

Thesis Dokument

On Radar

*Encounter Radiotracers on
Apple Vision Pro*



OnRadar

*Lukman Ascic
Audrey-Meret Louise Lohmann*

*Jürgen Späth
Paulina Zybinska*

On Radar

Encounter Radiotracers on Apple Vision Pro

Title: On Radar

Authors: Audrey-Meret Louise Lohmann

Lukman Aščić

Matrikel Nr: 21-587-753

21-587-662

Contact: +41 78 840 79 27

+41 79 947 80 02

Date: June 2024

© Zurich University of the Arts, Department Design, Interaction Design

Mentors: Prof. Jürgen Späth, Paulina Zybinska

Typeface: Inter



Figure 01 The authors, Duy Bui, 2024

Abstract

On Radar is a spatial computing app designed and built for Apple Vision Pro. Within the app, young people encounter the research of medicinal radiochemistry tailored for museums and exhibitions. By building radiotracers on their own, they engage with hands-on research through learning by doing – all while being in an immersive space where virtual chemical components blend with the real-world surrounding. They discover, follow, and learn: Inputs in their purest form – our eyes and hands – bring science closer than ever for the future student we dare to inspire.

Our project addresses fields of social, educational, and technological relevance. We asked ourselves how the field of medicinal radiochemistry can be showcased in a museal context for a young target audience to understand and interact with. In addition, we questioned the role of spatial computing as a suitable form of scientific communication.

In dialogue with specialists from the field of medicinal radiochemistry, scientific communication and education, spatial interaction and visualization methods were evaluated to break down complex matters for young visitors to unlock curiosity for.

The outcome of research, conceptualization, and development results in an app for which a foundation for the spatial computing platform visionOS as well as a case study for medicinal radiochemistry has been set.

Keywords

Apple Vision Pro, Spatial Computing, Radiotracers, Science Communication, Museum Visit



Figure 02 Additional teaser image, authors work, 2024

Acknowledgement

We would like to thank the following people who supported and motivated us during the preparation of this Bachelor thesis.

Our families, close ones, friends, colleagues,

Interaction Design, Design Department,
Zurich University of the Arts
Prof. Jürgen Späth,
Paulina Zybinska,
Nicole Foelsterl,
Matthias Kappeler,

Science Pavilion UZH, Faculty of Science,
University of Zurich
Dr. Morana Mihaljević,
Lisa Heierli,

Group Holland, Chemistry Department,
University of Zurich
Prof. Dr. Jason P. Holland,
Jonas Genz,
Eda Nisli,

go tec!

Martin Sengel,
Fredy Germann,

as well as all involved ZHdK instructors, advisors and students,
Science Pavilion UZH museum staff, HollandLab group members,
go tec! participants, the Apple Worldwide Developer Community
and Blender 3D communities.

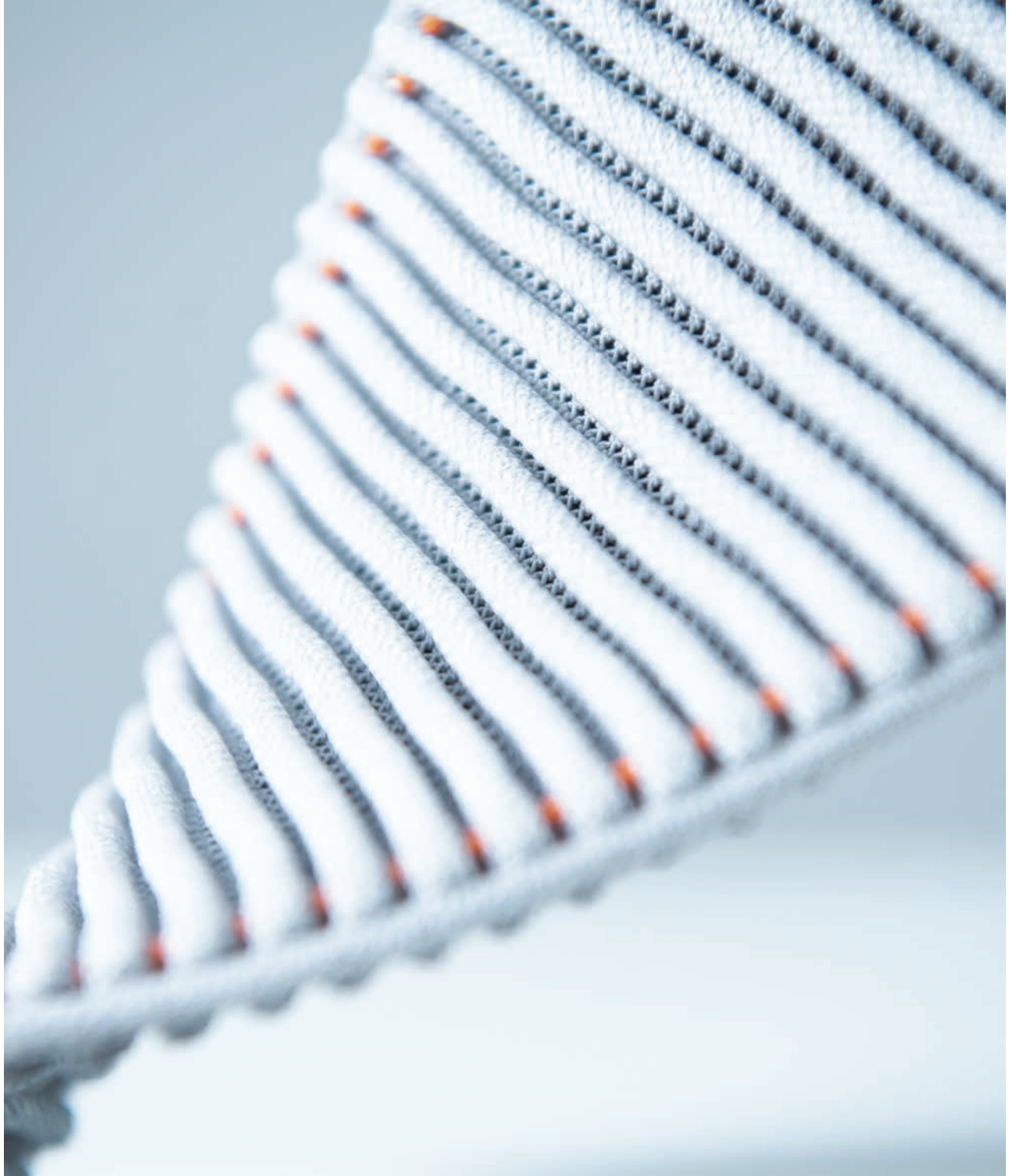


Figure 03 Apple vision pro headband, authors work, 2024

Table of contents

Abstract	4
Keywords	4
Acknowledgement	6
Abbreviations	10
Introduction	16
Partner	18
Cooperation Partner	18
Collaboration Partner	20
Holland Lab	20
Stakeholder Map	22
Motivation	24
Intended Outcome and Contribution	24
Chapter Overview	27
Research	28
Background and Context	28
Design Review	38
Conclusion	44
Research Question & Hypotheses	45
Methodology	47
Concept Development	56
Project Ideation	56
Field Research	58
Workshops	70
Concept	82
Prototype	90

Project Development	149
App Development	149
User Testing	168
Scientific Check	198
Project Communication	202
Result	208
Conclusion and Reflection	216
Reflection	216
Learnings	221
Conclusion	222
Contribution	224
Future Steps	224
Bibliography	226
References	226

Abbreviations

Abbreviation	Definition
AI	<p>Artificial Intelligence, as in the intelligence exhibited by machines, particularly computer systems, which are designed to perform tasks typically requiring human intelligence, such as visual perception, speech recognition, decision-making, and language translation. (Wikipedia contributors, 2024b)in its broadest sense, is intelligence exhibited by machines, particularly computer systems. It is a field of research in computer science that develops and studies methods and software that enable machines to perceive their environment and uses learning and intelligence to take actions that maximize their chances of achieving defined goals. Such machines may be called AIs.\nAI technology is widely used throughout industry, government, and science. Some high-profile applications include advanced web search engines (e.g., Google Search</p>
AR	<p>Augmented reality, as in any case in which an otherwise real environment is augmented by means of virtual, computer-generated objects. (Hayward, 2008)</p>
ARKit	<p>A framework for developing augmented reality experiences on Apple platforms.</p>

API	<p>Application Programming Interface, A contract that defines how two applications communicate together and how they handle the requests and responses. (Wikipedia contributors, 2024a) offering a service to other pieces of software. A document or standard that describes how to build or use such a connection or interface is called an API specification. A computer system that meets this standard is said to implement or expose an API. The term API may refer either to the specification or to the implementation. Whereas a system's user interface dictates how its end-users interact with the system in question, its API dictates how to write code that takes advantage of that system's capabilities.)</p> <p>In contrast to a user interface, which connects a computer to a person, an application programming interface connects computers or pieces of software to each other. It is not intended to be used directly by a person (the end user)</p>
Create ML	<p>An Apple framework that enables developers to train and deploy machine learning models on macOS devices in a user-friendly way. (Apple Inc., 2024)</p>

go tec!	<p>A foundation dedicated to promoting STEM education among youth in the Schaffhausen, Switzerland.</p> <p>Go tec! Provides resources and support for educators in integrating technology and technical skills into school curriculums. (go tec!, 2024)</p>
HCI	<p>Human-Computer Interaction, as the study of completing a task on a computer. HCI deals with the design, implementation and evaluation of the interaction of humans and computers. (Kim, 2015)human-computer interaction (HCI)</p>
LONG NIGHT	<p>Zurich's Long Night of Museums is an annual cultural event where museums across the city stay open late, offering special exhibitions and activities from evening until early morning. (Zürcher Museen, 2024)</p>
MR	<p>Mixed Reality, a term that includes both augmented reality (AR) and virtual reality (VR). (Hayward, 2008)</p>
RealityKit	<p>An advanced augmented reality framework developed by Apple with tools for photorealistic rendering, animations, and physics. (Apple, Inc., 2024m)</p>

Science Pavilion	The Science Pavilion UZH museum promotes research the research conducted of the University of Zurich's Faculty of Science and is located at the Irchel campus in Zurich, Switzerland.
SDK	Software Development Kit, An SDK is the culmination of tools that are required to develop software for a particular software. (Wikipedia contributors, 2023)
SwiftUI	SwiftUI is a Graphical User Interface framework that allows the building of interfaces across Apple platforms. (Apple, Inc., 2024p)
visionOS	An operating system by Apple designed for spatial computing on Apple Vision Pro. It utilizes SwiftUI and RealityKit to create immersive AR experiences through 3D rendering and advanced sensor integration. (Apple, Inc., 2024r)
VR	Virtual Reality, as in an environment where users are completely immersed in a synthetic, interactive world. (Hayward, 2008)

WWDC	The worldwide developer's conference (short WWDC) is a yearly event held by Apple Inc. where hundreds of developer community members, student scholars and Apple engineers meet to talk about the latest product updates or launch announcements. (Wikipedia contributors, 2024e)
Xcode	Xcode is Apple's integrated development environment that offers tools for creating apps for iPhone, iPad, Mac, Apple Watch, and Apple TV. (Apple, Inc., 2024u)

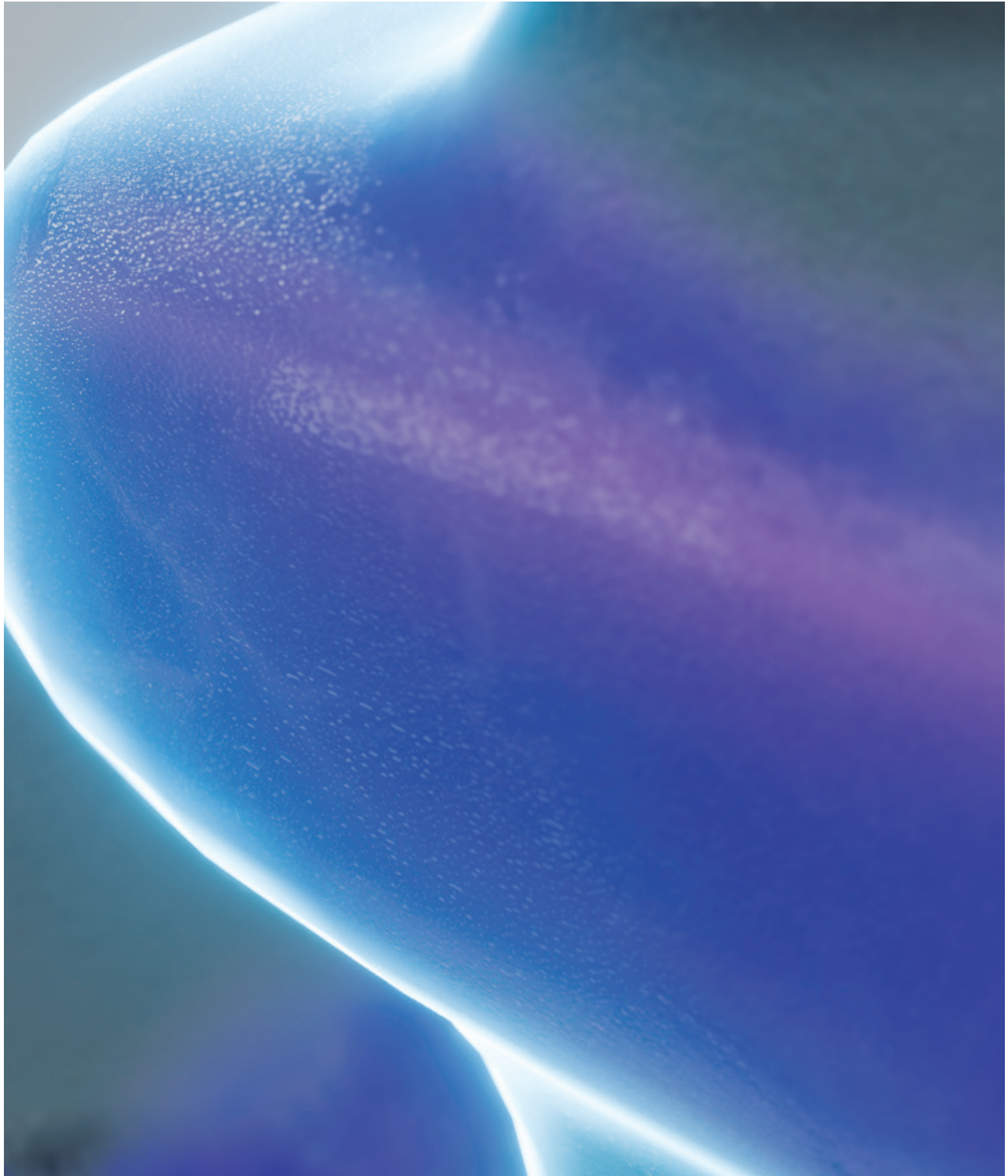


Figure 04 Close up antibody, authors work, 2024

Introduction

It was not long ago when museums were a place only elitist people could enter and visit. Over the past few decades, it has become one of the most important touristic attractions. Evermore, whole institutions dedicate and invest in public outreach where everybody can partake in exhibitions of social, educational, cultural, or scientific interest.

In this museal context, science communication plays a central role in reaching a broad audience with the goal of reaching 1.) awareness in the advancements of research fields and 2.) exposing the matters addressed. These goals influence health, education, innovation, and cultural appreciation.

However, communicating science not only means informing the public about recent discoveries. It means recognizing the significance of scientists, showing stance in combatting the spread of fake news, realizing it is not a competition and empowering society to meaningfully participate in it.

(Vermeeren et al., 2018)

(National Academies of Sciences, Engineering, and Medicine, 2017)

(National Academies of Sciences, Engineering, and Medicine, 2017)

In early conversations with the team from the Science Pavilion UZH museum, we found out how many more scientific projects lie behind the door due to its complex nature. In this project, we chose the field of medicinal radiochemistry to go through the process of explaining a topic that has not gained further outreach at a museum yet. We knew that the context in which the research projects are situated in depend on factors such as visitor demographic, its interests, knowledge, and duration of visit.

In the following pages, we present our cooperation partner, the Science Pavilion UZH museum, alongside our collaboration partner, HollandLab. We outline our motivation for building an app project and present the chosen methodological approach based on the background and context that lays the ground for science communication through spatial computing.

(National Academies of Sciences, Engineering, and Medicine, 2017)

Partner
Cooperation Partner

Science Pavilion UZH museum

The Science Pavilion UZH museum, located at the Irchel campus of the University of Zurich, showcases research done at the university's Faculty of Science. It is supervised by a team of fellow researchers, instructors and students dedicated in spreading and promoting the science conducted at the faculty in an accessible and diverse way.

(Science Pavilion
UZH, 2024)

The museum offers guided tours for individuals, groups or classes and is of free admission. Its location serves as a popular spot for showcasing the university as a place to study. Most classes visit the museum as part of an excursion, helping aspiring students decide which tertiary educational path they would take.

(Science Pavilion
UZH, 2024)

Exhibitions are curated to mediate a wide range of fields, from biology over anthropology to geography, through interactive installations or guided augmented reality complemented by audio or video.

(Science Pavilion
UZH, 2024)



Figure 05 Science Pavillion building, Michele Di Fede,

Collaboration Partner
Holland Lab

HollandLab is a research group at the University of Zurich's Chemistry Department lead by Prof. Dr. Jason P. Holland. Their research is focused on the synthesis, development, and production of radiotracers in a medical context with its application found in the imaging and treatment of cancer. Projects are of highly interdisciplinary nature: they interface with chemistry, biochemistry, and molecular medicine. In assisting us with the understanding of the research conducted, we had direct contact with two PhD students from Holland's group: Eda Nisli and Jonas Genz .

(Holland, 2024)



Figure 06 laboratory UZ I 5, Luca Zanier, 2021

Stakeholder Map

Research is an interdisciplinary field where many parties have a stake. So is its communication and visualization. It can function as an advertisement of the capabilities of all institutions involved. For the realization of this project, all institutions had a stake in the outcome.

The following stakeholder map shows how each of our partners were included in this project, serving as a representation of responsibility and inclusion. All involved partners included in the stakeholder map are named. When dealing with the matter of communicating and visualizing scientific research for a museum showcase, we have to recognize that all institutions, namely the Zurich University of the Arts and the University of Zurich, will have a stake in the outcome.

As the authors of this Bachelor's project, our involvement had the most influence and stake in the project. Jonas and Eda were hands-on and involved as well. They had especially high influence on the result of the project, as it was clear from the get-go that our visualization had to be scientifically accurate. When a prototype or sketch was not up to the scientific standard, we had to change it and had not much leeway. Our mentors Paulina Zybinska and Jürgen Späth had a high influence. They, on the other hand, were our guidance from an Interaction Design perspective.



Figure 07 Stakeholder map with all parties involved, authors work, 2024.

Motivation

Intended Outcome and Contribution

Advances in Computer Vision reshape how we interact with the world. This brings challenges as well as new opportunities. For us designers, new platforms are constantly on the radar. And with the reveal of Apple Vision Pro on June 5th, 2023, we observe the dawn of a new spatial computing platform. I (Lukman) was lucky enough to attend WWDC on that day in person and contemplate the choice of platform for a Bachelor's project in Interaction Design early on.

(Apple, Inc., 2023a)

With every new and enhanced spatial capability Apple Vision Pro brings, the dealbreaker is its tight integration to the existing development environment Xcode that is already used for developing apps on iPhone, iPad, and Apple Watch. Even more, the user interface of the new spatial operating system visionOS is based off SwiftUI – Apple's framework for building user interfaces programmatically for all existing platforms since its introduction in 2019. As soon as the latest beta of Xcode with visionOS support came out, I began exploring around.

(Apple, Inc., 2020b)

Additionally, a new developer program was introduced to facilitate the process for designers and developers. With Reality Composer Pro, Apple promises to enhance the workflow for arranging, editing, previewing, and loading imported 3D assets to the codebase.

(Apple, Inc., 2023c)

Audrey and I both recognized the potential and possibilities spatial computing, with its new tools to develop and design, unlock for us. We teamed up to complement on each other's fields of background in software development and graphic design to take the early chance and adopt our project to the Apple Vision Pro. A few weeks after the keynote, the project was grounded with a cooperation with the Science Pavilion UZH museum.



Figure 08 Apple Vision Pro at the Steve Jobs Theatre, author's work, 2023.



Figure 09 Apple CEO Tim Cook on stage, author's work, 2023.



Figure 10 Apple Park, author's work, 2023.

And with that, we saw the next big opportunity this Bachelor project could take with it: To bring the work that excites the everyday researcher closer to the public and for it to understand its social relevance. Challenge accepted.

The intended contribution for our project will therefore be split into two parts. First, we want to intervene in a chosen research field and bring its outcomes and values closer to the public in a broken-down manner, highlighting its social, medical, and political relevance. Second, and from a technological and design point of view, we both set foot into the era of spatial computing and design an app for the Apple Vision Pro around our chosen research topic.

Chapter Overview

In 'Research', we lay the theoretical ground and identify gaps of intervention with related works of similar nature to situate our app in. We then define our approach with chosen methodologies suited for the conceptualization and development of our project.

'Concept Development' discusses the ways in which we identified pain points through observations, including the Science Pavilion UZH museum and the Technorama science museum. We test our assumptions against a workshop with the researchers from HollandLab and address important design decisions that have come along the way.

In parallel, the app's storyboard, accompanied by rapid prototyping methods, has been developed addressing the justification for spatial computing, selection of immersion and content for our app.

'Project Development' documents the design and development of On Radar. We test the information architecture and user flow with the Science Pavilion Museum staff, group members of HollandLab and in a classroom setting with our targeted audience at go tec!

We conclude the project in 'Conclusion and Reflection', reflecting on our process, outcome, shortcomings, and future possibilities.

Research

Background and Context

Spatial Computing

Human Computer Interaction

One of the earliest interactions with computers can be found in the Command Line Interface. The user gets a simple text input, where the language of the computer is spoken. By typing out the commands, the actions are performed. Command Line Interfaces are still in use today. As it is a very efficient way of communicating with a computer, a Command Line is a great tool for repetitive and high volume tasks.

(Hassan, 2023)

With the implementation of GUI's, a wider range of potential users could interact with computers through graphical elements like tabs and buttons. With the easier interaction, users lost speed. By implementing shortcuts, two layers of interactions were present. While professionals relied on shortcuts, hobbyists interacted with the computer through GUI's.

(Schaffer et al., 2011)

The next step was for users to communicate via computers. This became possible with the internet. Explaining the internet was a challenge for designers and developers. Functionalities like "downloading" and "uploading" had to be explained to users, without requiring a full technical breakdown. Selective information became the norm, where only the core functionalities got explained. Private companies like Google & co fulfilled the need for sifting through information on the internet.

With handheld computers, Human-Computer Interaction became more intimate. Users could take their computers everywhere, integrating them into daily life. This shift brought challenges for designers and developers, as users had to learn new, gesture-based interactions using their fingers. The screen became the central input and output surface,

requiring simplicity. Companies like Apple excelled by making handheld computers easy to use, understanding they would become a bodily extension of the user. Mobile computing rapidly became essential and remains so today. Human-computer interaction (HCI)

(Kim, 2015)

The next step from mobile computing was bringing the computer closer to the body. Technology became smaller, collecting both active and passive data from the user. Wearable devices gather and interpret body data, enabling user interaction. Bluetooth transmission, proven with headphones in 2007, spurred widespread experimentation with wearables. With portable computers (mobile phones) already common, Bluetooth enabled seamless data transfer between wearables and phones. These devices offered the advantage of hands-free interaction, becoming popular in outerwear. However, they lacked intuitive and efficient on-device interaction methods.

(Müller & Wiedemann, 2023)

(Reliance Digital, 2019)

Voice and natural language processing addressed the challenge of interacting with tiny tech. Voice assistants like Siri and Alexa are recent, but voice recognition dates to 1952 with Bell Labs' "Audrey". This machine, occupying a six-foot-high relay rack, recognized phonemes. Voice assistants offer a human-like interaction, making computers more accessible, especially for users who cannot interact physically. They can perform many actions but still suffer from inaccuracy, particularly in non-English languages. In augmented reality, gestures play a crucial role, allowing users to stay immersed in the virtual world while staying anchored. Gestures that are learned and performed help maintain user focus on their surroundings.

(Moskvitch, 2017)

(Mynatt et al., 2010)

Virtual Reality refers to the qualities of a computer program. The most important ideal of a VR program refers to the alteration of perception of the user. The Alteration through engineering is more important than if the environment feels real or is virtual. In that notion, one of the proposed terms for

(LaValle, 2023)

the field of VR is “perception engineering” A crucial aspect of VR is interactivity. The VR experience depends on actions taken by the user. The user has partial control over what is happening in the experience. Some of the actions, that the user takes, transfers to the VR realm. VR comes in several levels of realness. Realness in the sense, that the experience is as closely to the real world. The appropriate level of realness depends on the task that the developer/ designer wants to accomplish with VR. A higher rendition of realness usually comes with higher development costs and time, as well with higher hardware requirements. It is important to define the task the program has to serve, so the VR experience can fulfil that task and does not get clogged up with an inappropriate amount of “realness”.

VR can be captured or rendered: Captured VR refers to the capture of 360° videos, that can be the texture for the environment. Rendered VR refers to 3D environments through which the user can move. Captured VR is for experiences, where the user is quite static, but a high level of similarities to the real world is desired. The experience is more scripted and less dynamic. Examples would be speaking courses and training courses. Rendered VR looks generally synthetic, but gifts full interactivity. The user can move through the environment and is not restricted to everything captured. Rendered VR is generally used in games and interactive online experience like the metaverse and VR chat.

Even though Artificial Intelligence has made strides in the months that led up to the writing of this Bachelor thesis, it will not take up a crucial part. Regarding HCI Artificial Intelligence can be understood as a feature that has the potential to enhance every stage of HCI. From predictive text completion to complex GUI assistance, AI will have a large hand in the future of HCI. The current, sometimes clumsy implementation of AI in current HCI shows, that a new challenge is upon designers and developers.

There are further ways of Human-Computer Interactions being developed. These aim to intertwine the human and the computer in further ways. With the goal that the human and the computer can benefit from the full potential of each other. Honorable mentions are Brain-Computer Interfaces. These devices aim to completely dissolve the barrier between the human brain and the computer. These ideas have been discussed in the field for a couple years now but have not yet been implemented in a non-medical way.

Apple Vision Pro

Spatial computing aims to free the computer completely of its physical hardware. The computer itself and its interface should be able to communicate freely and seamlessly with the world around it. In its ideal implementation, the user should not realize that they are currently using a computer. The computer blends with the surroundings. This gets achieved through a vast array of sensors and cameras in the device. A clever use of interfaces and user experience is crucial to achieve the blended look. There seems to be an uncanny valley when it comes to interaction. When the model behaves too little and too much like the real world, the user can get irritated and disorientated. There does not seem to be much study on this topic, but the existence of phenomena like VR-sickness points to a phenomenon like that.

Apple Vision Pro was announced June 5th, 2023, at WWDC and later released on February 2nd, 2024, starting in the US only. It is a wearable spatial computing device users look through and primarily interact with eyes, hands, and voice. It features physically moving lenses, infrared eye tracking, hand scan, and a new operating system visionOS. It is powered by the Apple R1 chip that processes light conditions, passthrough latency close to real time, colors, and brightness.

(Apple, Inc., 2023b, 2024b)

With a similar look to iPadOS, apps on visionOS therefore feel familiar to the apps we already use on iPad, iPhone, and Mac but in a new design language. The new glass interface design paradigm makes windows blend with the real-world.

visionOS

In visionOS, we define three characteristic building blocks that make up a spatial computing app: Windows, Volumes, and Immersive Spaces.

(Apple, Inc., 2024f)

Windows are the most familiar elements we know from the desktop from forty years ago, allowing us to have a visual representation of multiple programs opened. These windows can – just as on the desktop screen – be resized and moved in space. Windows are made up of two-dimensional UI elements and can include 3D objects.

Volumes, on the other hand, give the windows a third dimension on the Z-axis and allow incorporating more advanced 3D visualization that can be integrated together with UI elements and made interactive. They can also be rearranged in real space.

(Apple, Inc., 2024r)

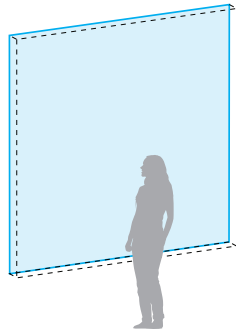


Figure 11 Window Apple Vision Pro, authors work, 2024

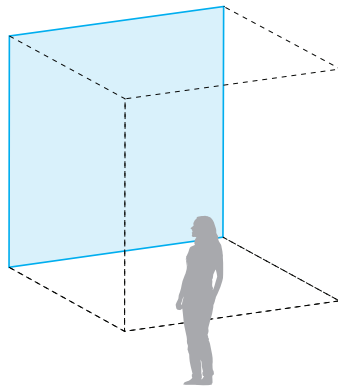


Figure 12 Volume Apple Vision Pro, authors work, 2024

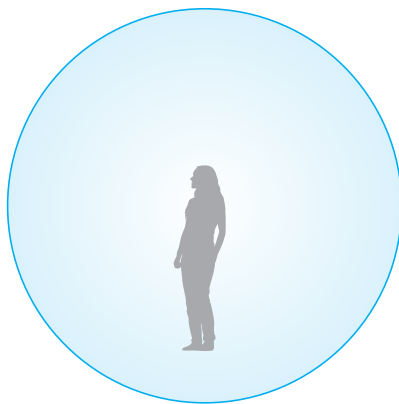


Figure 13 Immersive space Apple Vision Pro, authors work, 2024

Even though the visionOS user interface design system is based on iPadOS, there is new territory to be examined, namely Volumes and Immersive spaces.

Volumes, compared to windows, give the additional depth we did not have before. This means that virtual 3D objects can be displayed that act as windows but include a Z-axis in space.

With Immersive Spaces, visionOS provides three levels of immersion: mixed-, progressive - and full Immersive Spaces (equivalent to virtual environment systems). A full Immersive Space takes up the whole real environment and covers it with a virtual skybox. In a mixed Immersive Space. the user still has the real environment in sight but with additional virtual 3D objects in the app's environment. Progressive Immersive Spaces allow control of how much the real-world environment gets covered by a virtual skybox.

(Apple, Inc., 2024g, 2024j)

Key Features

One of the first defining characteristics of visionOS is the so-called Persona, as in a digitally reconstructed version of the wearer. After scanning eyes, hands, and facial expressions from outside the device with the device, the user can virtually represent themselves in group calls. It is a one-time setup and scans only the hands and face of the wearer, but not the whole body.

(Apple, Inc., 2024e)

Spatial Audio was already a highly anticipated feature that shall complement augmented reality in the early days, and Apple Vision Pro transforms the binaural sound with its auditive spatial capabilities: sound plays from wherever location in space the app is located in.

When it comes to the physical bounds of a display, be it on the phone, laptop or external display, Apple Vision Pro frees the constraint of screen real estate. On visionOS, Windows and Volumes can reside anywhere the users want them to be. And with Passthrough, people around the wearer still appear from the outside, even within an Immersive Space.

(Apple, Inc., 2023b)

In an effort to enhance the social aspect while wearing the device, Apple Vision Pro includes a lenticular film on its outer screen to display the eyes of users when having eye contact with EyeSight. Upon creating ones Persona, the scanned eyes are also used to be shown through a glow to make them appear like its sunk in wearer's face.

Apple, Inc., 2024s)

Radiotracers

Medicinal radiochemistry is a research field in medical science and chemistry that focuses on the development and production of radiotracers with its primary goal to diagnose and treat cancer. These radiolabeled compounds are designed to target specific antibodies. A radiotracer can be synthesized in such a way that enables precise localization and treatment of a specific disease and allows characterization of different kinds of cancer. Next to designing the drugs that target very specific kinds of cancer, radioactive nuclides are attached which emit gamma rays for researchers and medical personnel to detect. characterisation and application of radiolabelled compounds for use in diagnostic and therapeutic medicine requires a diverse skill set. This article highlights a selection of our ongoing projects that aim to provide new synthetic methods and radiochemical tools for building molecular imaging agents with various radionuclides

Compared to radiation therapy, a treatment method in which patients get exposed to radiation with the risk of serious side-effects, radiotracers are injected into the body that travel to only specific parts of it. This helps doctors more precisely locate where the tumor is. (Hall et al., 2022; Lamb et al., 2020) computed tomography or magnetic resonance (M)R

(Lamb et al., 2020)

Museum Visit

Understanding the motivations of museum visitors is crucial in order to tailor experiences that meets the visitor needs better, enhances engagement and learning. Approaching the visit in a form of dynamic and context-specific nature compared to traditional demographic-based segmentation allows museums to focus on identity-related motivations such as learning, the likelihood of repeat visits, positive feedback loop and further engagement.

In the context of our project, the Science Pavilion UZH museum will be our outlet for not just interested people but the future generations to come. By make engagement with complex matters simplified, we aspire to communicate medicinal radiochemistry in a way that gives those visitors more context over what to expect in a potential study and how it will impact society. (Falk, n.d.)

(Falk, n.d.)

Science Communication

Science is deeply embedded in our lives. We increasingly integrate scientific information with personal values in some form to make informed decisions. An effective communication of science is central. These outreaches possess different approaches, depending on whether its goal is to inform, persuade or engage us.

One challenge in science communication is the combat against misinformation. In our case, especially when dealing with a research field that draws form other domains, it is one of our uppermost values to uphold scientific accuracy when presenting our final outcome to the public.

(National Academies of Sciences, Engineering, and Medicine, 2017)

(National Academies of Sciences, Engineering, and Medicine, 2017)



Figure 14 Laboratory HollandLab, authors work, 2024.

Design Review

MoleculARweb

is a web-based augmented reality platform that visualizes virtual representations of chemical formulas in the real world surrounding. Developed at EPFL and through international collaboration, it has established as a cost-effective, accessible, and interactive platform where students and educators build their own molecules. The platform features over twenty activities covering molecular shapes, atomic and molecular orbitals, hydrogen bonding, protein structures and more and is available in multiple languages.

