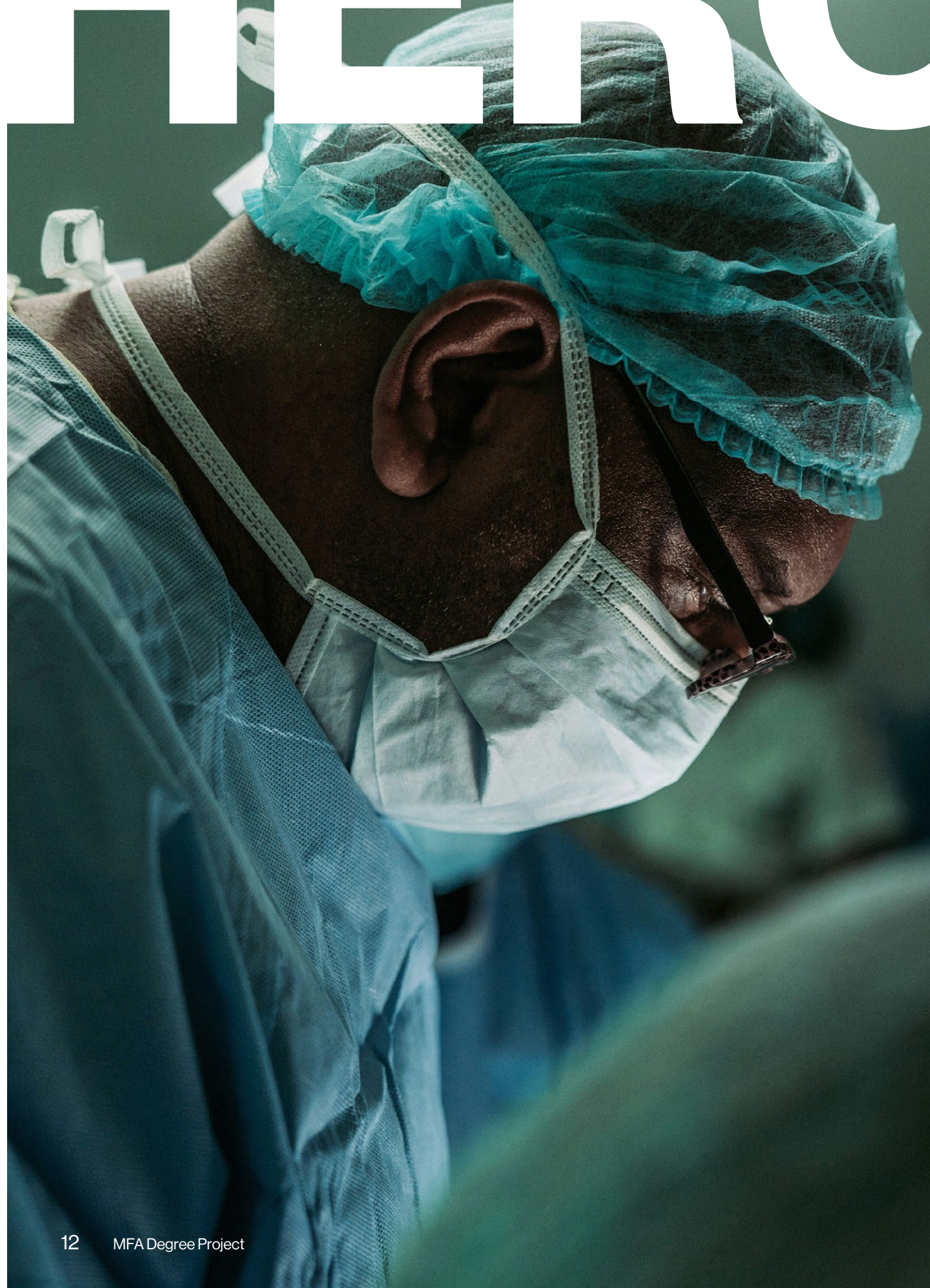


Thomas Müller.

Co-Founder & CEO

Sensory In/Output.
 Hapticlabs.io.

HERO



Mission & Motivation.

Meaningful Impact.

Creating for Care: Helping to help.


My passion for medical design has grown through various professional experiences, from agency and corporate in-house settings to collaborations within the APD program. A pivotal moment in this journey was my six-month internship at Laerdal Global Health, where I had the opportunity to dive deep into the realm of medical training. This experience broadened my perspective on industrial and UX design and introduced me to the exciting intersection of educational design. It reinforced my commitment to pursuing a medical-focused thesis—one that empowers healthcare professionals, educates, and drives meaningful impact.

I am drawn to innovative projects that solve real-world problems with measurable outcomes. By improving surgical training, this project has the potential to enhance both education and healthcare quality, aligning with my core values as a designer. The intersection of physical and digital realms has always fascinated me, and this project perfectly embodies that balance—integrating two personal fields of interest: tangible input devices and immersive XR technology to create a holistic, user-centered solution.

The complexity of redesigning immersive surgical tools presents an exciting technical challenge, combining ergonomics, mechanics, and material studies with emerging XR technologies. The mechanical design and size of surgical tools make this project particularly well-suited for an iterative and hands-on development process, which I both enjoy and excel at. Unlike many XR applications that could be replaced by existing solutions, this project addresses a clear, unmet need—making its development not just an engaging design challenge but a valuable and impactful endeavor.

Beyond its immediate application in surgical training, this project also strengthens my versatility as a designer, positioning me for both agency and corporate opportunities. The focus on medical training tools aligns with the technical depth and structured development processes found in corporate healthcare design. Simultaneously, the consumer-electronics-inspired nature of the input devices, with their refined aesthetics and engaging interaction design, appeals to the broader consumer-product sector—bridging two career pathways and opening doors to the agency landscape.

2 Method.



interviews 12
highlights 534
field visits 3
min. AV 817
contacts 21
surgeons 4
companies 4

Research Process.

Deep Dive.



Surgical Education & XR Opportunities.

To understand the challenges in surgical education and XR integration, I conducted in-depth research on healthcare systems, surgical training, and emerging technologies. Interviews with Swedish and German surgical professionals, from students to experts and educators, revealed key pain points.

Field visits in hospitals and skill labs provided first-hand insights into training methods. Using 3D scanning, I explored AR applications and prototyped surgical instruments for referencing. Regular feedback from UID, Above, and Logitech guided the process. Synthesizing findings, I tried to identify key user needs and opportunities, enabling to set clear design goals in order to bridge the gap between virtual training and real-world surgical practice.

Why Does This Matter?

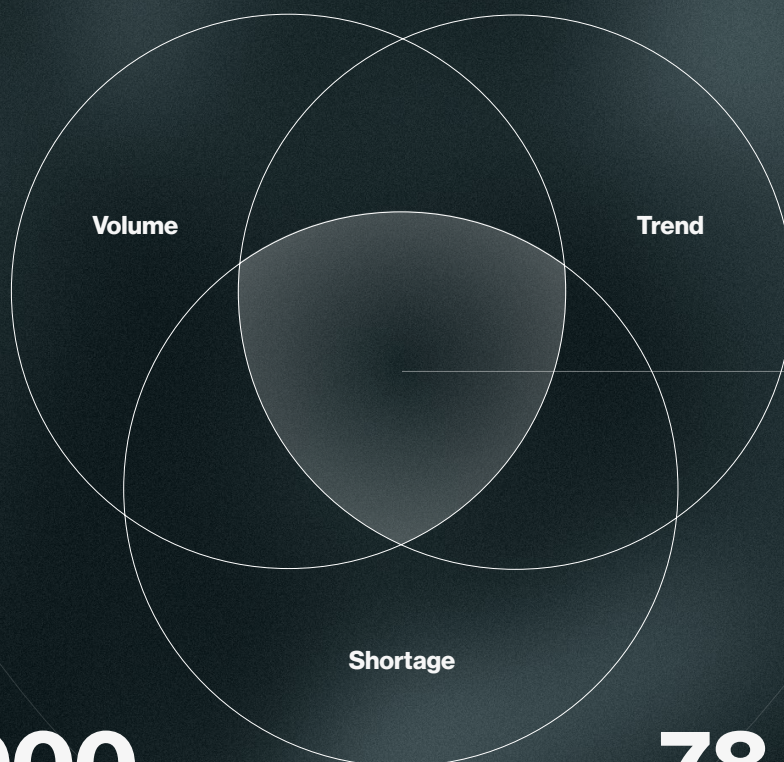
US. Western Representative.

+9x OR.

On average surgical procedures in a lifetime .⁹
Great commonness.

+10-50%.

Expected increase of surgical workload by 2030.¹⁰ Aging population.



-23.000. Surgeons.

Lack by 2032. Projected shortage of 100.000 HCP by 2028.¹²¹³ Global Trend.

78-95%. Lack XP.

Little formal teaching. 45-78% no time in OR.¹⁴
Huge lack of experience.

J&J Institute

"Today, we have a real problem—on a global basis, there's not enough access to safe healthcare because we don't have enough surgeons trained."¹⁶

Sandra Humbles.

VP, Global Education Solutions
Johnson & Johnson Medical Devices

Future of Surgery: Ageing and Demographics.

Surgical education is facing critical challenges as the demand for better training methods continues to grow. In the U.S., serving as a representative example for Western healthcare, the surgical workload is projected to increase by 10–50% by 2030, driven by an aging population, demographic shifts, and the retirement of senior surgeons.¹⁰ By the end of 2022, 25.6% of practicing surgeons were over 65, indicating a looming generational shift in the workforce.¹¹

Compounding this issue, the healthcare system is projected to face a shortage of 100,000 healthcare workers by 2028, including a deficit of 23,000 surgeons by 2032.^{12,13}

Despite these increasing demands, many trainees receive limited hands-on experience before performing real procedures, with 78%-95% in the UK receiving no formal teaching and 45%-78% spending no time in the operating theatre, regularly performing core surgical skills during their education.¹⁴ This skills gap raises concerns about ethical practices, patient safety, training efficiency, and the overall preparedness of future surgeons.

WHO & SDG.

5 Priorities.



**World Health
Organization**

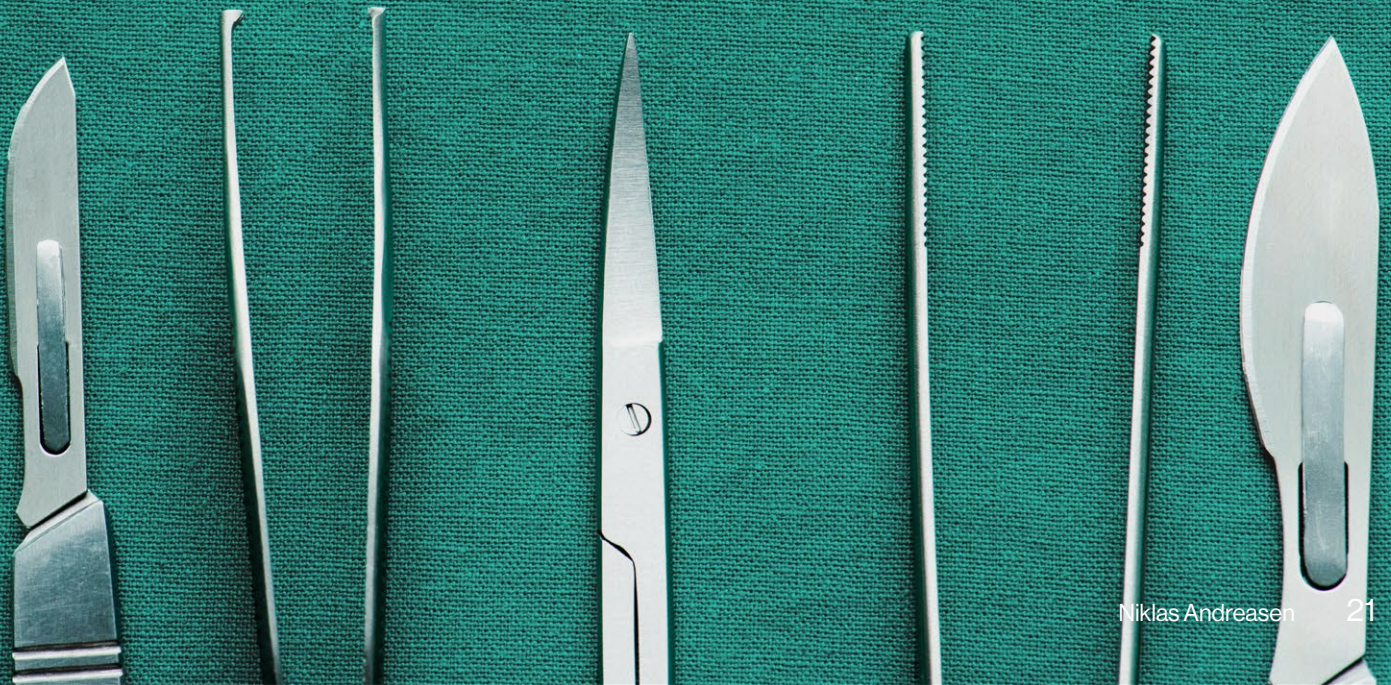
WHO's Priorities for Surgical Education and Healthcare Systems.

1. **Rapid Scaling Up of the Health Workforce:** WHO emphasizes the need to rapidly increase the number of trained healthcare professionals, including surgeons, to address global shortages.²⁰
2. **Transforming Health Professionals' Education:** WHO guidelines focus on transforming and scaling up health professionals' education and training to improve the quality and relevance of the healthcare workforce.²¹
3. **Strengthening Surgical Care Systems:** WHO has convened meetings to draft priorities for surgical care scale-up, recognizing the importance of improving surgical education and training as part of overall healthcare system strengthening.²²
4. **Competency-Based Training:** There is a shift towards competency-based education models in surgical training, with a focus on developing well-rounded physician surgeons who possess not only technical skills but also non-technical competencies.²³
5. **Technology Integration:** As surgical practices evolve with technological advancements, WHO recognizes the need for surgical education to keep pace, incorporating new technologies and simulation-based training.²⁴

3 GOOD HEALTH
AND WELL-BEING



4 QUALITY
EDUCATION



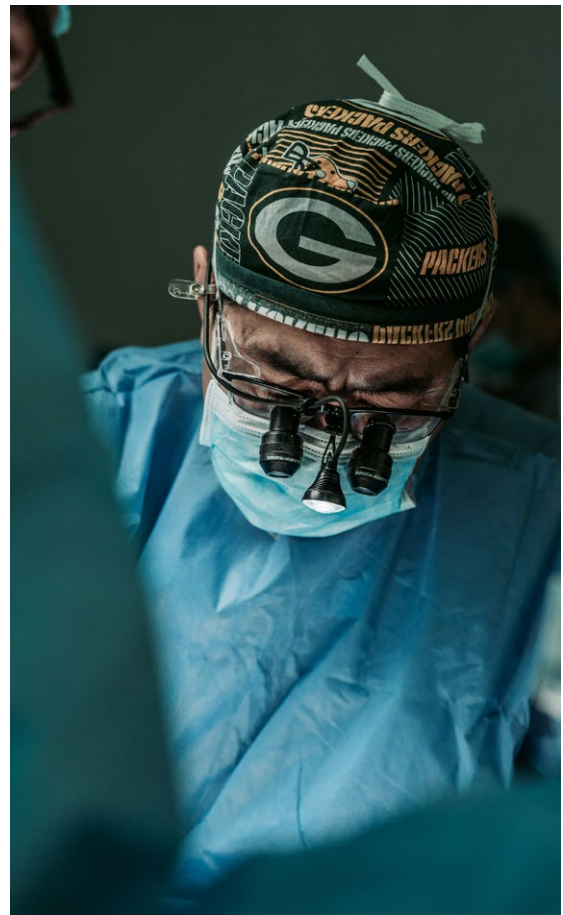
Stakeholder Map.

Far-reaching.

Main User.

Potential Costumer.

Secondary User.



Learners.

Medical students, junior doctors, surgical residents, EMS personnel, junior nurses & OR assistants, and fellows in surgical subspecialties.

Acquire theoretical knowledge and practical skills through structured education, and hands-on training, progressively building competence in surgical techniques and clinical decision-making.

Mentors.

Experienced practicing surgeons, field experts, senior physicians, senior EMS professionals, and mentorship networks.

Mentors provide direct feedback for learners throughout the surgical residency programme, initially guiding and later supervising the procedures performed together with residents.

Secondary User.

Potential Costumer.

Other Stakeholder.



Educators, Hospital & Faculty.

Medical universities & teaching hospitals, educators & faculty staff, residency program directors, hospital simulation labs, accreditation & certification bodies.

Local institutions and professionals shape surgical education, provide training environments, ensure competency standards, and oversee certification processes.

Others & Environment.

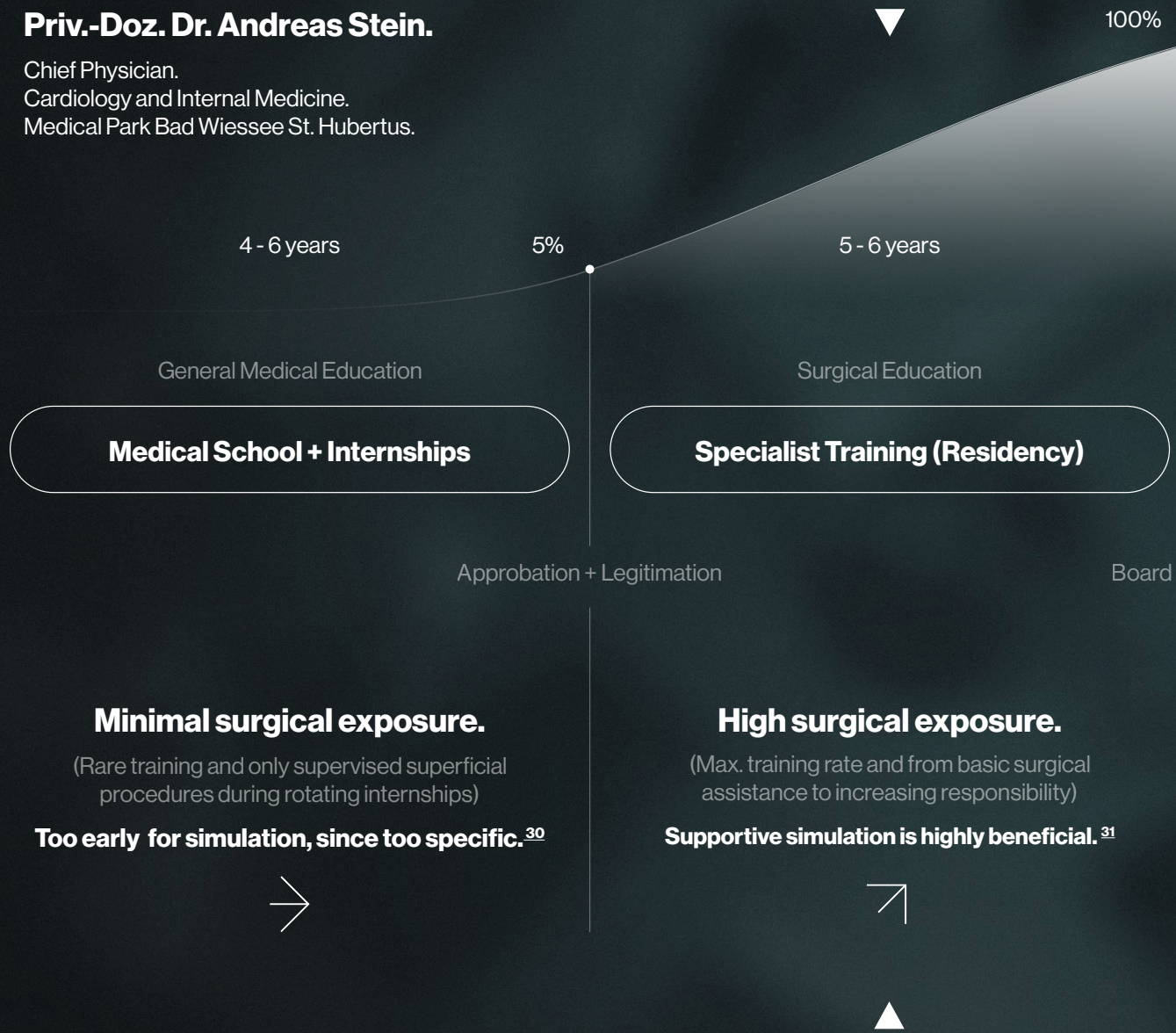
Healthcare providers, local regulations & policy makers, governmental institutions, medical curricula & academic institutions.

Entities influence surgical education by setting policies, funding programs, regulating training standards, and integrating evolving medical practices into academic and professional frameworks.

"The **resident** is the **perfect target group** to benefit improved training!" ²⁹

Priv.-Doz. Dr. Andreas Stein.

Chief Physician.
Cardiology and Internal Medicine.
Medical Park Bad Wiessee St. Hubertus.



Surgical Education.

Extensive Preparation.

SE/DE/US data.

Patient Examination + Surgery
Knowledge & Skill Level

∞

Evtl. 1-3 years & ongoing

Surgical Subspecialisation & Practice

Evtl. Fellowship and Career

Certification

Near-full autonomy.

(Routine, increasing complexity
and responsibility)

Confused by "wrong" feel of simulation.³²



Limited Time & Maximum Training Pace.

Surgical education is a rigorous, multi-stage process that begins in medical school, where students gain extensive theoretical knowledge, but receive minimal surgical exposure, often limited to superficial treatment and suturing practice. After earning their medical degree, aspiring surgeons enter a sur-

gical internship, gaining foundations in patient care and assisting in superficial procedures. The intensive practical training occurs during residency, which lasts several years and provides progressively increasing surgical exposure, from assisting in operations to performing complex procedures under supervision. By the final stages of training, surgeons achieve near-full autonomy, preparing them for practice in academic, hospital, or private settings.



Introduction in Medical School.

Training Modalities.



Field Trip I: Medical Students.

During my first field trip to Norrlands Universitetssjukhus, I observed one of the two annual introduction and rotation sessions at Clinicum Betula, the hospital's educational unit. I gained valuable insights on how medical students are familiarised to surgical

principles while still enrolled in university. Witnessing how foundational skills are taught provided deeper insights into the educational methodologies and knowledge levels at this stage. Engaging with students allowed me to explore their perspectives on operative training and discuss what they feel is lacking in their preparation for residency, shaping my understanding of early surgical education.

Educational Methodology.

Apprenticeship.

From Observation to Action: Surgical Training Today.

Surgical education remains deeply rooted in the apprenticeship model, where knowledge and technical skills are passed down from experienced mentors to learners. Despite rapid advancements in medical science, diagnostics, and treatment options, the fundamental method of training surgeons has remained relatively unchanged. Trainees gradually develop proficiency through direct observation, supervised practice, and eventually, independent performance.

However, early clinical exposure often leans more toward passive learning, with medical students and junior trainees frequently observing rather than actively engaging in procedures. The reality today is that learners often perform their first procedures on living patients and not in simulation, gradually refining their skills under close supervision. The challenge lies in balancing patient safety with the need for hands-on experience, ensuring that future surgeons gain both theoretical knowledge and practical competency under expert guidance.

"Plenty of procedures are being **trained on the living patients** due to a lack of simulation—it's **far from optimal.**" ³⁷

Markku Happamäki.

Senior Physician, Surgeon & Lecturer.
Department of Diagnostics and Intervention.
Norrlands Universitetssjukhus.

"All my **technical flaws were pointed out** and I perceived that as a **privilage**—but **not everybody has access to** such a great and **invested mentor.**" ³⁸

Oskar Franklin, MD/PhD.

Department of Diagnostics and Intervention.
Norrlands Universitetssjukhus.



Skill- & Scenario-based Learning.

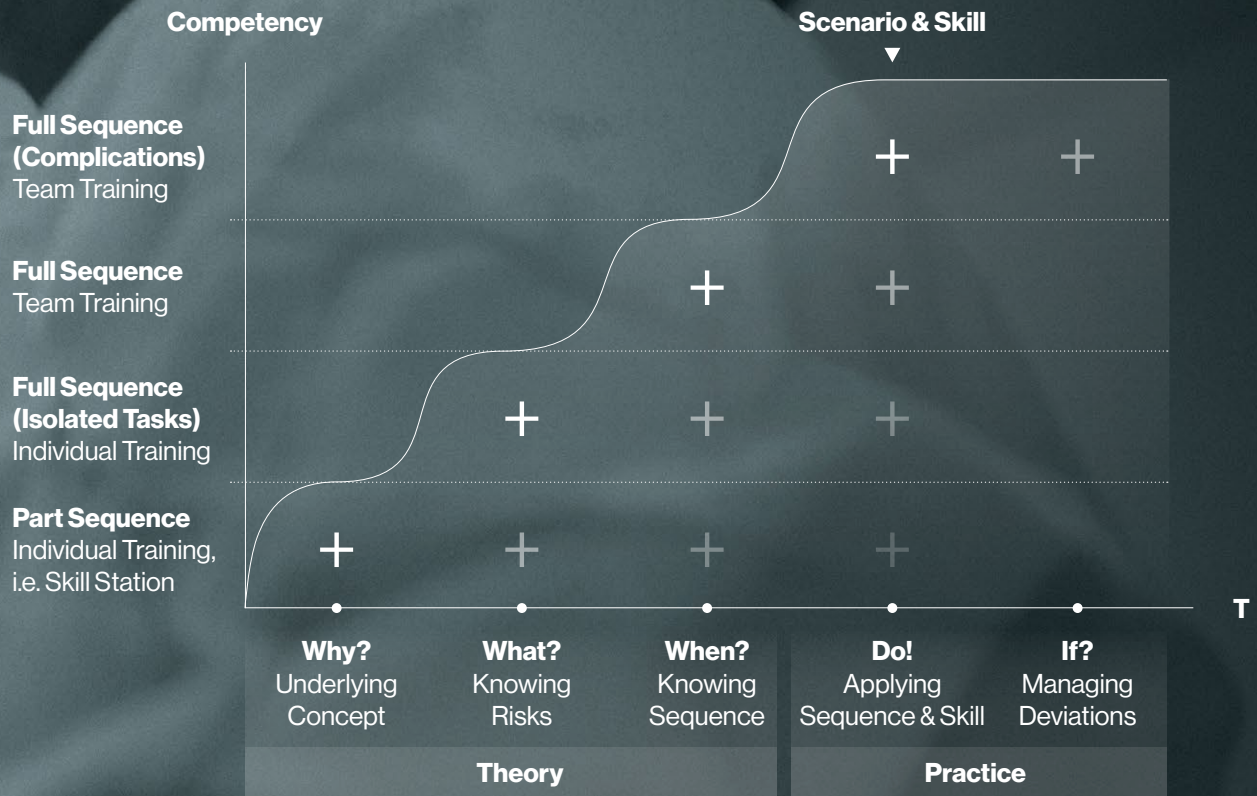
Definition.

Skill-based.

Knowing how to grip, use and interact with the tool to achieve the right effect is a technical skill.

Scenario-based.

Handing the right tool, at the right time is clinical decision-making and part of a larger sequence of steps.



"The **reality** is that it always **has to be a mixture of scenario-based and skill-based training**, to prepare adequately." ⁴²

Priv.-Doz. Dr. Andreas Stein.

Chief Physician.
Cardiology and Internal Medicine.
Medical Park Bad Wiessee St. Hubertus.

"**Skill-based training requires** a lot of **validation, way more than scenario-based training.**" ⁴³

Jenna Fizel.

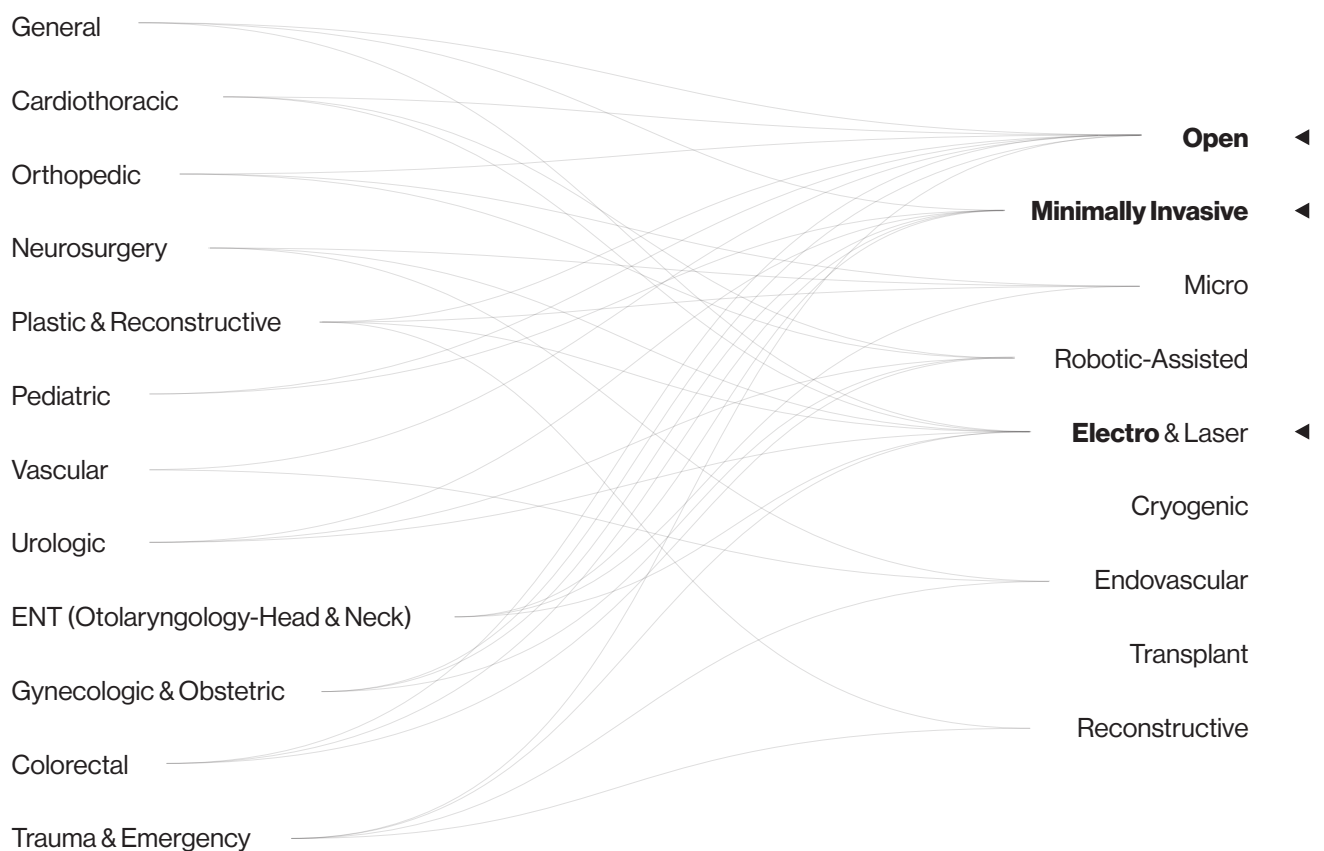
Global Head of Emerging Technology.
IDEO.

Surgical Fields & Approaches.

Specialisations.

Major Specialisations.

Primary Approaches & Tools.



6 residency paths & 36 subspecialties.