(Rodríguez et al., 2021)

The most interesting aspect of this web-app is that everyone can build their own structural formulas. A nice feature is the premade examples section everyone can select and immediately preview with their camera. An earlier version required physical tokens to be scanned in order to show the 3D molecular structures, but newer versions of the site no longer require them.

(Rodríguez & Abriata, 2024)

What are Molecules?

As part of the meanwhile discontinued Google Expeditions platform, this project presented molecular visualization in AR, illustrating the practical applications of AR in science education and highlighting its role in visualizing complex concepts.

There are many more topics ranging from various fields of science, and the web-based version narrates these topics in broken down chunks guided through “scrollytelling”: As the reader scrolls, new pages appear that explain and evolve the topic in a chronological order.

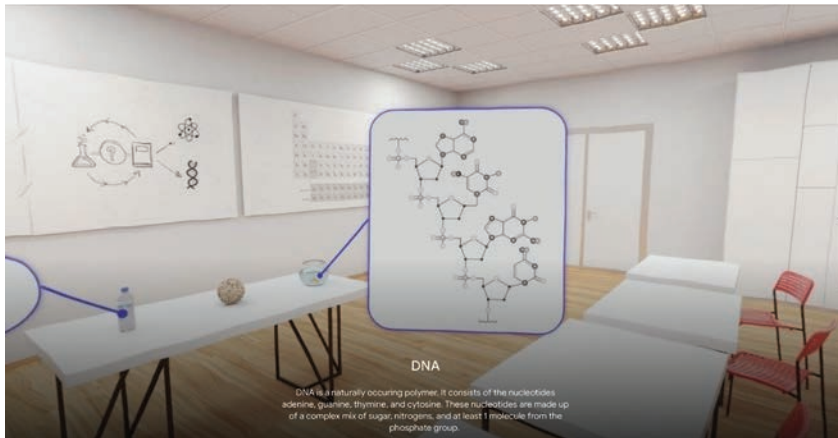


Figure 15 What are Molecules? (Vida Systems, 2023)

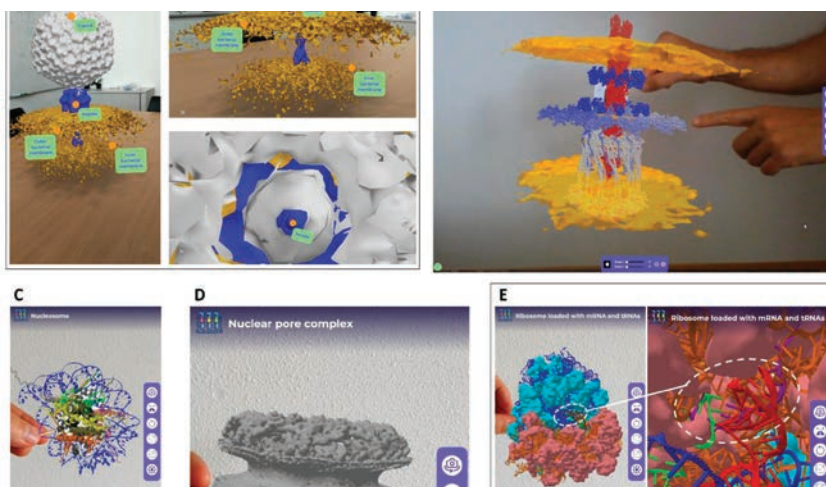


Figure 16 What are Molecules? (Vida Systems, 2023)

The strongest aspect we recognize in this work is less the AR aspect, but its method of narration. We could see taking this approach – in breaking down a topic smaller parts and presenting it along the flow – along our conceptualization process.

Figure Merge Cube ED

Merge Cube showcases practical educational implementations of AR and demonstrates its potential in fostering immersive and interactive learning experiences through physical cubes. The overall service is made up of a physical cube and companion apps.

(Merge Labs, Inc., 2023)

Paired with various Merge EDU apps like Merge Explorer, Merge HoloGlobe, Merge Object Viewer or Merge Scanner, students can interact with virtual 3D content and simulations when holding their tablet above the Merge cube.

(Merge Labs, Inc., 2023)

We like how one physical object can be incorporated with multiple apps. This is especially a strong use case when dealing with many platforms, such as Android and iOS devices.

Elements 4D

Gone bankrupt in 2019, Daqri's Elements 4D, similar to the Merge Cube, provided foundational understanding of AR applications in education, specifically in chemistry, that is accompanied by a physical object. The service is made up of a set of physical cubic objects and a companion app bringing them to life.

(Ha, 2019)

(DAQRI, 2023)

Elements 4D's most interesting part is its interplay when interacting with multiple physical objects. In the context of chemistry, combining two or more chemical parts informs the learners how reactions are formed.



Figure 17 Merge Cube EDU (Merge Labs, Inc., 2023)



Figure 18 Elements 4D (DAQRI, 2014)

Artivive

Artivive is an augmented reality app that scans for specific graphics to anchor a virtual, moving layer on top of. It is mostly used for museums, exhibitions, and art installations. With an application, visitors can hold their camera above an artwork of interest. This livens it up with additional animations, giving more context and depth about what the artist wants to showcase.

(Artivive GmbH,
2024)

This intervention is done in a less insistent way, so the observer can enjoy the artwork with or without the additional layer of computing and interaction.

The Apple Park app

The Apple Park app allows the user to grasp the extent of the Apple Park, prepositioned to a smaller scale model. With the use of augmented reality, an additional layer of information is placed on the model and shows the Apple Park Building and its environment anchored to the model.

(Apple, Inc., 2017)

This app makes great use of the illusion and play with scale. By bringing the massive building closer to the scale of the observer, one can start to grasp the dimensions and details condensed on this space.



Figure 19 Figure Artive (Artive GmbH, 2023)



Figure 20 Figure Apple Park app (Swift, 2023)



Figure 21 Figure Apple Park app, authors work, 2023

Conclusion

While we do not see apps alone justifying the need for Apple Vision Pro, it is its hardware capabilities it promises we anticipate combining our project with. To make augmented reality systems most compelling, virtual object layers have to seamlessly and meaningfully blend with real-world objects that enhance the user's perception and knowledge. We have assessed six related projects that showcase these connections between the physical and the digital in different ways.

(Aliaga, 1997; Feiner & Macintyre, 1993)

We are most inspired by the work Rodríguez et al. have realized with MoleculARweb. But the fact that a person can create any chemical formula meant that these objects had to be used in some context, especially in an educational environment, to be of any means. We therefore assume that existing pre-knowledge is required to make most use of this.

Apple Vision Pro is the first spatial computer Apple claims users do not look at, but through. However, it is important to note that the actual world looked through is still a reconstructed camera feed, rendered by two displays with such a high pixel display density, dynamic range and shutter speed that it almost feels like looking to the real world. And even though visionOS offers an infinite canvas to place, manage and build apps, we see this freedom as an additional parameter to channel the needed amount of space that fits the needs of our target group – just as with the infinite possibilities with building a molecule in MoleculARweb.

(Apple, Inc., 2024b)

Lastly, effective science communication requires both researchers and practitioners to collaborate. We see ourselves intervening in many intersecting domains of this project: keeping in mind the motivations of our young museum visitors, addressing the importance of radiotracers, and communicating it meaningfully on the spatial computing platform.

(National Academies of Sciences, Engineering, and Medicine, 2017)

Research Question & Hypotheses

The research question guides the research and design process, aiming to be answerable within the project. It serves as a guiding beacon, demanding simplicity despite the complex topic. The hypothesis, designed to be proven or disproven, provides a more permanent format to bring structure to the fluid design process.

This project works with two research questions. This allows us to further the field that we would want to investigate and prove or disprove with our work.

The research around radiotracer is complicated and multidisciplinary. It is usually conducted by people with a lot of pre knowledge, usually already approaching their PhDs. The material the research works with, is contaminated with radioactivity. This makes it difficult to explain through traditional exhibitions, presenting an opportunity for innovative explanatory methods. From this observation, we can formulate the first research question.

Is the research around radiotracers suited to be used in an explanatory spatial computing application?

From this research question the hypotheses can be formulated. Radiochemistry is a field of chemistry that relies on a lot of pre knowledge, is not able to be exhibited in a traditional sense and has a great importance from a societal sense. This makes the research ideal to be exhibited through explanatory spatial computing.

Spatial computing offers an intuitive and revolutionary form of computing, changing both personal and spatial relationships with computers. Users interact with a discreet, invisible computing layer in their environment. This innovation is ideal for explaining complex subjects. As this layer can fill the knowledge gap that might exist between the observer

and the topic at hand. The Apple Vision Pro, that is the newest device on the frontier of spatial computing is the perfect device to bring to museums and exhibitions, so visitors can experience the research around radiotracers. From this hypothesis our second research question forms.

Is the Apple Vision Pro a valid use case in this project?

These two questions should be answered in the course of this these. The finite answer can be found in the concluding chapter.

Methodology

Design methodologies describe Methods in design, that are used, to further the design process, gain insights in the structural and fundamental problems in the project. Identify the users, and the core problems that could happen within the process.

(Gregory, 1966)

First there are general remarks about design methodologies and the choosing of which design methodologies would be suited for the process that was laying ahead. Some design methodologies attempt to recognize and rationalize the whole design process. That might be a suitable for a process that takes place in the hands of one person or a few.

(Gregory, 1966)

For our Design Process, we decided to split it up into the different stages. First, we started to identify the requirements from our partners. We made sure to implement a feedback round into this process, as we wanted to make sure, that the requirements were deeply clear on all sides. As the next step we analyzed the requirements that our partners had for the work. What was of importance in this step, was our own inclusion as partners. As we had to include our own needs and requirements as well.

After taking in all this information, we went through a sifting process. We had to evaluate, what of the information was relevant for us, and what already gave us a starting point. In the next step we needed to check what was the feasibility of our project. We needed to identify how our minimal viable product could look like and the work upwards of this, to arrive at a final product that would be satisfactory in its interactivity, design, and execution for all involved partners. In every step of this process, we needed to include the approval of our external partners. This seek of approval also gave us a valuable feedback step.

One topic that came into importance at this stage was the art of problem solving. We encountered many problems of smaller and bigger importance while working on this project. These problems and the solution we found will be described in detail in the respective sections of this thesis. A big part of the thesis was the organization of Production that had to be done on our part. An organization of production includes the coordination of schedules when which milestones had to be met and who had to do which kind of work.

Early on we decided to not work in a separation, but to acquire both all the skills that would be required to finish the project. This way we did not run into bottlenecks that could not be solved. In this step we included the user testing as well. Because of the nature of this project, we had to plan a big amount of user testing, that could either disprove our thesis, but also gift us with valuable insights. These steps of the design process are inspired and followed by Greogry (1966). We did not include a marketing step, as this step needs to be accomplished by the Science Pavilion.

In a short list, the design process was planned to look like this:

01. Analysis of Customer's Requirements
02. Sifting
03. Feasibility Study
04. Sponsor's Approval
05. Problem-solving
06. Production Organization

In all the steps we implemented different methods, that could give us the required output, that we needed to have in this stage. In the following sub chapters the different methods are described, how they work, what insight we hoped to get from them, and in which stages of the Design Methods they were implemented.

(Gregory, 1966)

Conversation

Conversation was a big part of our design methodology; one could even call it a methodology in itself. In every step of our process, we utilized conversations of every kind to affirm and confirm our feelings according to the project. We also early realized that conversions were not only for us a beacon of trust and understanding, but for our partners and mentors as well. By having frequent conversations and meetings about the project, we could act early, when something did not seem to go according to plan. This dynamic was also why we choose to have a very strict meeting and mentoring schedule. Our calendar saved us during these organizational tasks.

Internal Progress Sessions

Internal progress sessions were a direct mirror of the progress sessions that were utilized in the process by the department itself. An internal progress session had several goals.

01. Communication of current state
02. Check in with partners.
03. Update of timeline
04. Micaceous discussion, based on current state.
05. Feedback
06. Communication and definition of next steps

For the communication of the current state, we prepared a small presentation that would be visual based, using as little text as possible. We wanted to visually stimulate as much as possible, as it is much easier to discuss images that words. We also had to get early on, that both parties were functioning with a different amount of knowledge. We came from the background as designers and had a different language and qualification. Communicating predominantly with words, levelled the playing field for all the participants. We had this learning early on after our first meetings, were we

started to gain insights in the communication of our partners and the differences in vocabulary. We always included a check in, as we wanted to be secure in the direction that we were heading. This alleviated the constant struggle and anxiety of not going into the right direction and having to change course in a drastic way later. The timeline and the updating of the timeline was of importance. We had a timeslot for discussion. These discussions were often based around the current state but could also be about other concerns. This was a good addition to the internal progress session, as it provided all the members with an open space to talk concerns but also parts everybody was happy with. The feedback was scheduled, we wanted to have a clear structure, that could provide us with as much information as possible. This gave us also the opportunity to sift through the information and pick the most valuable parts.

These internal progress sessions were definitely scheduled. We wanted to have such a schedule, so all the participants always knew when the next meeting would be held. This held us to a higher standard of work and kept our accountability high.

Meetups

Meetups were defined as small get togethers, where ideas could be discussed in a participative way. These had loose goals defined in the start, but no direct road map on how we would like to arrive there. These meetups were held mostly with our partners or experts. The first objective was to find understanding. Whenever we encountered a problem, that could not be solved in our hands, we inquired our partners for resources and knowledge. These meetups were mostly limited to one hour. The time constraint furthered a discussion, that could be held in a timely manner. After the meeting we were meticulous to create a protocol. That gave us enough information to have a session, in which we could sift through the information and decide what was valuable

and what could be discarded or saved for a later date. These short and efficient meetups were essential in the phases of Analysis of Customer's Requirements, Feasibility study.

Workshops

A workshop in the field of design is a collaborative session that is focused on different or part of the design process. A workshop is either held to start or to make progress on a design project. A Design Workshop must have two or more participants in the field of the project. This could be a group of users, or experts. The chosen participants for the workshop greatly depend on the question that should be answered by the end of the workshop. In a Design Workshop, different methods can be used to further understanding or define the problem. Design Workshops are often used as beacons in Design Thinking. They serve as an important tool to level the playing field between the different parts and participants in a Project.v

(Norman, 2013)

(Diehl, 2019)

These aspects of workshops made them interesting for us to use in our design process. We early on identified that our project was a machine of many parts. And due to the diverse fields of expertise we had to find a common ground. Also was it a great way to include our partners in our design process. User testing could also be conducted in a workshop setting.

Field Research

Field research is a form of data collection. It is classified as a qualitative method. With this method one aims to observe and understand. Field research is usually done in the respective natural environment. For this project, some of the field research was done in an observative way. To create something new, we had to observe what was already happening. This method was for us to assess how elements were already implemented in respective museums and exhibitions. The importance lied in the way the bystanders were interacting with these elements. From these good and bad examples ideas could be derived.

The second part of field research was done in a participant observation. For this part we chose to curate the space where the research was happening. This way we could concentrate on the kind of data that we wanted to collect. Especially in environments where it would not have made sense for us to be present all the time. Considering the fact, that we were also working with science that revolves around radioactivity, it was not possible to interact with the material every step of the way.

Storyboarding

A storyboard is in its basic concept the linear telling of a story. The medium that is the storyboard is made from simple text, to rendered drawings. Even 3D modelling and Photography are used in storyboards. Storyboards are a good way to test and tell if a story is logical, sufficient and round in its storytelling.

(Katz, 1991)

Storyboards are not only used in film and animation but get extensively used in application conception and development. Developing a robust storyboard from the start, that can hold up in discussion and scrutiny makes it easier in the process to not lose the idea that you started with. On another

note, storyboards can also limit the creative process. They can create rigid guidelines, that can make it hard to iterate, as it is harder to leave a concept when it is sketched out and developed. That's why it is important to see storyboards as temporary prototypes that are only one step closer to the project. Having this mindset makes it easier to follow the storyboard but also to reflect on it in a critical way.

We evaluated the pro and contra points of storyboards and evaluated, that prototyping with storyboards is the way to go in our project. Having a visual language to describe our concept and ideas was critical for our process, as it allowed us to communicate better and more efficient with our mentor and Partners. Also was it possible to develop and establish a common visual language that every participant could agree on. Having this visual language made it easier to focus on the content and the interactions. Also considering, that our application was multi-sensory we decided to not only have one linear sketch-line-up. But work with different tracks for the different sensory experiences. Splitting this up and working with all the sensors in mind gave us the opportunity to create a storyboard that could guide us in the creative process and development of the whole work.

Visual Prototypes

We had a strong vision on the visuality of our application. Yet we had the problem that we could only preview our look and feel on screens. This 2D environment was great to see how our models and visuals would look in a web environment, but in consideration of what we had planned it was not the ideal environment. It lacked the feeling and interaction with the objects in the AR space.

Here we discovered a solution. As we already were building in Reality Composer Pro, we were able to preview our models in AR, using the Apple Vision Pro and some of its functionalities. Having a low fidelity space, that made interaction and visual confirmation easy and straight forward helped us immensely in the development of our project. Every model and asset that was made for the application was tested and previewed in the AR space, to control and confirm its effectiveness. We did not want to lose important real estate on objects, that were not effective in their communication and viability.

Blogs

Blogging is in its practice a way of documenting and publishing our process. In one way it was important for us to have a great overview of our process, as it would make writing about the process easier. But the blog also served a psychological purpose. Considering that this thesis is not a sprint, but rather a marathon, the blog was a good reminder of what we had done in this time. It alleviated the feeling of not having done enough. It was easy to go back to what we had documented and reading through the process. The blog was a central hub for ideals, protocols, and To-Do lists, giving us a great overview of the roadblocks that we had passed and the road ahead.

Concept Development

Project Ideation

The ideation for this project began in the early stages of the Summer 2023, We knew, that in the end of the last year of our studies there would be a Bachelors project to be completed. We got the hint, that the University of Zurich, via the Science Pavilion, was looking for collaboration partners for the next exhibition in the museum. They were looking for a project, that would focus on Mixed Reality and explain one of their research topics better. Just a couple of weeks before, the Apple Vision Pro was announced. The promotional material looked extremely promising. Without knowing about a possible release date, we wanted to work with spatial computing, or a variation of it.

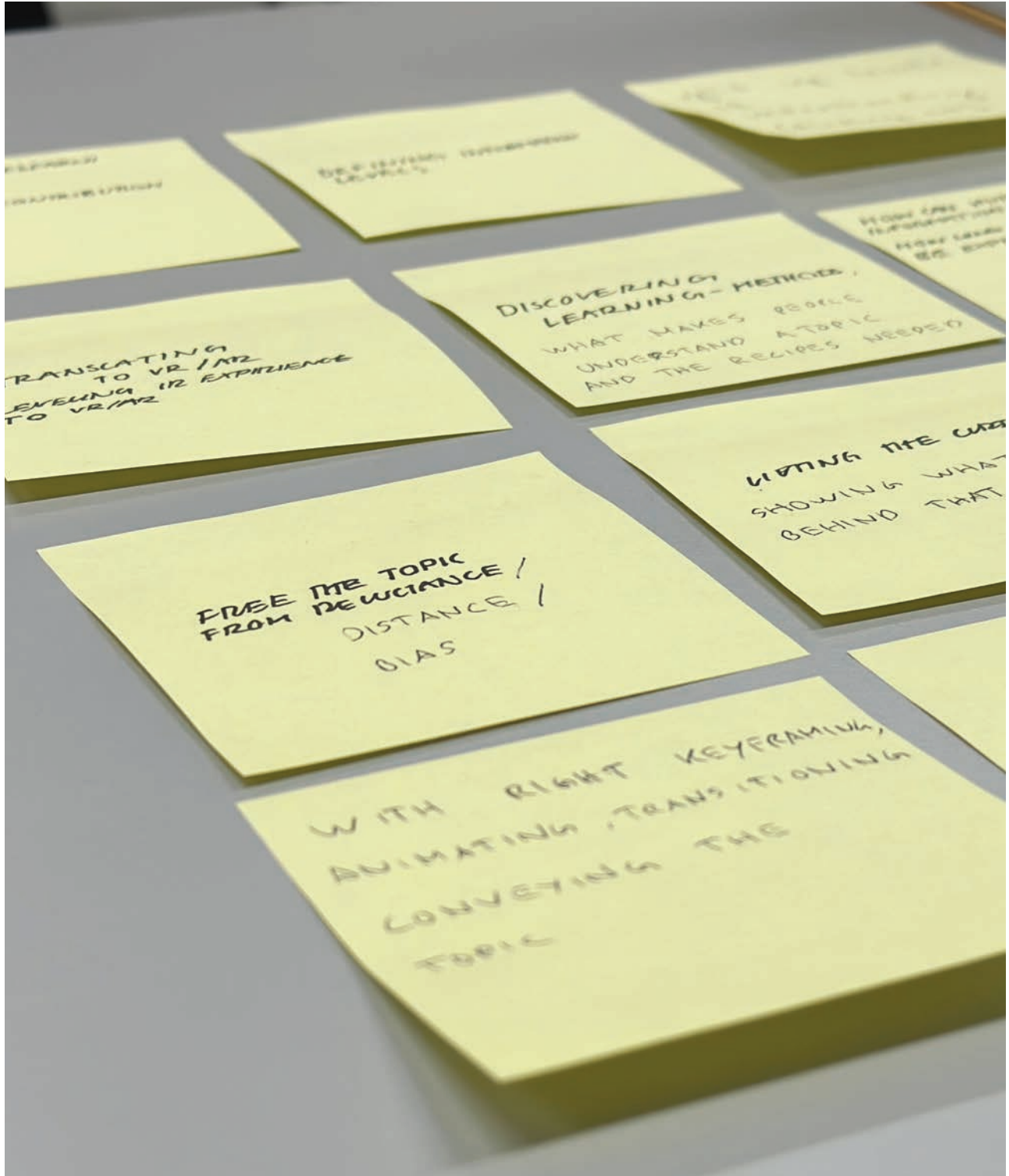


Figure 22 Concept development, authors work, 2024

Field Research

Science Pavilion UZH

Upon entering the Pavilion, one is immediately struck by the blend of traditional and digital educational methods. Touch tables and QR codes are ubiquitous, indicating a strong focus on interactive technologies. The digital interfaces, especially touch tables, are designed to be accessible even to wheelchair users. This reflects a conscious effort to stay inclusive.

The QR codes offer a gateway to two types of experiences: standard web content and an AR app Artivive. While setting up Artivive is straightforward, the process of engaging with the AR posed some challenges: It requires not only a smartphone but also the proficiency to use the app effectively. These hurdles, while seemingly minor, can significantly impact the user experience, especially for those less familiar with such technology.

The abstract artworks on the glass windows, when viewed through Artivive, come alive with animations and interactive elements. This transformation from static art to dynamic, immersive experiences exemplifies the potential of AR in enhancing the educational impact of museum exhibits. However, the challenge lies in making this technology accessible and intuitive for all visitors, regardless of their technological proficiency.

Beyond the digital artifacts, the Pavilion also features traditional educational tools like chalkboards and flip cards. These elements invite instant interaction and provide a contrast to the high-tech variants. This juxtaposition raises important questions about the balance between technology and traditional educational methods in modern museums. While technology can enhance learning, it is crucial not to overshadow the simplicity and directness of conventional



Figure 23 Image Science Pavilion, authors work, 2024

tools. The textual content of the exhibition also merits attention. The Pavilion attempts to distil complex scientific concepts into understandable language. However, the density and length of these texts can make the space feel cramped and overwhelming.

The introduction of Simple Language format is a commendable effort to make the content more accessible, but the execution still grapples with the challenge of presenting dense scientific information in an engaging and digestible manner.

Visitor demographics during our observations were skewed, with limited engagement from the younger audience. This could be attributed to various factors, including the timing of our visit and ongoing school vacations. Nevertheless, it highlights the challenge of attracting and retaining the interest of the intended demographic, particularly the younger generation. The space is filled with a mass of exhibits and information, yet the complexity remains. This observation necessitates more refined approach to presenting scientific concepts.

On our field encounters at the Science Pavilion UZH museum, we exposed the gaps and opportunities in the current landscape of scientific education and communication. The Pavilion's efforts in integrating digital technologies, especially AR, are commendable, but the effectiveness of these tools in genuinely enhancing understanding and engagement needs further exploration.

As we move forward with our project, these observations will serve as a foundational layer. They provide a real-world context for our project, emphasizing the significance of our work in contributing to the field of scientific communication in a museal context. Our goal is to address these challenges observed, leveraging spatial computing to make scientific concepts not only more accessible but also

engaging for the younger audience.

In summary, the Science Pavilion at UZH presents a microcosm of the challenges and opportunities in scientific communication today. Our visits were important in shaping our understanding of the current state of this field and will influence our approach in later steps. As we delve deeper into our project, we aim to build upon these observations with workshops, storyboards, and prototypes.

HollandLab, Laboratory Tour

Before the start of our project, we organized a first laboratory visit at HollandLab's research place at the Irchel campus in November 2023. We knew this was not our last visit and therefore had a second laboratory tour planned for the following year. The goal of these lab visits was to get first-hand insights and access to the rooms, appliances, and materials we from desk research otherwise could not get a hold of.

We were intrigued by the loads of new information, but the first served us well to get an early feeling of the everyday tasks. We also got to meet Jason, the group's lead as well as Jonas and Eda, the PhD students we are in direct contact with.



Figure 24 Laboratory HollandLab, authors work, 2024

Science Center, Technorama

We asked ourselves the question to what extent a physically oriented museum at its very core leads to long term visitor engagement. This is one of Falks (n.d.) core questions that reflects on visitors' memories and learning connected with their motivations, personal relevance, and emotional engagement in museum experiences.

What can we learn and take from Technorama as the cathedral of science communication for children? How can we translate visitor motivation and the museum experience that encourages long-term engagement and learning into the spatial realm? What factors could we leverage and what challenges face us?

01. *The Shortcoming: 1:1 Translation*

The first key finding is at the same time our conclusion and hopeful outlook for the upcoming potentials we define. Foremost, it is that we simply cannot translate physical artefacts exhibited. The agencies and affordances differ in how we interact with an object at hand – buttons, strings, switches. Virtual objects, one the other hand, offer controllers that determine interaction with the augmented or virtual environment and objects. In an ideal setting would constitute of interaction with inputs of most natural way: our hands and eyes with precision tracking.

Trying to mimic the real-world equivalent of Technorama's exhibitions is not impossible. It can look beautiful; it could even look better. But we need to ask the fundamental question if these experiences can be translated one to one? It is also a justified question to ask why not to use spatial computing applications for these exhibitions.

We deduce three angle points for intervention, namely to 1.) enhance existing exhibited artefacts by adding an



Figure 25 Example of 1:1 translation at Technorama, authors work, 2024

augmented, virtual, mixed, or modified layer, to overcome the physical boundaries of 2.) scale and 3.) visibility.

02. *Potential: Enhancement*

Already existing physical places or artefacts could be enhanced by augmented reality as 'add-ons'. Serving more as just 'a playground table' mimicking a laboratory situation, we can manipulate the situation by displaying an overlaid interface affording further interaction. For example, the synthesis of radio nuclear particles in our case could involve existing physical objects and by following a sequence of interactions we could track which steps were successful and in which steps the user has room for improvement.

03. *Potential: Scale*

Scaling in mixed reality (MR) offers the opportunity to transcend the physical limitations of space and size, allowing users to explore objects and phenomena at scales either too large or too small to be experienced in a conventional museum setting like Technorama. By leveraging MR, we can magnify atomic entities to a size where their structure and behavior are observable or alternatively, shrink vast systems to fit within the confines of a room. An example of an MR application could enable users to delve into the atomic structure of a radioactive molecule. It bridges the gap between abstract knowledge and tangible experience, allowing visitors to interact with and manipulate the subject matter in ways that were previously not possible. It offers a way to explore complex scientific concepts that are often challenging to convey through traditional means.

04. *Potential: Visibility*

We see great potential in showcasing phenomena that cannot be seen with the bare eye. Through MR, we can showcase hidden forces like magnetic fields, visualize the flow of

energy, or observe particles in a reaction. For example, students could witness the process of radionuclide exposure at the cellular level or observe the docking of radiotracers at cancerous cell in the human body. By rendering the invisible visible, MR enables learners to perceive and interact with the world in a way not seen. And because we are dealing with radioactive chemistry, it would have not been possible to expose the visitors to a subject that deals with radiation of such degree it could pose harm to the human body. Through scale, visibility, and secure measurements we see potential to make the research from HollandLab accessible to as many visitors as we can.

05. *Real sized laboratories*

The first visit gave us an overview of the artefacts at display and how these rather small-scaled stations served its purpose for explaining one topic of interest. In our second visit, we paid particular attention to the participative aspect in a practical context: the laboratory. Technorama offers laboratory settings designed for high school children to get a feel of the chemistry, physics and biology taught. With challenging experiments, they get a hands-on experience with the matter at hand.

Conclusion Observation

The field research exposed us to the relevant places we will intervene in.

At the Science Pavilion UZH museum, we found that the exhibition layout in presenting scientific research is dense, especially considering the text labels displayed. On the other hand, great effort has been made to incorporate augmented reality, experienced through a third-party app called Artivive. The app turns static artworks, found along the exhibitions as well as outside of the museum, into animated graphics complementing these textual explanations.

With our tour at HollandLab we met our collaborator. They gave us first-hand insights into the daily research of building radiotracers and set the context for the upcoming content of our app.

(Artivive GmbH,
2024)

At the Technorama museum, we asked ourselves what story we can tell and to what extent do we want to reach our visitors? Taken into notice from our observations in the field research, we see five domains we can transform from the real museum exhibition experience to the digital realm: scale, time, visibility, accessibility, and safety.

Even though all five aspects can be translated into a 2d application, the question also arises in how we might leverage spatial computing capabilities in a museum context to tell a story more engaging, understandable, memorable than in 2d, which in the end shall give us an insight to the research questions set at the beginning.



Figure 26 Artefact Technorama, authors work, 2024

Workshops

Workshop Group HollandLab

Having a workshop with our collaboration partners was important early on. It was very clear for us that we were working in and with a field where we were not the experts. The need for a workshop with the PhD students from HollandLab came from a need to understand. We were looking for information, that could only be obtained with asking the experts. After we evaluated the need for a workshop and decided that it would be indispensable, we looked at possible dates and participants that could be interested in participating. After receiving the date and the number of participants we got started with the conceptualization.

Conceptualization

The primary goal that we wanted to achieve in the workshop, was a full user journey of the research our participants were conducting. A user journey describes the full process a person or a group takes to achieve a goal. Especially important for us was to research what were the difficulties and struggles the researchers face when completing their goal and how they solve the problems that arise. From the research we had conducted on our own, we had created our own journey map. This journey map also was heavily based on the storyboard we had at that time. In the process of evaluating this map we identified the assumptions that we made. The goal of the journey map we planned to create with the researchers was to check those assumptions and to be able to correct and revalidate the assumptions.

(usability.de GmbH & Co. KG, 2024)

The following important assumptions were taken.

01. *The process of research follows a non-linear path.*
02. *The process of research is done in the UZH.*
03. *The process can be split up in different neat paths.*

We had made a stakeholder map early on in our process. But this map was filled with assumptions and different interest, that we had not yet confirmed or disproven. Making a stakeholder map together with the participants and checking their position in the project as well as our own was important for the further process of our project. We anticipated that if we would form a stakeholder map together with the participants, that the role of the participants would be clear from the get-go and could create a good environment where everyone would be able to communicate and collaborate.

For the human component of the workshop, we planned an ice breaker exercise and a cool down exercise.

The icebreaker exercise was designed to bring the participants into the mood to share and to collaborate. It consisted of different questions according to the roles they had in the workshop, as well as a fun question that would tell everyone something about the person they were sitting with. The challenge there was, that we came into an environment as perceived expert where we were not experts in. All the participants had already worked together for a good amount of time and were familiar with the environment. The challenge was to create an equilibrium that would make the workshop enjoyable and productive. This environment was important, as it was crucial for us to achieve the output that we were looking for.

As we had a stark predefined timeslot of two hours, all the timing and planning was done in notion. Having this overview gave us a good look out on time, so we did not go over the allotted time and were able to conceive the requested data.

The course of the workshop was the following:

01. Welcome
02. Icebreaker
03. Stakeholder map
04. Break
05. Research user journey.
06. Cooldown
07. Thank you.

After the workshop we implemented a feedback round. One was in person right after the workshop, and one was via a survey. By having a two teered system like this, we hoped for a better feedback session. The participants could give the immediate feedback, but also let the experience fester in their minds for a couple of days and the give private anonymous feedback

Implementation

The workshop began with a ten-minute delay due to scheduling confusion. We adapted creatively to avoid rushing the participants.

The icebreaker sheet was well-received. Participants, especially two new to our project, quickly engaged, discussing their roles and contributions. The light-hearted questions eased the atmosphere and conveyed a welcoming, inclusive environment.

The stakeholder map was in its execution fairly uninteresting. Our assumptions were confirmed, and the participants were happy to contribute. It was more interesting for the two participants that had not been included into the project yet. Defining their position on the map gave the group a sense of importance.

The forming of the user journey was taking up the most time of the workshop. We made the user journey in a participative way, where everyone could and was asked to talk and to contribute. One of us was talking and the other person was writing. Yet the decision of what got written down was made by the group and not by the person writing. It was interesting to see how the researchers were impressed and surprised by the complexity of their process and how it scaled over time. We worked with Freeform. An application that is akin to Miro but saved locally. Using this we were easily able to write down the remarks and make connections. Doing the User journey together was beneficial, as we could use our expertise in interaction design and keep track of the steps and of the importance of the steps.

The cool down and sketching exercise was beneficial for the mind of everyone, after the rather exhausting process of the user journey, this segment was used for a quick overview and a discussion of the target of the project. What it

should hit and were it could miss. Our immediate feeling after the workshop was a very positive one. The participants were happy with the outcome, felt included and had fun.

Findings

The immediate finding of the stakeholder map was, that we were rather correct with our assumptions, but that we underestimated the impact of our participants in our project. Correcting this was good finding from the map.