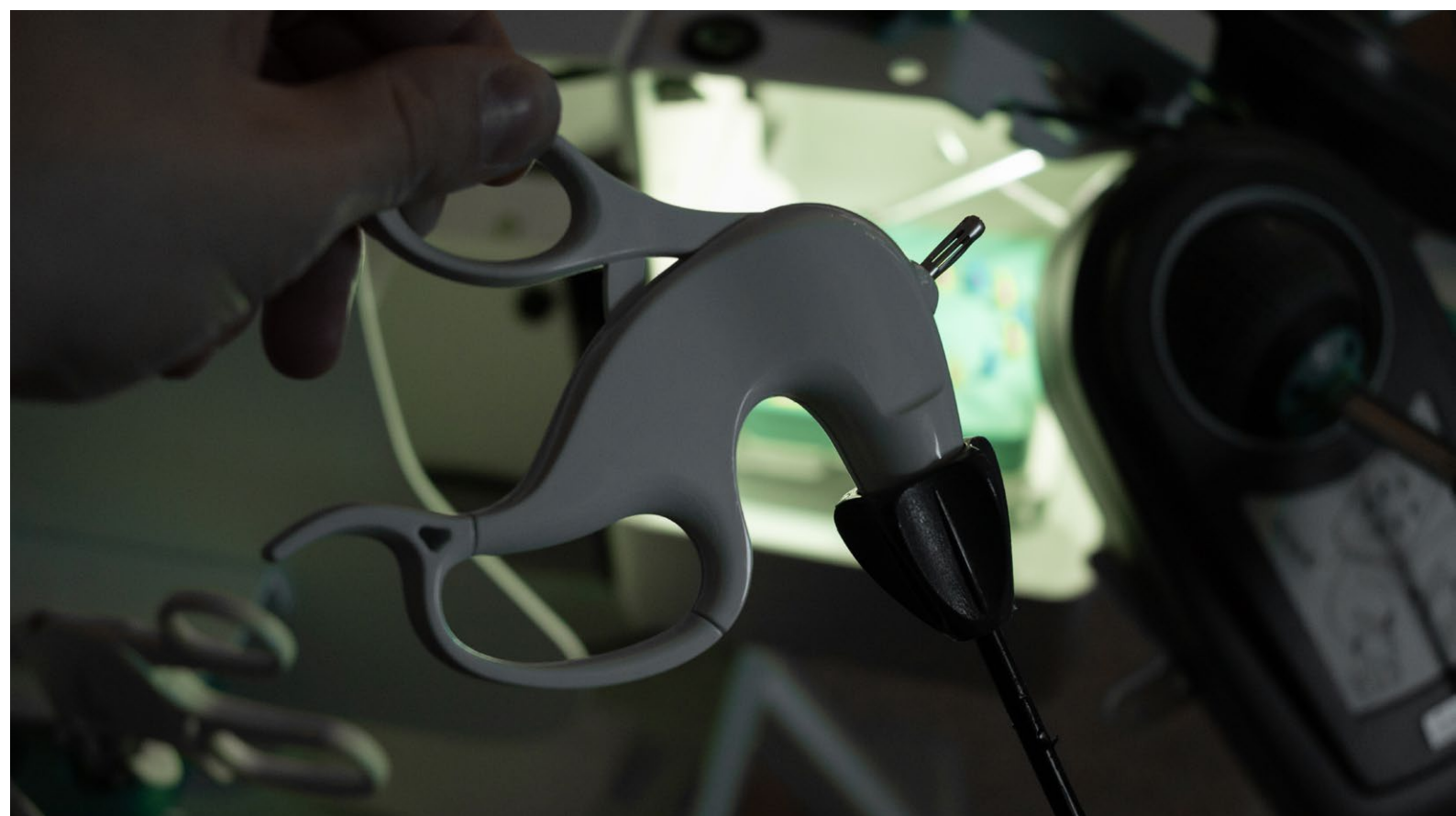
Open surgery often combined with electro and minimally invasive surgery tools remain critical and build the foundation across almost all surgical specialties. Robotic-assisted surgery is particularly relevant in urology, gynecology, general surgery, and orthopedics. Micro and endovascular procedures are playing a vital role in neuro, and vascular surgery.

"Laparoscopic and robotic simulation on we have in-house, but there is nothing suitable for open surgery." ⁴⁵

Markku Happamäki.

Senior Physician, Surgeon & Lecturer.
Department of Diagnostics and Intervention.
Norrlands Universitetssjukhus.





Laparoscopic Simulation.

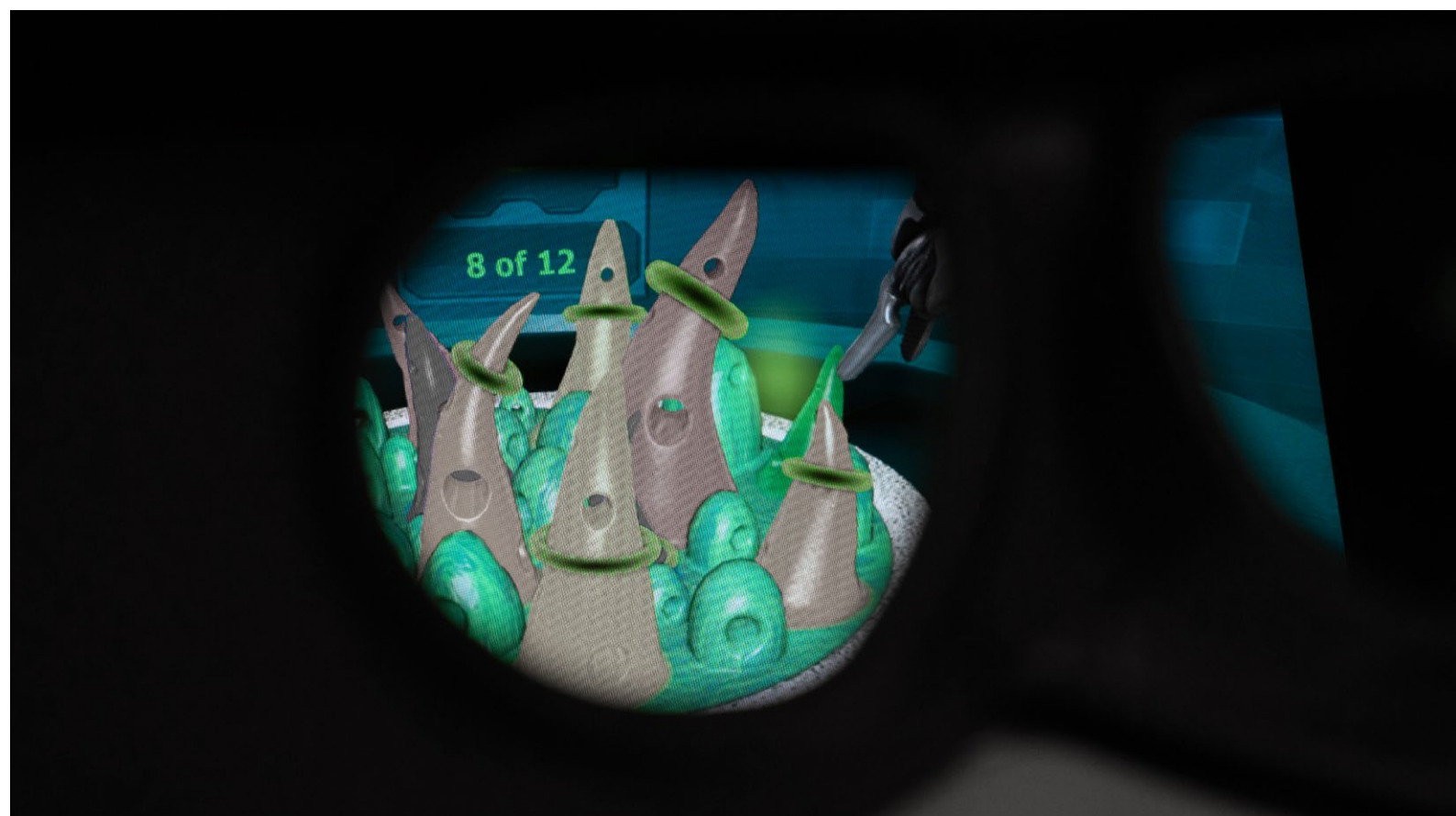
Training Modalities.



Field Trip II: What & How to Train.

On my second field trip to Norrlands Universitetssjukhus, I visited the Department of Diagnostics and Intervention, gaining access to the surgeons' current training stations. A key focus was the laparoscopic simulator, designed to develop technical

skills for minimally invasive surgery. Observing this system in use provided a deeper understanding of both its capabilities and constraints—how it facilitates skill-building through controlled exercises, yet also where it falls short in replicating the complexity of real procedures. This offered valuable insights into the physical dimensions, feedback, and the expected learning outcomes of current training tools.



Robotic-assisted Simulation.

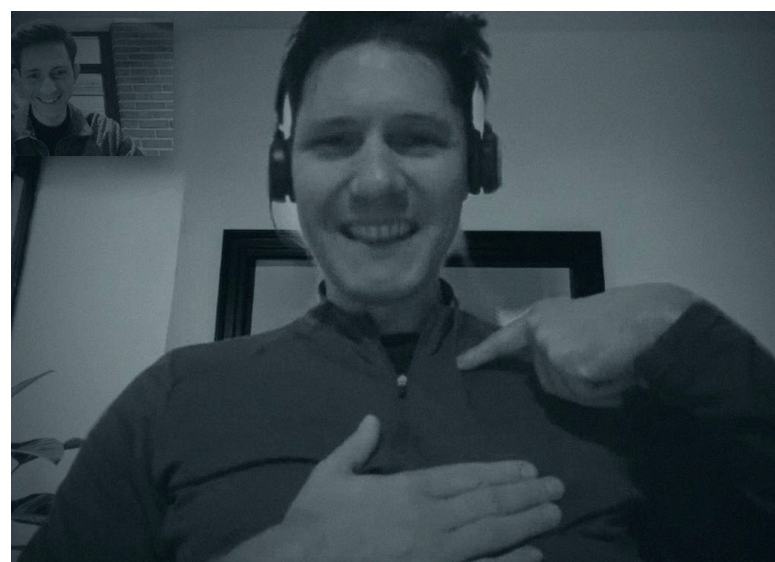
Training Modalities.



Field Trip III: What & How to Train.

During my third field visit to the surgical ward at Norrlands Universitetssjukhus, I had the unique opportunity to observe and interact with the Intuitive Surgery Da Vinci System, a state-of-the-art robotic-assisted surgical platform. Reserved for proce-

dures, this system is only available for training on weekends. I was able to test the machine firsthand, simultaneously controlling its four robotic arms while receiving post-performance feedback. This session provided invaluable insights into relevant surgical technique parameters and how these systems enhance capabilities while introducing new challenges in control and haptic response.



Med. + Tech.



Interviews.

3 Key Quotes.

"Quality assurance sets standards for **surgery—quality, time, cost, and patient safety**. Every operation is **averaged**, and **deviations** can cause you **serious issue**. Training **new surgeons** is tough since they often **miss procedure times**. Supervising stresses me out more than operating myself because **they must learn, yet I still need to step in. If they could practice** every step at home, it would help immensely."^{56 57}

Priv.-Doz. Dr. Andreas Stein.

Chief Physician.
Cardiology and Internal Medicine.
Medical Park Bad Wiessee St. Hubertus.

"If I'm scheduled for surgery tomorrow, I try to **prepare by reading** up on it, but it's not easy. I delve into a lot of literature like surgical atlases, but they **aren't visual and detailed enough for every procedure**. In the end, a lot comes down to **learning by doing**. A real simulation-based preparation would be amazing—it would make working through my training catalogue so much easier."⁵⁸

Cornelius Kramer.

TUM Medical Graduate
Resident in Trauma Surgery and Orthopaedics.
Barmherzige Brüder Hospital Munich.

"I experienced this, both at the hospital and at the university—they are **waiting for access to these skill stations**, but it's just **so limited availability**. But this is exactly where it would be **interesting to get performance data**, because a **mentor can't be with every student all the time**. Then, they would then also be able to give **individual feedback** and step in to support early if necessary."^{59 60 61}

Thomas Müller.

Co-Founder & CEO
Hapticlabs.io.

User Journey, Pain Points & Opportunities.

Status Quo.

General Medical Education

Surgical Education

Medical School + Internships

Specialist Training (Residency)

Patient Examination + Surgery
Knowledge & Skill Level



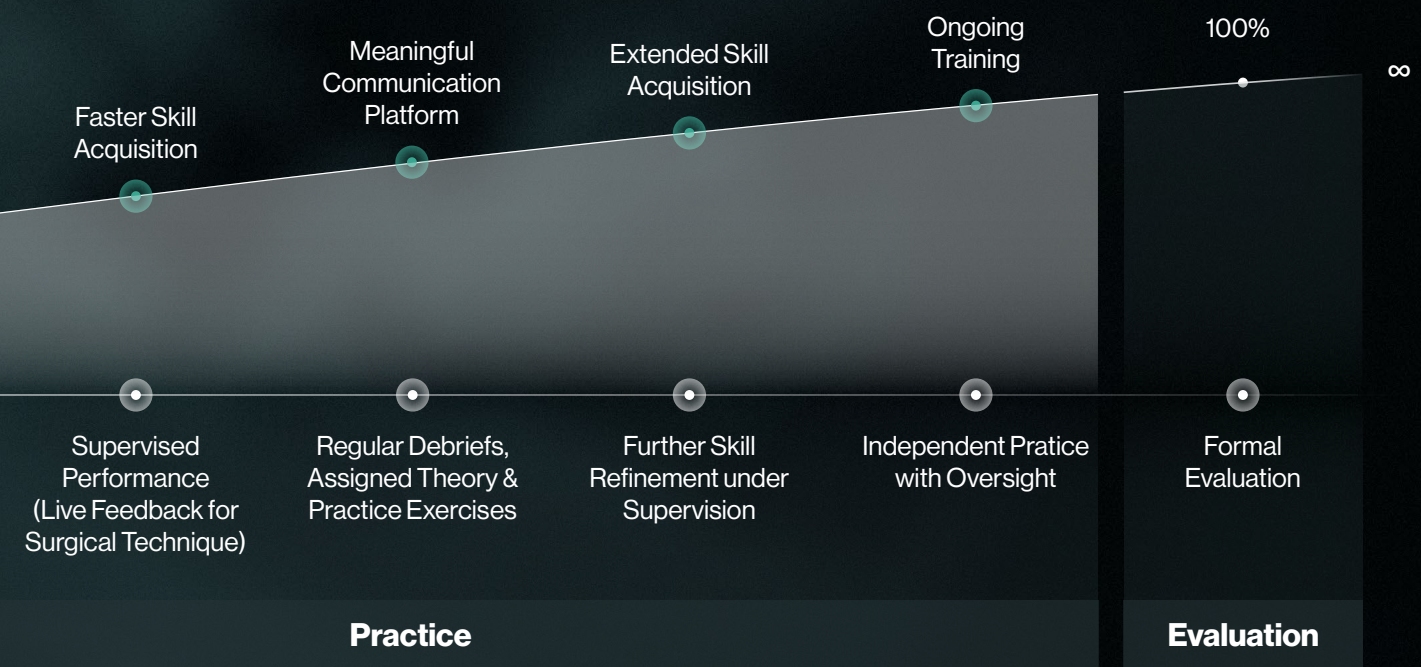
- Missing Tangible, Engaging & Effective Preparatory Learning Solution
- Gaps between Theory & Practice (Content & Timing)

- Lack of Individual, Risk-Free, Open Surgery Simulation
- No Holistic Skill & Scenario Simulation
- Outdated, Inefficient or Missing Training Tools
- Hindered Access and Perceived Shortage in XR
- Low Accessibility: Stationarity (Resident Rotation), High Demand & Low Number (Price) of Skill-Stations
- Lack of Objective Feedback & Insights from Unsaved Performance Data
- Lack of Immersiveness: Tactile Feel & Feedback of XR Tools, Lack of Contextual Interaction, Latency FPS & Scenario Jumps in XR

- Training on Living Patients
- Lacking Individual & Team Training Time (Quality Assurance)
- Additional Stress for Learner & Mentor during Practice (Quality Assurance)
- Low Mentor Availability Besides Cases

Surgical Subspecialisation & Practice

Evtl. Fellowship and Career



- Loss of Intangible Knowledge: Mentor Technique
- No Preparation for Extensive Strain

- Lacking Meaningful Communication Platform
- Missing Possibility to Adjust Simulation Complexity
- Little Time to Debrief and Reflecting on Skill Levels

- Missing Modality to Keep Training After Evaluation

Step

Pain Point

Opportunity



Market. ↗

+27.9 bil \$ by 2032. ⁶³
+27% CAGR. ⁶⁴

Skill. ↗

+230% surg. performance. ⁶⁵
+20% surg. speed. ⁶⁶
+13.7% success rate. ⁶⁷

Adoption. ↗

+89% acceptance rate. ⁶⁸

The Future is Now.

XR is emerging as a transformative tool in surgical education, offering immersive and interactive simulations that enhance skill acquisition and procedural understanding. Medical training increasingly adopts XR-based learning, providing students and professionals with high-quality, hands-on educational experiences that traditional methods often lack.

Research has shown that XR significantly improves surgical performance, precision, and learning retention, helping trainees refine their techniques more effectively before transitioning to real-world procedures.⁶⁹ Unlike traditional learning approaches that rely heavily on passive observation or static resources, XR enables real-time interaction with surgical environments, fostering intuitive learning and spatial awareness crucial for developing the required technical expertise.

Why Extended Reality (XR)?

New Opportunities.

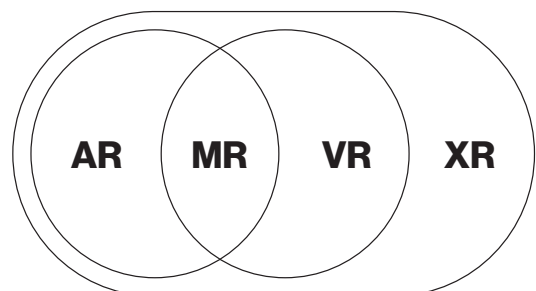
"You want your residents at the first time they touch a patient to be really ready for that moment, and that's what virtual reality (VR) has allowed us to do." ⁷⁰

Sandra Humbles.