The findings of the user journey were the most surprising and important. The user journey that we had created based on our storyboard greatly underestimated the non-linearity of the research process. The international effort was not represented on our storyboards. Most processes that were taken did not give a result. It was starting to get clear, that research was not characterized by the successes, but by the different failures that in their entirety would lead to a success. Looking at how the journey was held up; we could identify different touch points that could be implemented in a visualization. The researchers must test the effect of the tracers in the specimen but are not able to see the immediate effect of the tracers. Being able to make this effect experienceable could be a great impact on not only our intended target group. The research process could not be split up in different neat paths. Through the non-linearity of the research and how the different parts were completing and competing a simple chapter-based application was not possible anymore. We had to get creative again and find a way of reconceptualizing the application and its storytelling.

From these findings our assumptions changed to the following

01. *The process of research follows a non-linear path* ↪ *The process of research is non-linear and follows no predefined path.*
02. *The process of research is done in the UZH* ↪ *The process takes international effort and is not only done at UZH.*
03. *The process can be split up in different neat paths* ↪ *The process cannot be split up in neat chapters, as every part of the process influences the other.*

The next step was to look at the findings and implement them in our process and project, so we could represent the process in an adequate way.

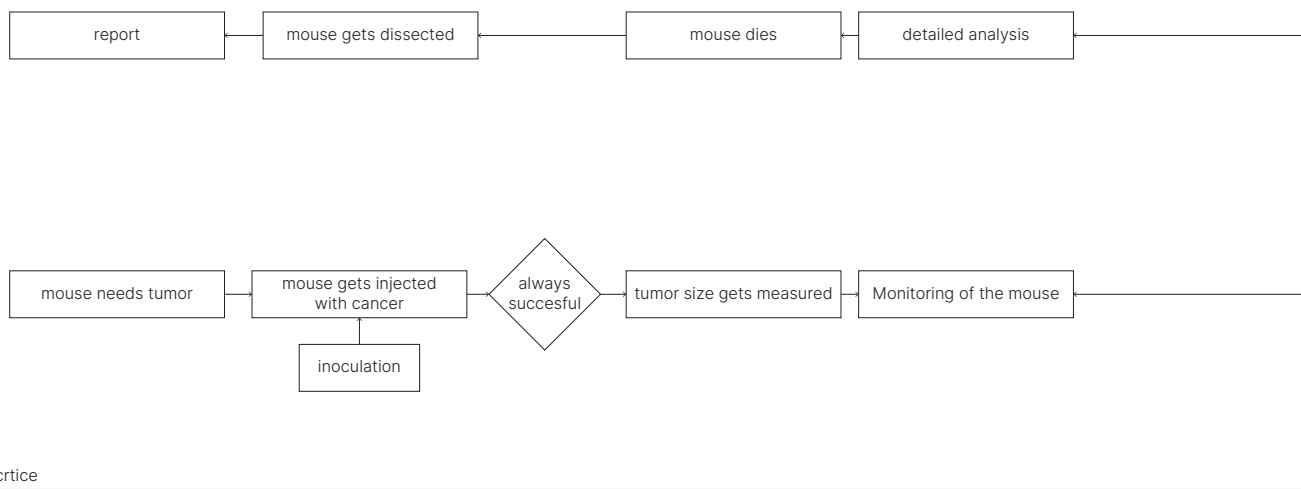
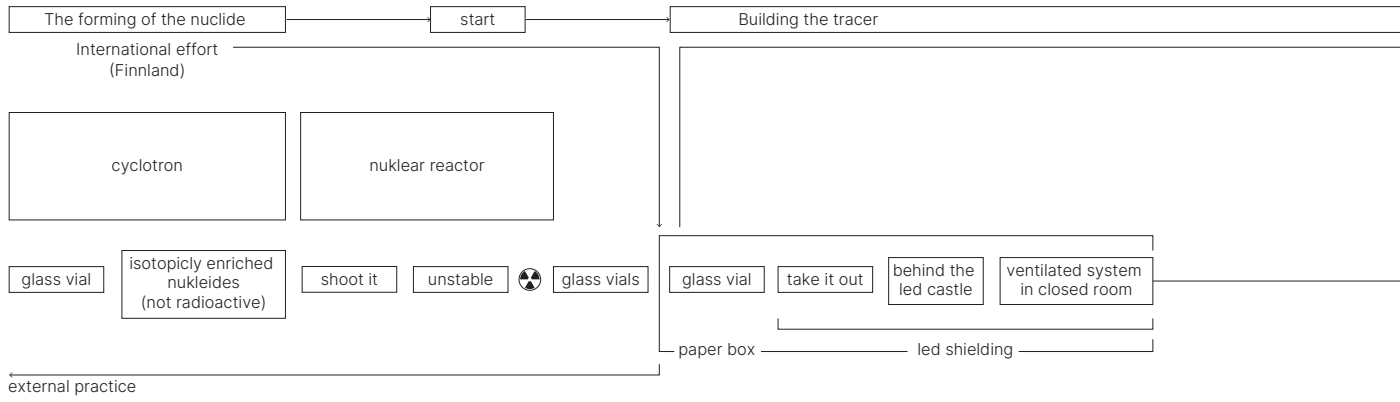


Figure 27 Flowchart research, authors work, 2024



Figure 28 Workshop HollandLab, authors work, 2024



Figure 29 Jonas Genz wearing the Apple Vision Pro, authors work, 2024.



Figure 30 Workshop group HollandLab, authors work, 2024



Figure 31 Creation of the user journey, authors work, 2024

Concept

Design Decisions

Design decisions must be made. Processes can only progress, when at certain points decisions are made and applied to the process. Every decision comes with a certain amount of insecurity. The process of this work was no different. To arrive at the best possible outcome, a system for decisions had to be made.

As this project and thesis is an interlocked work of many great minds with different expectations a system for decision making had to be made. Some decisions had to be made because of time crunches, but there was an effort to make decisions in a logical but radical way. Radical in the sense, that when a decision would be made, that in the after math the decision would not be a constant topic that could come up.

Yet, there was a readiness to question decisions that had been made before. As from time-to-time decisions can be made in a rush or an emotional way and must be reversed. For these cases a clean file system was important. To decide did not mean to trash, just the taking of a crossroad and leaving some ideas and concepts behind. This security of keeping made the decision process easier, as there was clarity in the decisions made but not a fainting finality.

Who is it for?

When designing an idea that has been formed into a concept, one of the first question a designer must have, is who they are designing for. The answer to this question influences everything from the initial ideation, through the design process and the evaluation of this processes.

For this project it was already in the initial stages of the process clear who the end user of the application would

entail. But one should not neglect the people and professionals that are not initially considered in the product but are immediately affected by it.

The end user of the product was largely decided by the location of interaction of the application. The application will be used on a central device, that is in the Science Pavilion at the University of Zurich in the Irchel Park campus. The Science Pavilion is an institution that is tightly knit with the university itself. There is no fee to enter and experience the exhibition. It was clear that the application would have to be designed with a large population group in mind, but that there needed to be a concentration on a certain user group. From an early suggestion, the push was to concentrate on juveniles aged 14 to 18 that are visiting the Science Pavilion in an educational context. That decision influenced the choice of people we talked to, the workshop we planned, the participation of the workshop and the desired outcome that could come of these.

Another group that should not be neglected, is the people conducting the research that served to be explained an exhibited. The PhD students that worked under the umbrella of HollandLab needed to find their conducted research represented in a scientifically correct way, without an absurd amount of simplification. This instance provided an interesting group of people that had a direct or indirect influence over the product.

It was clear that not every person could be satisfied to the maximum with the product, but there must be an effort to include as many perspectives and stakeholders as possible. One Question that also had to be asked from the start was the question of accessibility. As it was clear from an early stage, that Mixed Reality would be integrated in the product,

the perspective of potential users that would not be acquainted or comfortable with Mixed Reality had to be implemented.

In the end we decide to concentrate on the user-group interacting with the application and to include the researchers as much as possible in the design process. That way we expected to find a high appreciation of the application from the end user and a high level of contentment of the researchers that conduct this important research and make it visible to the public. From this system we expected to have high level of satisfaction on all parts.

One of the most challenging aspects of the question of "Who is it for?" was the realization, that the project would also be for us. Yes, the stakeholders had to be happy, but we had to be as well. It was not an easy task to not remove us completely from the equation and only work with and for our partners. We were partners in this as well and had an equal say in which decisions were made and how they were made. This realization gave peace at a certain part, but also reinforced the pressure and responsibility that was there on our hands and minds.



Figure 32 Irchel campus university of zurich, authors work, 2024

Where should it be?

Why Science Pavilion

One part of our early research was, how we could fire people with enthusiasm for research and the research process. Also making people familiar with spatial computing and showing its advancements and limitations. Also, we wanted to have a space to show our final product, as we are proud of our work and want it to be seen. One part of our studies we were not happy with, is that most of the time the work we do has no time to breath and be experienced. Placing our work in a museum meant that it would be experienced and visited. This opportunity filled us with a great amount of pride but pressure as well. The Science Pavilion was ideal in this regard, as it is a free museum and the people visiting have a certain interest for science and the process. Creating something that would excite them as well was a great motivator in our work.

On another note, the Science Pavilion is in a unique position, from a museum's perspective. The exhibits are based on the research that is being conducted in the university itself. A lot of the traffic to the museum is generated by pupils that either come with their classes as an expedition in the frame of a school topic, or classes that visit the science pavilion in the frame of an expedition where they visit different universities in Zurich to have a better understanding of what and if they wanted to study. In this user group, we saw great potential. We were in the position to create an exhibit, that could show pupils, that the chemistry they could study here, would be completely different than the one that they were accustomed to but be based on the prerequisite knowledge.

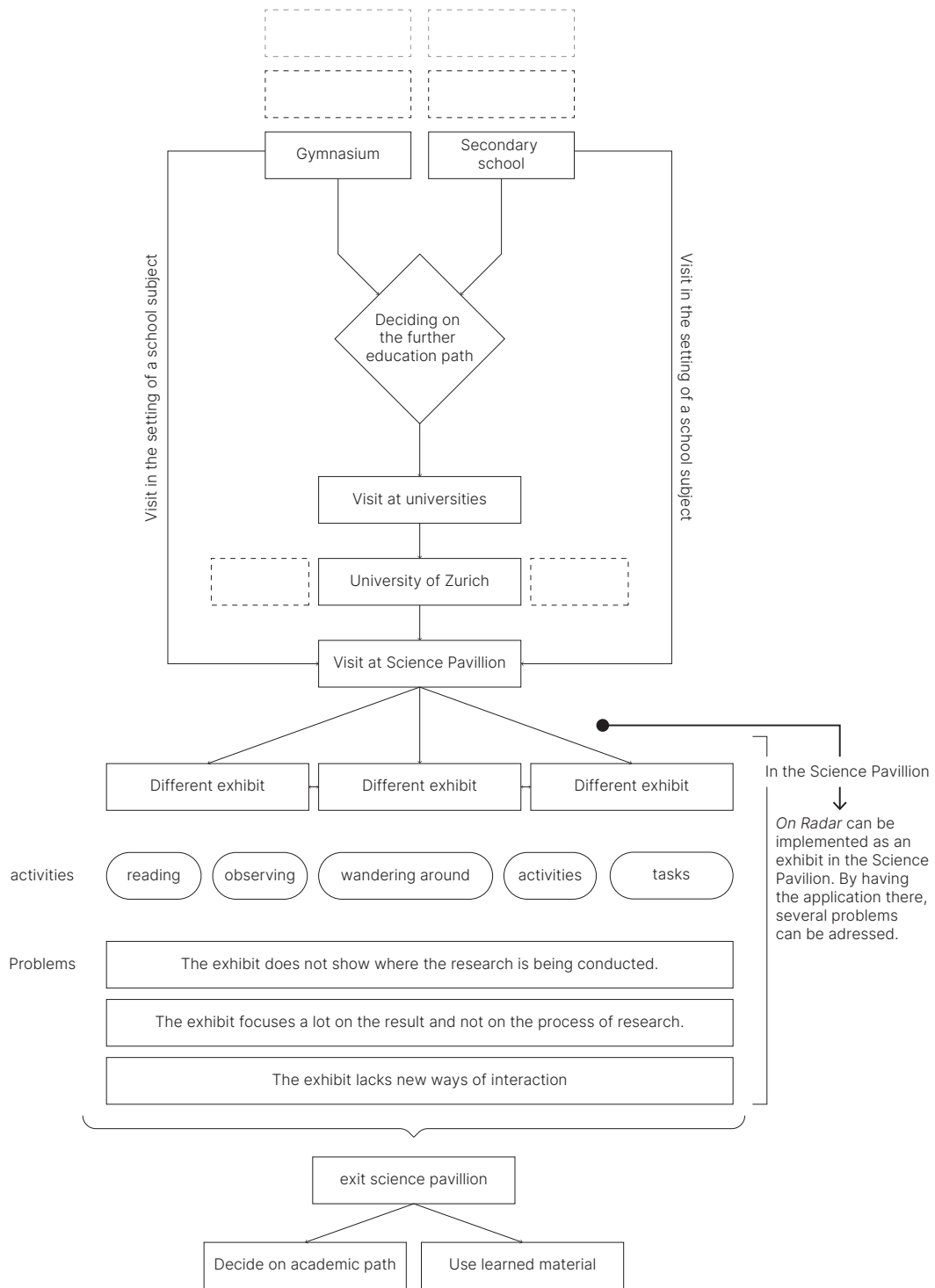


Figure 33 User Journey visitor, authors work, 2024.

The ethics of animal experimentation and the visualization

In our work and conception, we got confronted with the theme and ethics of animal testing. It was a topic early on, after our first visit in the laboratories of the UZH when they showed and explained their research process including animals. We were interested in showing the process but were not sure in what way and visualization. Looking at their research and ethics process including the animals, we decided to form a code of conduct about how we would treat this sensitive topic in our application. We were aware, that we are not making an application about the treatment and testing of animals in research context. But we did not want to exclude the topic in its entirety as it was a big part of the research process. As the researchers treated the animals in an ethical way, we had to treat the animals in an ethical way as well. There was no way of showing the brutality of the animal testing, but we wanted to hint at the important part the animals play in the research.

In the field research, namely in the first and second lab visit, we had observed how the facilities looked where the animal testing was being conducted. We were not present when the test was done, but we were provided with images. These images were of brutal matter, and could not be visualized in a way, that there would not be any backlash from the stakeholders.

The partners from the Science Pavilion did not want to have the animal test visualized in a graphic way. They were not completely opposed to the idea of showing it, but they had certain guidelines in place that we would have to adhere to. They did not want to have the mouse modelled in a cartoony way. But also they did not want to have the mouse modelled in a too realistic way. It was very important, that the mouse would have fur. The mice that get used for the test are naked with visible tumors protruding from the skin. An exact

visualization of this image would not be accepted.

For the visualization of the mouse itself science visualization publication were consulted. Looking how the experts dealt with socially cute animals getting visualized in brutal situations helped with the conceptualization.

It was clear that there would need to be a certain level of abstraction, but the animal could not be too lifelike and cute. It started to feel like a play with the dignity of the animal. How cute can an animal be, so that it is still considered for animal testing. Macabre questions like these started to arise in the process of the visualization.

Platform Choice

As Interaction Designers, it is less of our job – if even not – how to impose the newest technology to the people. Where we come into play is how we make sure the best user experience is given when confronted with a complex topic. As abstract as the topic of medicinal radiochemistry can get, it is in our evaluation to choose which platform to mediate the matter in an understandable manner, while leveraging the platform's capabilities.

But the choice of platform is not always motivated by technology itself, it is also the problems we face and the solutions we have at hand or in mind. We must ask ourselves from the ground up what platform and its capabilities fit to 1.) make visitors feel comfortable using the Apple Vision Pro and 2.) with it showcase and explain our research topic.

With that in mind, we start intertwining both platform capabilities and research content in the concept developments to come.

Prototype

In the entirety of the process, we always researched and prototype simultaneously. Not splitting up our process in a pure prototyping- and research part was of great advantage for us: With every step that we took in our research we had the flexibility reshape our prototypes and its usage.

Taking this approach kept our process dynamic. It also let us easily change aspects of our prototypes and iterate on them not based on feelings, but on research and new discoveries.

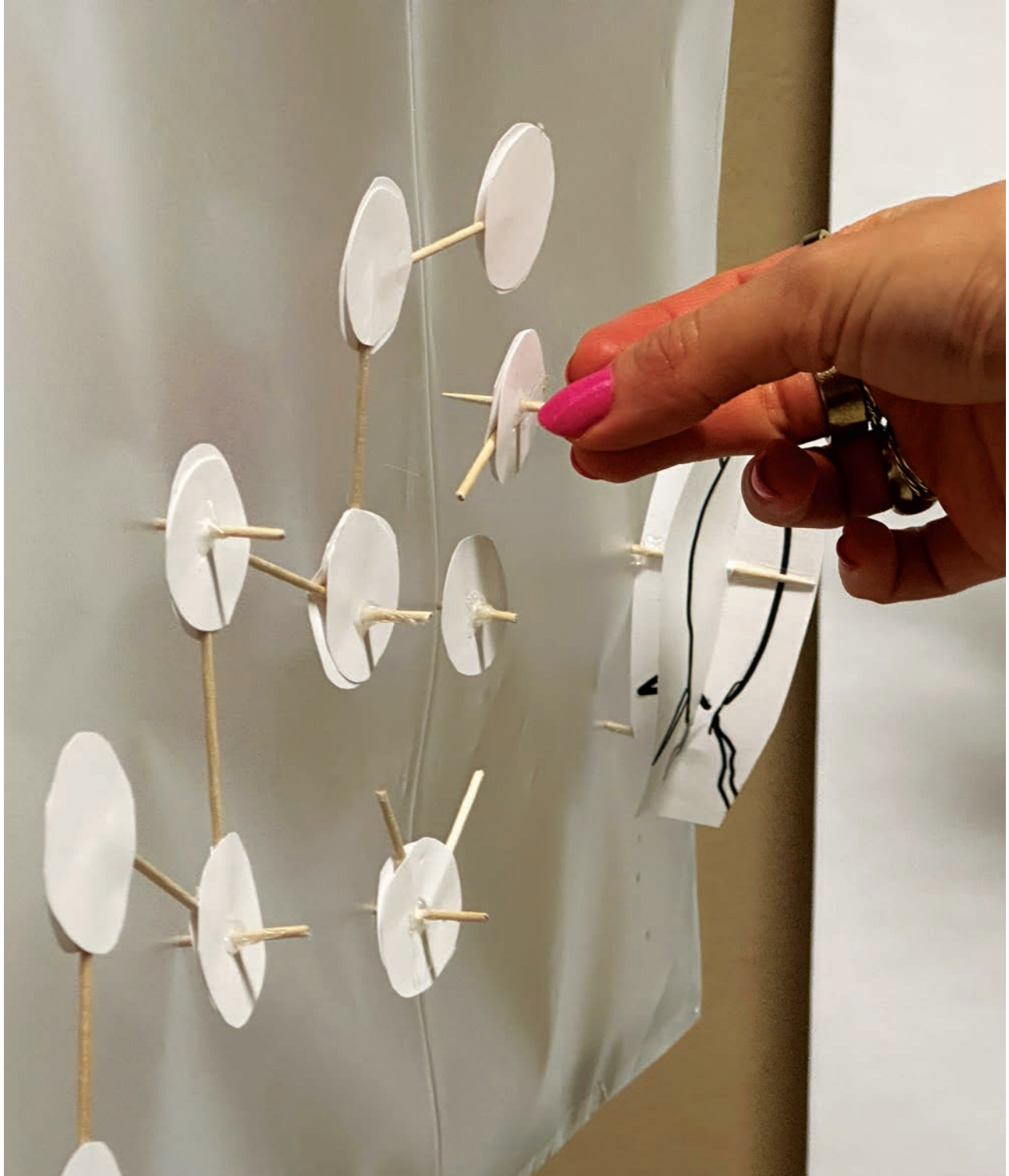


Figure 34 Paper Prototype for AR, authors work, 2023

Storyboards Scenarios

The following scenarios were the first step before iterating on a complete storyboard. They consist of smaller storyboards that address specific situations that could be showcased in the application, with no direct correlation to one another at this stage. The idea behind them was to provide a way of rapid communication tangible enough for our mentors and involved partners to discuss and evaluate with.

With this method being the very first step for us to conceptualize our research into a graspable concept, we also thought about suitable gestures and three-dimensional visualizations that could make the research understandable based on our assumptions.

Scenario 1

The first scenario explained the structure of radiotracers through various levels of scale. The user could zoom in and out with a pinch gesture through the different levels, accompanied with information of detail and brief explanation.

Starting with the model of a virtual 3D tumor representation, the effect of the radiotracer would be shown with an attached window through a tap gesture that gets displayed over its model. Through zooming, the user would discover more in-depth information about the radiotracer along the way.

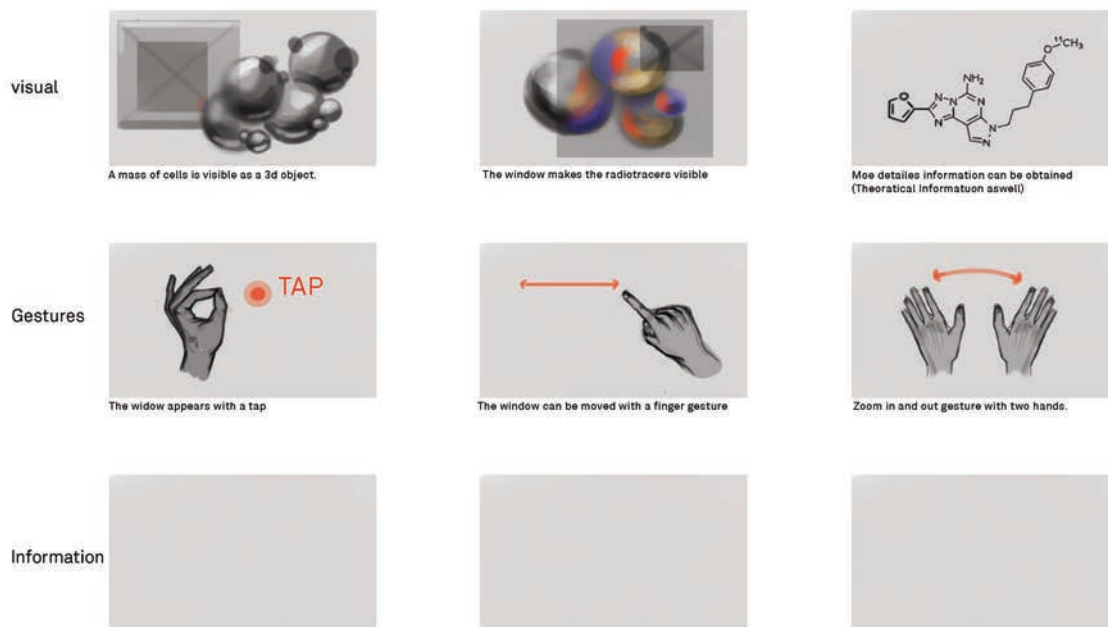


Figure 35 Scenario 1, authors work, 2024.

The positives of this scenario were that the usability would be great and intuitive, yet the information displayed would be of a very high level to be understood. Also, we expected that the density of information would have to be quite high, and the content therefore kept short, so that the user would understand what they were looking at.

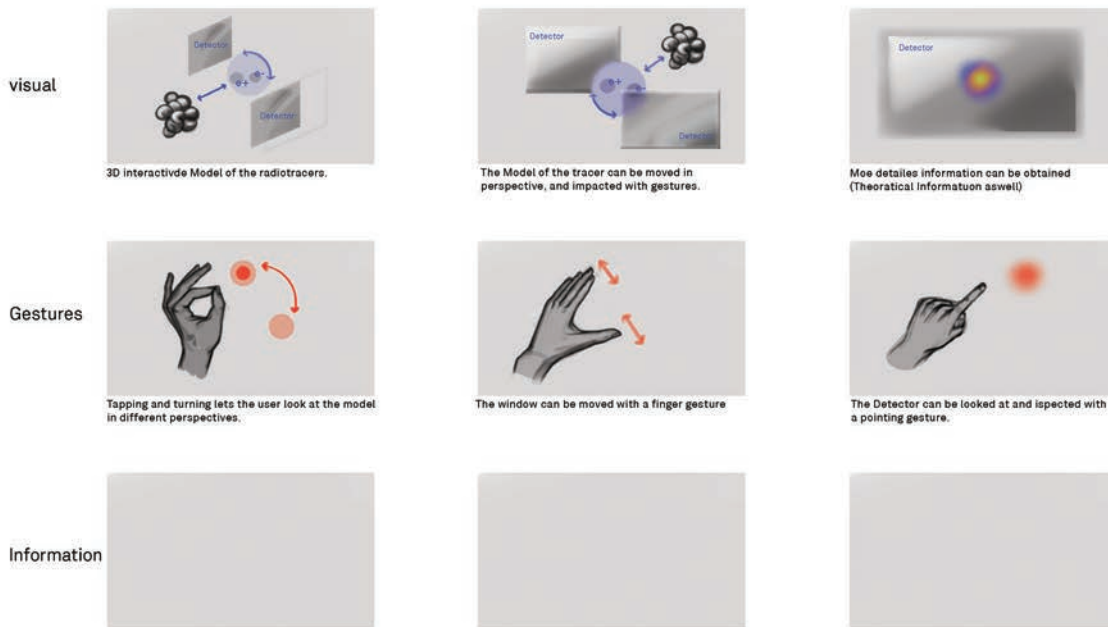


Figure 36 Scenario 2, authors work, 2024.

Scenario 2

In a second scenario, the forming of a radiotracer could be interacted with by pinching and rotating the model. Upon action, different information layers would show up and inform the forming of radiotracers.

The positives about this scenario were that the gestures were implemented in such a way that they could also help with the understanding of the material. Yet the information would have to entitle some written text for people who are not yet familiar with material.

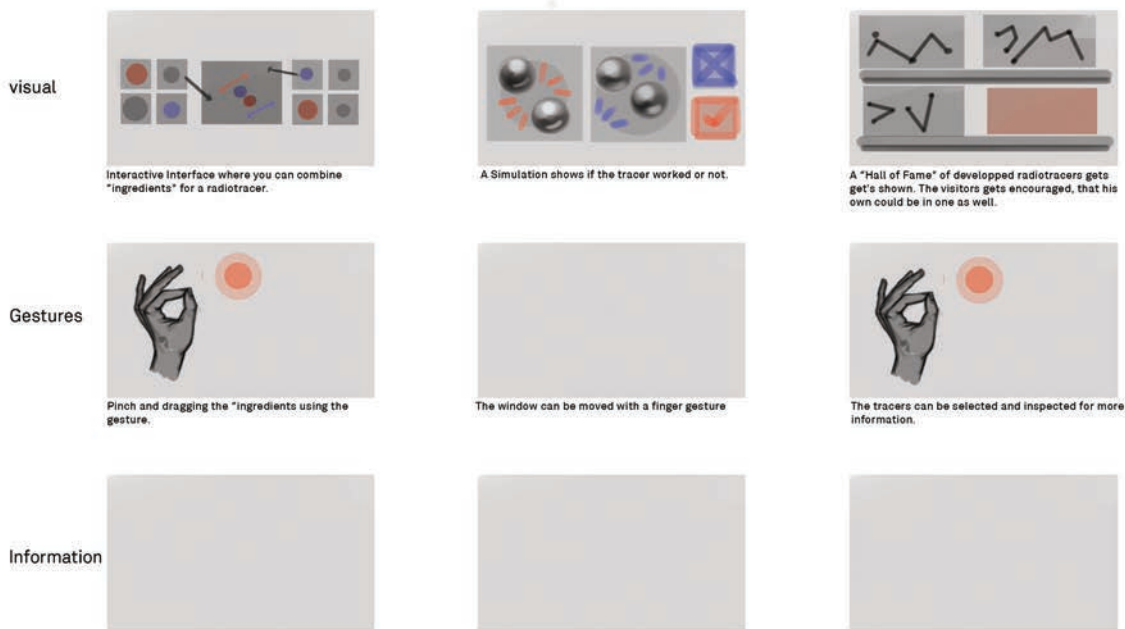


Figure 37 Scenario 4, authors work, 2024.

Scenario 3

In the third scenario, the potential user would see the effect of the radiotracer exposed on their own body. A virtual projection would be mapped onto the user and show how the radiotracer was impacting their body.

The interesting thing about this scenario was, that it would not really utilize gestures. It could be part of additional content in which the gestures would be implemented separately from one another.

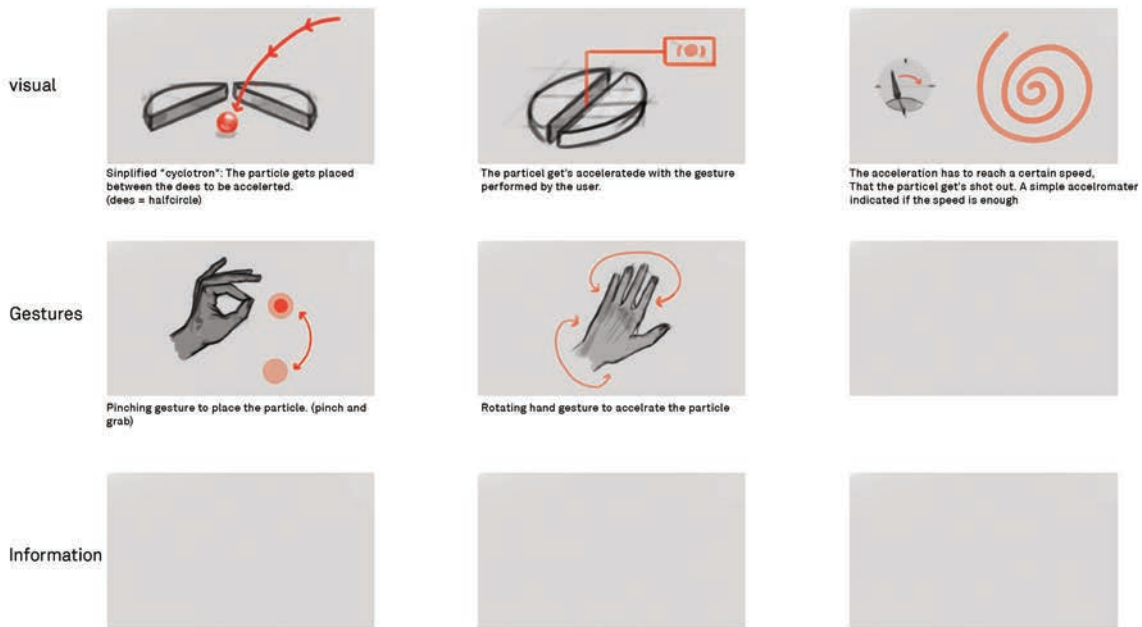


Figure 38 Scenario 5, authors work, 2024.

Scenario 4

Scenario four shows how the user would be able to build their own radiotracer with a toolbox. The interaction involves simple drag-and-drop gestures. By building the radiotracer, the user would understand which components form one and how those different parts interact with each other.

The good thing about this scenario was that it was very scientifically accurate. The feedback of the researchers was highly positive. They also liked the idea of having to build your own radiotracer, as this is what they are doing on the daily. The biggest critique of this scenario lies in its implementation where it doesn't justify the need for spatial computing. The drag-and-drop interaction was not specific to the platform and could be easily done on a two-dimensional screen.

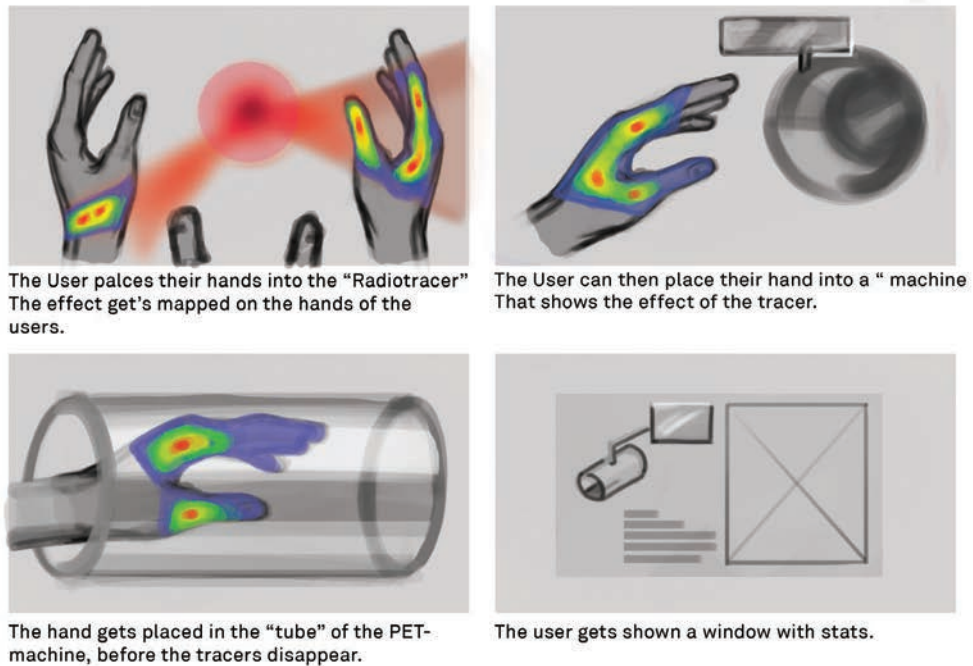


Figure 39 Scenario 3, authors work, 2024.

Scenario 5

In the fifth and last scenario, the idea was to explain how a cyclotron works – a device used to create and involve the radioactive part of the radiotracer. By custom gestures the user would operate the cyclotron and imitate the movement of the particle rotation in the machine. This interaction invites a bodily approach to be taken into the learning.

An immediate critique of this scenario was the fact that the particle in real life would spin way to fast to be imitated by a human.

Findings

The scenarios were presented in a first internal meeting with the interaction design department and separately with only mentors and partners involved. Presenting our content to our peers and partners gave us the advantage of a wide range of feedback.

Presenting the scenarios to our peers was enlightening, as they had never interacted with the content that we tried to converse. There was some confusion about the explanation of the content. It was interesting to see how much additional information would be needed to convey the themes of the research. There was also some confusion about what we had tried to communicate. We made the mistake of labelling our scenarios as storyboards incorrectly, what gave of the idea, that they were conveying the idea of the whole application.

The questions of usability and onboarding came up quite often. This was a disappointment in the sense, that it was not the feedback that we were wishing for. We had in mind, that an onboarding process would be needed and designed, but we did not want to use this session for the critique on this process. We expected this to be something that we would explore with our mentors and convey in user testing.

Presenting in the internal Meeting focused on different things than the presentation to our peers. Here the scientific accuracy of the different scenarios came to scrutiny. We had some time to adjust between internal meeting and the class session, what lead us to apply some of the critiques in communication that we had received in the class session. We called the scenarios by their fitting name and disclaimed, that we were not talking about the while flow of the application, but rather small segments. The scenarios were received positively and were looked under for their scientific accuracy. We did not pass with flying colors but had to revise some of our concepts. A point that came up and overlapped between the

two sessions, that we would have to include different scenarios into the application, so the user could understand and experience the understanding of the research.

After these sessions and feedback, we learned that there would not be a way to just have one aspect of the process in the application. We would need to include different aspects of the research to convey what the research was doing and what potential it had for the people profiting from it.

We took the following points from the findings of our scenario.

01. *There needs to be an onboarding to include the user in the virtual environment.*
02. *There need to be several segments that include different aspects of the science.*
03. *The interaction with the material should be intuitive and connected to the content.*

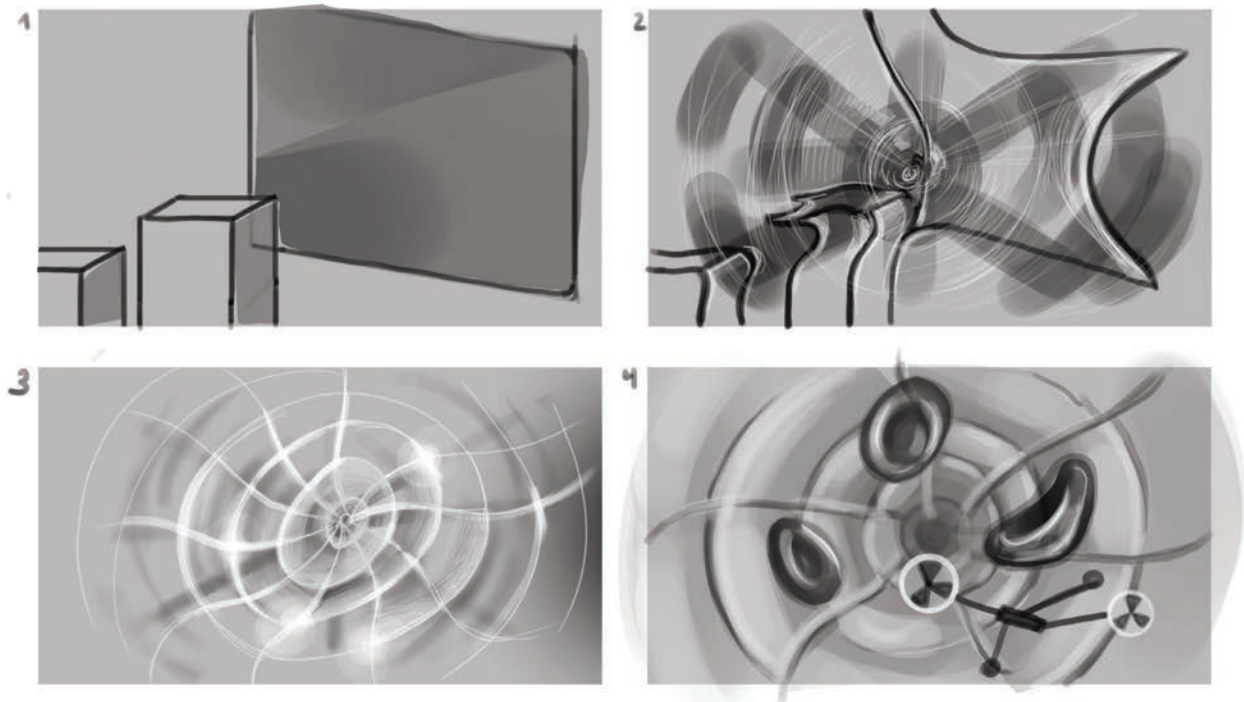


Figure 40 Storyboard Version 1, sheet 1, authors work, 2024.

Storyboard Version 1

In this storyboard, we took our scenarios, evaluated in each, what we liked best and what seemed to work, and combined them into one extensive storyboard. This storyboard served to understand the flow of the application and communication. The application got divided into three different chapters. Each of those chapters served to visualize one of the stages of the development and forming of the tracers,

Chapter 1

The onboarding of the visitor would be in an animation. The user would be teleported into the bloodstream and see the tracer interact with the target cell. This animation would not be interactive and would serve as a simple explanation of

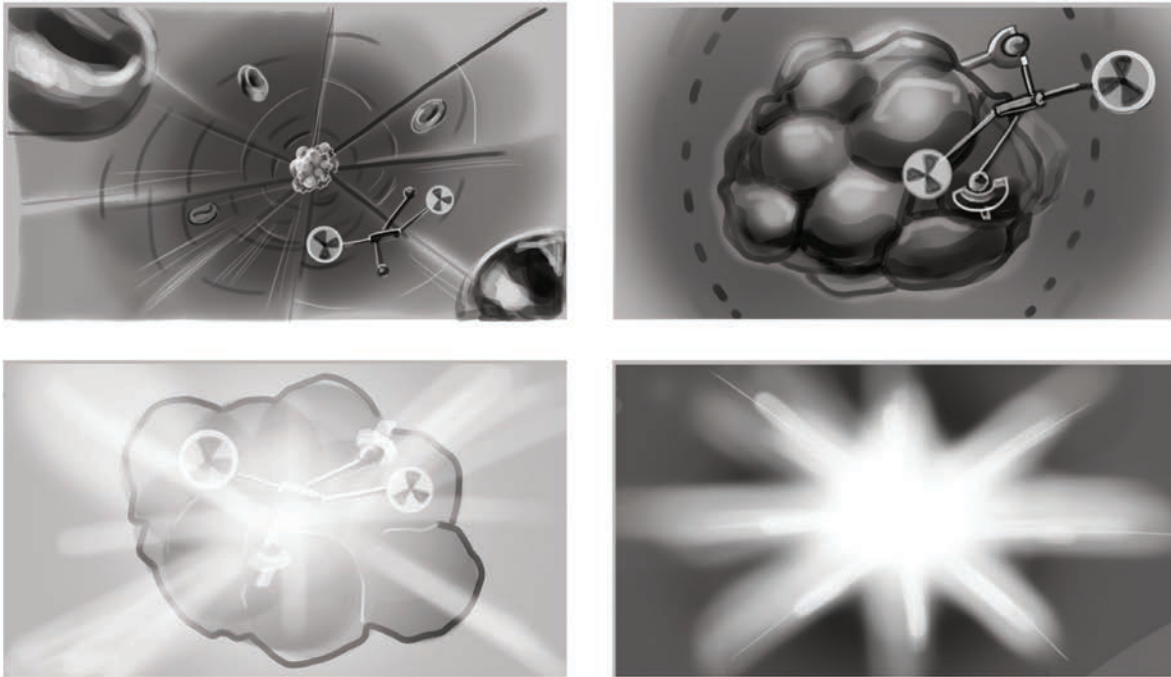


Figure 41 Storyboard Version 1, sheet 2, authors work, 2024.

what the tracer does in the blood. There would be some labels to describe what was happening in the screen, but the objective would be to observe.

Chapter 2

The fourth scenario would be used but in a slight variation. The user could build their own tracer, according to the one that was just on screen. There would be the inclusion of a lab mouse, that would serve as an indicator to if the tracer was built right. There would be an element of trial and error, that would mimic the real-world experience of the researchers in the lab.

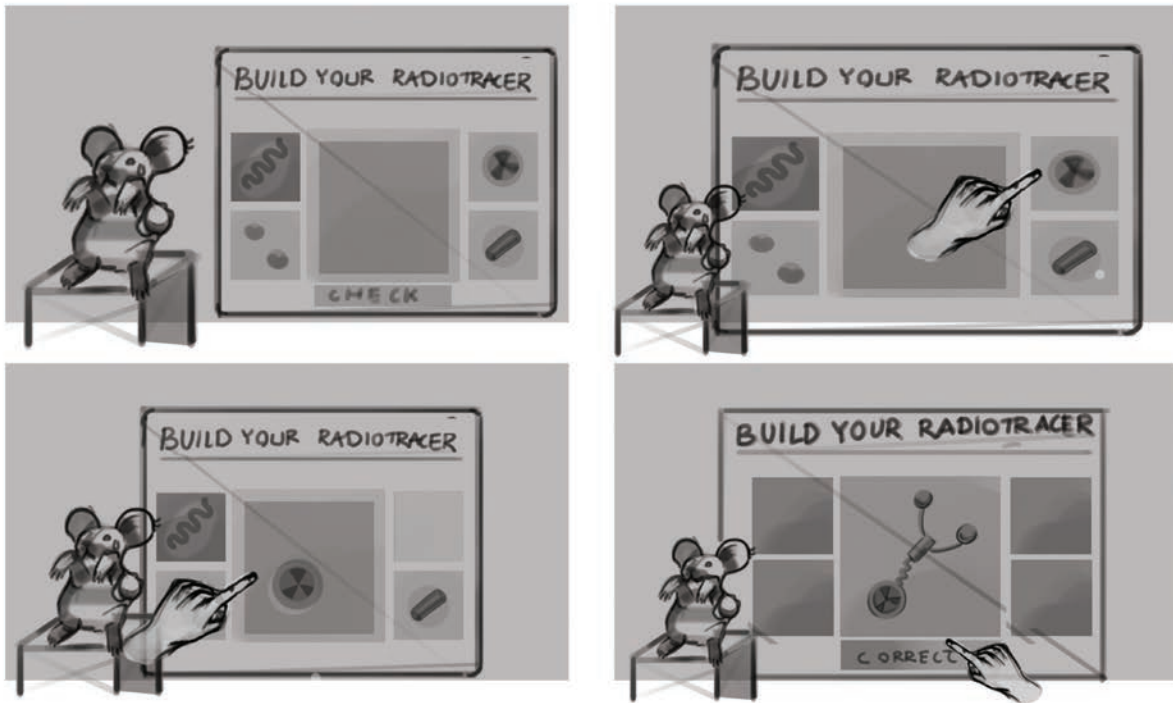


Figure 42 Storyboard Version 1, sheet 3, authors work, 2024.

Chapter 3

The tracer that was just built would be used in the lab mouse. The user could then see how the tracer affected themselves (or how it did not affect them, as the user is not assumed to have a growth). The user could then observe how the mouse would get better. The tumor on the mouse would slowly disappear, giving the user the feeling, that they “cured” the mouse.

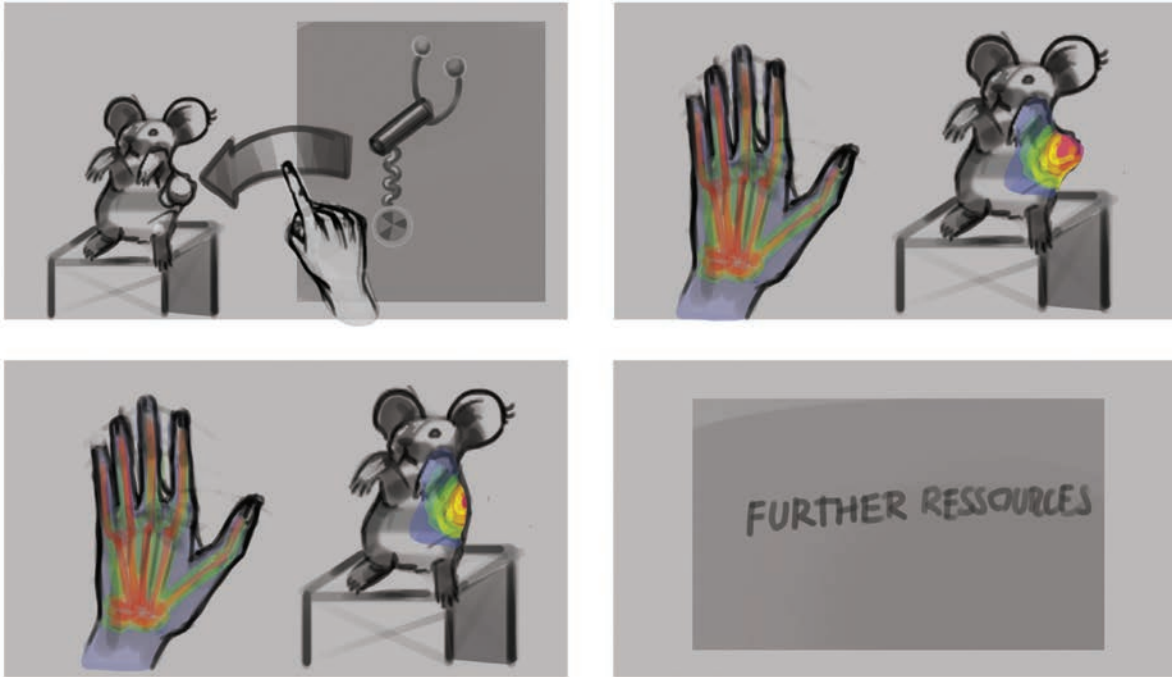


Figure 43 Storyboard Version 1, sheet 4, authors work, 2024.

Findings

This first version of the storyboard was shown in mentoring and the first internal progress session. The feedback in the internal meetings was positive, yet the aspect of the reason for AR was still lacking. The information layer was not clear enough yet. The conclusion of the mentoring was that an important step had been made, but that the product was still littered with conceptual holes. The critique from the internal session was positive as well, but they had questions. One of the questions that arose quite early was the question around the animal. If the animal should be shown and in what way. There was a brutality in the animal testing that we were neither allowed, nor willing to show.

Yet there was the demand, that the animal should not be stylized to an absurd amount. There was the demand, that there shouldn't be a mechanic in the application, that would make it possible to harm the animal. Another point was the demand that the user should not experience the effect of the tracer on their own body, as that would communicate, that they somehow needed the medication developed. This also went hand in hand with the rule, that researchers should not experiment with their own products. What they evaluated in a positive way, was the intro animation. It was received in a positive way to show the user instantly what the application and visualization is about.

From this feedback we identified three points that we would implement in our next storyboard.

01. *The implementation of the mouse must be made with dignity.*
02. *The user should not interact with the tracer directly.*
03. *The understanding of the material must be better conceived.*

Storyboard Version 2

The plot of this storyboard is virtually the same, with some notable differences. This storyboard was more detailed in its interaction. The steps that the user would take to complete the application were there. Also, we implemented the three findings we took from the first storyboard. The mouse would have a realistic idle state but could not directly be interacted with. The mouse should further serve as an indicator of the process of the research, with the immediate goal to heal the mouse. We kept the chapter structure, but tried to connect the chapters together, so the non-linearity of the research would be clearer. We removed the interaction of the user with the tracer itself completely, as we did not see a way to implement it, that would adhere to the standard that they set for us.

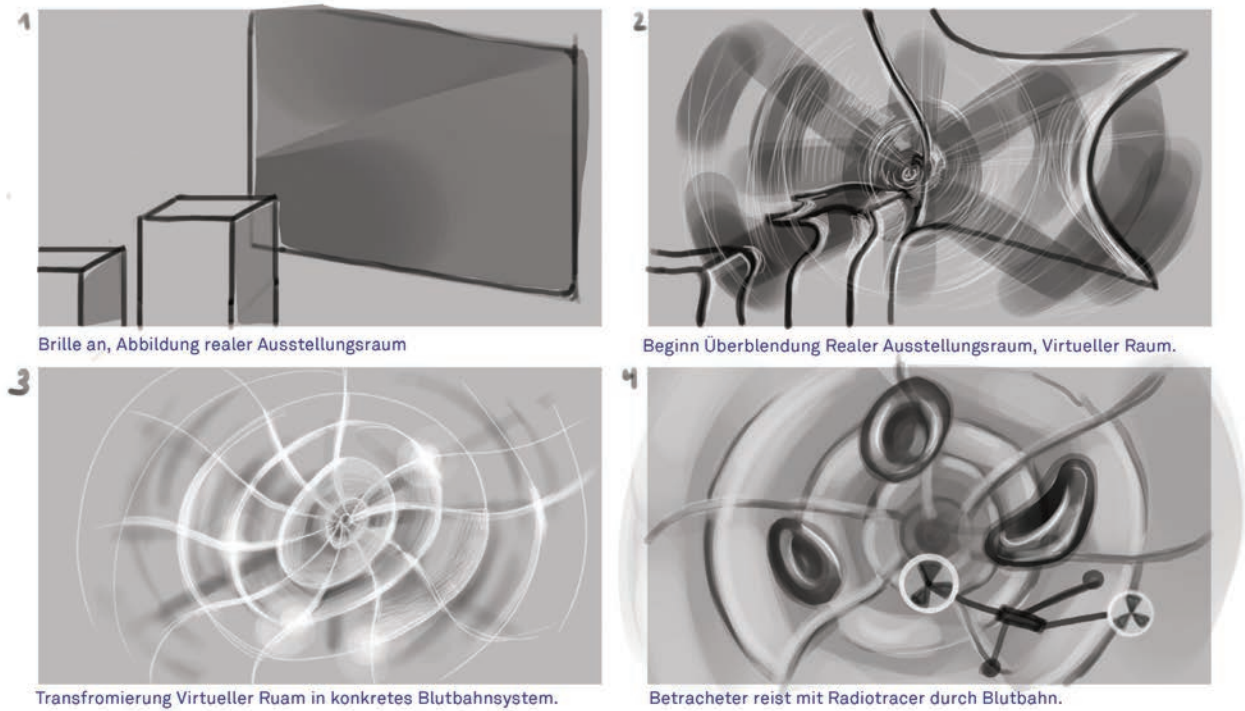


Figure 44 Storyboard Version 2, sheet 1, authors work, 2024.

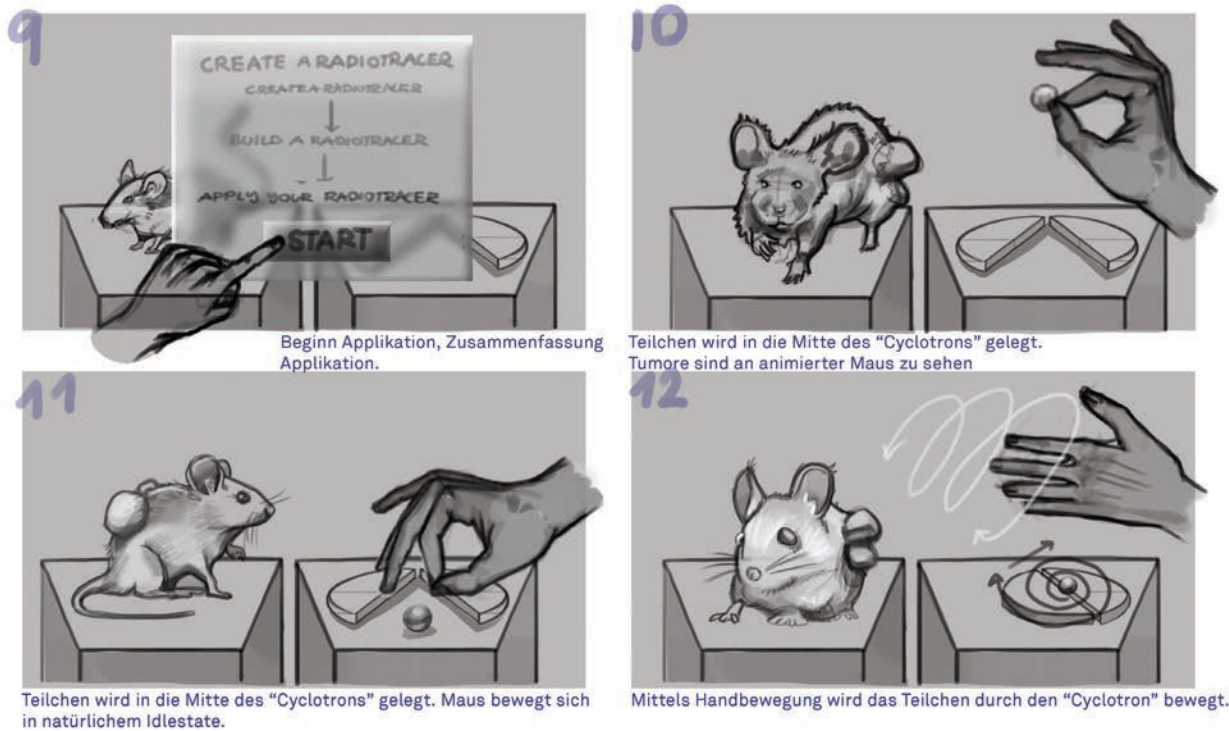


Figure 45 Storyboard Version 2, sheet 3, authors work, 2024.

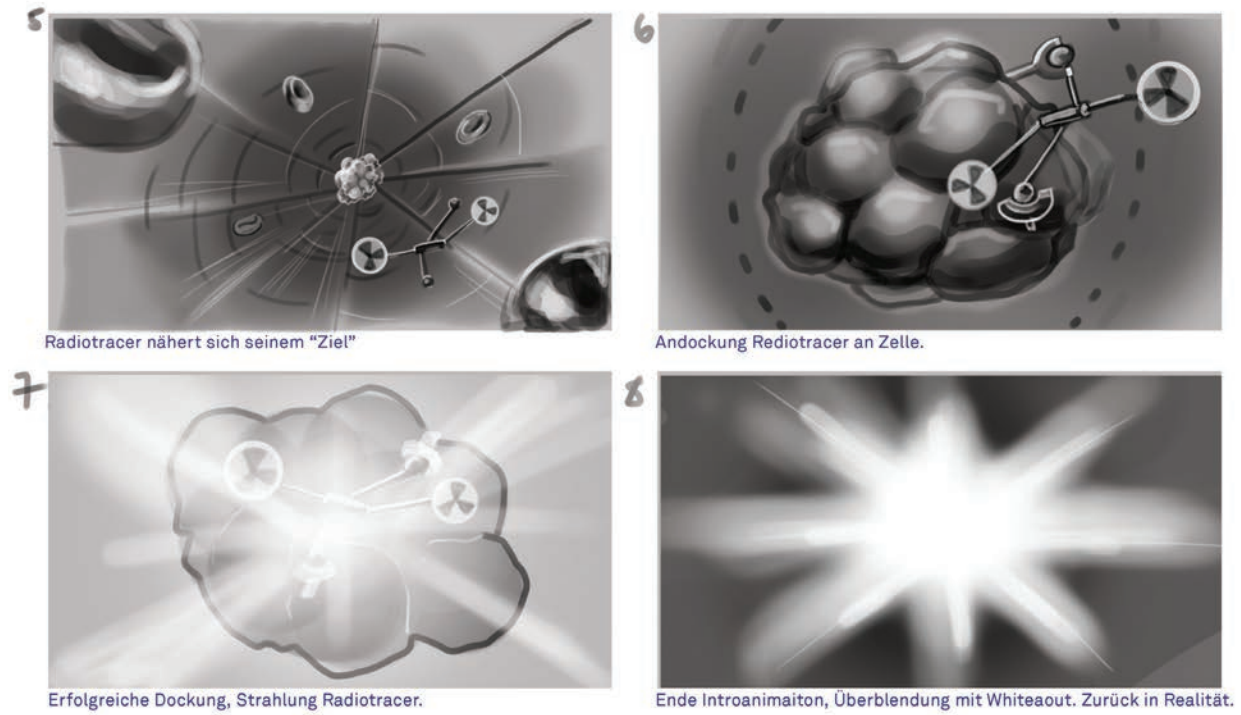


Figure 46 Storyboard Version 2, sheet 2, authors work, 2024.

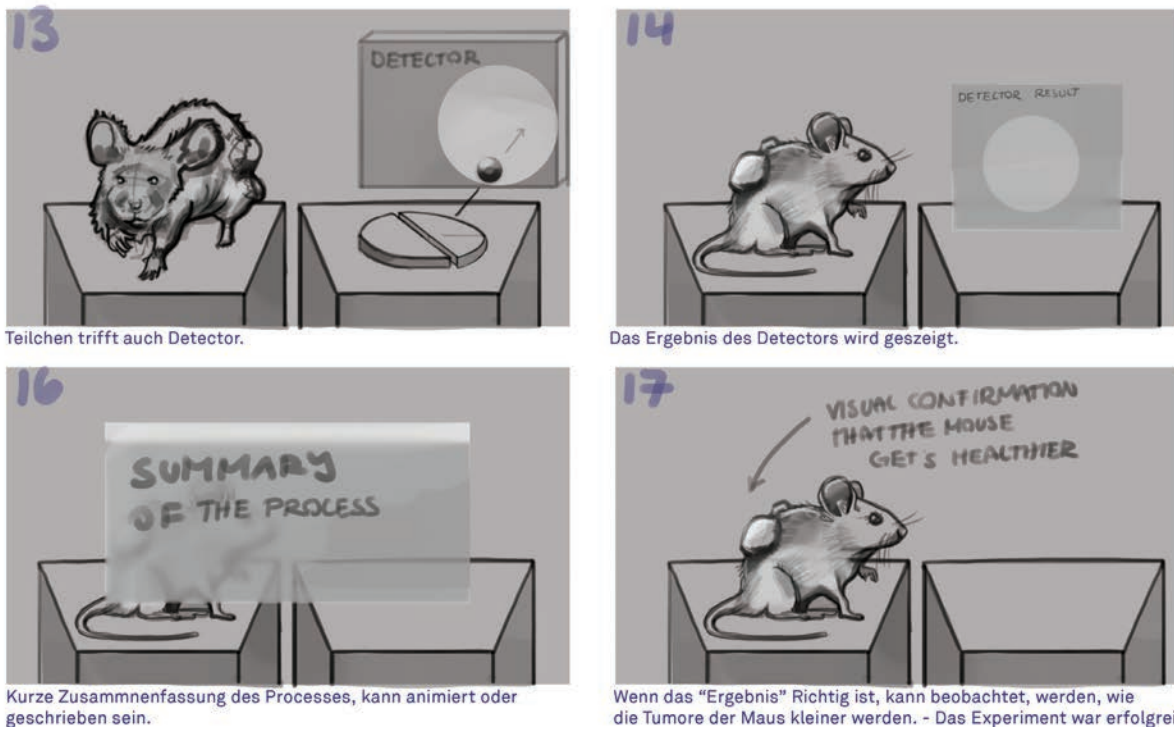


Figure 47 Storyboard Version 2, sheet 4, authors work, 2024

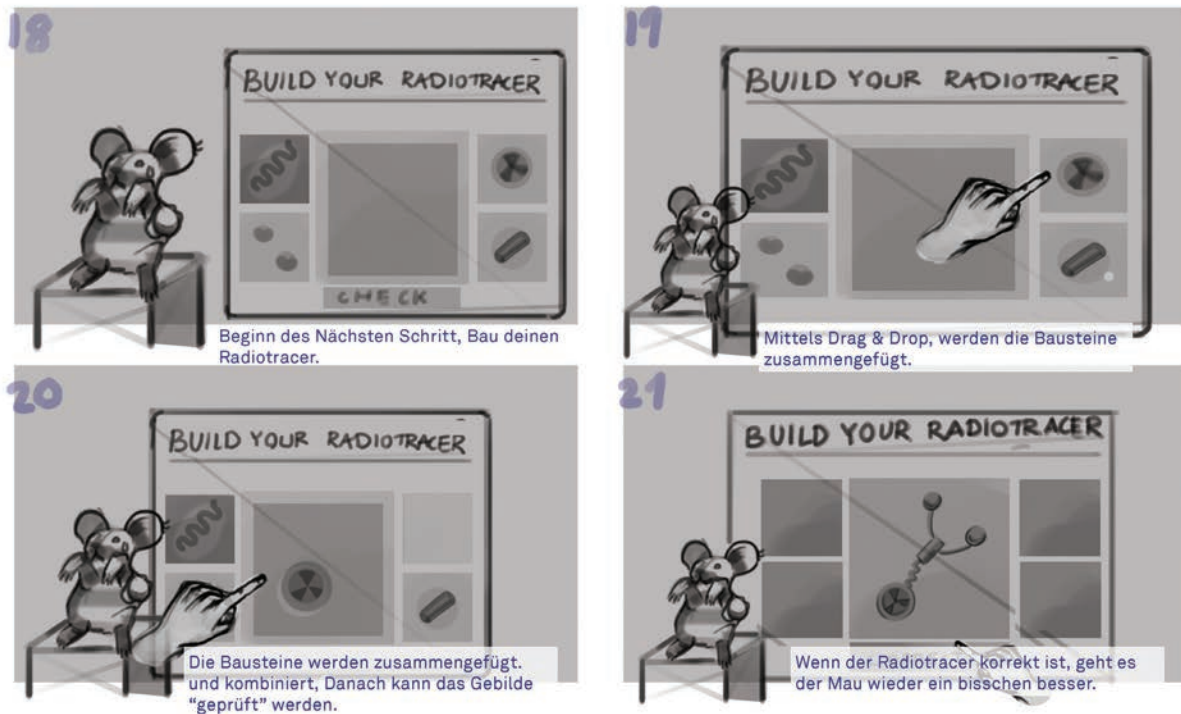


Figure 48 Storyboard Version 2, sheet 5, authors work, 2024.

Findings

We presented this storyboard in the Internal Progress Session 2 and the Progress Session 2. Our partners were happy with the storyboard, the accuracy was on a good level, and they were happy with the intention behind our application. In the Progress Session, our peers understood what we tried to convey and how we wanted to do it. The story seemed to be understandable, and the content looked clear.

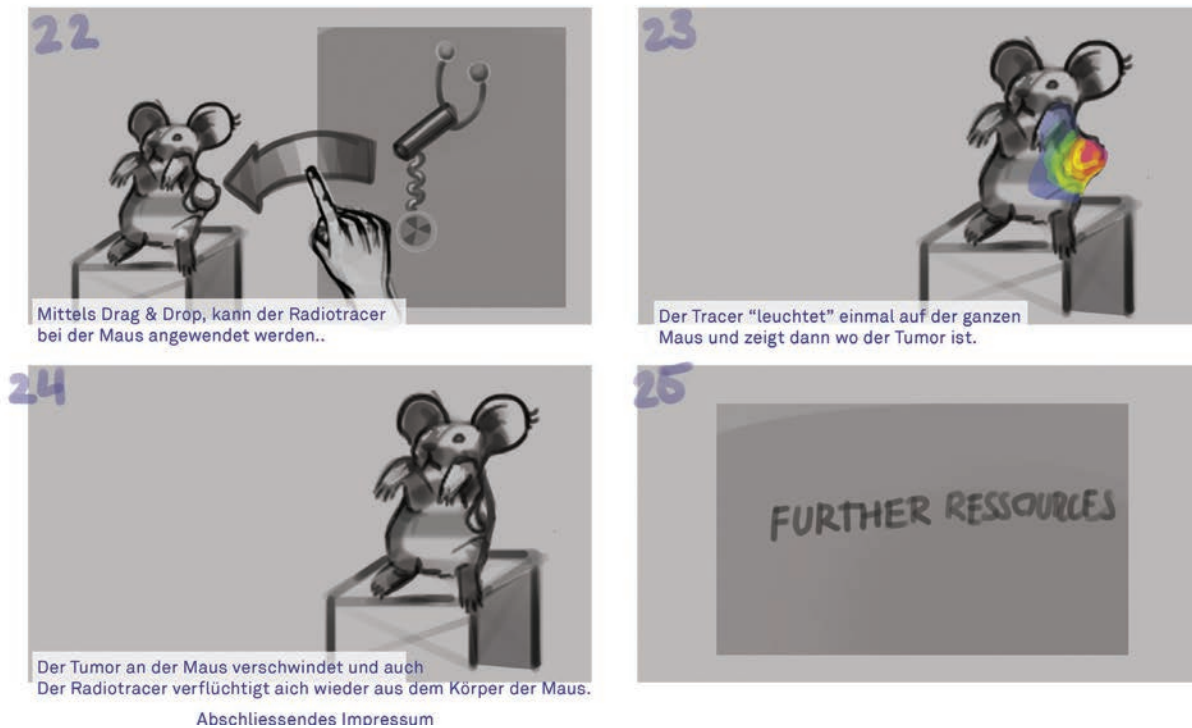


Figure 49 Storyboard Version 2, sheet 5, authors work, 2024.

We had some critiques about our showing of the animal and how we decided not to project the reality of animal testing into our application, but we had our code of conduct, and it was clear that we are not making an application about the reality of animal testing in research, but rather do not want to minimize the animal testing that is taking place in the research. All in all, the resonance was positive and great.

Then, towards the end of March, we got the Apple Vision Pro and started testing the capabilities of the device.

Hardware testing

Internal User Platform Testing

We had two aspects of interaction in mind to test: eye- and hand precision. In a very first user test, we handed the Apple Vision Pro to our third-year class colleagues to let them try it out with eyes and hands set up by Lukman first, then by themselves.

While in every case no hand set-up had to be redone by colleagues, almost every person had to undergo individual eye setup for its tracking to be precise. In most cases, intended controls and surfaces were not highlighted or highlighted by another UI element. The hand setup was less of an issue because every person could in real space either spatially reach the UI by hand or perform taps. However, for less tall people the windows and volumes appeared to be wider away, so they had to walk or sometimes even jump towards the desired UI elements they wanted to select with their eyes. Even though a long press on the Digital Crown rearranged all windows and volumes towards the users' center field of view in space, it was still a hassle to get the precision under control. (Apple, Inc., 2024!)