VP, Global Education Solutions
Johnson & Johnson Medical Devices



Studies show that XR training provided by companies like UpSurgeOn, Fundamental VR or HaptX is well-received among medical trainees, who report higher engagement, satisfaction, and confidence in their abilities. Its tangible nature fosters a deeper understanding of workflows, allowing to practice repeatedly in a controlled, risk-free environment. By bridging theory and practice, it empowers to refine skills with precision and autonomy. It makes training more accessible, effective, and scalable.



Current Limitations of XR.

Crucial Tactility.

XR Potential: The Missing Pieces.

While XR holds great promise for surgical education, current systems face significant limitations that hinder widespread adoption and effectiveness. Accessibility remains a major issue, as open surgery XR training stations are stationary, expensive, and limited in number—restricting availability for trainees, especially those in rotating residency programs who frequently move between facilities and require flexible home training solutions.

Beyond accessibility, the realism of XR training tools is another major shortfall. Existing systems often rely on general-purpose controllers that fail to replicate the precise ergonomics, tactile feedback, and mechanical functionality of real surgical instruments. This disconnect limits skill transfer and reduces the effectiveness of training. Without high-fidelity, precision-focused simulations, XR struggles to provide the level of accuracy required for skill development, ultimately limiting its impact in surgical education.

"As you pinpoint, there is a gap between reality and the simulated world. The last three years I have been developing a [VR] simulation in trauma care that trains decision making **only much due to the limitations of controllers and the hinders to simulate hands on performance." ⁷¹**

Markku Happamäki.

Senior Physician, Surgeon & Lecturer.
Department of Diagnostics and Intervention.
Norrlands Universitetssjukhus.

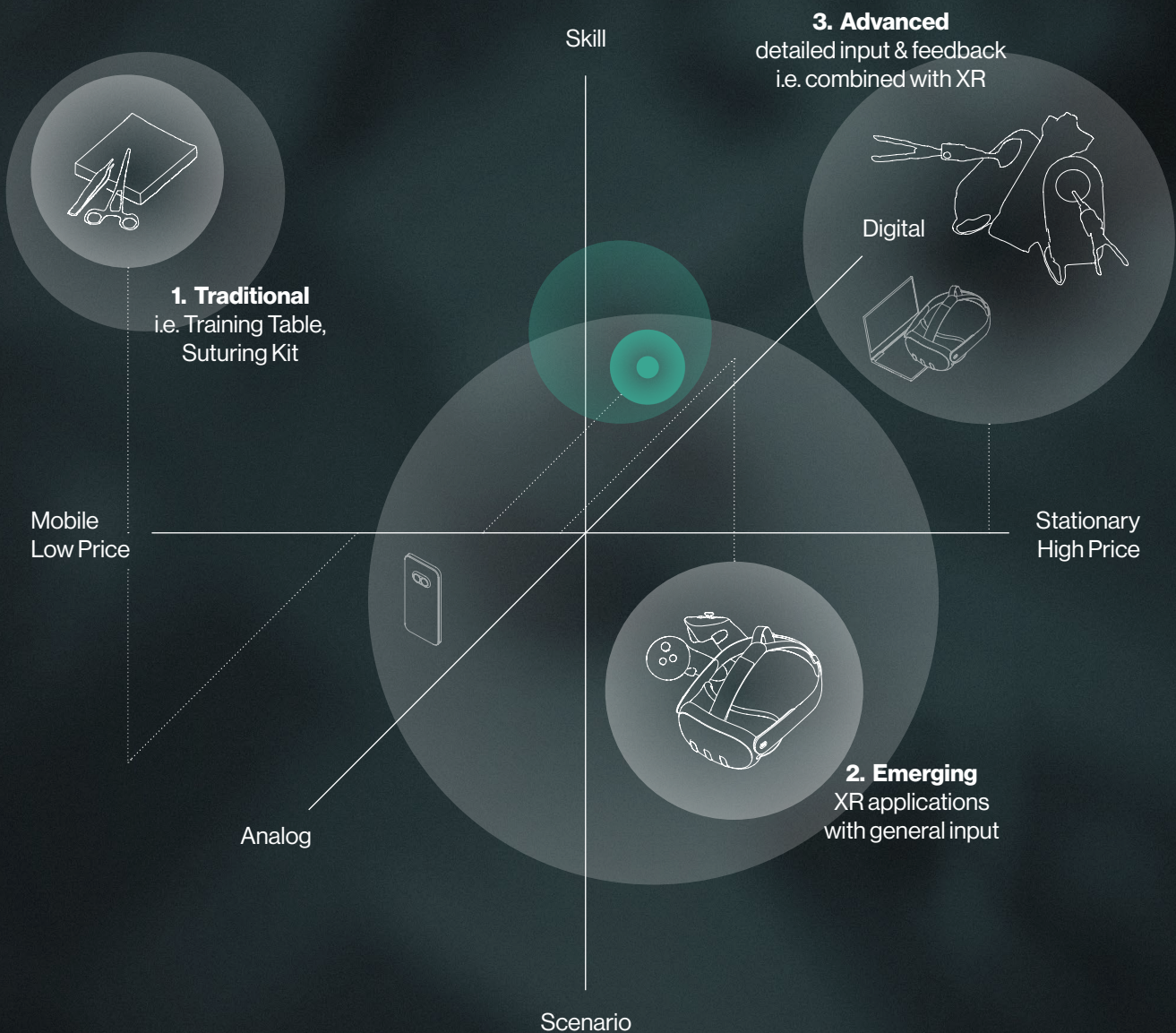
40% success-rate.
vs.
0% success-rate.


Haptic VR led to 40% first-try safe surgical drill depths, compared to 0% without haptics.⁷³ Major difference.

Tactile feel, mechanics and feedback are key!

Benchmarking of Training Solutions.

Hardware & Software.



 Identified project space

Skill based. ↗

Da Vinci Robotic Training

Laparoscopic Training

Training Table

Suturing Kit

CATHI Endovascular Simulation



▶ **UpSurgeOn**

FundamentalVR (MX Ink)

HaptX



Johnson & Johnson x Meta

SyncVR Medical

Connect The Dots

Oxford Medical Simulation

Skillup4u

VR4Healthcare

SimX VR

TraumaSim

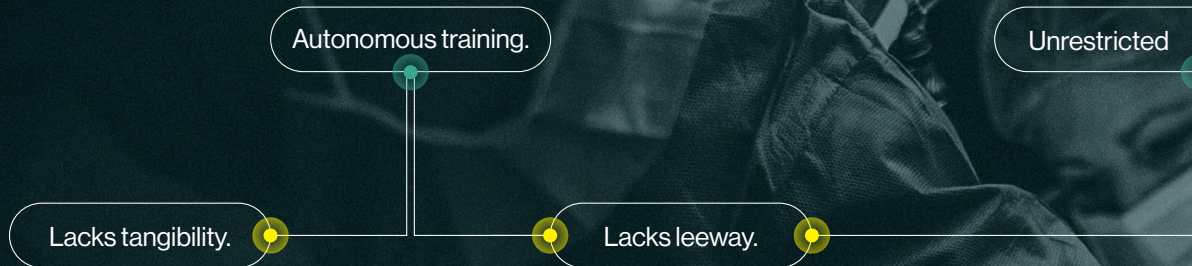
Scenario based. ↗

USP: Accessible, Tangible & Effective.

This project aims to bridge the gap between mobile, low-cost solutions and high-end, stationary systems, offering an accessible, tangible, and effective alternative for XR-based surgical training. Unlike purely analog models, it integrates digital performance tracking and an immersive environment while preserving a realistic, tactile input experience. By striking a balance between scenario-based learning and isolated skill training, it enables users to refine specific techniques while also understanding their role within full surgical workflows. This scalable and portable approach expands training beyond traditional lab environments—supporting residents at the most demanding stage of their surgical education and ensuring consistent skill development.

Key Challenges & Opportunities.

Summary.



Preparation by reading.
No tangible & effective representation or training.

Procedure time bottlenecks.
No risk-free environment and continuous feedback to train with.

Cornelius Kramer.

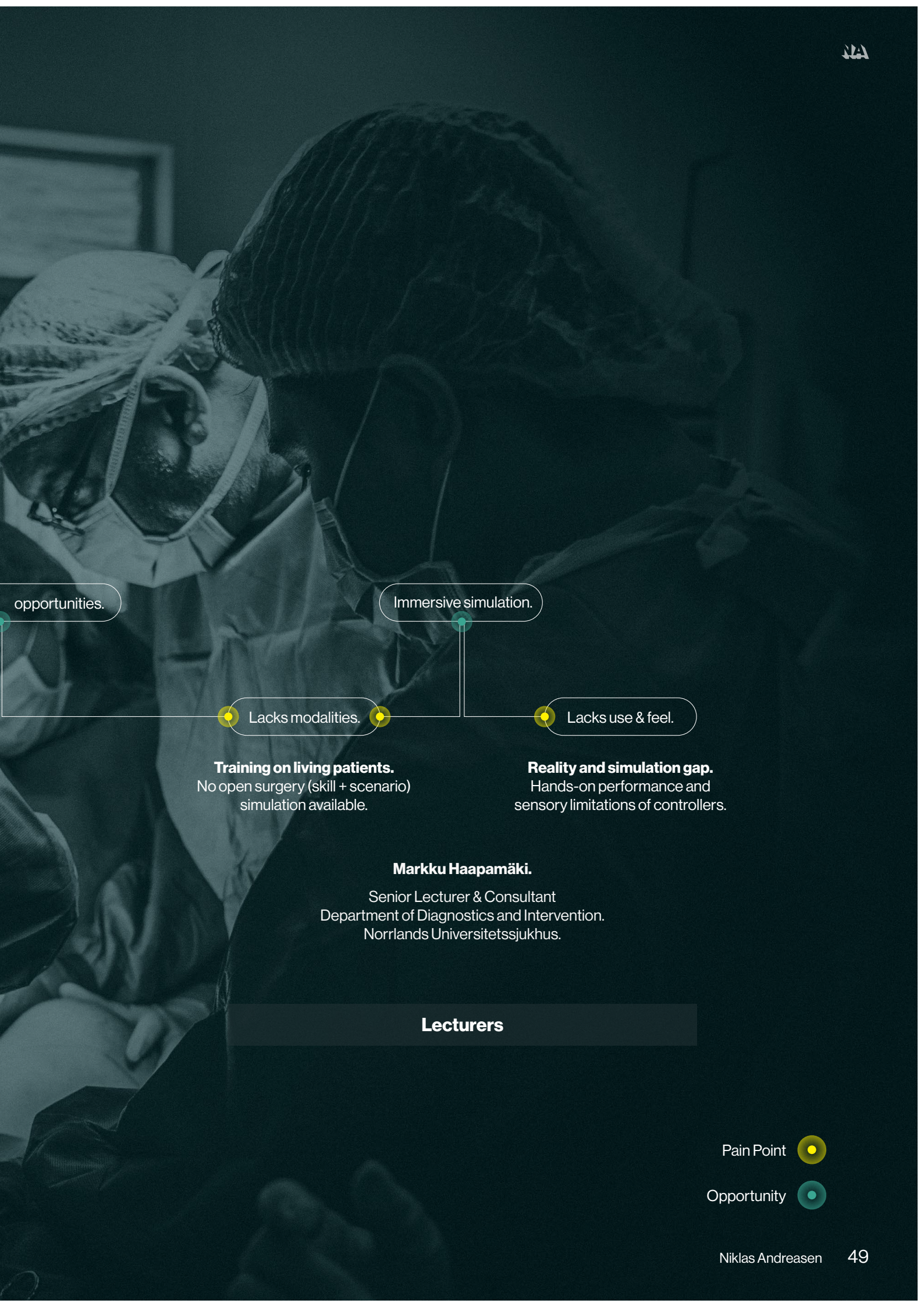
TUM Medical Graduate
Resident in Trauma Surgery and Orthopaedics.
Barmherzige Brüder Hospital Munich.

Priv.-Doz. Dr. Andreas Stein.

Chief Physician.
Cardiology and Internal Medicine.
Medical Park Bad Wiessee St. Hubertus.

Residents

Management



opportunities.

Immersive simulation.

Lacks modalities.

Lacks use & feel.


Training on living patients.
No open surgery (skill + scenario) simulation available.


Reality and simulation gap.
Hands-on performance and sensory limitations of controllers.

Markku Haapamäki.

Senior Lecturer & Consultant
Department of Diagnostics and Intervention.
Norrlands Universitetssjukhus.

Lecturers

Pain Point 

Opportunity 

A Holistic Package.

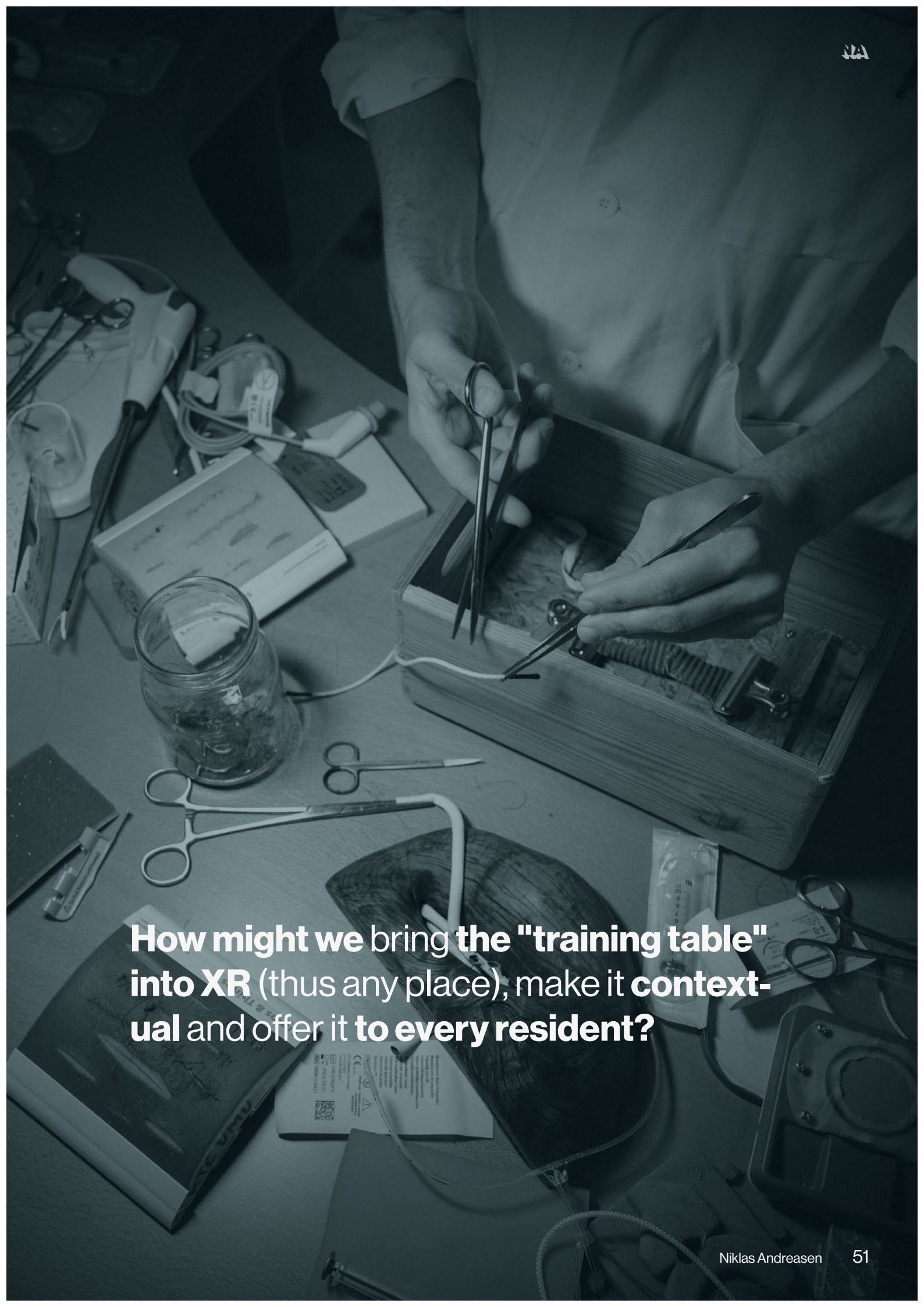
The Wishlist.