Why is precision most important? A correctly, desired, intended initiated user input builds on top of every fluid user experience on the journey. We must make sure that the visitors can take on the headset without further setup on the system settings while maintaining precision for every eye constellation, even in edge cases. Our greatest challenge lies in the upholding of precision the current headset and its operating system version provide.

If someone mis-clicks a control without intention, we lose a user as much as we would introduce an additional, redundant click in the user flow. We know we are dealing with an important currency. The users' retention is fragile in this

stage, especially when it comes to familiarizing oneself with a new platform with interactions to first grasp and learn from.

People feel intrigued if the device or the design does not do something they intended to. And it is not the users' fault. In addition to the reason of platform choice comes the responsibility to also explain the platform to newcomers: Onboarding will therefore play a central role. The fundament of our application therefore lies in the user ergonomics of the headset on one hand, and on an onboarding experience that familiarizes the user with spatial interactions they already know from the two-dimensional world – only then we can move on in the journey.

We then realized that we had a problem. The storyboard and how we had conceptualized it was perfect for a VR device, but did not show and legitimize our use of the vision pro. In mentors, peers and partners understanding the capabilities of the vision lied in the Augmented reality components and not in its VR. Yes, the technical capabilities were interesting and impressive. But if we wanted to do an VR application, we could have done this with any VR-glasses on the market. Those would have been more accessible for a fraction of the price. We started with marking every frame in the story that could be done in an iPad and discarded those.

It was not only the technical aspect that started to give us a feeling, that this could not be the final storyboard, but also how the story was working now. We were unsure if we even conveyed the research process. And by asking us these questions after Progress Session 2. We decided to go back to our roots, look at our credos and ask the experts for guidance and help.

Our findings from this storyboard were the following:

01. *We need to work with AR in mind, interacting with screens in a virtual world does not cut it.*
02. *The user needs to explore and understand.*
03. *We have no clue how research works.*
04. *We need sound.*

For our next iteration we decided to have a workshop with the researchers, The findings of the workshop can be read in the chapter: Workshop HollandLab - Findings. We went back into the research phase and decided to focus not on an application that would be in a scholarly way but be more optimized for an exhibition setting.

From this research phase we had one important finding. The research was so complicated and requires such an amount of pre knowledge, that we could not in good faith assume, that there would be a way to visualize this in an adequate way that it would be fair for the pre-knowledge of our target group. We did not want to have the user leave the application with a feeling of defeat and non-understanding. This would have the opposite effect on our target group that what we wanted to achieve. The process of research could be communicated, but it would be more interesting and valuable to have the user experience and discover the outcome of the research. By communicating this we could really show, why this extensive research was done. Communicating the outcome would be our new target.

For the final conceptualization we decided to focus on UX/UI guidelines that would be set by apple, as it was the platform we are developing on, but adapt them to a way that would suit us the best. One thing that we immediately noticed was, that the intro-animation would be a great jumping of

place to start the new storyboard. We decided to make the intro animation interactive and use it as a starting point to

We had also neglected the soundscape of the animation. We could use sound to back up our visualization and use it for a more inclusive and more accessible experience. The sound for our application should come from the lab where the work was conducted that we were visualizing. In our second laboratory visit, we captured the sound.

Storyboard Version 3

In this storyboard we implemented our findings from all the previous storyboards. We concentrated on the parts that had already been cleared for their scientific accuracy. We also concentrated on the part that would be most suited for immersion. It was also an argument, that we would concentrate on the result of the result of the research. This would also allow us to not concentrate on the animal testing. As the animal testing is a tool to achieve the result of the research. The core idea was to have the intro animation interactive.

After a short onboarding, that shows the user the core interactions and gestures, the user would be in a bloodstream. The elements of the blood would fly around the user. The elements like the blood cells and different elements in the blood would be interactive and could be tapped for further information. This mechanic would incentivize the user to find out about the elements on their own. The user would then travel with the tracer through the bloodstream until it would find and interact with the cancer cell. The time gesture would be accessible all the time, so the user could watch the interaction between the elements in slow motion or sped up. However, the speed they preferred. The implementation of scale would show the user, what was happening with the tracer in the bloodstream and how it interacted with the cancerous cell. In an end animation, the user could see how the tracer could treat the cancer, and make it shrink with the use of radiation.

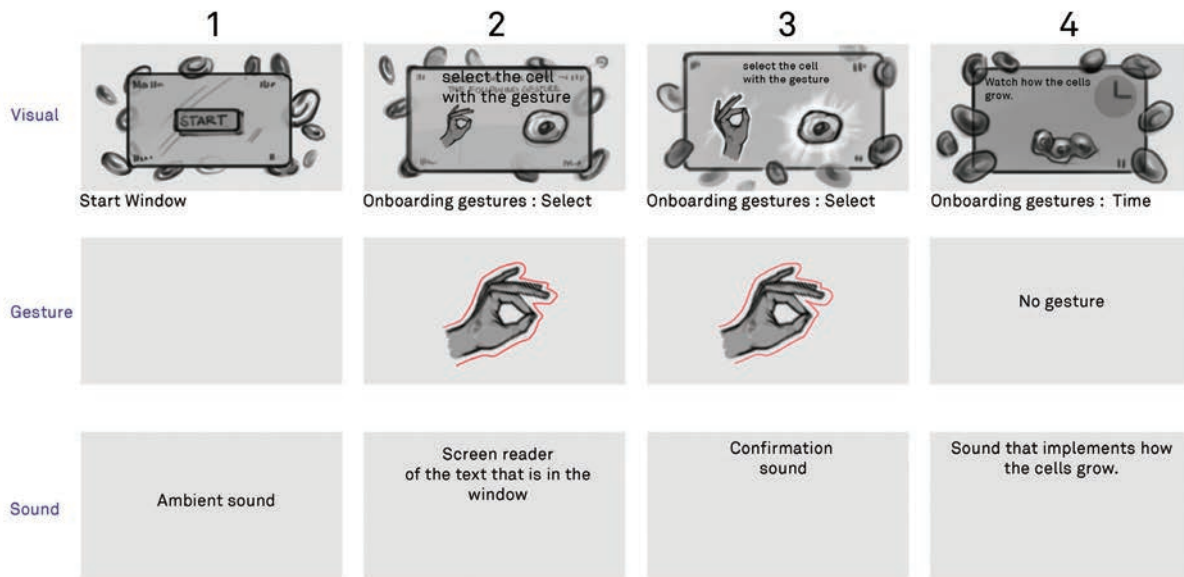


Figure 50 Storyboard Version 3, sheet 1, authors work, 2024

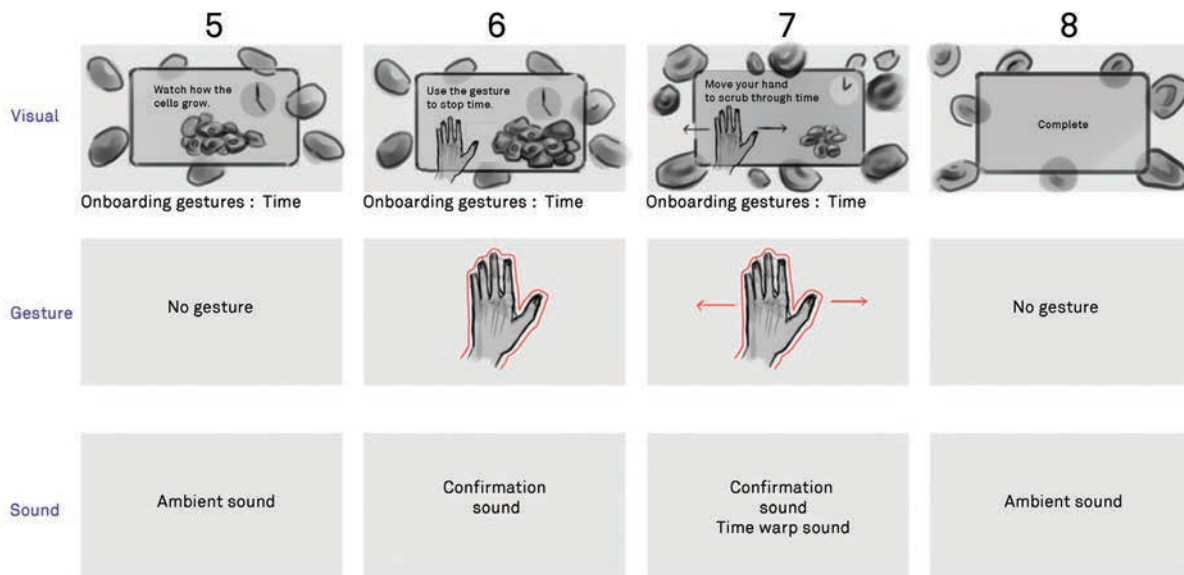


Figure 51 Storyboard Version 3, sheet 2, authors work, 2024

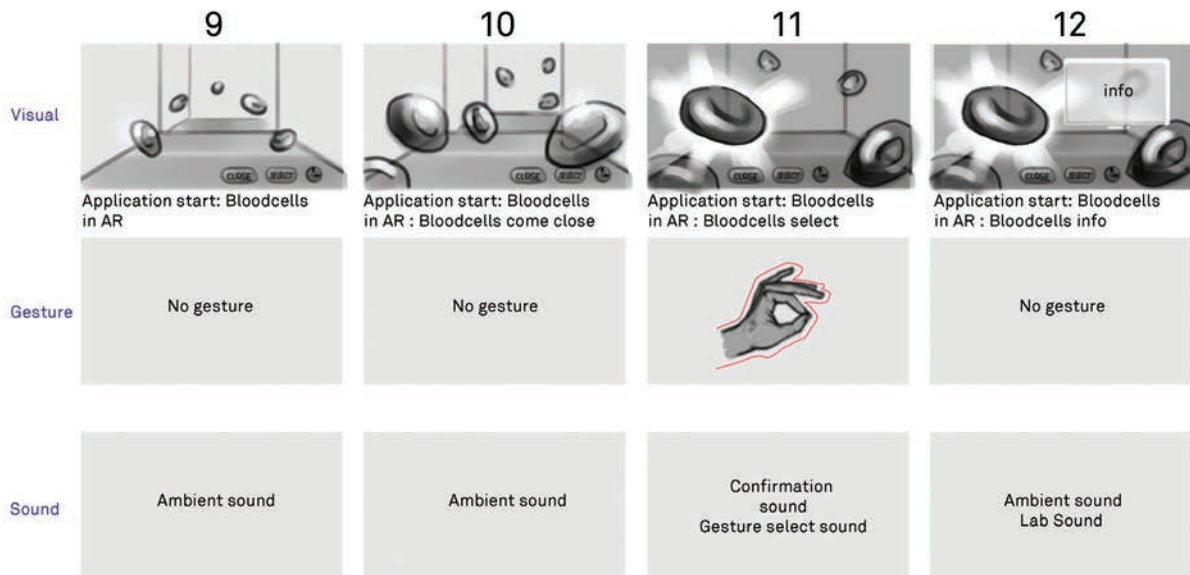


Figure 52 Storyboard Version 3, sheet 3, authors work, 2024

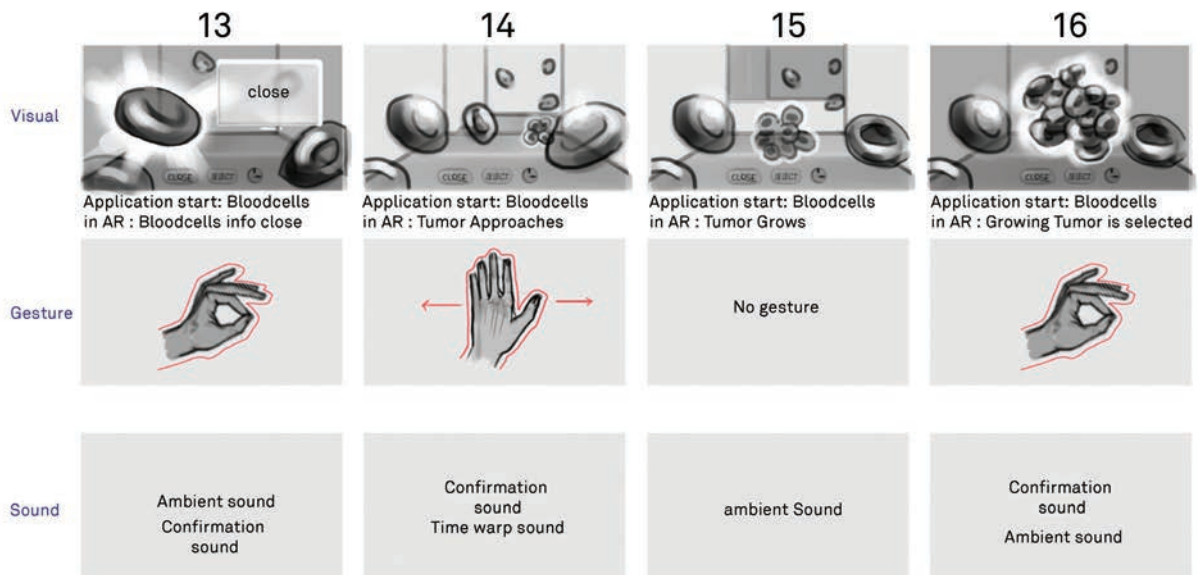


Figure 53 Storyboard Version 3, sheet 4, authors work, 2024

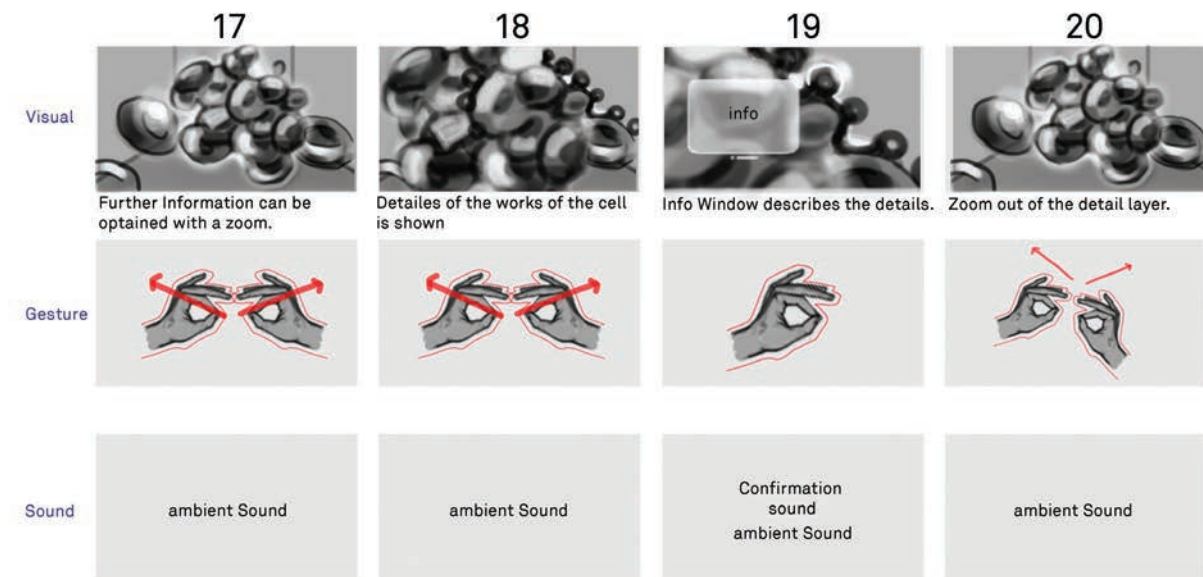


Figure 54 Storyboard Version 3, sheet 5, authors work, 2024

We also added a sound Layer onto the storyboard. This could give us an idea how the application could sound. How we could use sound as an indicator to what was happening on the visual layer of the application. We also hoped to introduce a greater feeling of immersion.

After creating the storyboard, we felt like we were on the right track. To us the storyboard felt coherent and would give the user a great understanding of the story of the research and what the result of the research could be. We thought by not concentrating on the process, it would be more interesting to the user and further understanding.

For the first time we had also included an onboarding process that would explain the user how the different gestures would work and what they could experience. The

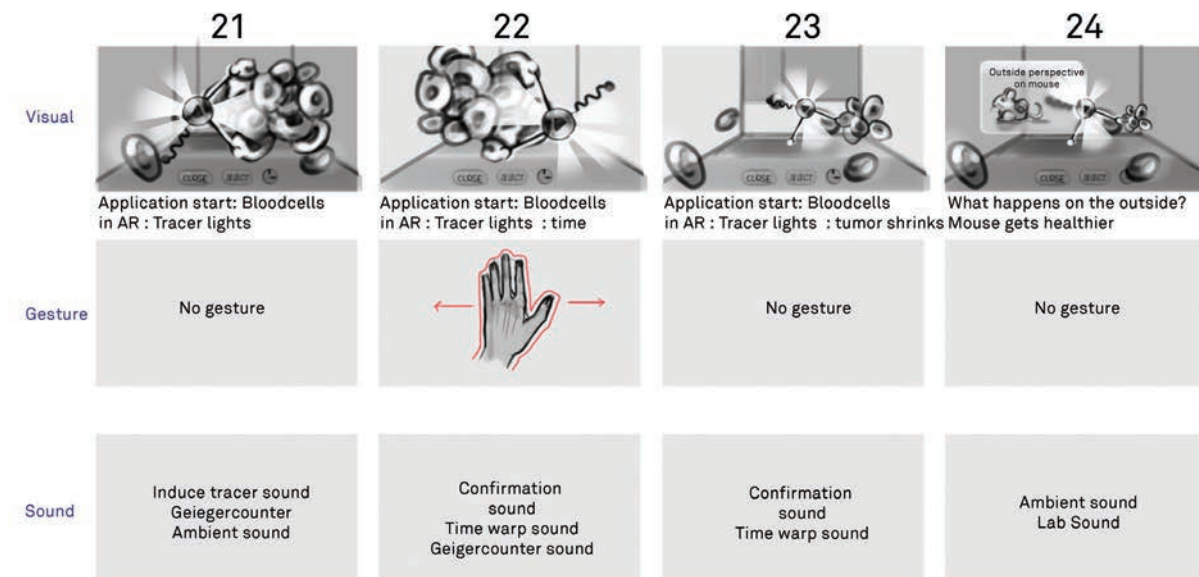


Figure 55 Storyboard Version 3, sheet 6, authors work, 2024

onboarding process would be already in the theme of the application, so the user would already be immersed in the topic of the application.

Findings

We then tested the storyboard by showing and explaining it to our peers and mentors. The critique that we received was not positive. The core critique was, that we had not considered that our application had to be an AR application. If this was not a given. We would not have a well thought argument to using the vision pro. By trying to cut out as much of the classic 2D interaction, we ended up with an application that would not showcase the augmented reality capabilities of the Apple Vision Pro. The problem was not that we cut as much as we could, but that we had not considered the

strengths that our storyboards before had exhibited. The storyboard in this current version would be better fitted for a Virtual Reality application. This is not a terrible state, but it does not align with our vision.

Another critique was, that the user would not understand what was happening in the application. For us it was very clear what was happening and how it would translate to the user and the topic. This problem was arising, as we were too involved with the topic. We had researched and understood what the research was and how it would be translated. To us it made sense, but we had neglected our intended user base. They were not as involved with the topic and the research. They would wear the Apple Vision Pro and would have a time to adjust with the interaction and the technological and then be able to be receptive for the topic of the application.

The last point that we had neglected, that we could and should not shy away of showing the process of the research. Even if it included animal testing. It would be disingenuous to omit that part.

We had to regroup and think about the research that we had done. We had to look at our findings that we concluded from our storyboards before and not let us blind by the capabilities of our hardware. We had thought of an augmented reality application and wanted to reach that goal. We feared implementing real-life objects. We had to shed that fear. We had a great team of partners behind us, that could provide us with the material that we could use in our application and the showcase of it. The research would be the core part of the application nether less. Concentrating only on the result of the research would result in an interesting application, but it would not communicate what our partners are doing on the daily. By using Augmented Reality, we could let the user experience how research is conducted and how the results are obtained. Only exhibiting the result would not highlight the

months and years it takes the researchers to arrive at the result.

The implementation of sound was a great addition and most of the participants asked about the story were happy with this idea, as it would underline the communication of the application.

Our findings after this internal reflection were the following:

01. *We must include the topic of animal testing.*
02. *We must concentrate on what we researched; the process of the research must be the thematic focus of the application.*
03. *For an application to fit into the range of Augmented Reality it needs to interact with the “real world”*

We took these findings into the creation of our final storyboard. We chose to keep the onboarding as it was received well and felt complete. Yet we would have to modify it to match the new storyboard.

Storyboard Version 4

For this storyboard we looked at all the storyboards we had done before and reflected on our goals and ambitions that we had for this project. Of each finding of the storyboard, we chose one that we wanted to have implemented and prove justice too. For the process of choosing what findings to implement we looked at our design methodologies. The technique of sifting seemed to have them most impact. We could write down all the findings, see where we had duplicates and what could be considered outliers. We went back to our credo “show don’t tell” and investigated what our

partners were expecting from us, but also what we were expecting from us. This process deemed to be highly important. Looking back at everything we had done so far, and how we should continue gave us the confidence to go about continuing this journey.

The core findings:

01. *We must concentrate on the process of research. This is the interesting part and can lead to the understanding of the result of the research.*
02. *We must include the topic of animal testing and treat the animal in our application with as much dignity as the researchers are treating the animal.*
03. *The application must interact with real world objects. Only this way the application could be a true Augmented Reality application.*

Not included in the core findings is the sound. We predicted that we would come into a time constraint, and as we both were not trained, nor fairly talented in sound engineering, we decided to keep sound in mind, but to not put our focus on this aspect of our work. We would need to have a soundscape for our application, but we decided to keep this aspect as simple as possible, there could also be an effectiveness in having the soundscape be simple, as the soundscape would then not distract from the content but rather underline the content.

Before drawing our final storyboard, we also chose to do extensive testing with the headset. In these testing we evaluated what was interesting to interact with.



Figure 56 Home, authors work, 2023

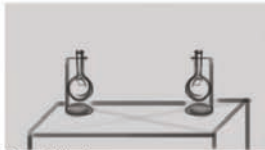
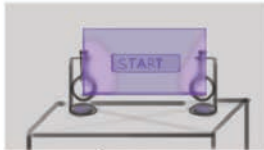


	1	2	3	4
Visual	 Start Window	 Start	 Onboarding gestures : Select	 Start Window
Gesture	No gesture	No gesture	No gesture	No gesture
Sound	Ambient sound		Confirmation sound	Ambient sound

Figure 57 Storyboard final, sheet 2, authors work, 2024.

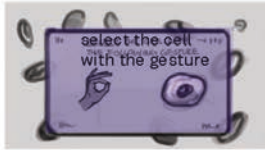





	5	6	7	8
Visual	 select the cell with the gesture	 Onboarding gestures : Select	 complete	 start experience
Gesture			No gesture	No gesture
Sound	Confirmation sound Ambient sound	Confirmation sound Ambient sound	Confirmation sound Ambient sound	Confirmation sound Ambient sound

Figure 58 Storyboard final, sheet 2, authors work, 2024

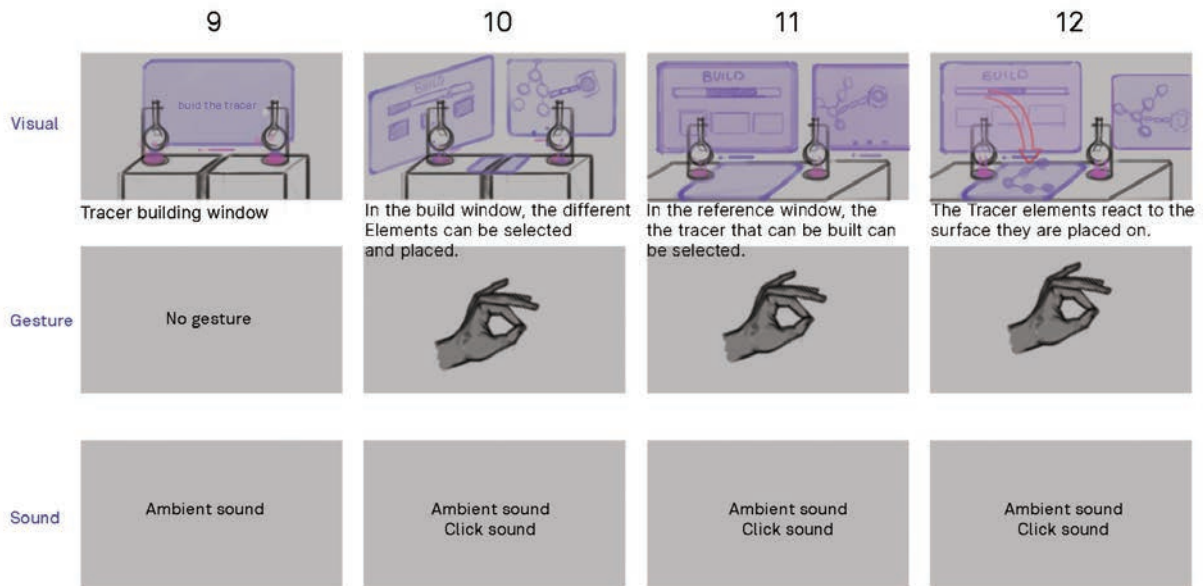


Figure 59 Storyboard final, sheet 3, authors work, 2024.

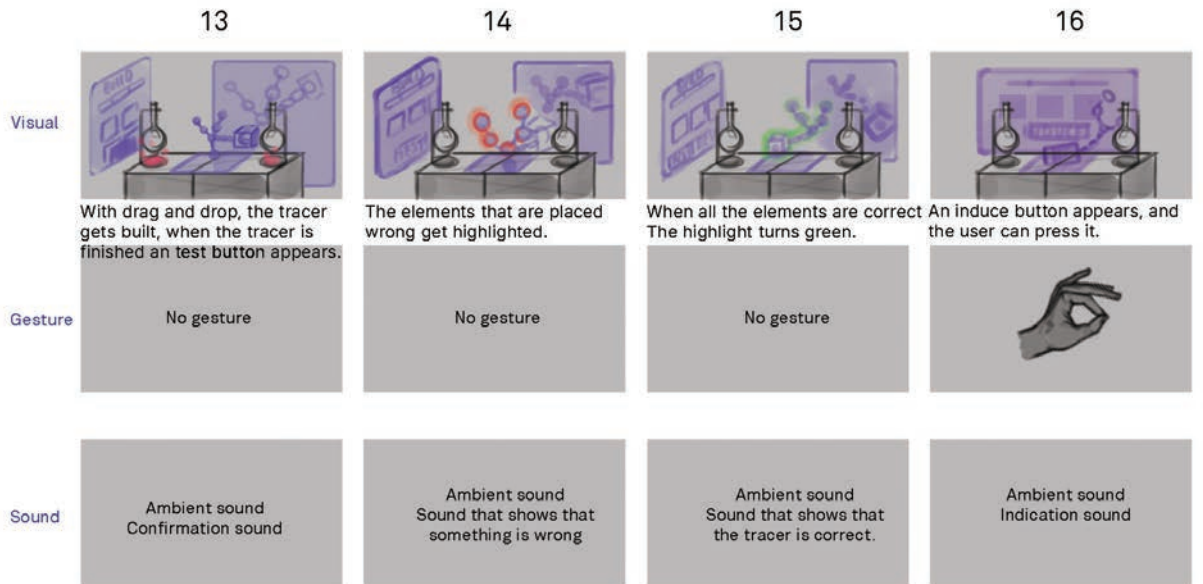


Figure 60 Storyboard final, sheet 4, authors work, 2024.

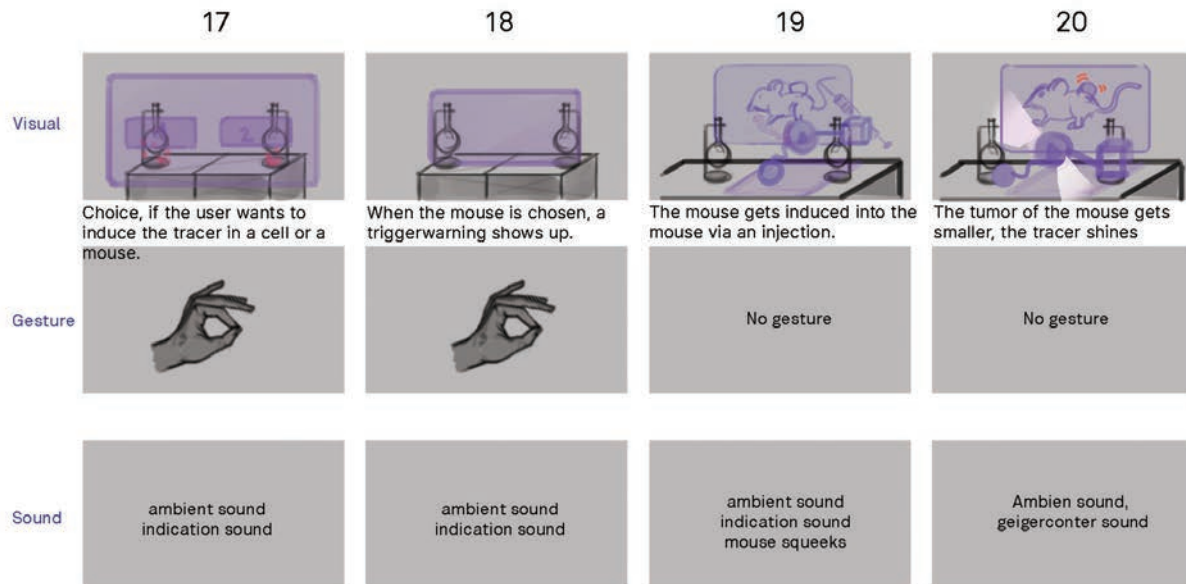


Figure 61 Storyboard final, sheet 5, authors work, 2024.

Looking back at our research we decided to focus the application on the building of radiotracers. We took the User journey of the workshop that we had conducted with the researchers of the University of Zurich and looked at that process. The user would now create the radiotracer from a reference screen. The decision behind the reference screen and how we validated this decision can be read in the chapter user testing. Depicting the building of the radiotracer fulfilled the first one of our core findings. We could show to the user what the different parts of the radiotracer are, and how they attach to each other. This interaction also gave us the chance to depict, what is the specialty of HollandLab. The research specializes in finding new ways to attach these radiotracers together, so they are more stable and usable.

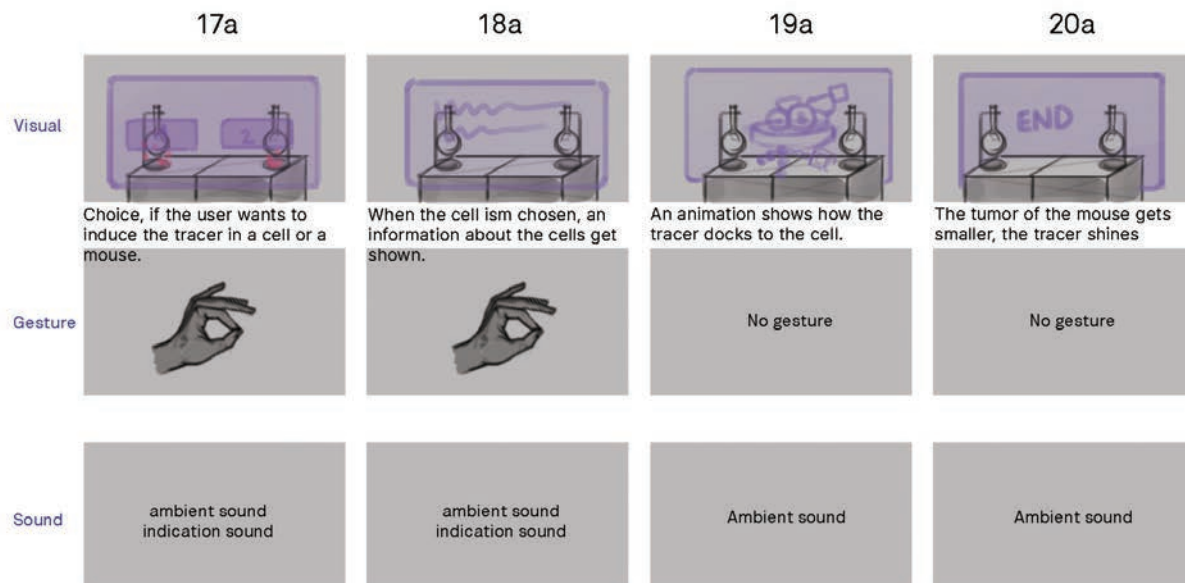


Figure 62 Storyboard final, sheet 6, authors work, 2024.

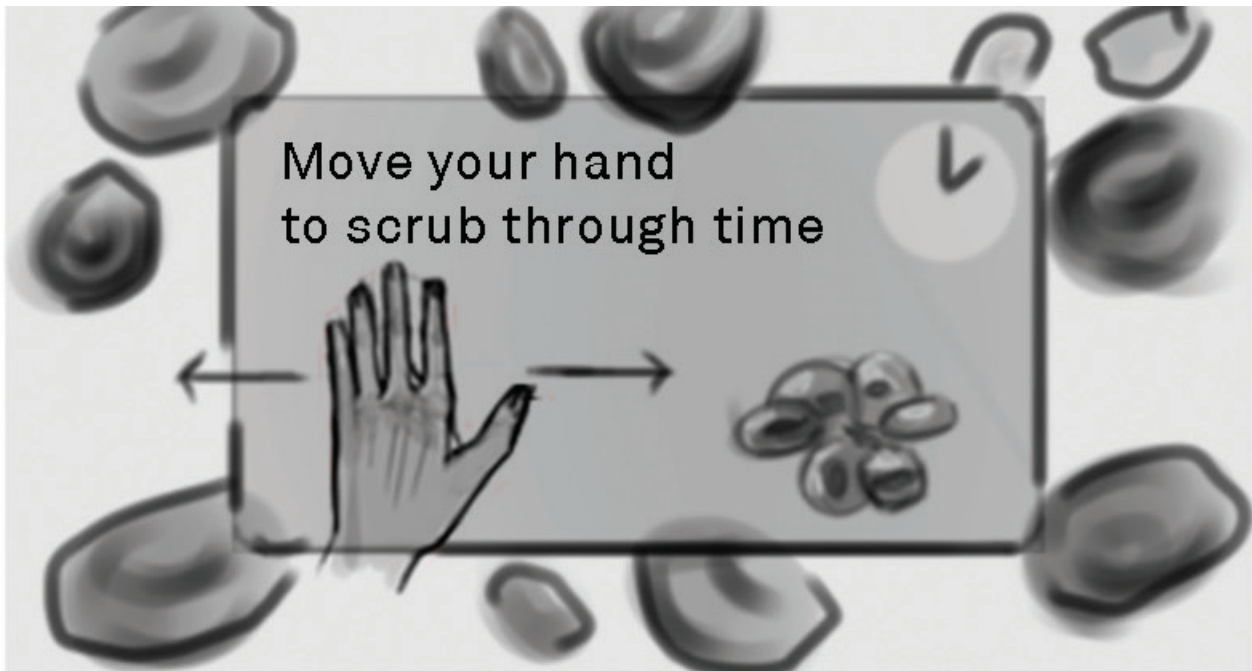
The built radiotracer could now be induced into either a mouse or a disembodied clump of cells. The user would have to take the decision themselves if they wanted to see the animal testing or not. This made it possible for us to depict the animal testing in a more detailed view. The benefit was as well, that we could show two different functions of the tracer. If the user induces the tracer into the cells, they could see how the antibody attaches to the cancerous cell. If the user induces the tracer into the mouse, the user can observe how the tumor on the mouse gets smaller. We felt like it would be fairer to the user, if they could choose how they want to induce the tracer. We wanted to show how animal testing has its part in research, but we also cannot force every user into getting this perspective. The testing of tracers is not only done in mice, cell cultures get used as well and not depicting that would be a negligence on our part.

We implemented real life objects onto our application. The application would now detect the two flasks and interact with them. By creating this simple interaction, we could create the illusion, that the laboratory becomes alive with the application. We can also use this simple micro interaction to make the scene more pleasing and interesting to the eye for the visitor. We found in this interaction a nice analogy, that the laboratory would reveal itself and basically become functional through the vision pro. This was also the usage of Augmented Reality that we had intended.

We had to let go of the time gesture. In first technical tests it deemed to be technically very difficult to implement. We never received very positive feedback of the time gesture, so we decided that it did not further the narrative of the application enough to warrant the expense it would require to implement.

Findings

This was the final storyboard. After we had created this storyboard, we went into the development and design of the application. From this storyboard we learned that we should have had more trust in our research. Creating three benchmarks onto which we built the storyboard seemed to be more fruitful in this stage than to just implement the findings from the last storyboard. Creating these benchmarks from all the last storyboards gave us the impression that we had implemented the whole process into our final storyboard. We could see what had influenced which decision. And so most decisions were funded and did not feel like assumptions.



Onboarding gestures : Time



Figure 63 Storyboard Version 3, sheet 2, authors work, 2024

Previewing virtual 3D content

One important method of making our storyboards visually and digitally tangible was previewing our intended 3D content without having to code. This is a conscious decision as to not invest time in an advanced technical prototype during a phase where the concept idea is not finalized yet. We wanted to iterate on one more storyboard version before moving on to a more complex prototype was deemed viable, but for our case that would mean the start of the actual app.

The no-code workflow is an effort Apple is making with Reality Composer Pro and has made so with Create ML, to create 3D virtual content and preview them directly to the Apple Vision Pro or, respectively, to train object detection classifiers without the need of Xcode.

(Apple, Inc., 2024c;
Apple Inc., 2024)

As we now have obtained the device, we started using this feature in regard of our tighter time schedule. We also used this method to our advantage as an acceleration of the concept phase. It is important to note that previewing our 3D models from Reality Composer Pro into real space was a disabled feature until we connected the device. Since the stage of the third storyboard version, this form of rapid previewing has followed until the end of the project.

(Apple, Inc., 2024h)



Figure 64 Preview of the blood cell mode, author's work, 2024.

Previewing the storyboard and video in 3D

In preparation for the third and last meeting in the design department, we on one hand prepared a video to communicate the user flow developed from our storyboard iterations. While this was more time-intensive to model and keyframe, it was an efficient solution in presenting our viable proposal as a programmed version would not be ready by that time.

On the other hand, we wanted to showcase the look and feel of the app by staging it in a 3D reconstruction to view from different angles. Both the video and the 3D reconstruction of the dedicated space were well received. It communicated what we had in mind in a timely manner.

From the last storyboard we created an animated video. This gave us an idea of the flow of the application. It was also good to see how the visuals and the sound would interact. We had not implemented the reference window yet in the video, but still it was a valuable test. From this video prototype we learned, that. It would not need too much sound. Short but impactful sounds would be more valuable than a complicated soundscape. The video was also a good way to show how the application would look to our partners. After they saw the video, we received the go to start with the development and final design.

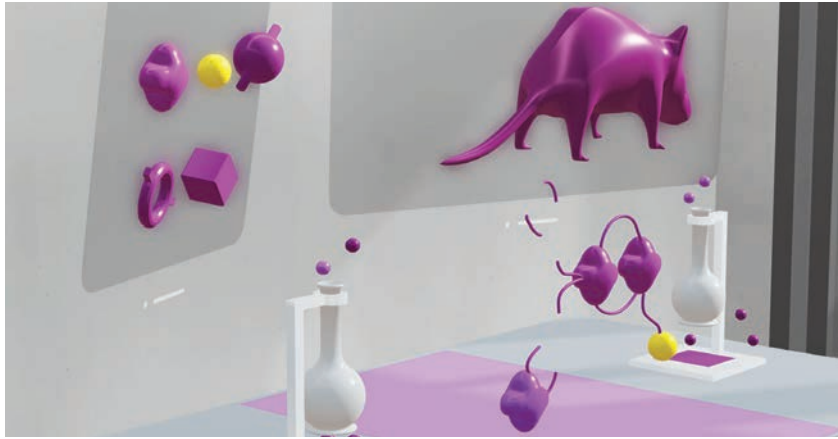


Figure 65 bezel.it prototype, authors work, 2024.



Figure 66 Screenshot Video Prototype, authors work, 2024



Figure 67 Screenshot Video Prototype, authors work, 2024

Happy Path prototype

The flow designed in Figma would mimic the building of the radiotracer. The user had to arrange three different elements in a in the beginning specified pattern. The interaction was a drag and drop interaction, the shapes were simple squares in different shades of grey. The user had to arrange the elements and could then test if they had found the desired combination. The test was that they had to compare two different outputs that the combination generated. If the outputs matched the combination was the correct one. The whole user interface was designed to be as boring as possible from a user experience standpoint. Having it as boring as possible would give us some leeway in our own design, as this would be more colorful and interactive.

The prototype was presented at the Progress Session 2, were in total five of our peers interacted with is. The data was collected in maze. This gave us a better overview of what was happening and how long participants were interacting with it.



Figure 68 Figma prototype start screen, authors work, 2024

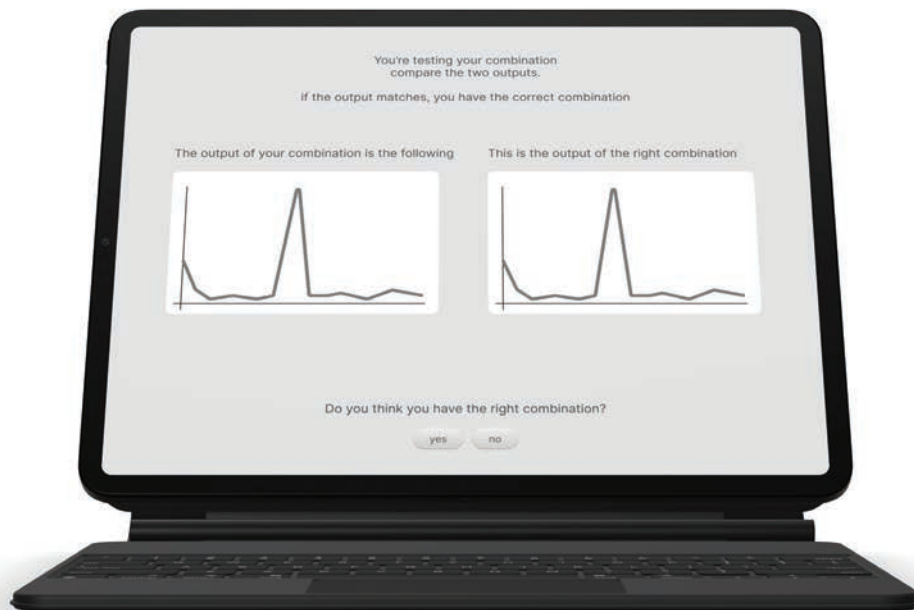


Figure 69 Figma prototype test screen, authors work, 2024

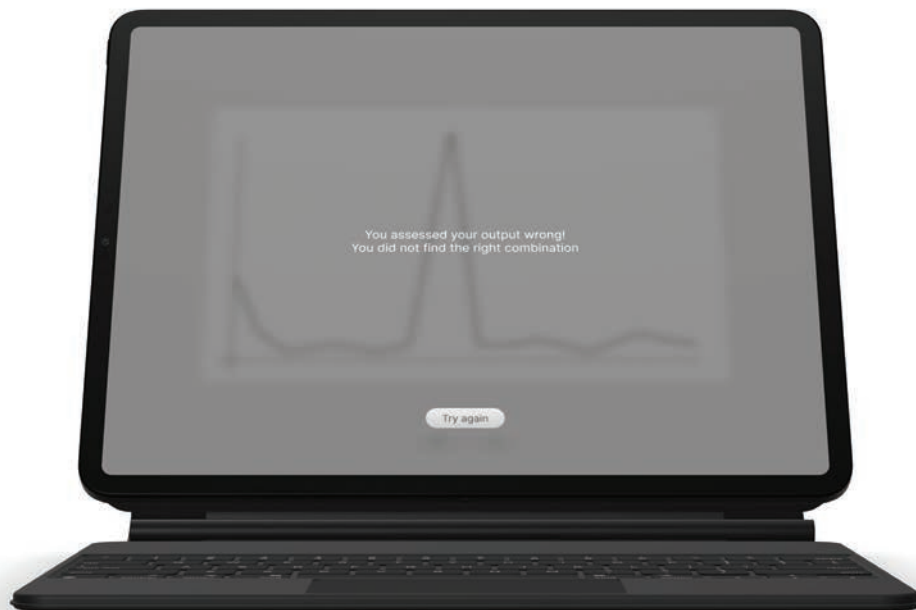


Figure 70 Figma prototype end screen, authors work, 2024

Findings

This prototype gave us the insight, that the user is not very tolerant to boredom, but very eager to achieve a goal. In the data we could see that some users were very eager to achieve the desired combination and interacted with the prototype for a long time given its visual language. Other users got bored very fast and gave up. In the questionnaire that was appended in the end of the test, participants that had a short interaction time told, that they did stop the program as they did not know for what they should find the desired combination. Users that interacted with the program for a long time stated, that they wanted to find the combination out of satisfaction and eager. We were present at the flow and could observe our participants. In most we could see some visible signs of distress and frustration. From that we concluded that it would be important for the user to know why they were completing the application. There needed to be a clear communication on the goal of the “game”. The program could not take too long, it should have some difficulties to it, but not too much. We had to find a sweet spot between difficulty and intuition.

Creating the prototype gave us another finding. It became clear to us, that we were dealing with mathematical permutation. The combination of the tracer would be a non-linear permutation. This was the case because the elements would be in a 3D realm. The combination that came from the combination could be rotated and moved in the 3D space, so the position of the individual element would not matter, but how the elements were chained together and their position in the chain. This meant, that there actually were not that many possibilities to arrange the elements. This meant, that the process of creating the combination had to be difficult enough, so the user would not just try everything through without learning anything.

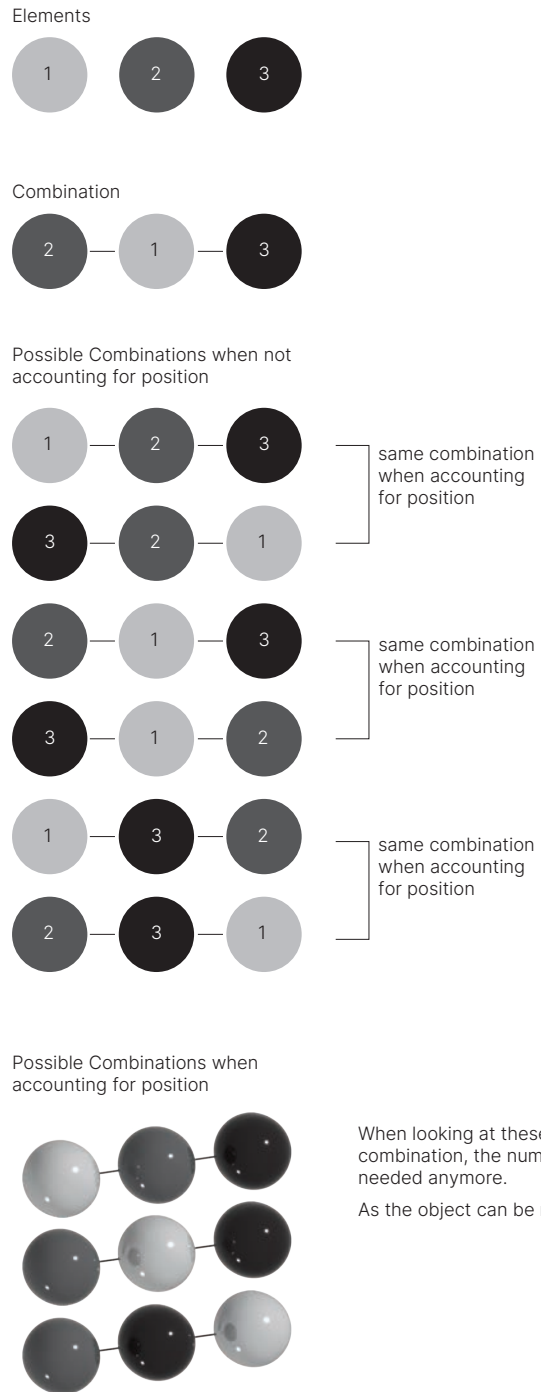


Figure 71 Graph showing the permutation, author's work, 2024

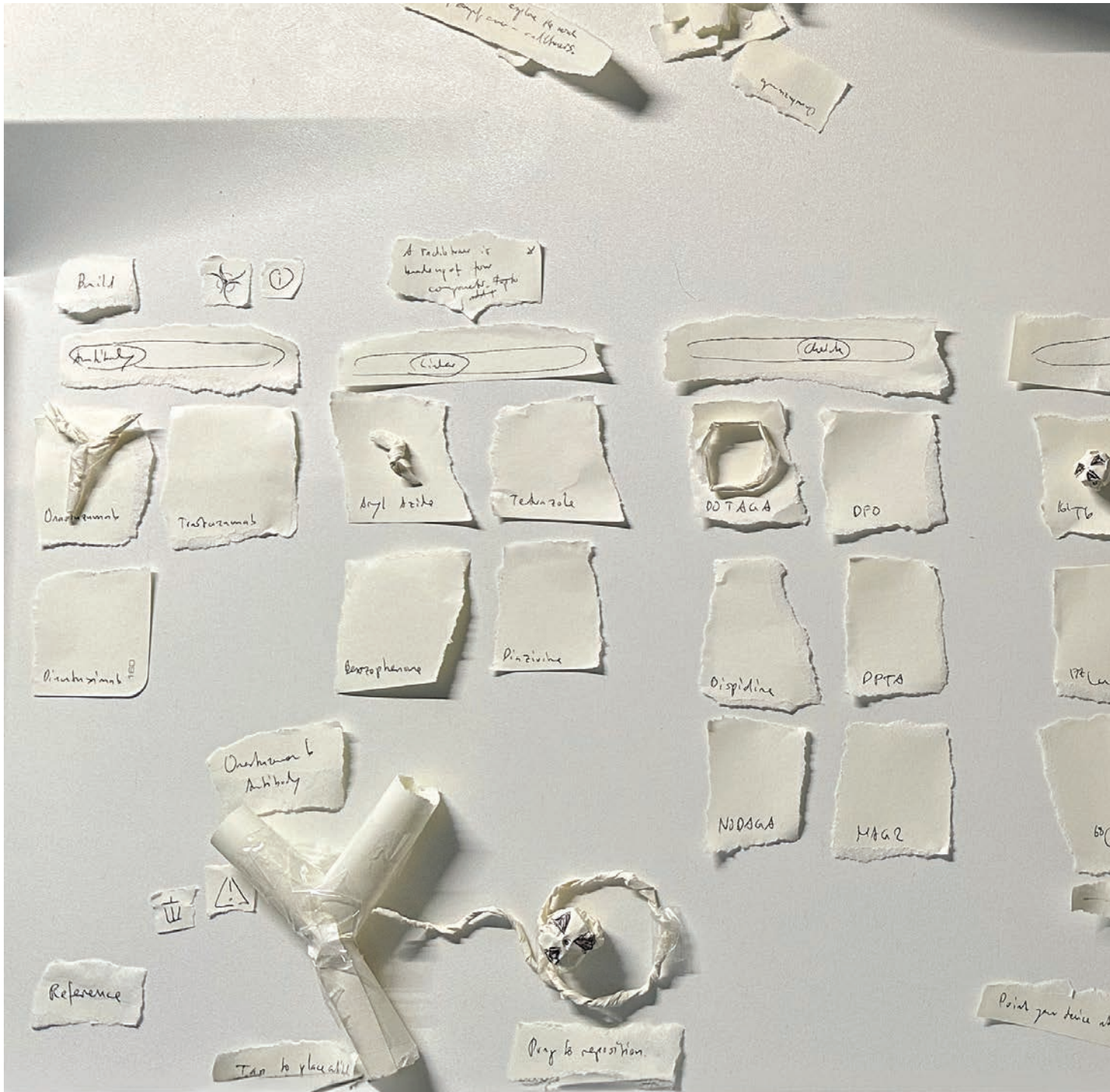
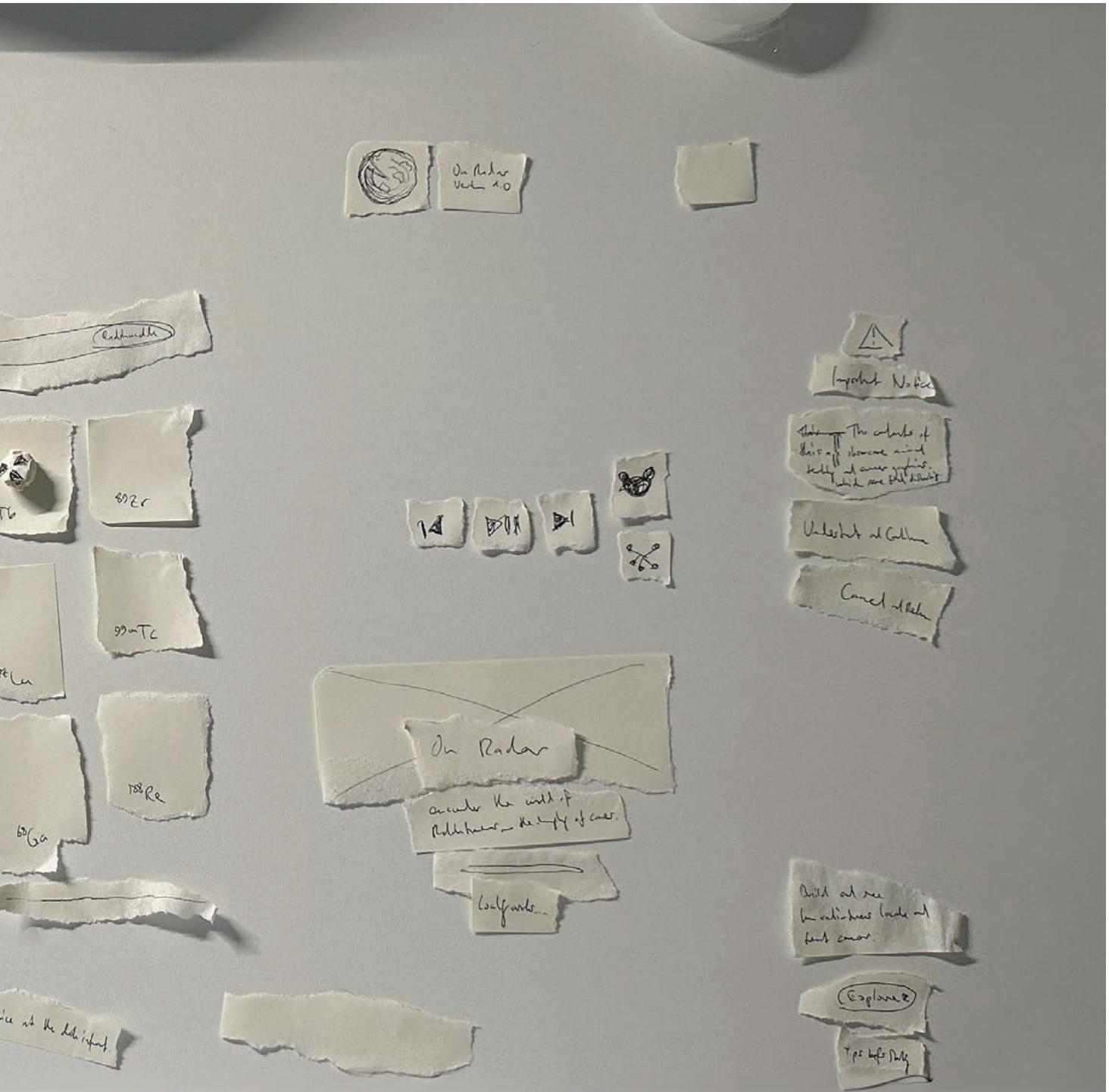


Figure 72 Paper Prototype of the UI elements, authors work, 2024



Production Pipeline

In effort to make the app project of our thesis reproduc- ible for interested readers, we wanted to dedicate a chapter on the tools, development environments, and frameworks we used to make On Radar compile on the Apple Vision Pro.

The main production pipeline can be generally split in a.) modelling and texturing the virtual 3D content and b.) pro- gramming the app that bundles 3D assets, logic, and user interface. We create and animate our models in Blender, tex- ture them in Adobe Substance Painter 3D to export them as USDZ files, which are then imported in Reality Composer Pro. From there we prepare our assets to be linked with Xcode, the development environment for building on the Apple Vi- sion Pro. We use SwiftUI, RealityKit and ARKit as our main frameworks to handle user interface, gestures, tracking and logic. With Git, we document our steps towards realization of the final app.

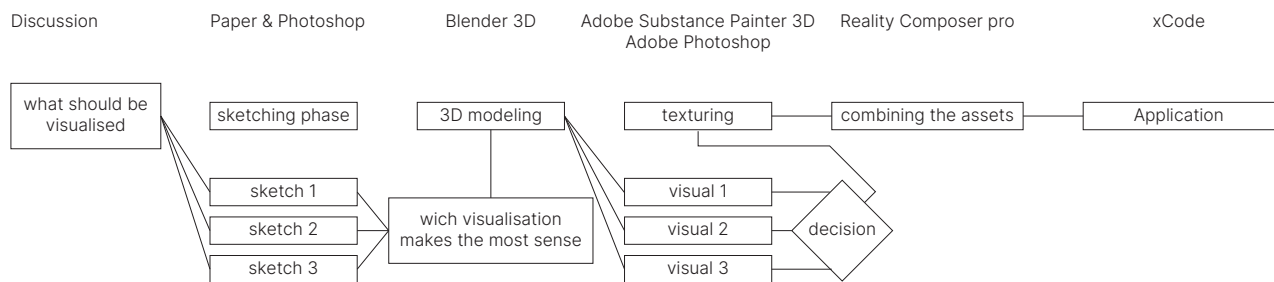


Figure 73 Production Pipeline graph, authors work, 2024.

Blender

Blender is an open-source, free 3D modelling program. We evaluated different solutions for our modelling but ended on Blender for the following points. Upon this fact, there are a lot of sources that can be found on the internet. Every problem that has occurred to someone with Blender has occurred to another person as well. For nearly every problem there exists a plug-in or a tutorial. The fact, that both of us had several years of experience with Blender and its workflow made it an easy choice. There is the critique in Blender, that it is not the industry standard and because of that reason, it makes it hard to collaborate with other creatives. But the Blender community is extensive, and we were not working with outside help. The integration of Blender into our workflow was easy and intuitive, why we did not regret the choice.

The fact that we were not planning to do any sorts of texturing in Blender also was ideal. We could use Blender as a standalone modelling software and choose different, better suited software for texture painting.

Substance Painter 3D

In early sketches we tried to do our texturing in Blender as well to have everything done in one software. We quickly realized that Blender is not optimized for the creation of assets for Reality Composer Pro. The biggest setback is that due to the qualities of spatial computing we were working with a real time render. A real time render is a render engine that is working with continuous data input. This makes it impossible to prebake materials, especially normal maps. One of the hardest problems we faced when working with Substance Painter 3D, was that the seams of the UV-maps started to appear. This gave the models a cheap quality, that we were not looking to have. The problem with this problem was, that the error was not consistent over the models. With some models we faced this problem, while other where

completely fine. It was not clear if it was a bug in the software (this was highly unlikely, as Substance Painter 3D is the industry standard when texturing 3D models.) or if it was a problem with the UV unwrapping. By furthering our understanding of the USDZ format, we were able to eliminate that problem.

USDZ

Early on we were confronted with the new file format USDZ. It was integral in our workflow with Reality Composer Pro and Xcode. The USDZ format (Universal Scene Description Zip) is a format that is based on the universal scene description framework by Pixar. It is a format that includes all the necessary details to display a 3D object, without external dependencies. Considering that we did all modelling in Blender, it was perfect for our workflow. Once we got all the different components that a USDZ file contains, it was easy to choose the best suited software for each of the component. Figuring out the USDZ export from Blender was tricky, but thanks to the open-source community not impossible to figure out. An interesting thing about the format was, that it has some limitations. Mostly considering shading information. We decided to embrace these limitations and include them into our design guidelines.

(Cloudinary, 2024)

The USDZ format works with a root system. This means that every mesh is placed in its own scene with its own origin. By figuring out how we could only export the root that was directly attached to the mesh we solved the problem of different root systems overriding their origins. This fixed the shading issues as the UV maps took their coordinates from the root.

Reality Composer Pro

Reality Composer Pro is an integrated application of the open developer tools in Xcode, developed and designed by Apple Inc. and released in 2023. It is aimed for importing, editing, and previewing USDZ formatted files, audio, and custom materials and much more. The developer tool prepares the accompanied classes and structures for us to programmatically incorporate them in our app code base, in which all our imported models and files are created at build-time, so no further computation is needed in app run time.

(Apple, Inc., 2024h)

The app offers an ability to preview our imported 3d models, allowing us to quickly get an early feeling of how objects are situated in the real space. The preview system noteworthy and for the design process helpful features 1.) scaling through zoom, 2.) all-axis rotation through pinch and rotate, 3.) placement on any desired location in real space and 4.) reaction to the light conditions in the real environment. In Reality Composer Pro, after importing, we place our desired 3d models, audio files and particle emitters on a so-called scene. One scene is therefore made up of many objects we want to display in our app later. A Reality Composer Pro project consists of multiple scenes.

(Apple, Inc., 2024h)

(Apple, Inc., 2024h)

Xcode

Xcode is the integrated development environment by Apple Inc. used for building apps, frameworks, and platform extensions for all Apple platforms, namely iOS, iPadOS, watchOS, tvOS and most recently visionOS. The latest version of Xcode 15, just as Reality Composer Pro, also comes in favor of the design process, namely with its own preview system. Since Apple's introduction of its new UI framework SwiftUI in 2019, the workflow has not just been eased for developers, but it opened the door widely for designers to take part in UI-level development. The new preview canvas renders UI and code side by side on the IDE and allows any code change

to immediately re-render the canvas. The previous workflow required compiling and building the whole app project every time the developer makes a change in the code. We now have a real-time editor to view our changes made to the coded UI.

Without touching deeper levels of the code base, we can thus intertwine our design practice closer to the UI- and UX engineering aspect of prototyping, leaving the lower-level, abstract aspects of the code base to the software developer.

(Apple, Inc., 2024t, 2024p)

An Xcode project includes all the supporting files, including code, assets and packages that are compiled for installation on the headset. The Reality Composer Pro project is also stored in the Xcode project hierarchy but decoupled as a standalone Swift Package. This allows us to separate the code from the 3d model domains and keep the project as clean and decoupled as possible, while still having access to the respective files.

(Apple, Inc., 2024t, 2024h)

Xcode simulator

Among the open developer tools such as Reality Composer Pro is the Simulator app that comes bundled with Xcode, and it is also tightly coupled with the IDE. This program, as the name suggests, allows us to run multiple simulations of Apple's operating systems on the Apple Vision Pro or iPad and more platforms without having to rely on a real device. However, when it comes to hardware capabilities such as sensors or cameras, we must fall back to a real device. Testing gesture input or ARKit and RealityKit features undisputedly require us to test on real devices.

(Apple, Inc., 2024i, 2024t)

Testing our assumptions and iteration through an actual device is an important aspect of our process. Not even the visionOS simulator on Xcode could bring us close to the findings than experiencing the prototypes on the device. Nonetheless, the simulator gave us more advanced preview

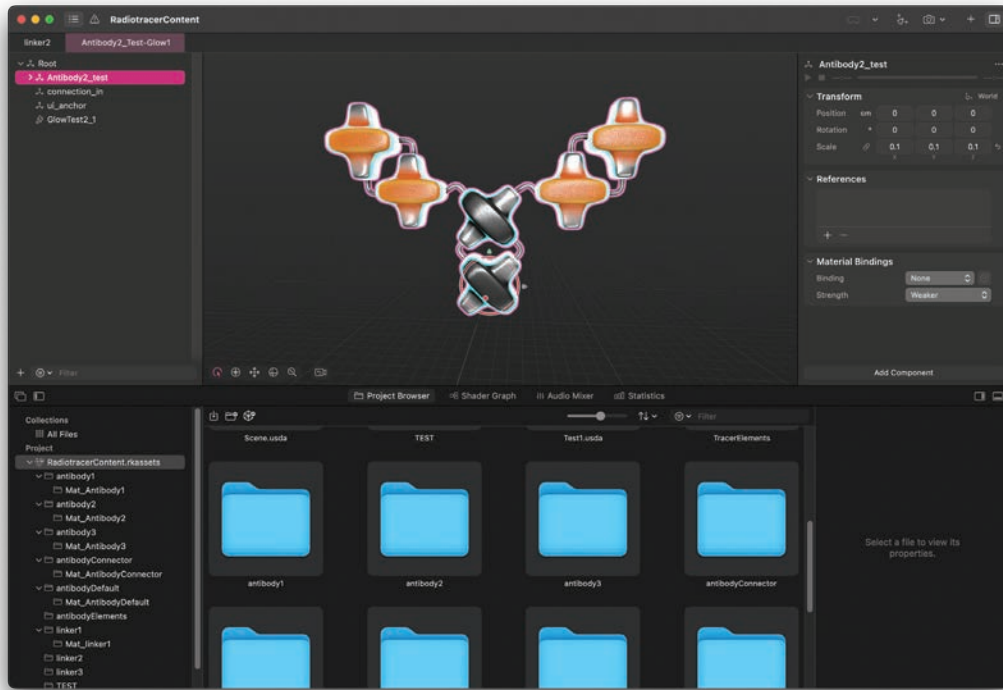


Figure 74 Screenshot Reality Composer pro, authors work, 2024

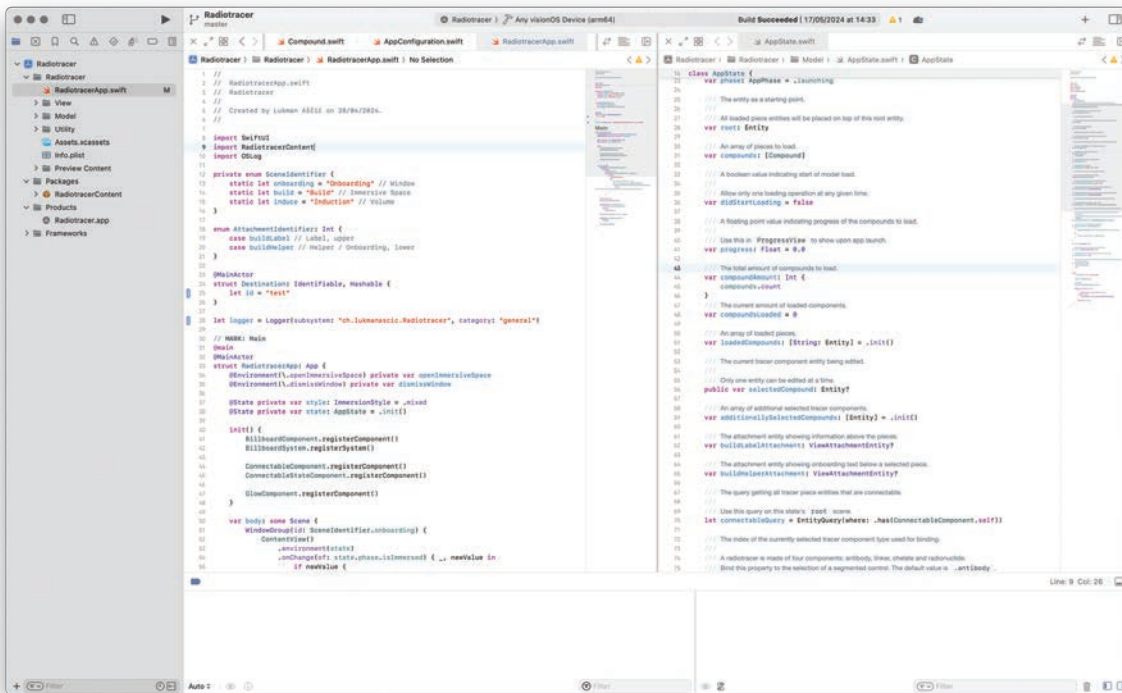


Figure 75 Screenshot Xcode, authors work, 2024.

settings with run-time logs and debugger messages. Also, on-device testing is not always needed so it depends on which previewing method suits best for use: Reality Composer Pro for just previewing 3D models, Xcode previews for quick manual UI tests along 3D models, Xcode simulator for debugging or the actual device in manual user tests for instant feedback gathering.