- ▶ **Main surgical tools: scalpel, forceps (3 types), scissors.**
- ▶ **Practice on surgical catalogue for residency, as well as in detached dexterity exercises.**
- ▶ **The mix of skill- and scenario-based training.**
- ▶ **Being able to adjust complexity level.**
- ▶ **Tactile representation, but not necessarily haptic feedback.**

"If you were able to **practise the steps** repeatedly on your own beforehand, you'd **free up** so much **capacity** in the OR. It **doesn't matter if it feels a little different**—the value lies beyond in being able to **train anywhere, independently, on the matter, repeatedly and risk-free with objective feedback.**" ^{82 83}

Priv.-Doz. Dr. Andreas Stein.

Chief Physician.
Cardiology and Internal Medicine.
Medical Park Bad Wiessee St. Hubertus.



How might we bring the "training table" into XR (thus any place), make it contextual and offer it to every resident?

Goals + Wishes.

Outlook.

Goals.

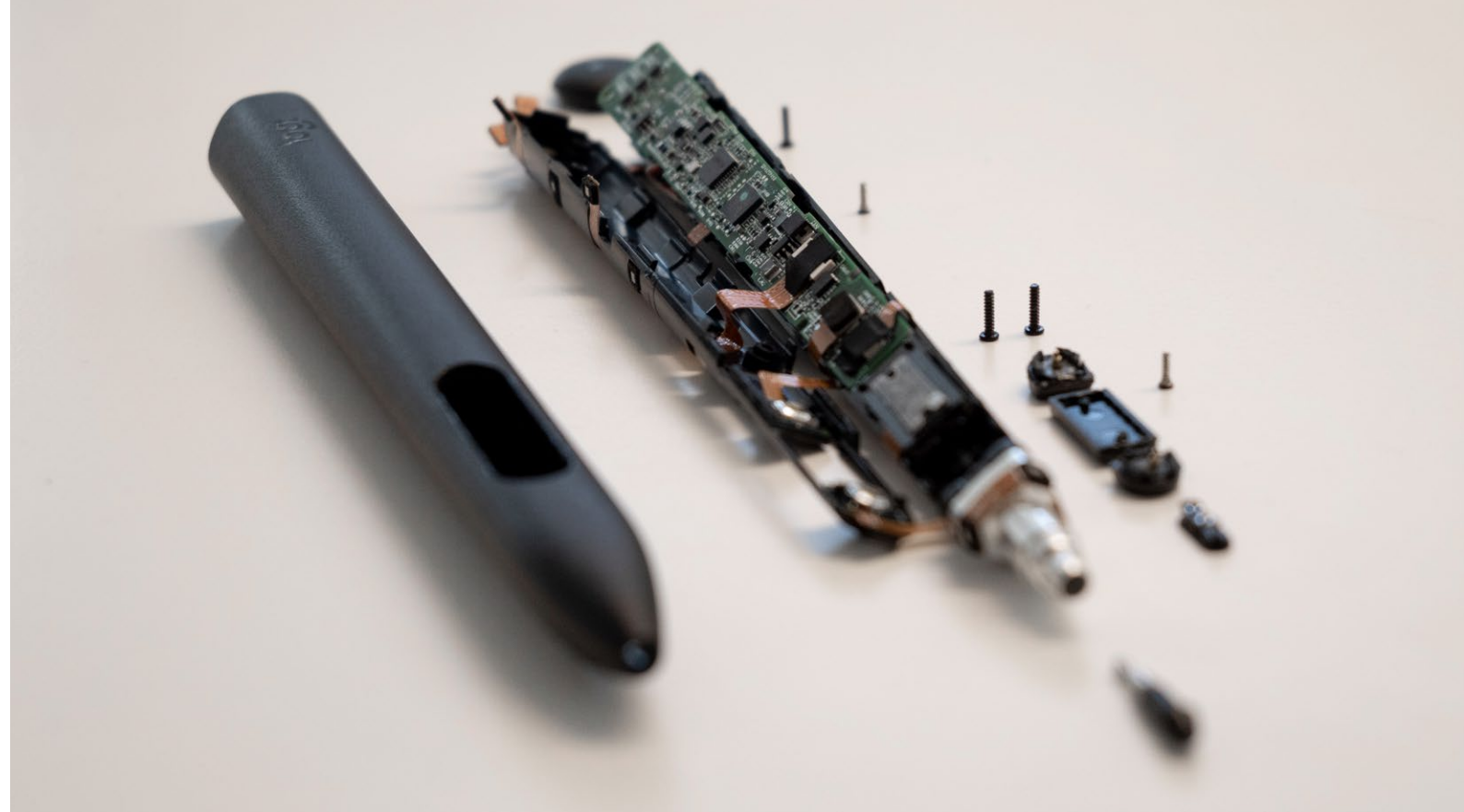
1. Proposing a future vision of a skill- and scenario-based training blend.
2. Conveying the current challenges and demands in surgical training.
3. "Phygital" product experience incorporating immersive, multimodal controllers for XR technologies and digitalisation of the learning and training process/platform.
4. Highlighting USPs of high-potential niche, improved affordability and accessibility, individual representation, realism and immersiveness.
5. Experimenting with XR and prototyping on a rough application for open surgery simulation training.
6. Documenting the process through high quality photos.
7. Emphasizing the design through stunning visual representation (still renders + short GIFs).

Wishes.

1. Connecting physical prototypes to prototyped XR application.
2. Creating a physical model.
3. Compelling and long teaser animation or short explanatory video.

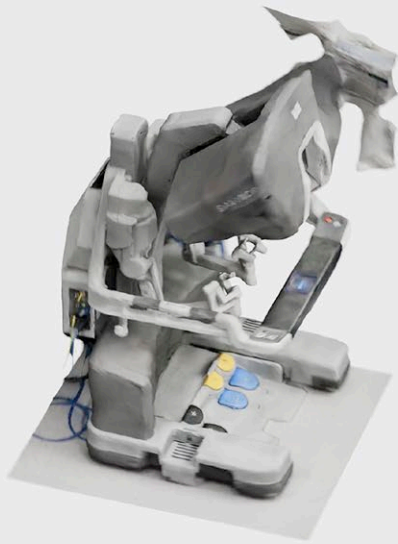


3 Ideation.



Ideation Process.

Workshops, 3D Prints, Technical Packages & MR Experiments.



Unit 2
Laparoscopic Simulator

Surgical Intervention
Norrlands Universitetssjukhus
250209



From Research to Rapid Process.

After defining my goals and wishes, the process quickly became hands-on. I conducted both individual and group post-it storms to iterate around key concept pillars and follow up on opportunities that emerged from the research phase. Using cardbo-

ard stands, I organized and mapped relevant surgical tools, drawing connections between them. I then moved into prototyping, combining my hospital 3D scans, online models, and own builds to 3D print and evaluate instrument forms. I also disassembled a Logitech MX Ink to analyze its internal components and manufacturing. Borrowing a Meta Quest 3, I tested initial prototypes and interaction flows in XR.



XR Documentation & Experiments.

XR in Practice.

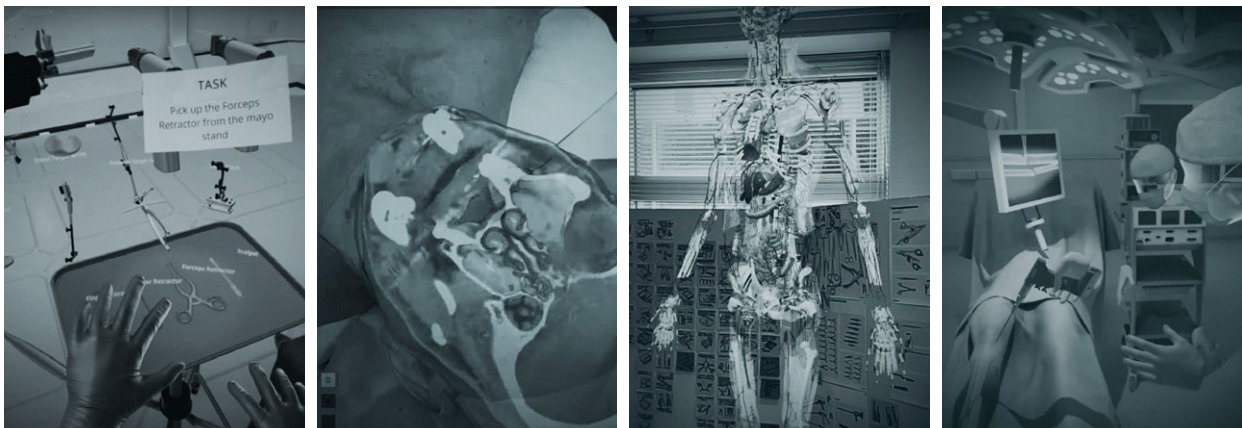
Creating for Care: Helping to help.

To build on the research I had already done earlier in the project, I dedicated a focused phase to hands-on exploration and observation within XR environments, to understand the current state of technology, but also to test how it could realistically support surgical education. I experimented with a range of tools and setups, including immersive VR surgical simulations and AR-based anatomical visualizations projected into physical space. These sessions helped me reflect on key interaction patterns, the role of gesture-based input, and how well virtual tools mapped to real-world hand movements and task precision.

As part of this phase, I also took a closer look at my contact Markku Haapamäki's self-developed simulation scenario, which offered a more grounded and tailored perspective on procedural workflows and system thinking within XR. Observing how this kind of bespoke simulation was structured, both in terms of pacing and interaction, helped me consider how scripted, scenario-based learning could, or in some cases should not, be integrated into my own concept. It also raised valuable questions around immersion, task relevance, and feedback design.

The VR-based scenarios, particularly those designed for multi-user collaboration, provided useful insights into how spatial awareness and communication function in virtual surgical training. Meanwhile, the AR experiments highlighted both the potential and limitations of layering anatomical content into real-world space, especially in terms of depth perception and alignment with the user's physical environment.

Throughout this phase, I captured screenshots and screen recordings to document interaction patterns, assess feedback mechanisms, and evaluate user engagement across setups. These documented and own experiments helped clarify where XR can enhance surgical training and where it still falls short without physical interaction. It supported my decision to pursue a hybrid approach that integrates the clarity and flexibility of XR with the tactility and precision of physical tools.



Endoscopic.

Minimally invasive surgery using flexible scopes to visualize and treat internal pathways.

Orthopedic.

Focuses on bones, joints, and muscles, often involving fixation tools and implants.

General.

Traditional surgery with large incisions for direct access to internal organs or tissues.

Tool Grouping.

Fields, Shapes & Mechanisms.



Electrosurgical.

Use of electric current to cut or coagulate tissue with minimal bleeding and precision.

Laparoscopic.

Minimally invasive abdominal surgery using long instruments and cameras through small ports.

FESS.

Endoscopic nasal surgery to treat sinus issues via natural openings with minimal trauma.

Microsurgical.

Delicate surgery under magnification for fine structures like nerves, vessels, or eyes.

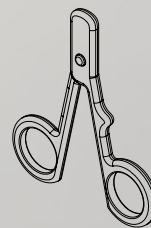
Identified Archetypes.



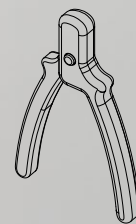
A



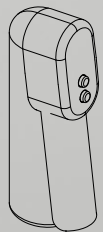
B



C



D



E

Grouping by Build, not by Field.

In the beginning of this project I tried to narrow down the selection of tools and concepts by focusing on specific surgical procedures or specialties. But once I began 3D printing and prototyping, I realized that despite the wide range of surgical instruments,

many share the exact same mechanical functions and forms across different fields. By identifying these overlaps and bridging only the minor variations between them, I could represent the majority of use cases without designing exclusively for a single discipline. Archetypes include scalpel-like forms (A), scissor-shaped bodies (C), tweezer or plier-like (B & D), and larger palm-held volumes (E).

Experience Blueprint.

Step by Step.



Acquire theory in digital and XR form

Start the system anytime at any location




Prepare the system(s) on any flat surface & make space

Log into your profile on Logitech's online platform

Lend and swap the system/pads from faculty/hospital material pools

Decide between individual/group, live/distant & action/teaching

Select your working position and decide for XR or screen based training

-  Analog
-  Digital
-  Hybrid

SURGICAL CONTEXT & DETAILED GAMY DEXTERITY EXERCISE



CONVENTIONAL SURGICAL PROCEDURES AND ADVANCED PRACTICE



SUTURING AND BASIC PRACTICES



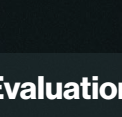
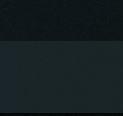
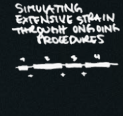
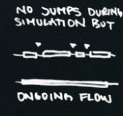
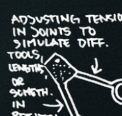
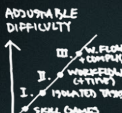
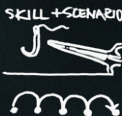
OPEN SURGERY + ELECTROCAUTERY



MINIMAL INVASIVE (ENDO + LAPAROSC.)



OTHER SURGICAL FIELDS



Practice

Evaluation

Adjust multimodal surgical tools & select learn/test

Capturing position & performance data at all times

Experience real-time interactive XR & the extensive strain

Choose between respective surgical context or dexterity exercises

Start operating on the perforated surgical pads

Use multimodal tools freely and experience haptic and scenario-based live feedback

Reflect alone/in team post-performance, capture progress & store intangible data

Shaping the Training Journey.

The experience blueprint revealed the overarching goal of the phygital product and clarified how it can practically align with today's teaching structure while still meaningfully expanding it. Spanning theory acquisition, preparation, practice, and evaluation,

the system introduces new modalities that increase tangibility, autonomy, and cognitive leeway. It reduces existing thresholds to participation, such as access, supervision, and time pressure and enables consistent, effective simulation-based training that remains relevant across all learner levels. Ultimately, it provided the foundation that guided the further development of the end-to-end learning experience.

Ideation Conclusion.

System Components.

Dual-Layer Setup.

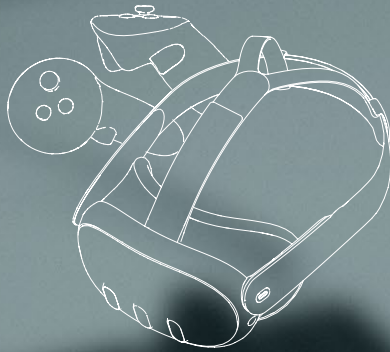
After defining the preferred user journey, the system I designed was clearly structured around a physical and a digital layer. The overall setup combines the application and learning platform, a XR headset, XR surgical controllers, and physical surgical pads for hands-on practice. Several key decision maker had to be considered moving forward.

Key Decision Maker.

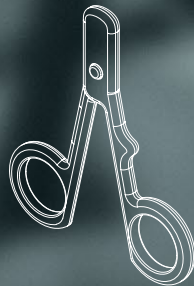
Basic Physicality Physically represent only the more relevant and challenging skill-based interactions.	Continous Accessibility With limited time, lower the threshold to start using the system.	Extensive Feedback Give instant and post-performance feedback, progress tracking and mentor share-outs.	Various Modes Incorporate different modes of self-led, group or remote live learning.
Private/Hospital Ownership Enable subscription-based, private basic and advanced faculty/hospital ownership.	Tool-based Division Surgical atlas led, enabling any surgical procedures the set of tools allows for.	Visionary Training Kit Designing a basic representative surgical training kit, including box, tools and pads.	Holistic Experience Focussing on the UX and representation, but emphasizing the ergonomic tools.

logi
TRAIN + LINK

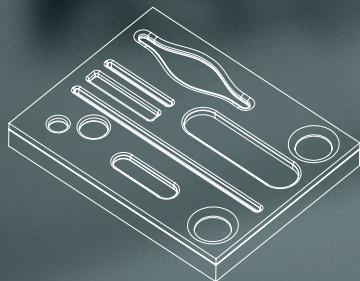
1. Digital Learning Platform.