Swift Programming Language

Since 2014, most app projects on Apple platforms are built with its own, and open-sourced, programming language Swift, while also still today, many large corporate projects are maintained with its predecessor Objective-C.

Swift is tightly integrated into the Xcode IDE and features native integration of the visionOS SDK and APIs for optimized run- and build time compiling. Throughout our thesis practice, we do not just program with the Swift language. We prototype with it, iterate, design, and engineer our user interfaces and experiences. The two core building blocks of the whole app project consists of the SwiftUI and RealityKit framework.

(Apple, Inc., 2024o; Wikipedia contributors, 2024d)

(Apple, Inc., 2024o, 2024t)

SwiftUI

Cocoa developers and designers used UIKit and UIStoryboard as the standardized toolkit for building the visual user interface on iOS. With the introduction of SwiftUI in 2019 Apple determined a new standard, involving no more UI storyboards that had to be first laid out for each device size class and later connected with code. In favor of a declarative syntax (old imperative) that is in pure code, now we have code and preview side by side in real time, without us having to deal with the UI storyboard anymore. Any change to the code we make, Xcode renders a new preview based on that change, thus accelerating the app design workflow.

(Apple, Inc., 2024q)

(Apple, Inc., 2024p)

RealityKit

The second main building block of our app project, next to rendering our user interface with SwiftUI, is RealityKit – responsible for rendering our 3d models, animations, and materials. In visionOS, RealityKit and SwiftUI are closely tied with one notable UI component for the platform: RealityView. The reality view component allows us to not only load our 3d models but to also attach SwiftUI views directly to the models.

(Apple, Inc., 2024m, 2024n)

For our design process, we have another additional shortcut before the advanced use of RealityView comes into play. In complementation of RealityView, we have a more simplified version called Model3D. Just like in Reality Composer Pro for no-code previewing 3d models, Model3D is the next step to programmatically display a 3d model without further setup, providing the absolute basics of displaying a 3d model on a SwiftUI view.

(Apple, Inc., 2024k, 2024n, 2024h)

Git

As 1.) part of our complete progress documenting the app development aspect steps, and as 2.) a structurization of the whole described pipeline in a repository, we work with Git – an under the hood development integration tool for developers to work on the same code base simultaneously.

(Chacon & Long, 2024; Wikipedia contributors, 2024c)

We use Git to commit each process and successful implementation to the stack, while each commit consists of a small set of changes made to files in the project folder hierarchy. In addition to commits, we work with so-called branches to separate the development, fixing and testing of new features and add-ons. Branches then contain these commits, which after peer-review get merged into the master (or main) branch – the stable, shippable state of the project. As a rule of thumb, every new feature, bug fix or experimentation is branched off the main branch and thus separated from each

other, until ready for merge.

Not all files in the program have to be included in our project pipeline: while we store Blender project files locally on our personal devices, the Xcode project must be in sync for each of us to have a compile-ready build on our local machines that we pull from our git-repository.

(Chacon & Long, 2024; Wikipedia contributors, 2024c)

Project Development

App Development

User Flow

The user flow for this application includes several layers. For one it displays what is happening on which window and in which window. This system allows to keep an overview on what is displayed when. This is not only important to assess, that the user is not overwhelmed by the amount of information that they find in the application, but also that we can keep the performance load of the assets in control. The user flow of an application can be as streamlined as possible, if the user must deal with long wait times, the user experience depreciates.

In addition, we need to decide at which stage of our app user flow we want to use which of the three visionOS UI building blocks: windows, volumes, and immersive spaces.

(Apple, Inc., 2024f)

How the research informed the design

The application should in its functionality represent the user journey that the researchers go through in their research. The user flow is constructed around the user journey that we had discovered and established with the researchers in the workshop (see chapter: Workshop – Group Holland-Lab).

An element that we identified as important was the non-linearity of the research. By implementing certain feedback loops, the hope was to communicate this nonlinearity in the overall user experience of the application. These feedback loops were designed to fit the pace that the researchers would have to take in their research.

One specific detail is the testing feedback loop (see figure 72). There was a discussion whether the user should receive the feedback if the connection is correct while building, or if the feedback should be a step that can be only accessed through testing the whole tracer that the user just had created. Looking at the user journey of the researchers it can be identified that they do not receive feedback while mixing their compounds. A series of tests have to be implemented after the researcher had “finished” the mixing of their compound. According to this, the decision was taken to implement the testing as a deliberate step that the user had to take when wanting to advance in the user flow of the application. Several other decisions regarding user experience were taken.

The user flow was then adapted into a workshop that was tested with the respective age group the application was designed for (see chapter: User Testing – Workshop Classroom go tec!), as well as in forms of user testing with both involved parties from museum and research group.

The flow around the animal testing was done with autonomy in mind. There the process is not accurate with the scientific process. The scientists cannot choose if they want to induce into an animal. But they make that decision with purpose in mind. Tracers get only induced into animals when the testing requires it. By having the selection of different tracers that could accomplish different goals, we could let the user make this assessment and decide if they want to induce into the animal. The recreation of this decision process was the goal, while giving the user the choose what they wanted to see and experience.

With our happy path testing (see chapter: Prototype – Happy Path testing) we could determine how many a.) feedback loops will be tolerated by and b.) how many combination options won't overwhelm the user. In this test it seemed that three variations seemed to be the ideal spot. This was also

advantageous for us as HollandLab produces three different tracers with three different functions. There was a plan to visualize more tracers but looking at our capabilities and feasibility, there would not be the capacity to achieve this while being just to all aspects of the visualization.

Interaction Identity

To have consistent interactions for the flow of the application, the decision was taken to have the same interactions in rotation over the application. This would make it easier for the user to identify which elements are interactive and what interactions are to be taken. This idea was taken from popular application that follow the same principle. The team behind the Apple Vision Pro has come up with a system for designers and developers as a guideline for the design of applications. These guidelines were closely studied and applied where possible and purpose. After the decision was taken to not include the “time gesture” anymore, it was clear, that the application would concentrate on the pinch and drag gesture. This was not unfortunate, as it gave the chance to think about the pinch and drag gesture and its purpose in every aspect of the application. Another purpose of this focus was that the assumption was nearly certain, that none of the potential users had ever used an Apple Vision Pro before. It would be wise to not overwhelm them with several interactions from the start of the journey.

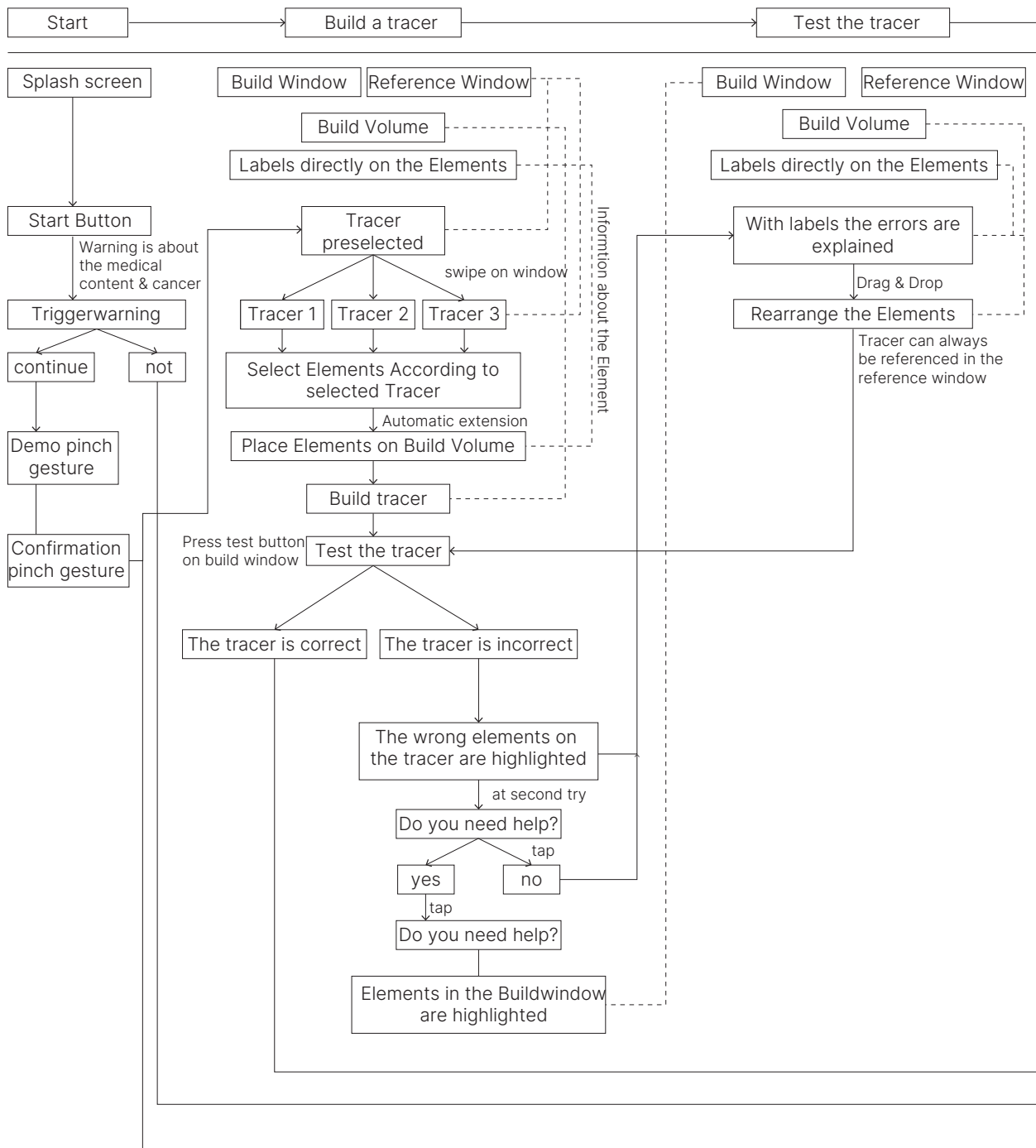
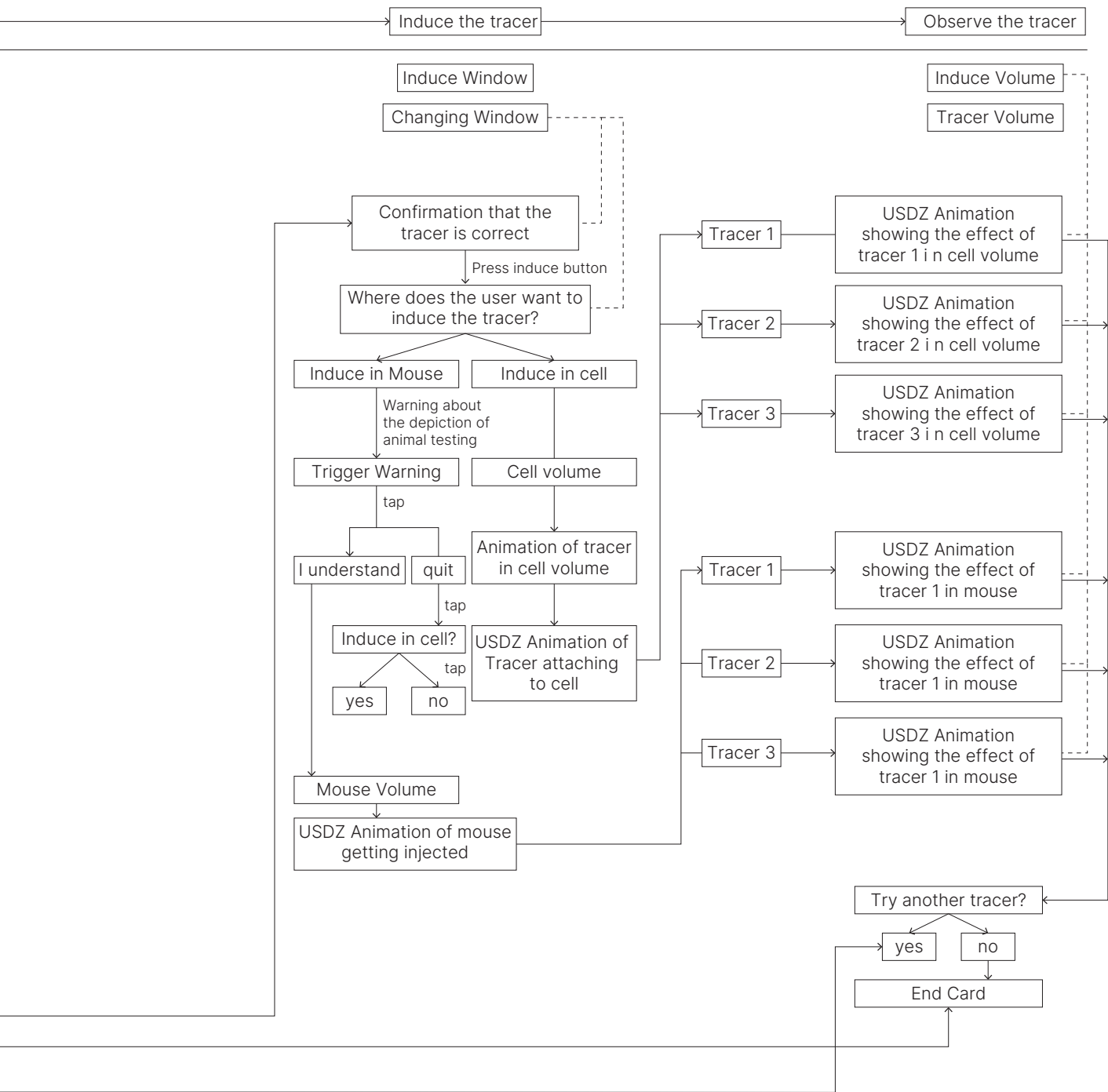


Figure 76 Flow of the application, author work, 2024.



Human Interface Guidelines

To make On Radar as enjoyable and didactically valuable, it should take advantage of features the likes of spatial audio, immersion, and the magic of having objects come to life. The materials should be crisp and sharp with qualities that tell a story and inspire wonder. Yet with all the possibilities there had to be set some restrictions. For the safety of the user and for accessibility reasons, not every moment needs to be fully immersed. Right after we got to try the Apple Vision Pro for the first time, we thought we should implement as much immersion as possible. But goals should be achieved with as little immersion as possible. When used sparsely, the immersion can function as a storytelling tool and fire the user with enthusiasm. But if full immersion is used excessively, it can create accessibility issues. Not everyone can be in virtual spaces for an extended amount of time. By limiting the usage of virtual spaces, we would honor the Augmented Reality aspect of our application and extend our possible user group.

(Apple, Inc., 2024g)

(LaValle, 2023)

To honor the human interface guidelines and to not throw the user into a full Immersive Space from the start the decision was taken, to start the application with a window.

By working with real-life objects, an anchor was placed in the real world for the user, by this the user would not move around an excessive amount. Having this feature would be beneficial for the safety of the user and bystanders.

It was important for content to start in the field of view of the user, otherwise there could be confusion to where things are located. And as there should not be too rapid movements it was to adhere to this concept. The anchors in the reality aspect of the augmented reality experience would also give the user an idea where to interact.

Every interaction that could be done with a gesture should also have UI that correlates with the interaction. This gives the user several parts to achieve their goal.

Visual Identity

The visual identity posed a challenge. The application should not feel like a school lesson, but also should not heavily remind the user of the schoolbooks that they already work with. Some concept of the visualization would have to be taken from the classic science visualization, but for the most part the idea was to create a visualization that communicates the concept without looking too scholarly.

Interface Design

The interface design largely adheres to the apple visual guidelines. As the ideal as that the application would fit into the apple ecosystem, it was not far off to adapt these guidelines to our application. From the expenditure it would take to create a new Interface Design and the specific user testing it would take to argument for such a feat, it would be excessive to develop such a feat in the timeframe given. Especially when there is a design that mostly works and exceeds our expectations.

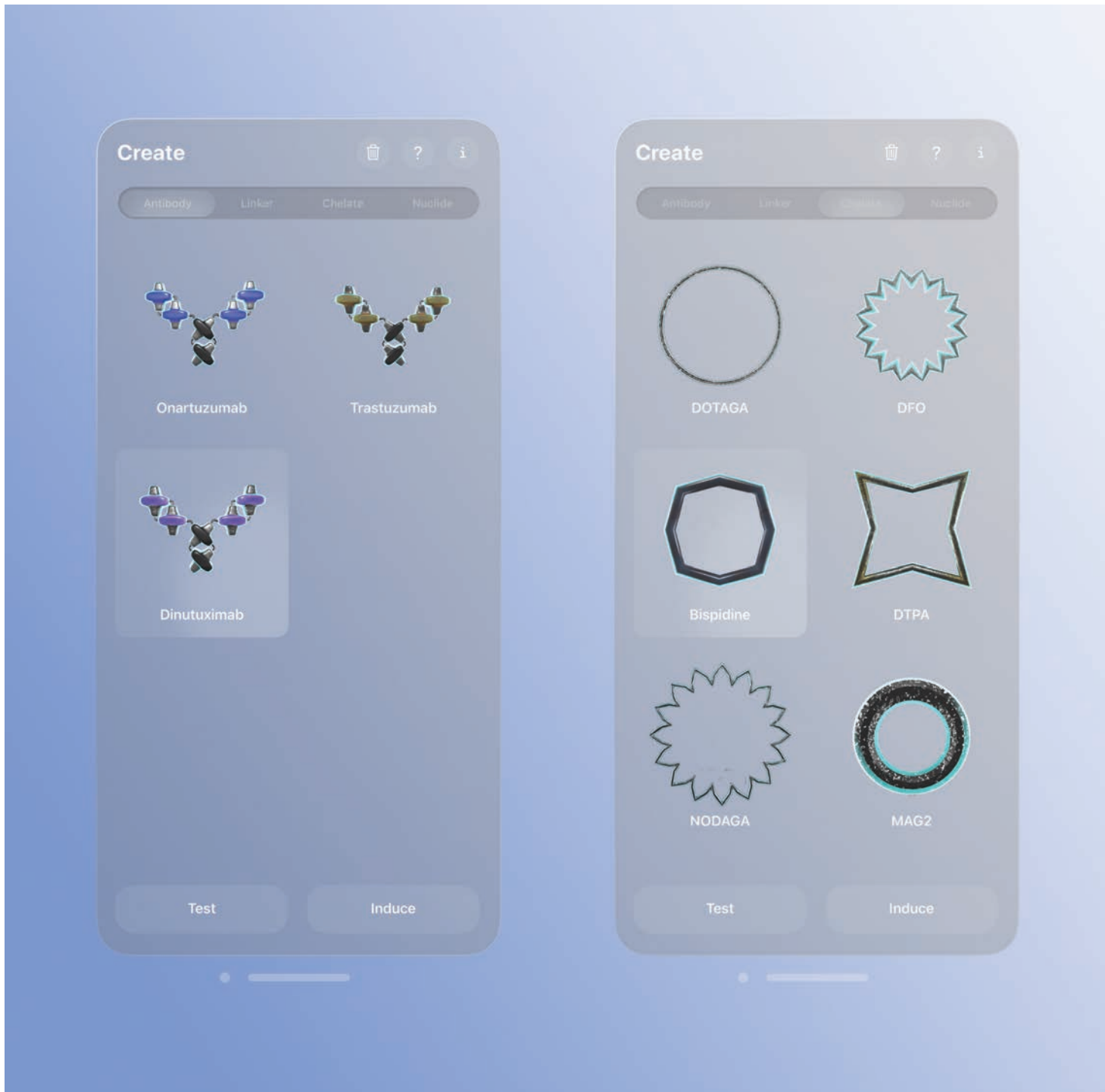
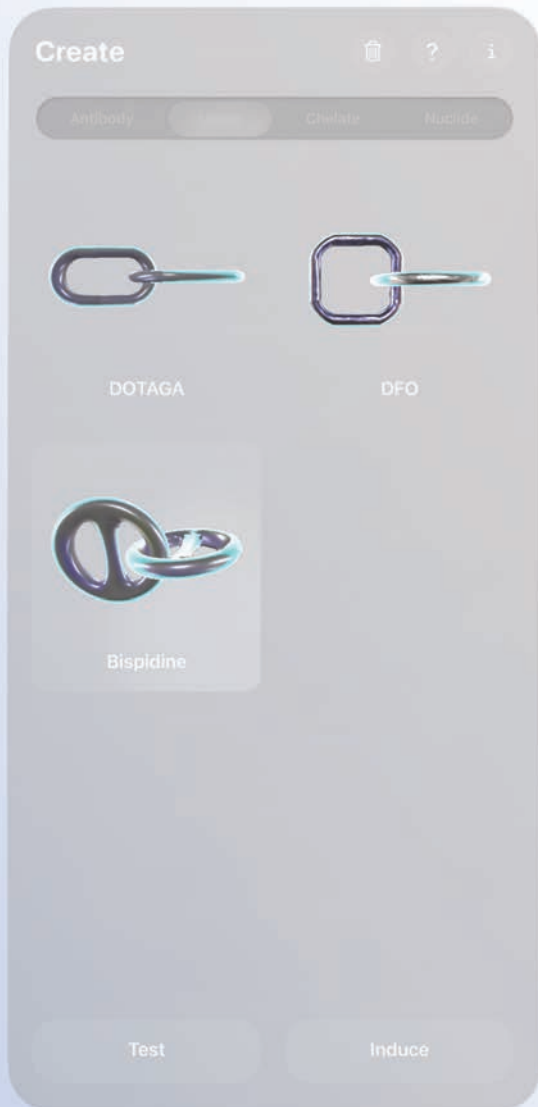


Figure 77 Windows overview, authors work, 2024



Translating Science Visualization into interactive 3D

Science visualization is largely in 2D and non-interactive. Yet it was a great source of inspiration when designing for the application. The visual communication of difficult to explain concepts was a source of learning, and inspiration. In its core the goal of scientific visualization is to make data understandable and graspable. We were not working with data in a traditional sense, but the interpretation of data. We had to create a derivative of this interpretation of the data. And make that derivative interactive, to further the understanding.

(Brodie et al., 2012)

To translate the science visualization into an interactive visualization, we enabled techniques of storytelling and gamification. So, the subject would be visualized in 3D and the interactive part would reference aspects of a game. This inspired us to have the visual aspect of the application reference games. We looked at different games and how they chose to work with visuals to create a consistent immersive experience.

For the chemical components, we could heavily rely on the visualization that had been done by Holland Lab. This made it easier to be scientifically accurate. There was not a reason to create an entirely new system, as this research was visualized in an understandable and intuitive way, that had to be translated into interactive 3D.

The structure that is displayed in figure 36 was the basis of our tracer visualization. From our meetings with the students from HollandLab we had to display the Y-structure and the chelate had to be around the nuclide. Otherwise, we were free in how we would visually describe the elements.

The different elements were isolated and visualizations for each would be constructed. The important aspect of the visualization was that the mesh of the model had to communicate what the element was for.

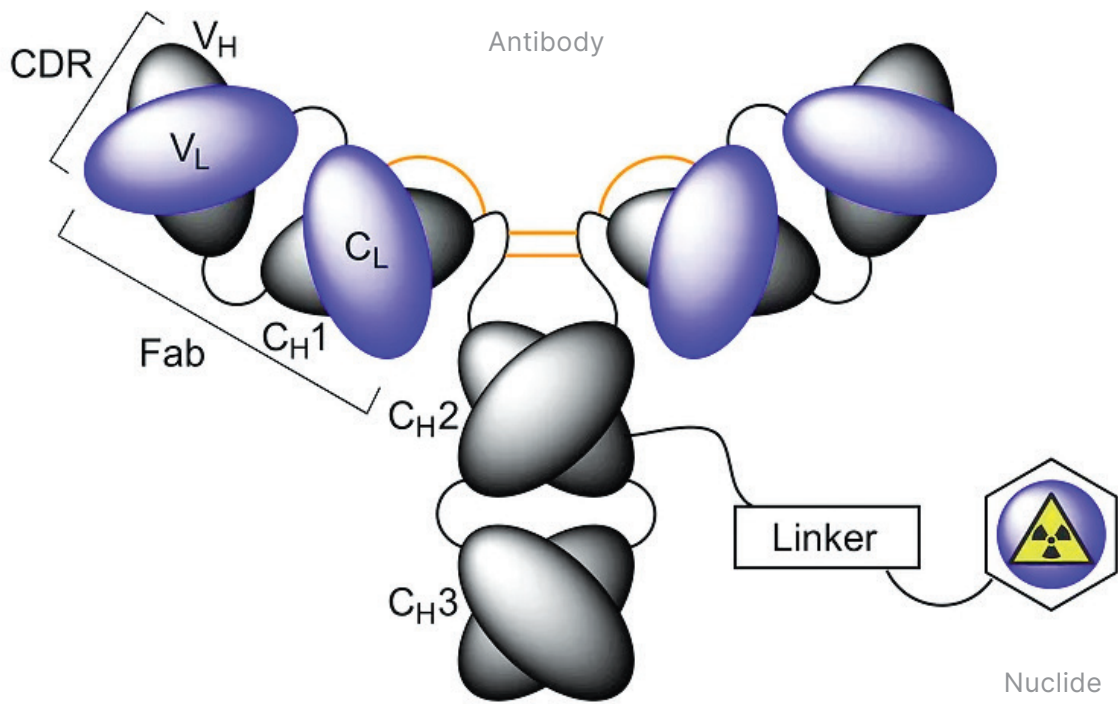


Figure 78 Visualization of a radiotracer, hollandlab.org, 2024

Visualizing animal testing

Animal testing does not get visualized often. Especially in an interactive way. This meant we had to be careful with the visuals that we chose. We did not want our visuals to look like a pamphlet about the brutality of animal testing. Yet we did not want to compromise and minimize the visuals. This meant to perform a visual balance act. The decision was taken to weave in between a realistic representation and a stylized abstraction.

While visualisations around animal testing are largely based on the politics around animal testing, we chose to represent the animal in a state where it wouldn't be ridiculed, but dignified. For that we looked at the behaviour of the real lab mouse and modeled our mouse of to that.

For our model we worked with a pre-rigged model, that we had found and paid for. This was done for time and skill reasons. This model was right in between the realism and the abstraction that we were looking for.

The rigging makes it possible to animate the mouse, so it would not be a dead thing without any life. For this task videos of mice behaving normally were searched and reviewed. In reality, laboratory mice are more lethargic and do not move around too much. But representing this movement would not let the user experience how the tracer can make the mouse get better.

Although laboratory mice are often bred to not have hair, we decided to go with a visualization, that would include hair. This was done on one hand, because the Science Pavilion requested it, but as well it was a decision to make the mouse still graspable as an animal that is not only there to be used. The hair would not be modelled, but painted on, in Adobe Substance Painter 3D. This was done for performance reasons. Having real hair, that would display physics was not important or the impact of the visualization, so there was no reason to create it.

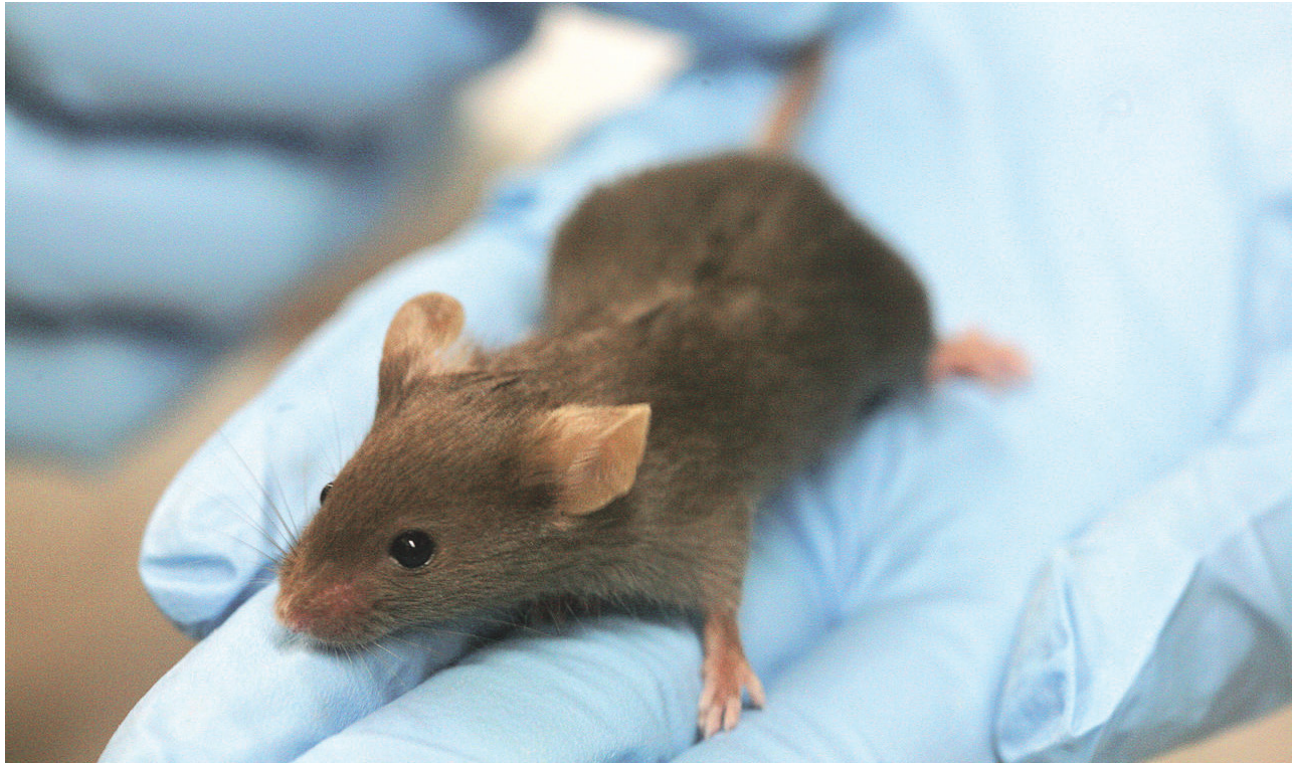


Figure 80 Lab mouse, wikipedia commons, 2014



Figure 79 Render of the mouse model, authors work, 2024

3D Style

The 3D style was low poly modeled. This was done to have the least amount of vertices as possible. Vertices are the points that construct a 3D model. The USDZ format allowed us to work with modifiers and would translate them. Modifiers are operators that manipulate the mesh without changing the amount of vertices. For low-poly models, as they are common in games and spatial computing, they are well regarded and tried and tested.

To have the model in its design represent what it was communicated, we were inspired by their functions.

The mesh of the linker would have to look like a chain, the different linkers would be variations of the chain. The links of the chain would be different and let the user differentiate between the different elements when selecting the elements and when looking at the reference window.

The meshes should not only be distinguishable by material and color, but also by shape. This was done to make it easier for the user to distinguish between the different elements, but the material capabilities of the Apple Vision Pro should also be shown off.

Materials

As we were working with building blocks, we were inspired by building materials when designing the materials for the elements. Having a wide variety of materials that were covered most aspects of materiality there is, it would be a nice showcase, and a good experience for the user. With the visuals of our project, we could provide our user group with some variety of what science communication could be and how it could look like.

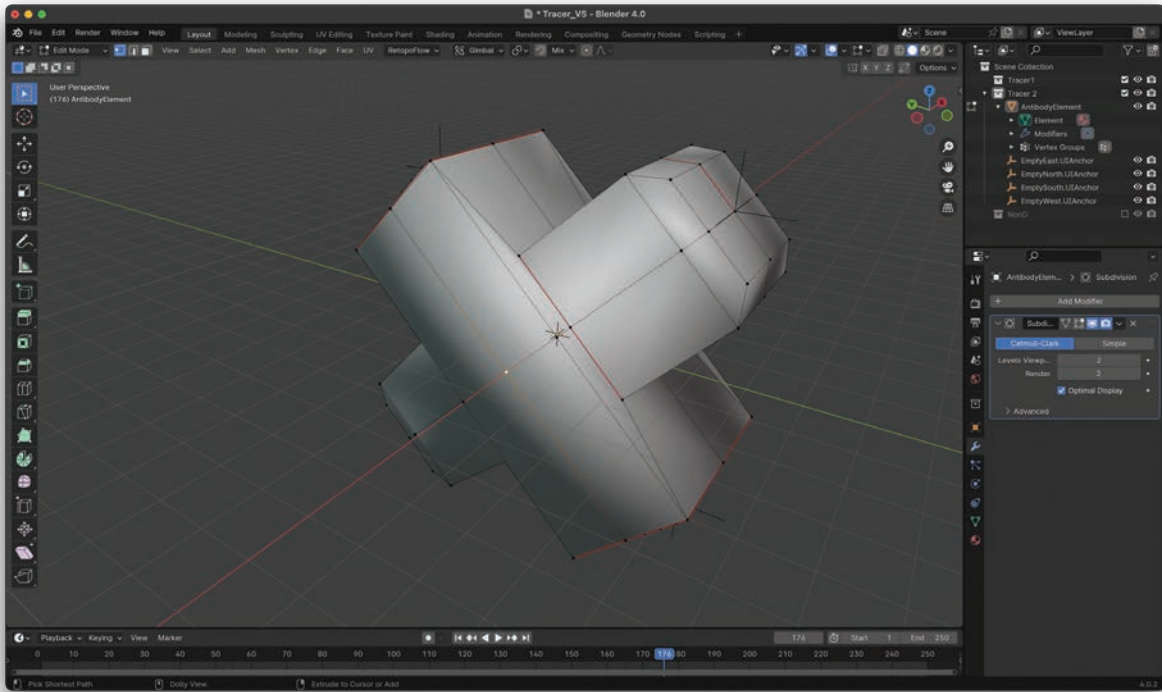


Figure 81 3D Model without modifier applied, authors work, 2024.