2. XR Headset.

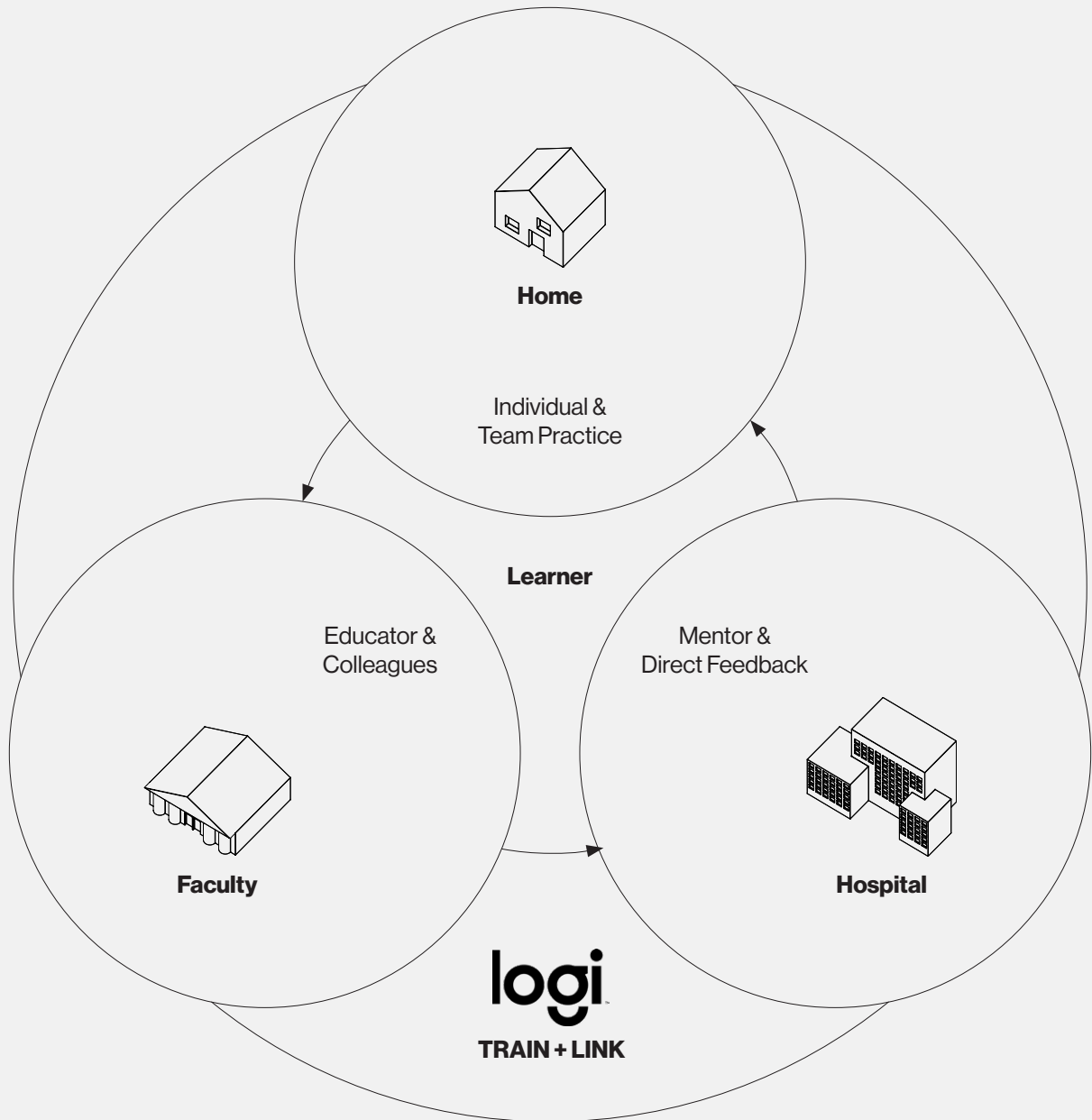


3. XR Surgical Instrument(s).



4. Surgical Pad(s).

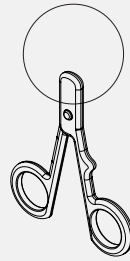
4 Design Directions.



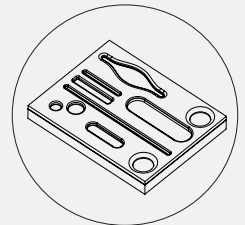
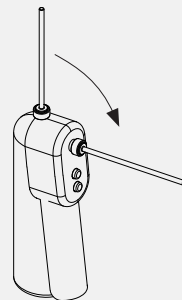
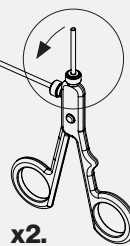
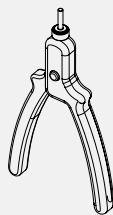
Concept Directions.

System & Packages.

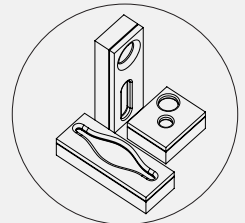
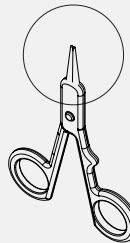
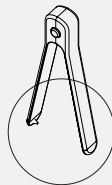
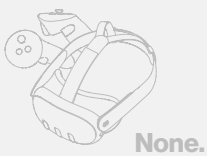
1. Wishlist.



2. All Fields.



3. Playground.



XR

A

D

B

C

E

Platform

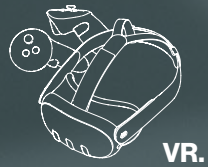
Balancing Tech & Tactility.

All three concept directions were closely related, differing mainly in the technologies used and the extent of their application. The first concept combined the most requested surgical instruments into in-air controllers, paired with a full VR experience. The

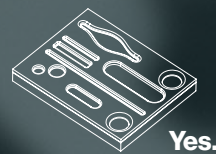
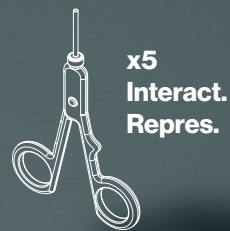
second concept blended a wider range of surgical fields by introducing more and flexible archetypes, enabling basic manipulation on a haptic surgical pad overlaid with a MR headset, increasing realism. The third concept, proposed by one of the surgeons, removed XR entirely but kept smart, fully functioning instruments that provide feedback when used on an analog, building block-like training environment.

**Concepts
+ Criteria**

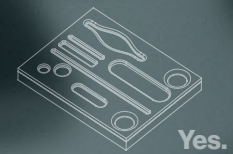
1. Wishlist.



2. All Fields.



3. Playground.



Ease of Use

+

○

○

Portability

++

○

-

Costs

+

○

-

Realism

--

+

++

Re-usability

++

+

-

Complexity

+

-

○

Flexibility

+

+

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Independence

++

+

-

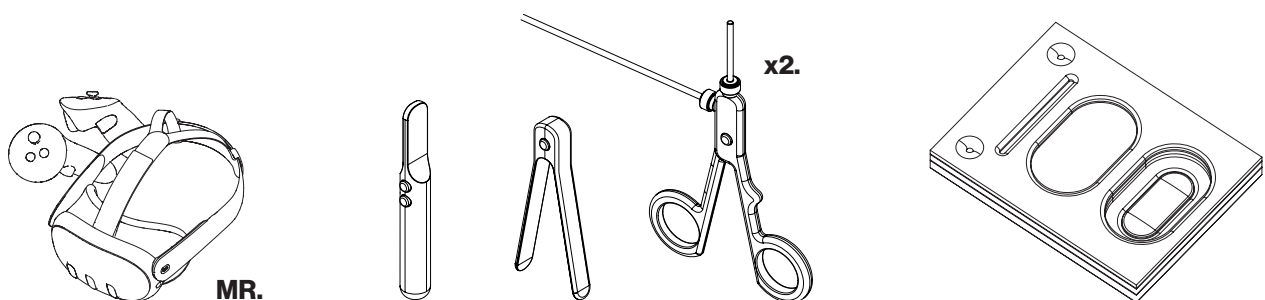
Evaluation.

VR/MR & Tool Amount/Selection/Function.

The Best of Both: 1 + 2.

After evaluating all concept directions, three key questions emerged that shaped the final design concept. First, should the tools be fully functional and potentially too constrained for multimodal use, physically simplified to preserve haptic feedback, or designed purely as visual replicas. Second, closely tied to the first, what is the minimal viable solution that preserves surgical realism while allowing for flexibility and ease of use, ultimately leading to the choice between MR and VR. And third, how many and which tools should be included in the basic kit before it becomes less mobile and more cumbersome.

The result was a compact system combining the three most requested tools by medical professionals with a tactile surgical pad for haptic feedback, enhanced by MR overlays to balance realism, adaptability, and efficiency.

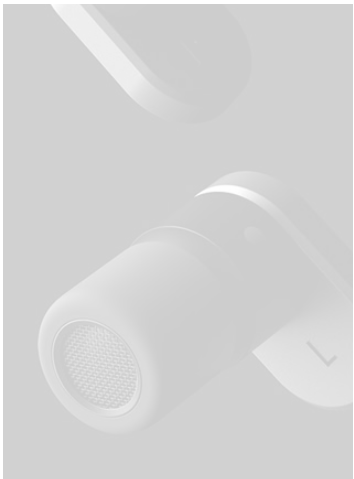
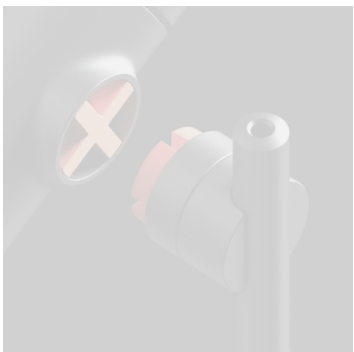


"I prefer the MR setup—with the pad and mentioned **openings on different tissue layers**. Add the **scalpel, tweezers, two pairs of scissors**, which are anyway indispensable, the **grip volume** and only if necessary pliers, and you're **equipped for everything** from microsurgery to orthopedic and trauma." ⁹⁵

"Pliers are usually only used for **wire cutting** and the **twisting of ends or similar rough work** on the bone. This is **not where the deep skill lies.**" ⁹⁶

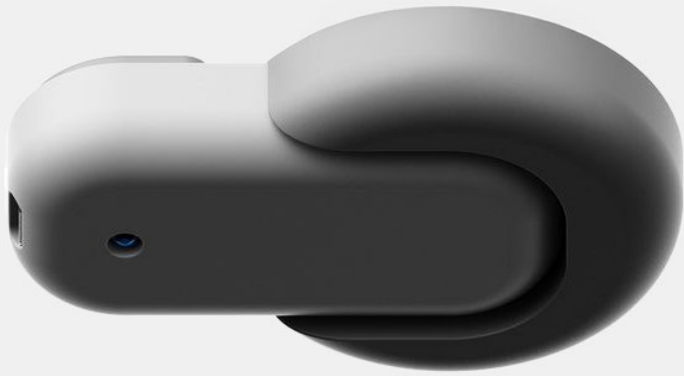
Cornelius Kramer.

TUM Medical Graduate
Resident in Trauma Surgery and Orthopaedics.
Barmherzige Brüder Hospital Munich.



Inspiration.

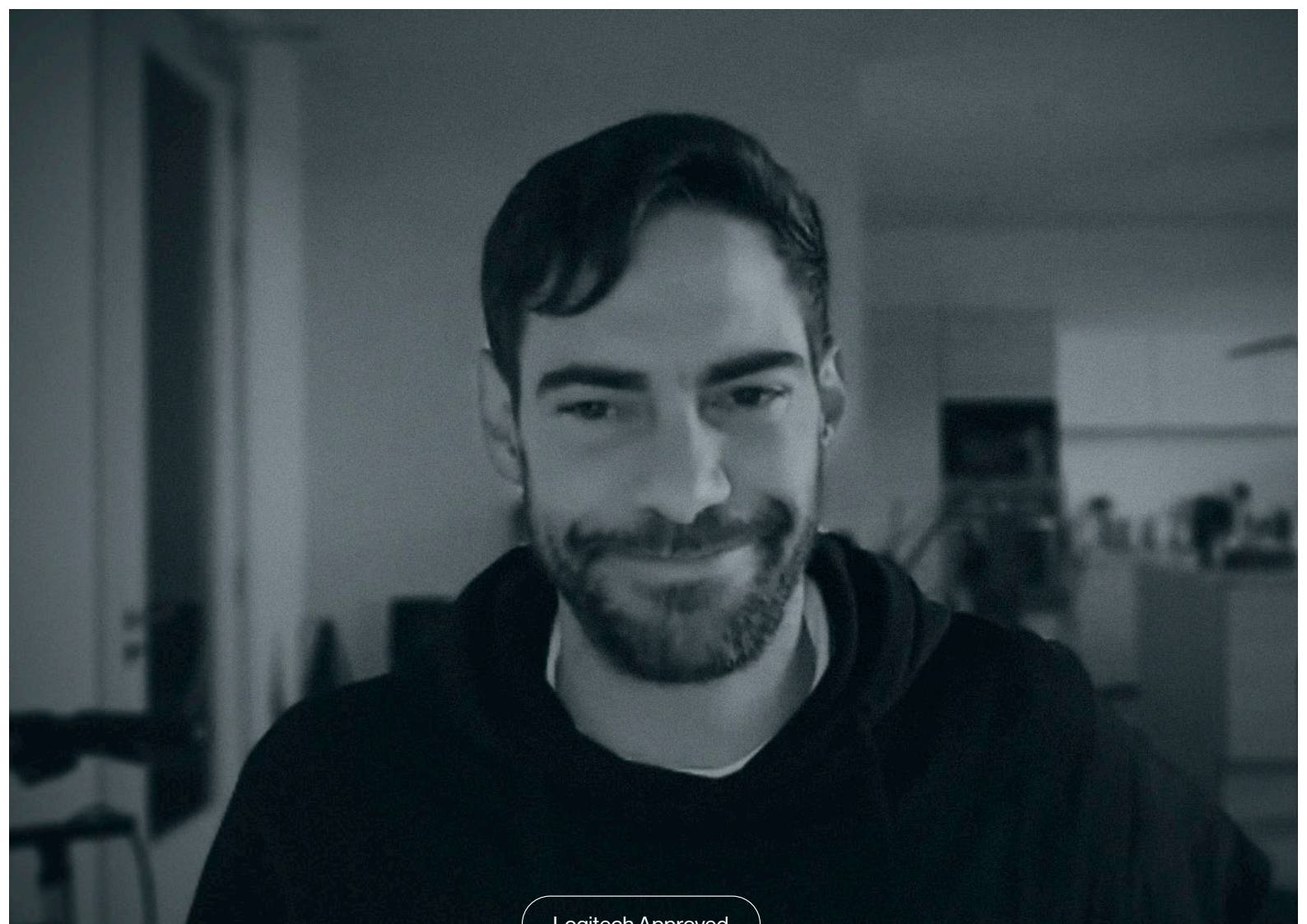
Rethinking Logitech Surgical.



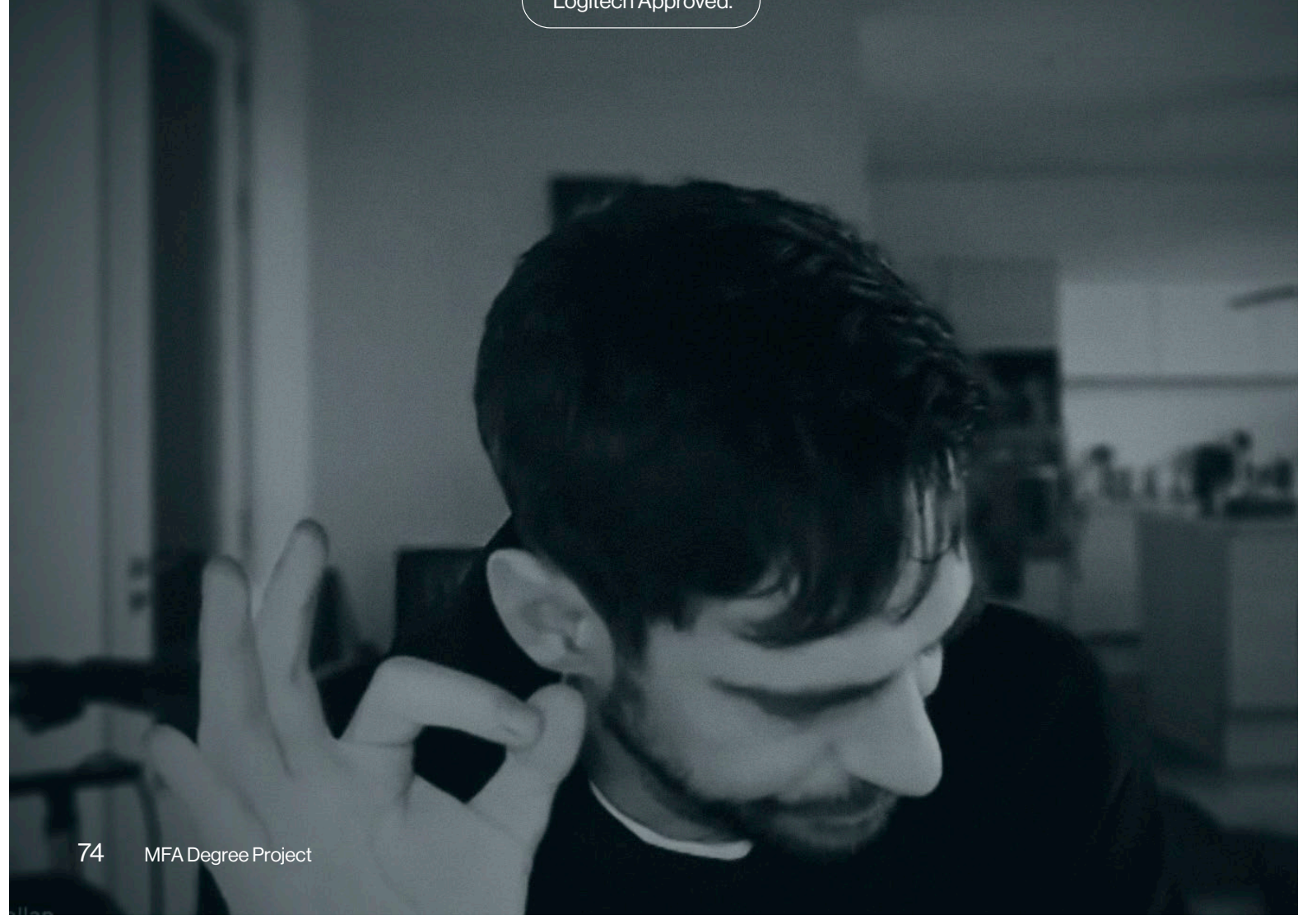
Context Related Shift in Design Language.

Already after the Ideation Presentation, Dhruvee Tyagi, Senior Industrial Designer at Above, provided valuable feedback on the moodboard, color palette, and materials. Rather than continuing strictly with Logitech’s classic CI and CMF, it became clear that

a new branch, Logitech Surgical, could be treated as its own opportunity. The visual language balances the professional context of premium medical training tools with a fresh, approachable tone: clean white surfaces paired with soft nude hues and subtle color accents. Smooth, shaved-off volumes reinforce the sense of ergonomics while preserving the structured feel of Logitech’s electronics heritage.



Logitech Approved.



Physical Product Requirements.

Technical Package Evaluation.

Surgical Controllers.

Ergonomic Grips	Tactile Grip Areas	Exchangable Tips	Capacitive Touchsens.
LiPo Battery	Charging Ports	PCB	BLE MCU
Torsion Spring	Mini Electr. Mag. Brake	PWM Brake Control	Metal Skeleton
Inside-Out Optic. Track	IMU Fusion	Monop./Power Buttons	LEDs

Surgical Pads.

Textured Silicone	Soft PU Foam	Shore A10-20 Rubber	Laparoscopic Inlays
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Case.

Injection Molded Case	USB-C Port	PCB	LiPo Battery
Charging Cable	LEDs	Inside-Out Optic. Track	IMU Fusion
Magnet Hinge			



Prototyping.

Sizes & Ergonomics.



From Screen to Scale.

I began prototyping early, as the ergonomics of the three selected tools were critical and needed to be validated from the start. 3D printing technical packages, sharing them with Logitech and averaging reference instruments helped define the bounding

box for each tool. Printing revealed key tolerances and hinge behaviors, which guided the transition from conceptual geometry to functional volumes. Multiple stages of iteration were 3D printed, making CAID, KeyShot, and physical prototyping a powerful combination. It was crucial not to lose the connection to real-world scale while spending long hours refining details on screen.



Design Development.

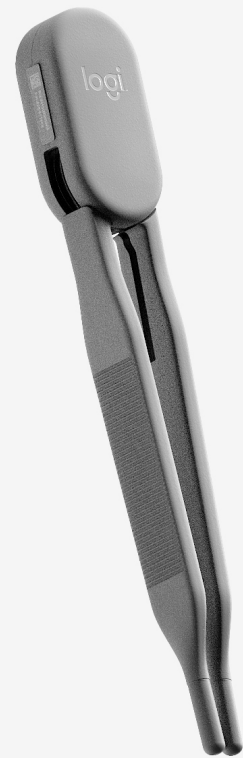
MX Pivot & MX Edge.



MX Product Family: Approachable & Capable.

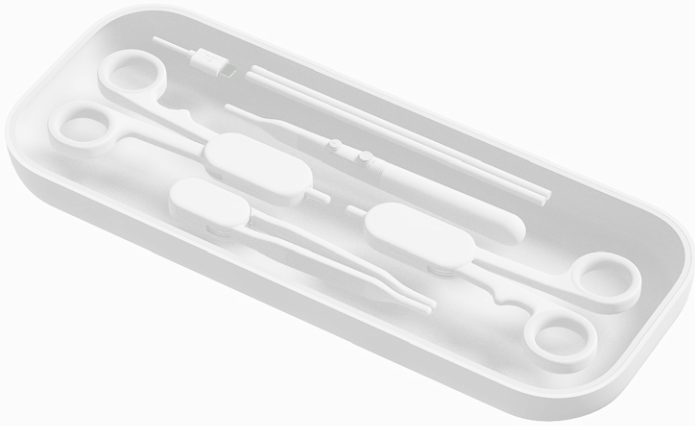
Logi MX became the well established abbreviation of Logitech's premium product lineup. I began developing MX Pivot first, being the most complex in my product family, combining ergonomic and mechanical challenges. Its head rotates 90° and features

interchangeable tips for laparoscopic procedures. A touch-sensitive surface allows to adjust clamp orientation intuitively. The pill-shaped form stays consistent in both positions while housing technical components. A safety label functions as a tamper-proof seal. MX Edge merges a thin scalpel-like front with a thicker electro-surgical handle, combining design elements consistent with MX Pivot's aesthetic.



Design Development.

MX Split & Case.



Tying everything Together: Mobile & Protected.

MX Split builds on the same mechanism and form as MX Pivot, using electromagnetic spring tension in the joint to simulate gripping between the tips. It also adopts the same grip texture as MX Edge, reinforcing the visual and tactile unity of the product

family. The travel case presents both tools and surgical pads at an even height, keeping them securely in place and clearly organized. Its top and bottom halves detach magnetically, allowing flexible positioning. Colored pads help differentiate training scenarios while referencing neutral skin tones. They are exchangeable after extensive use or for new scenarios. Multiple cases can be paired for larger setups.

5 Final Outcome.



logi™
MX Surgical

Challenge.

Surgical education is under increasing pressure. With growing procedural demands, limited access to hands-on training, and a projected shortage of skilled seniors, many residents face sparse opportunities to build real-world surgical skills before treating patients.

While XR platforms and simulation tools are gaining attention, they often focus on scenario-based decision-making and overlook the demanding physical reality of open surgery. Generic controllers lack the tactile feedback, tool fidelity, and workflow accuracy needed to develop crucial motor skills, muscle memory, and hand-eye coordination. The result is a disconnect between digital training tools and the physical demands of surgery.

Solution.

Logitech MX Surgical is a mobile and scalable training system to help close today's surgical experience gap. It combines multimodal XR controllers with a variety of stacked, interactive surgical pads and mixed-reality overlays. Designed for realism and range, the controllers replicate the tactile feel of the most commonly used tool archetypes while remaining adaptable across different instruments within each category.

This modular bundle enables residents to train in key fundamental techniques and complex procedures in a safe, repeatable, and context-rich environment, at home, in hospitals, or in educational settings. By mixing physical precision with digital depth and performance-based feedback, MX Surgical creates a more accessible, continuous, and realistic training modality, empowering residents to refine their skills independently to enter the operating room with greater readiness and confidence.



logi™

MX Surgical

"Tactile XR Surgical Training"

Training System for Extended Reality.

Master Thesis in Advanced Product Design

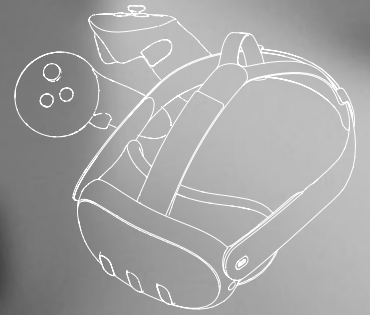
In collaboration with:
Logitech Europe SA



Democratising Training.

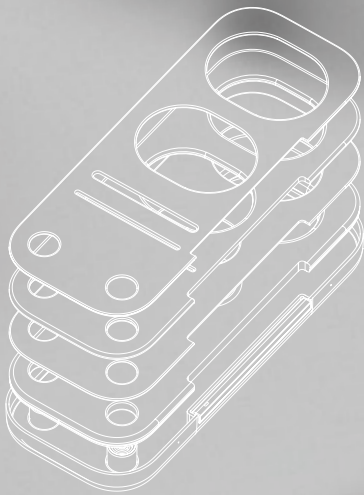
Affordable Modalities.

logi
TRAIN + LINK

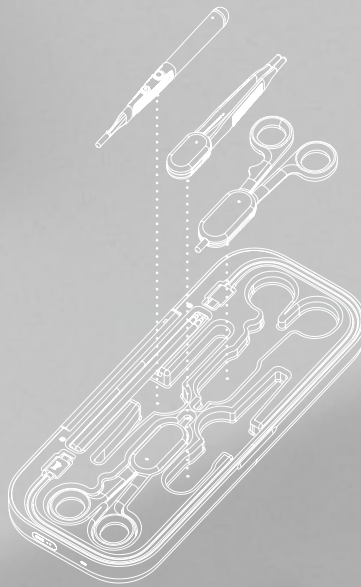


1. Digital Learning Platform.

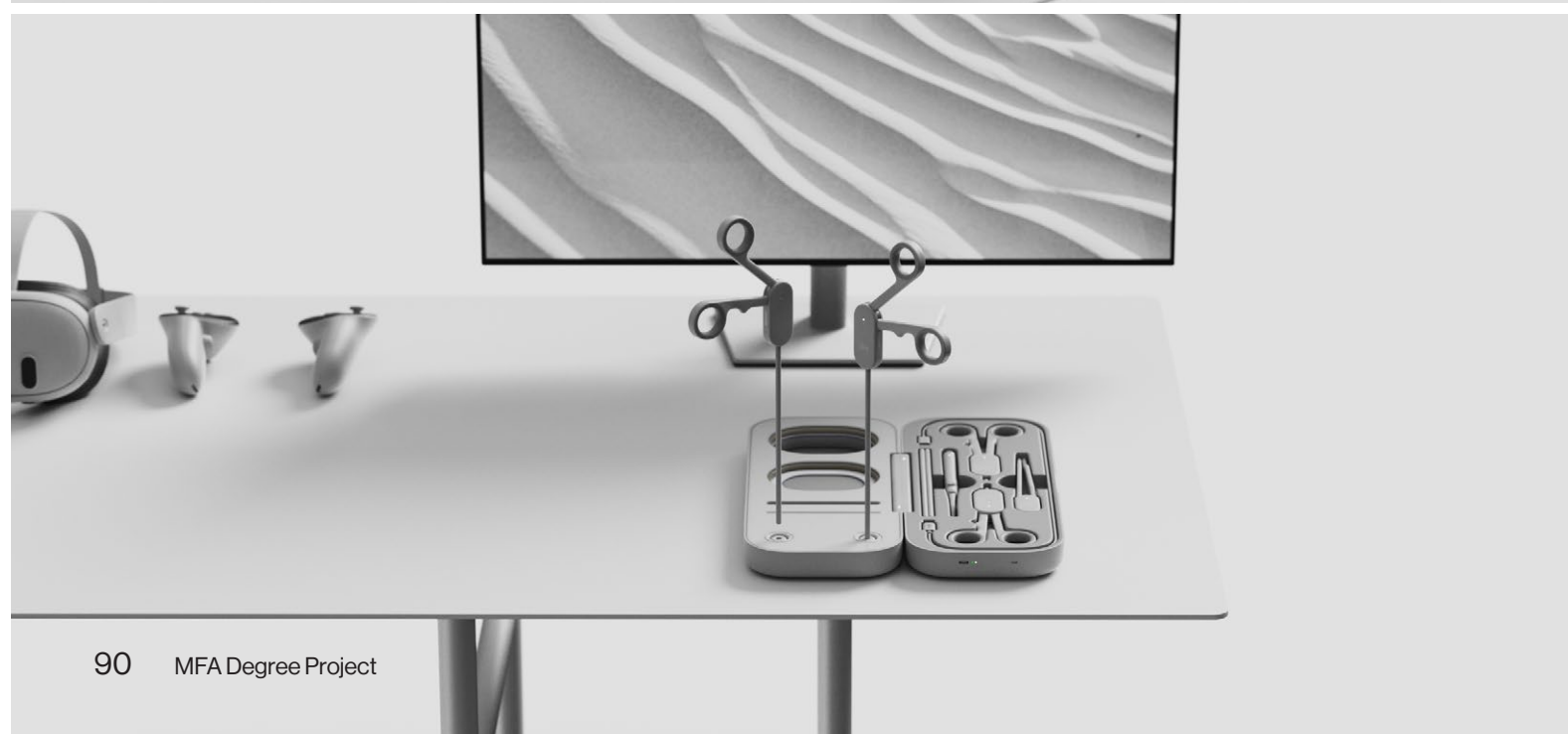
2. MR Headset.



**3. Modular
Surgical Pad(s)
+
Box.**



**4. XR Surgical
Instrument(s)
+
Box.**



Unrestricted Opportunities.

Personal & Mobile Workstation.

Independent Skill Building.

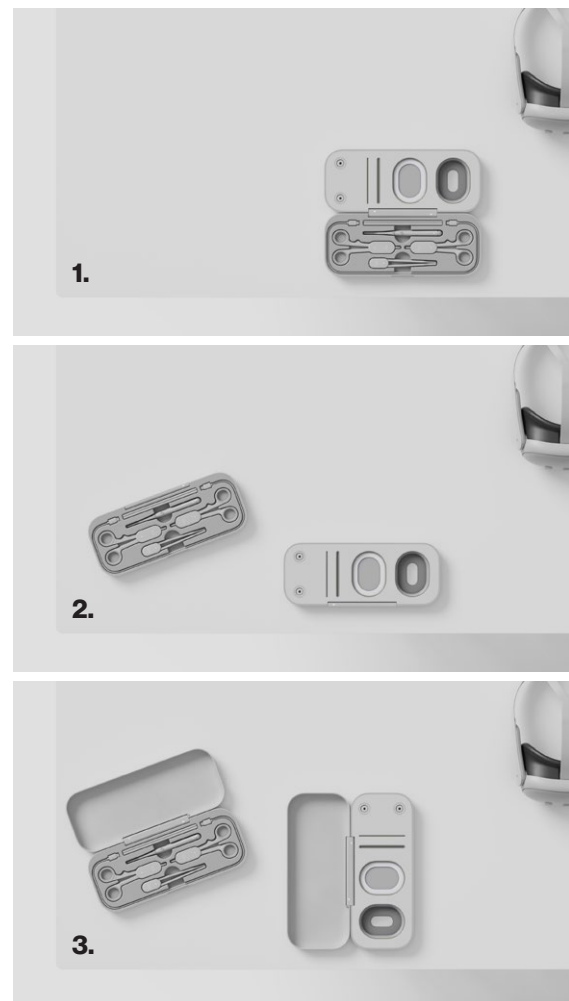
MX Surgical democratizes surgical training by offering an affordable and accessible alternative for hospitals, faculties, and individual learners. Full force-feedback training solutions today often reach into the low five-digit USD range. In contrast, MX Surgical provides a personal, mobile workstation that is not bound to specific facilities, scheduled time slots, or institutional availability.

To begin training, residents only need a mixed reality headset and the complete MX Surgical set. The example shown here represents the basic configuration, with the potential to expand into additional surgical fields or specialty-specific requirements in the future.

The magnetic case acts as both storage and workstation. When opened, one half securely holds the tools and accessories, positioned flush and charged inductively. The other half contains the surgical pads, each offering distinct material, stiffness, and texture profiles. Separating the two halves mirrors the spatial layout of an operating room, where tools are placed at a comfortable distance, and the operative situs directly in front of the resident.

Multiple sets can be combined to extend either the tool library or the workspace area, depending on the training scenario. The XR tools interact with the physical pads to simulate active surgical procedures. By progressing across the pads from left to right, residents create incisions, expose structures, and gradually reach deeper layers of tissue. Upon completing each step, the mixed reality system advances the projected anatomy by a few centimeters, revealing the next depth level and reinforcing continuity within the workflow.

The geometry and sequencing of these pads were developed together with clinical professionals to support a standard training pathway while still accommodating variations found across open, electrosurgical, and laparoscopic procedures. The aim is to cover a broad range of common scenarios without becoming overly prescriptive, enabling both structured practice and personalized exploration.





Endless Versatility.

Configurable Toolset.



Material Library.

Hospitals or faculties provide the modular systems, enabling residents to swap components and adapt training to specific surgical cases or specialties.

Real Use & Feel.

Closing Tactile Gaps.

Advanced Force Feedback Simulation.

The controllers combine movable components and adjustable resistance mechanics to replicate the varied shapes and tactile responses of each surgical instrument in use. By dynamically tuning spring tension and motion range in real time, each controller can mirror any tool within its respective archetype and even recreate immersive feedback like resistances or grips without a physical object. This enables users to “feel” virtual materials or re-experience the micro-interactions of the mentors.







Immersive MR Experience.

Prioritizing Training Time & Leeway.



Safe Space for Mastery.

With the immersive MR experience, long-standing challenges in surgical training are addressed. Residents have traditionally relied on real procedures for learning, working on living patients, under pressure, with limited room for mistakes. MX Surgical resha-

pes this dynamic. Residents can internalize workflows, techniques, timing, and precision in a controlled, risk-free setting that offers genuine cognitive leeway. They gain space to explore, repeat, and refine, supported by objective feedback that enables continuous improvement before entering the real OR. This ensures that active OR time is used for performing and not for learning the basics.

Intuitive Platform.

Collaborative Learning Network.



Connected Platform.

The system enables individual or team training through visual workflows, remote teaching, and a digital atlas with guided learning, dexterity tasks, and evolving test scenarios. Progress is tracked, feedback adapts, and results can be reviewed with mentors.





Realistic Learning Environment.

Tangible & Efficient Simulation.

Immersion Built for Progress.

The mixed reality environment blends physical tools, spatial interfaces, and a lifelike operating setting to create a training space that feels immediate, intuitive, and grounded in the realities of surgical work. The goal is to provide residents with an environment that mirrors the cognitive, spatial, and procedural landscape of the operating room while still offering the freedom and flexibility of a controlled simulation. The presence of the physical tray, the instruments, and the surrounding OR cues helps anchor the experience, reducing the abstraction often found in traditional VR training systems and enabling a far smoother transition from simulated tasks to real clinical practice.

Within this environment, residents can seamlessly shift between small dexterity exercises and full medical cases. Early training sessions might focus on simple precision tasks like isolating structures, controlling motion arcs, or practicing subtle tool manipulations. As confidence grows, the same tools and interface support increasingly complex workflows like layered dissections, stepwise surgical sequences, timed tasks, and full procedures. The system is designed to scale alongside the resident's development, ensuring that the setup remains relevant across beginner, intermediate, and advanced training needs. This progression creates a learning path that is both structured and adaptable, enabling to develop technical fluency at their own pace.

The integrated interface is intentionally lightweight and spatially aware. Residents can access menus, instructions, or reference material without breaking immersion or shifting focus away from the operative field. This fluid integration of information and collaboration aligns with modern OR practices, where surgical teams increasingly rely on digital overlays, imaging, and live guidance. The system's design ensures that information becomes an unobtrusive extension of the environment rather than an interruption, supporting decision-making and reinforcing procedural understanding.

By combining tactile elements, immersive visualization, and responsive digital guidance, the training experience becomes both tangible and highly efficient. Residents can review and repeat steps, refine precision, and revisit challenging tasks without the constraints of time, space, or supervision, while maintaining continuous access to their short- and long-term progress. The system also supports collaboration, enabling residents to join peers or mentors for shared sessions, guided practice, or collective case discussions. This level of realism and immediacy encourages deliberate practice, conscious, focused repetition that strengthens confidence, muscle memory, and procedural clarity, ultimately preparing residents not only to execute tasks, but to internalize the rhythm, flow, and mindset of surgery long before entering the real OR.

Autonomous Training.

Focus on Individual Needs.



Objective Performance Tracking.

The setup captures subtle motor patterns, tool handling, motion efficiency, accuracy, force control, and response timing, thus turning intangible aspects of surgical skill into actionable insights. This motion data grants access to knowledge traditionally passed down through mentorship during surgical residency, yet rarely formalized.



logi.
MX Surgical



Reflections & Conclusions.

Personal Recap.

General Reflection.

During the early phase of my thesis, I knew I wanted to work on a topic that felt both personally meaningful and technically challenging. I was drawn to the idea of creating something that not only explored emerging technologies, but also had the potential to make a positive impact, especially in the field of medical training. Collaborating with Logitech gave me the opportunity to build on their hardware ecosystem while exploring how phygital tools could be reimaged for surgical education. That combination of industrial design, extended reality, interaction, and real-world application felt like the right foundation for my thesis.

I approached the project with the mindset that I wanted to learn something new and grow my understanding of a field I was highly interested in but not too familiar with. The topic pushed me into areas like surgical ergonomics, hybrid haptics, and training workflows and I was amazed by how much depth and nuance I discovered along the way. Logitech offered me a lot of freedom in shaping the direction of the project, which allowed me to move between industrial design, technical prototyping, and system-level thinking.

In the beginning, I spent a lot of time researching the needs and realities of surgical professionals, and those insights helped guide the design decisions throughout the process. I also explored a range of tools and technologies, from mechanical resistance systems to XR overlays, and was able to experiment with how physical and digital layers could interact.

Looking back, I'm glad I chose a topic that gave me room to explore different disciplines while still staying grounded in a clear use case. The project challenged me in ways I didn't expect, but it also confirmed how much I enjoy working at the intersection of design, technology, and real-world impact.

Goals & Wishes.

This thesis began with a clear intention: to explore how XR, physical interaction, and surgical education could be meaningfully connected, not just in theory, but through a tangible, testable design. I wanted to propose a training system that combined skill-based repetition with scenario-driven learning, and I believe I was able to articulate a strong vision for how these layers could coexist.

I focused on designing a modular, phygital system. Not just a single product, but a connected set of tools, including three input device archetypes and a multi-layered surgical pad. My aim was to stay grounded in real training needs, and I think I succeeded in translating stakeholder insights, research, and ergonomic challenges into a coherent concept. That said, I did face limitations, particularly on the digital side. I wasn't able to connect the physical system to a live XR simulation, and real-time MR interaction could have been a thesis in itself. But I used the opportunity to explore early XR tools, educate myself on the tech landscape, and build a clear foundation that I'm still planning to build on, especially for the final presentation.

While my original goals focused on physical functionality and system design, I kept digital depth as part of my wishes and accepted that some aspects would remain conceptual for now. I would have loved to explore MR tracking or more advanced overlays, but time and complexity demanded focus.

Throughout the process, I made it a priority to document the project carefully, and I'm proud of the visual clarity and prototyping quality I was able to achieve. As I move into the final stretch, my goal is to tie everything together, with a physical model, compelling visuals, and hopefully some short animations to give a glimpse of the full vision.

Conclusion.

The outcome of this thesis is a concrete proposal for how physical interaction and extended reality can be combined to improve surgical training. The project focuses on designing input tools and tactile environments that are accessible, modular, and realistic, all within a system that could eventually support immersive, skill+scenario-based learning.

While I wasn't able to connect the physical prototypes with a live XR experience, I believe this built a strong foundation that can be expanded. Some technical aspects, like real-time integration or precise tool tracking would require further development and collaboration. The system isn't close to market-ready yet, but Logitech saw clear potential in the near future.

My goal wasn't just to design a set of devices, but to show how different training layers, mechanical, visual, and cognitive can be unified. I hope this work demonstrates a direction worth exploring, and that it contributes to a future of learning tools, not just in surgical education, but in any field where precision and skill matter.

Learnings.

This thesis challenged me to think holistically, across hardware, ergonomics, interaction, and education. I learned that it's one thing to build one compelling product, and quite another to create a product family embedded into a system where all parts work together logically and intuitively. One of the biggest challenges I faced was trying to merge ergonomic constraints with a consistent product family aesthetic. The physical and functional requirements sometimes pulled in different directions, and balancing them forced me to rethink what consistency really means.

Overall, I'm satisfied with the direction and outcome of this project. I would have loved to be more time-efficient in the second half, but I still feel that I managed to explore a lot. I believe the core concept is strong, and I hope the final presentation will make its unique value and potential clear. Even though I didn't accomplish everything I wished for in the very beginning, I believe I am able to propose a meaningful, more accessible future of surgical training.

Acknowledgment.

Relevant Insights.

Thank You.

I would like to thank everyone who supported me throughout this thesis journey.

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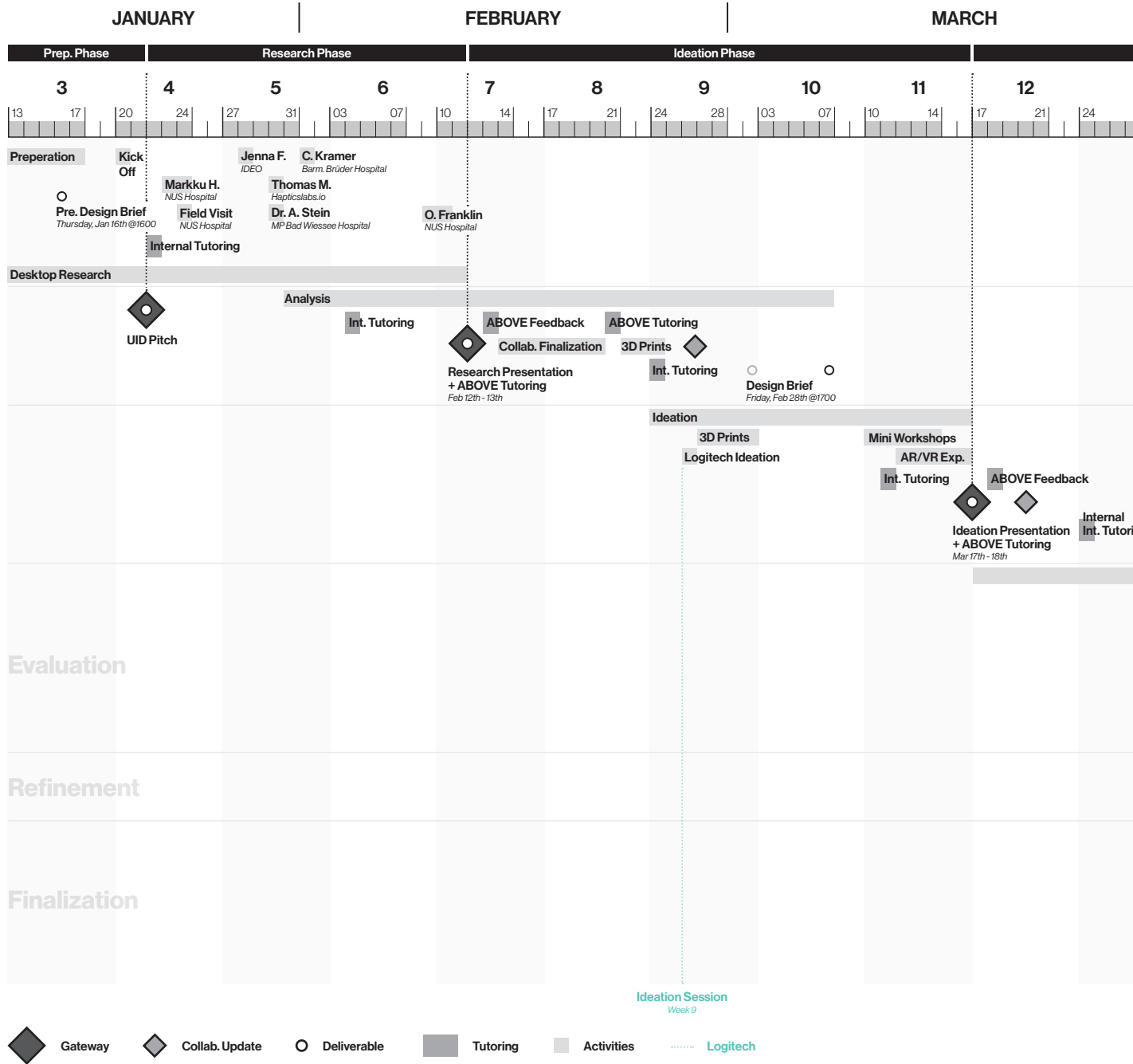
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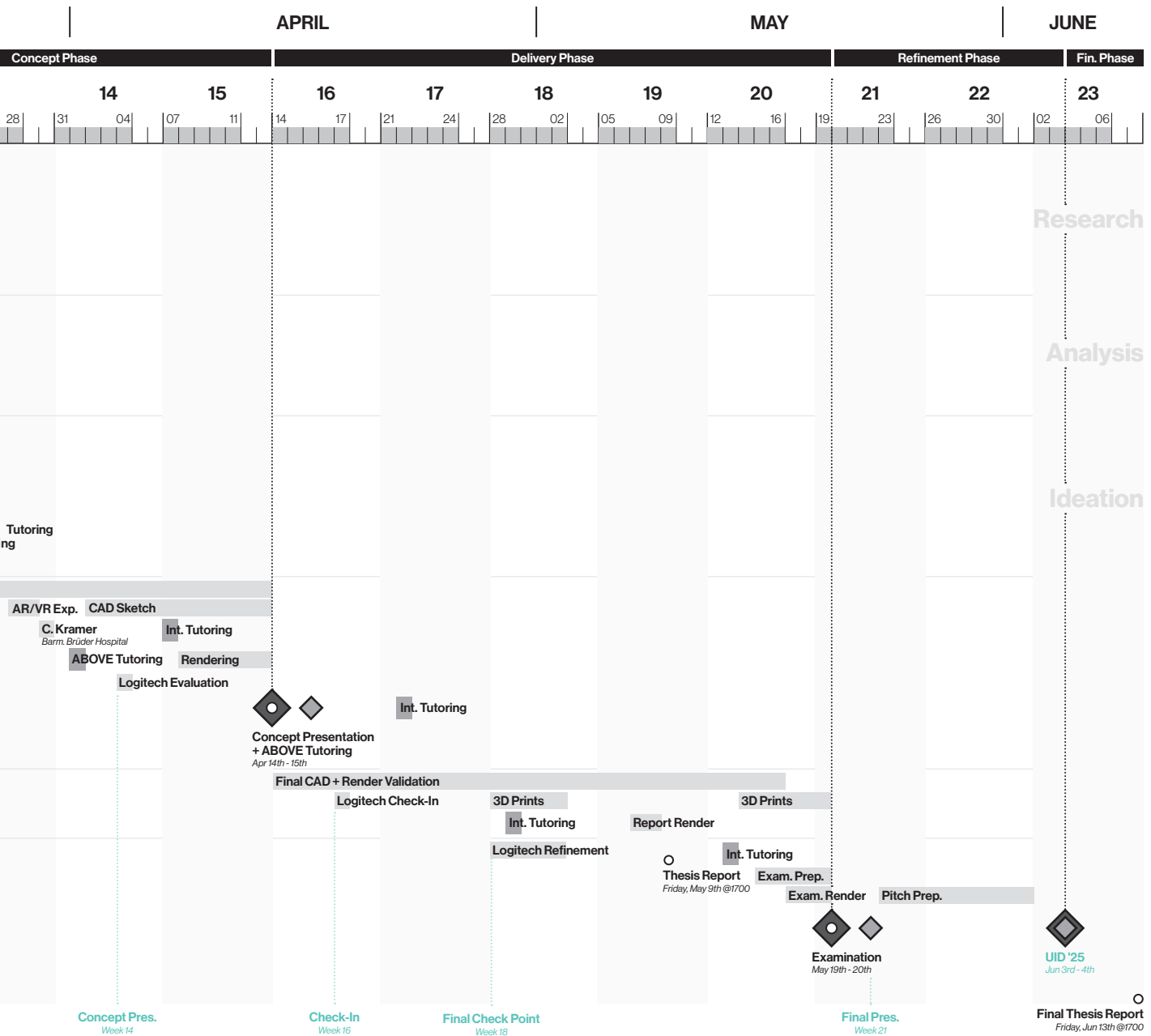
Last but not least, I want to thank my partner and my family—for always being there with patience, encouragement, and endless support as well as to my amazing classmates for their companionship, creative energy, and for making this final chapter of my studies truly memorable.

6 Appendix.

Time Schedule.

Actions & Gateways.





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Tactile XR Surgical Training
Surgical Training Kit for Extended Reality

Master Thesis
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