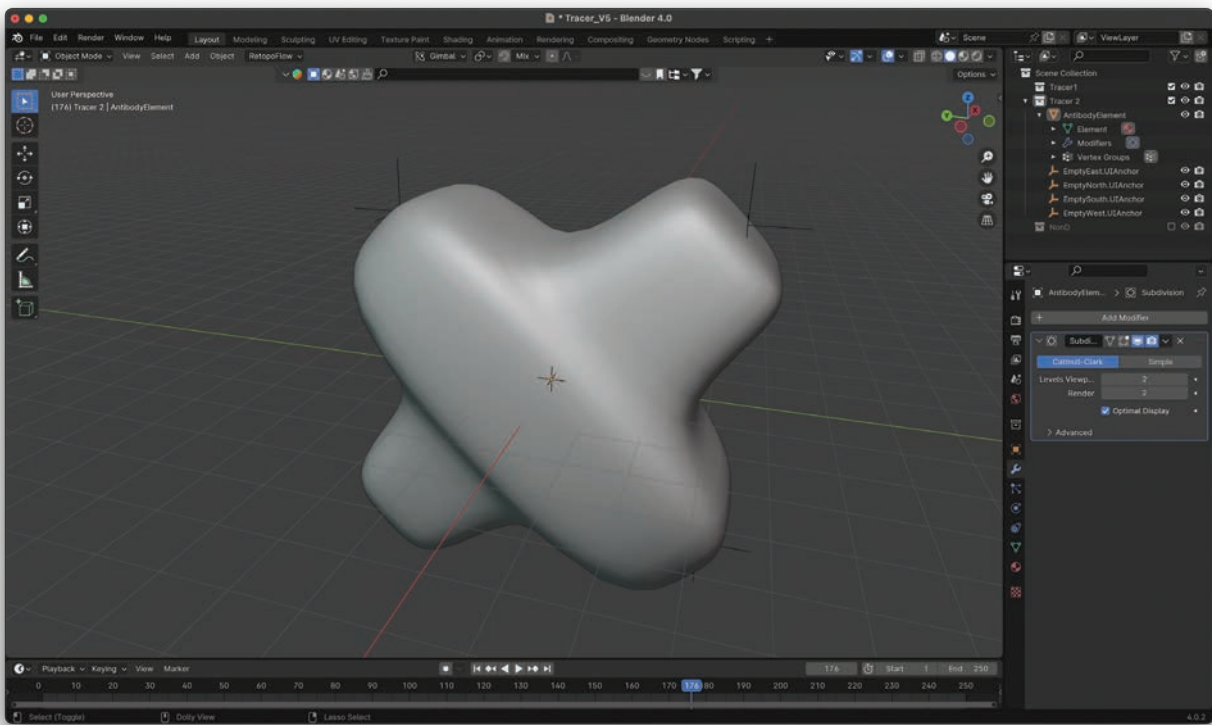


Figure 82 3D Model with modifier applied, authors work, 2024.



Figure 83 Mesh Linker 1, authors work, 2024.

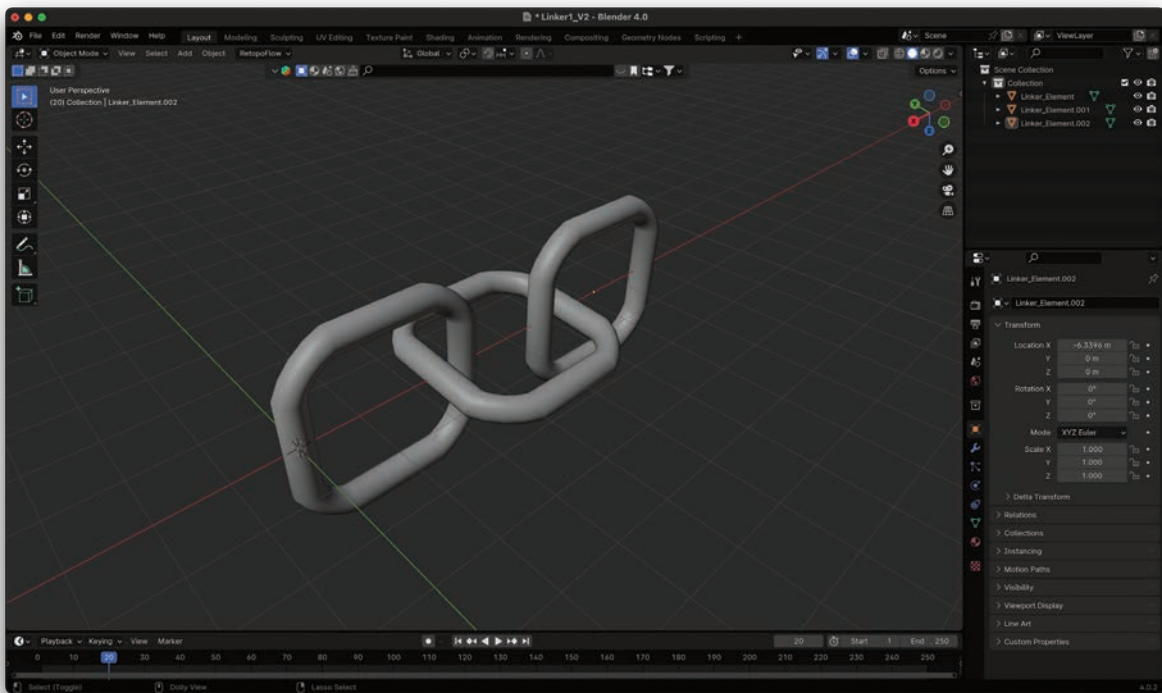


Figure 84 Mesh Linker 2, authors work, 2024.



Figure 85 Mesh Linker 3, authors work, 2024.

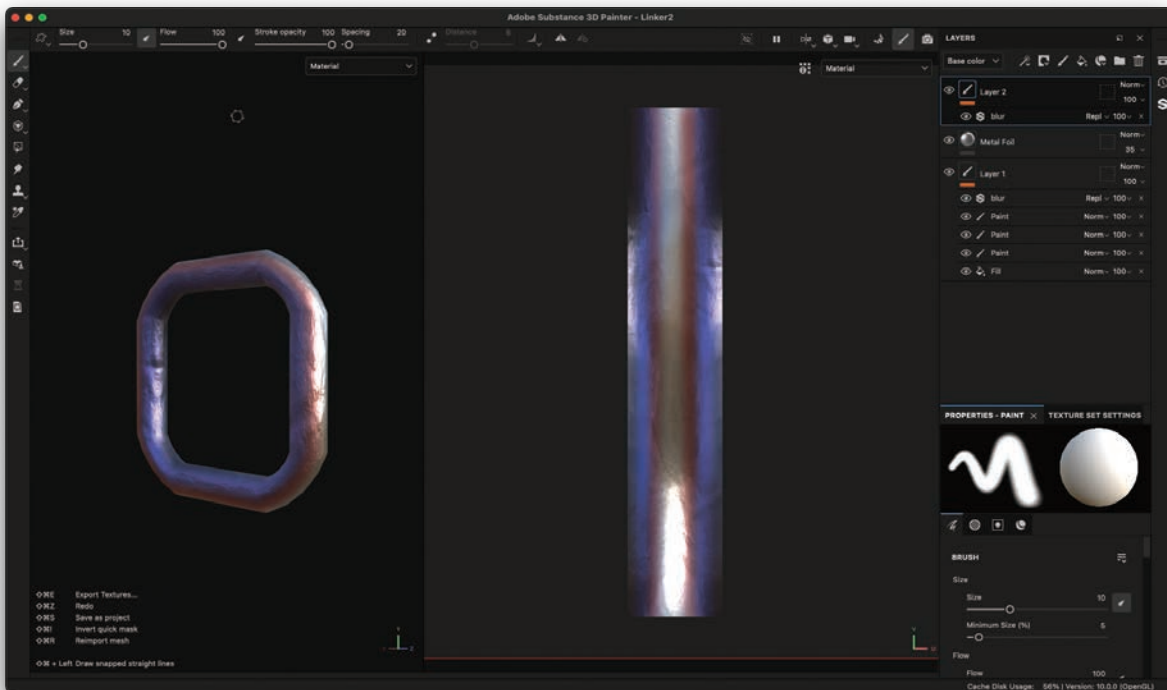


Figure 86 Material linker 2 in Adobe Substance Painter 3D, authors work, 2024

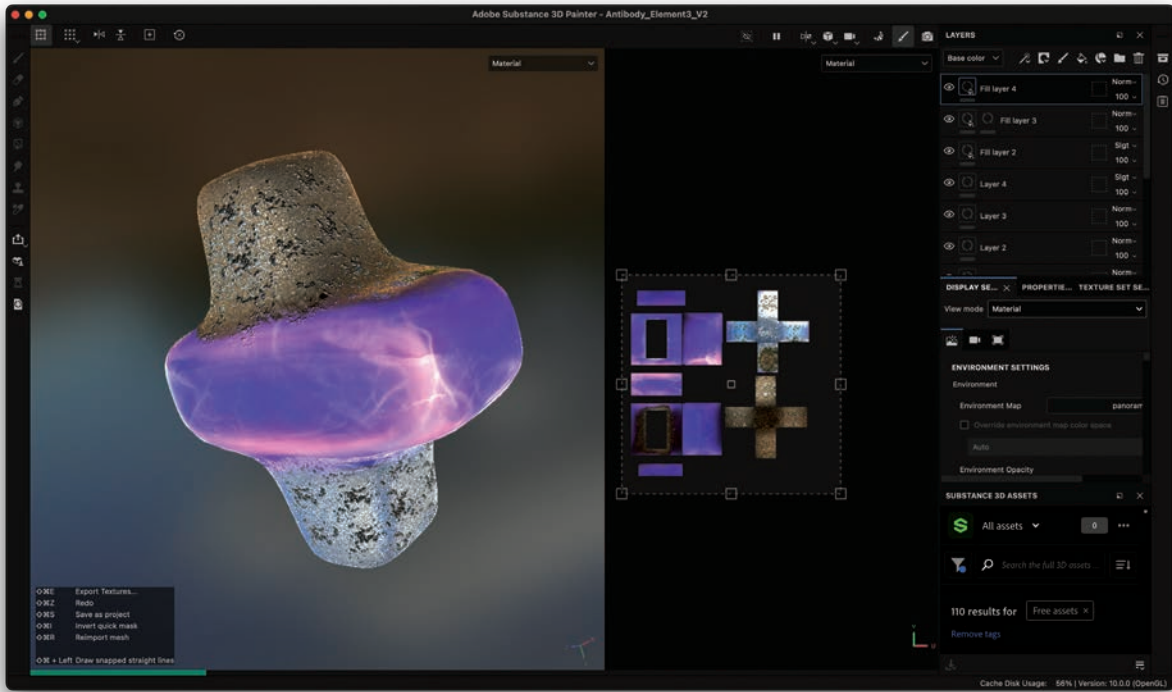


Figure 87 Material element antibody 3 in Adobe Substance Painter 3D, authors work, 2024

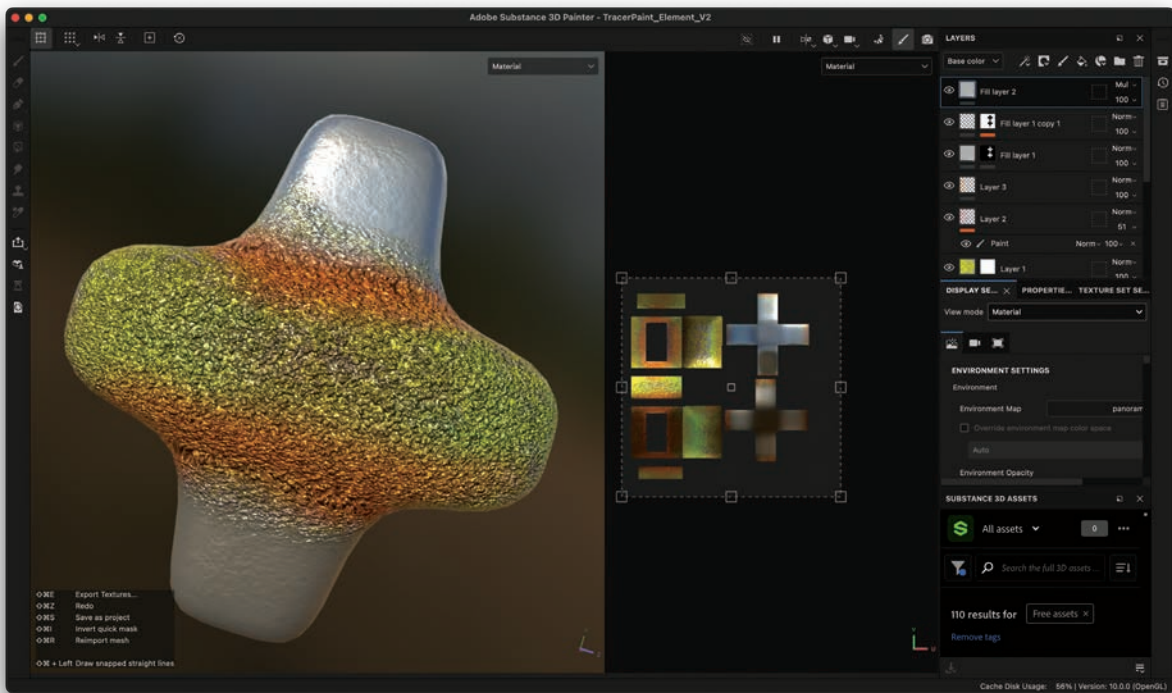


Figure 88 Material element antibody 2 in Adobe Substance Painter 3D, authors work, 2024

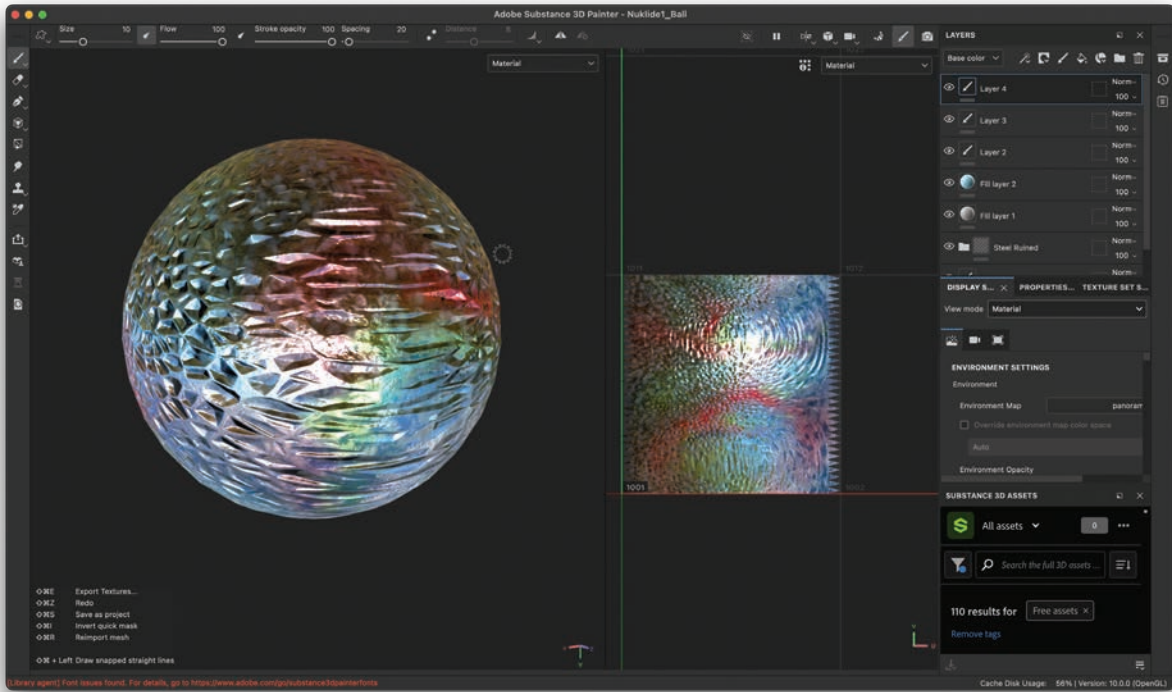


Figure 89 Material nuklide element in Adobe Substance Painter 3D, authors work, 2024

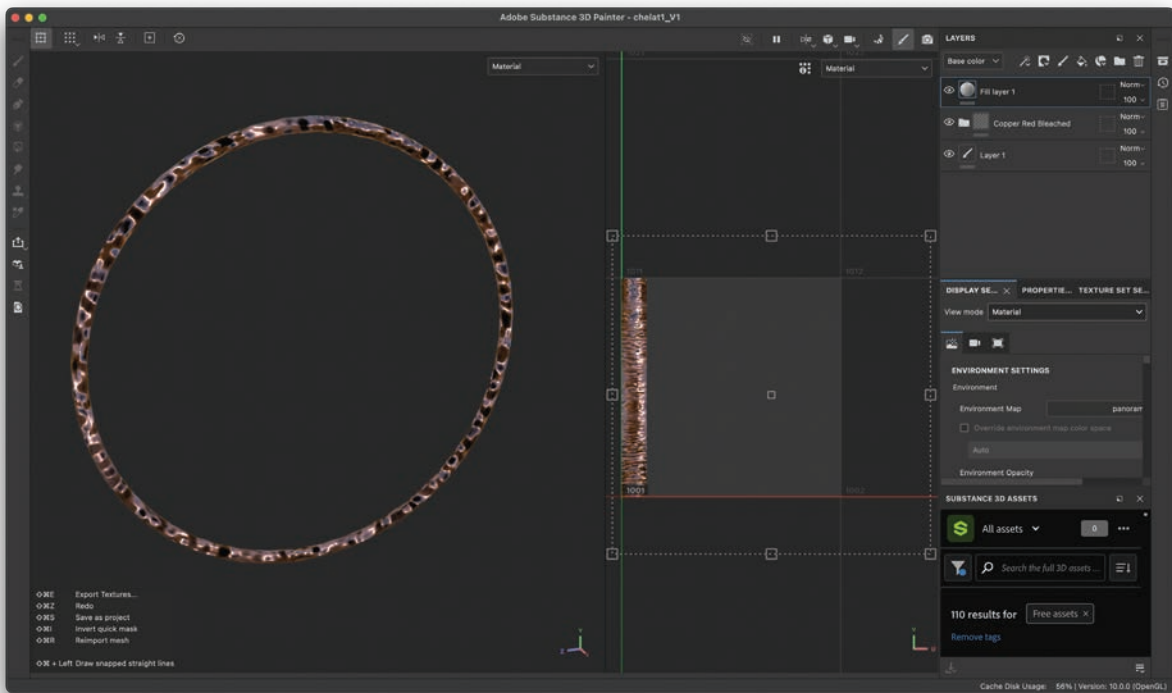


Figure 90 Material chelate 1 in Adobe Substance Painter 3D, authors work, 2024

User Testing

Workshop Classroom (go tec!)

Early on we were looking to have a Workshop with our target group. The ideal would be to have 10 to 20 pupils from the ages of thirteen to sixteen. This would also be the age group that would be best suited for our application. Considering, that we both are nearly a decade older than our target group it was important to meet with them and see what is interesting and engaging for them. The school go tec! Was very generous in allowing workshop planning, which gave us full creative control to achieve our data collection. The duration of the workshop would be 3-3.5h.

Considering the number of participants that we were expecting, it was evident, that we would not do a user testing in a traditional sense. We only had one headset and we expected it would not be fun to have the pupils test the application one by one. We understood that our application had a didactic claim. It was our goal to inspire enthusiasm for radio-chemistry and chemistry in general in our target group. With our two groups we would test the user flow of the application. In theory, by substituting the contents of the application with a different topic but keeping the same structure, we would have data that could show us, if our user flow would achieve the didactic success that we were looking for. In its essence our application aims to explain a complex topic to people that have no or limited previous knowledge. We created a workshop around Design Thinking and Augmented Reality that follows the user flow of our application. It was a great opportunity to let our user group interact with the Apple Vision Pro and see if it would fit, how long it would be comfortable and how quick they would be to learn the User Interface.

We organized two workshops with two different classes. This would give us the chance to apply the findings from our first workshop and test the revised concepts. It was

ideal to have this many participants as this gave us a wider collection of data points. We checked our assumptions by documenting the workshop with pictures and memory records, that we immediately captured and discussed on our way from Schaffhausen to Zurich. This hour of immediate reflection was great, as our memory was as fresh as it could be. We could not capture video, as we did not have the permission of all the pupils to capture their faces.

Conceptualization Workshop 1

Basis:

01. 23 Participants
02. Age: 15-16
03. 3.5h
04. Material:
05. Reality Composer on iPad (no LiDAR)
06. iPad
07. Predefined paper patterns for simple geometric forms
08. Scissors
09. Colored pencils
10. Loose paper
11. Adhesive tape
12. Glue

The main findings and assumptions that we wanted to check:

Assumptions:

01. *The User Interface of the vision pro needs a heavy instruction.*
02. *The medium would inspire creativity and action itself.*
03. *The User should not be bored with too much introduction.*
04. *The flow that we had created works with our target group. (See figure X)*The main Data that we wanted to collect:

Data:

05. *How long until a teenager is bored with the topic of Augmented Reality?*
06. *How long until a teenager is frustrated with a topic?*
07. *How big is the motivation to experiment?*
08. *How long until the vision pro hurts on the face?*

Workshop 1

Schedule:

01. Introduction
02. Who are we and what are we doing today?
03. What is design thinking and how can we use it in design.
04. Break
05. What is a paper prototype.
06. Paper Prototyping.
07. Break
08. Introduction to Reality Composer.
09. Translation of the Paper Prototype into AR.
10. Review and discussion.
11. Thank you.

Each point in the schedule would have an equivalent to a chapter in the user flow of the application. The introduction and design theory part were coherent with the explanation part of the radiotracers in the application. This part was constructed around a face-to-face teaching lesson. The pupils only had to listen and not interact. We did not set a specific goal of what we had to be done. A feeling of a sandbox was the inspiration. Everything would be possible, and in the prototyping and testing the pupils would get what was possible and worth perusing. This would be coherent with the building and testing of the radiotracers. By having the introduction into Design Thinking and prototyping, the pupils would understand by themselves, what interaction designers are doing and how they are doing it. By looking at the results of the paper prototypes and the AR prototypes we could evaluate if the pupils had understood the workshop.

The breaks in the schedule do not have an equivalent in the application. These are purely there, as we cannot expect from our user group to be activated and attentive for 3.5 hours. The break served a great opportunity to let the student test the vision pro and see how they interacted with the

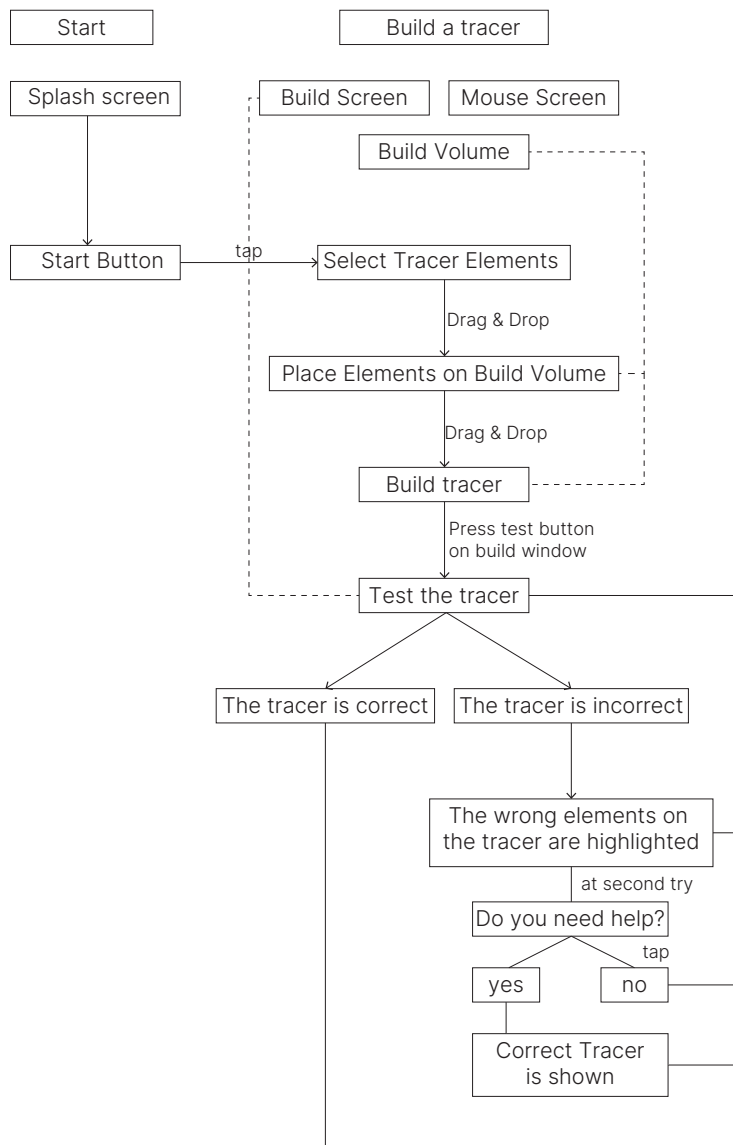
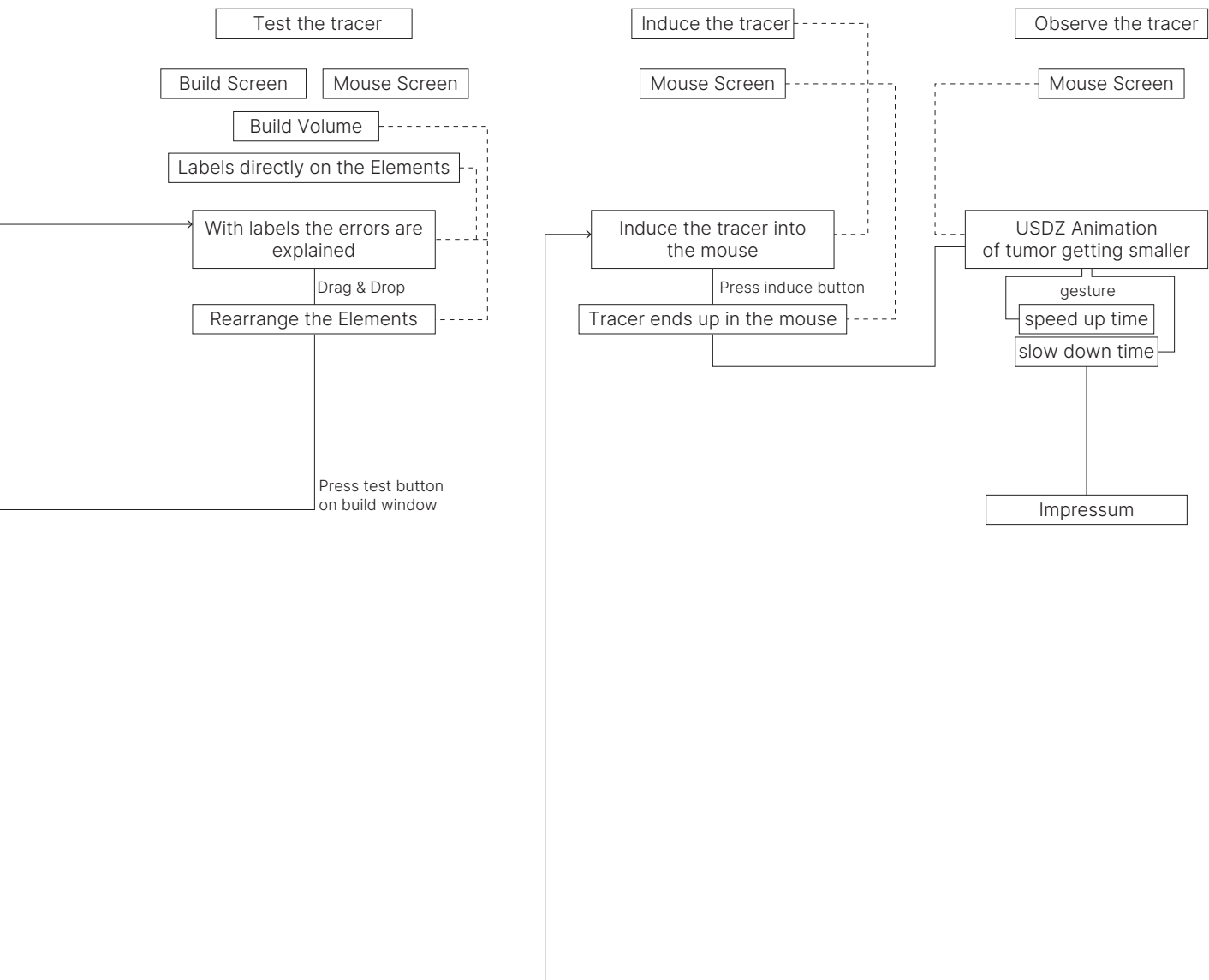


Figure 91 User Flow prototype, authors work, 2024.



tech and how long it took them to get accustomed to the User Interface. Also frankly, how long they could wear the vision pro, until the weight would start to feel uncomfortable on their faces.

Implementation Workshop 1

The day before the workshop we got the mail, that the Reality Composer could not be installed on the in-house iPads at go tec! This would be devastating, as there was no alternative to the application. We then decided to get as many iPads as possible from LeihS ZHdK and set them up by ourselves. We would then take these iPads to Schaffhausen. As we did not know if it would be possible to connect them to the Internet there, we set everything up and predownloaded all the models. This was stressful and took some of our confidence around the workshop. We were not sure if this had influenced the data collection, but we do not want to exclude the fact, that this stress could have had some influence on the first workshop.

Upon arrival, we set up materials for the workshop. The pupils were shy, which we had prepared for but did not expect. The theory part went quickly with little interaction. We had not explained the paper prototype session well, leading to many questions. We guided them without interfering too much. They used colored pencils to decorate predefined patterns, which was not our intention, given we had no rules at that time.

During the break, there was interest in Apple Vision Pro, but only about five participants could try it for five to seven minutes each. We set up a live transmission so others could see the screen with interactions, allowing us to observe their use of visionOS.

For the Reality Composer introduction, we demonstrated basic functions without handing them iPads, encouraging exploration. Most participants owned iPhones, so we expected quick adaptation. However, they asked many basic questions and were not as self-sufficient as expected. They were hesitant to show their creations, and attention waned in the last 15 minutes. Some abandoned projects did not meet their expectations. We wrapped up the workshop easily and on time.

Findings Workshop 1

We are not didactically trained. None of us had ever done a workshop with people this young. We do not have the proper training to qualitatively assess if our teaching has worked. For that we planned a short debrief with the teacher of the class and the teacher present of go tec! They were able to give us qualitative feedback on our teaching methods and workshop methods.

Immediately after the workshop we were happy with the outcome. Yet in the debrief we had some findings that we had not anticipated. The first and biggest one was that the method of having the pupils interacting on their own terms without a specific goal was not the ideal pace. They did not have an idea what was feasible and needed a frame to what would be possible on themselves.

Assumptions:

01. *“The User Interface of the Apple Vision Pro needs a heavy instruction.”*

The user interface system of the Apple Vision Pro does not need a lot of introductions. The pupils were fast with the understanding of the different interactions. After the eye set up, most of the testers got the logic behind selecting and the gestures quick. We could see this on the stream that showed us how they were interacting with the elements in visionOS.

02. *“The medium would inspire creativity and action itself.”*

The medium did and did not inspire creativity and wonder. From the results we could see that some of the pupils were very much immersed in the topic, but most did not know what to do with the playground that we gave them. We accredited this to the fact, that we had gave them too little guidance.

03. *“The user should not be bored with too much introduction.”*

We were surprised with how well they dealt with the theory part of the workshop. They listened attentive and the paper prototypes reflected some of the principles explained. We saw some great iteration in the prototypes. This meant that we had underestimated the tolerance of our user group for theoretic introduction.

04. *“The flow that we had created works with our target group. (See figure 86)”*

The flow did not work as we had intended. We needed to implement a clear goal that the pupils would be able to reach and get why they are reaching it. What worked was the

testing iteration. The pupils were interested in testing their prototypes and see where they could improve.

Data:

01. *“How long until a teenager is bored with the topic of Augmented Reality?”*

This depends on the personality of the teenager. Some are very interested in AR and for this they were eager to achieve what they had previously prototyped. Yet, when they were not interested in the matter from the get-go, it was very hard to motivate them to create a viable project. We could also attribute, that there was no clear goal.

02. *“How long until a teenager is frustrated with a topic?”*

We observed that the participants got very easily frustrated. We had to do a lot of support with the program and the process. We also observed that the participants would not try to solve a problem on their own, but rather just ask us for the desired solution. This was a difficult observation, as from that we concluded, that everything had to be very clear to be understood.

03. *“How big is the motivation to experiment?”*

The motivation to experiment was not there. Now this could be attributed to the concept of the workshop and the topic at hand. But we did not really feel an inclination to experiment. At some points, we had the feeling, that the pupils were waiting for the workshop to be finished.

04. *“How long until the vision pro hurts on the face?”*

On average it took around 7 to 10 minutes until the participants were complaining about the weight on their faces. There could also be seen visible red marks on their faces, that indicated, that there had to be a considerable weight on the face.

Form the teachers we received the following feedback. They thought that the material was well presented in an engaging way, but that we would have to engage the pupils in a more digital way into the topic. We would also have to give them a clear topic, that they would have to achieve in their own way. By having these mechanics, they would start to experiment on their own. They recommended Edupad to us. Edupad is a free browser-based text editor. In this tool, everybody within the same URL can write at the same time and see their peers' texts. We and the teachers had observed some shyness in the pupils about participation. We expected to have a higher engagement, when not everyone had to speak to engage.

With these findings we started with the adaption of the workshop for the second workshop iteration.



Figure 92 Workshop go-tec 1, authors work, 2024

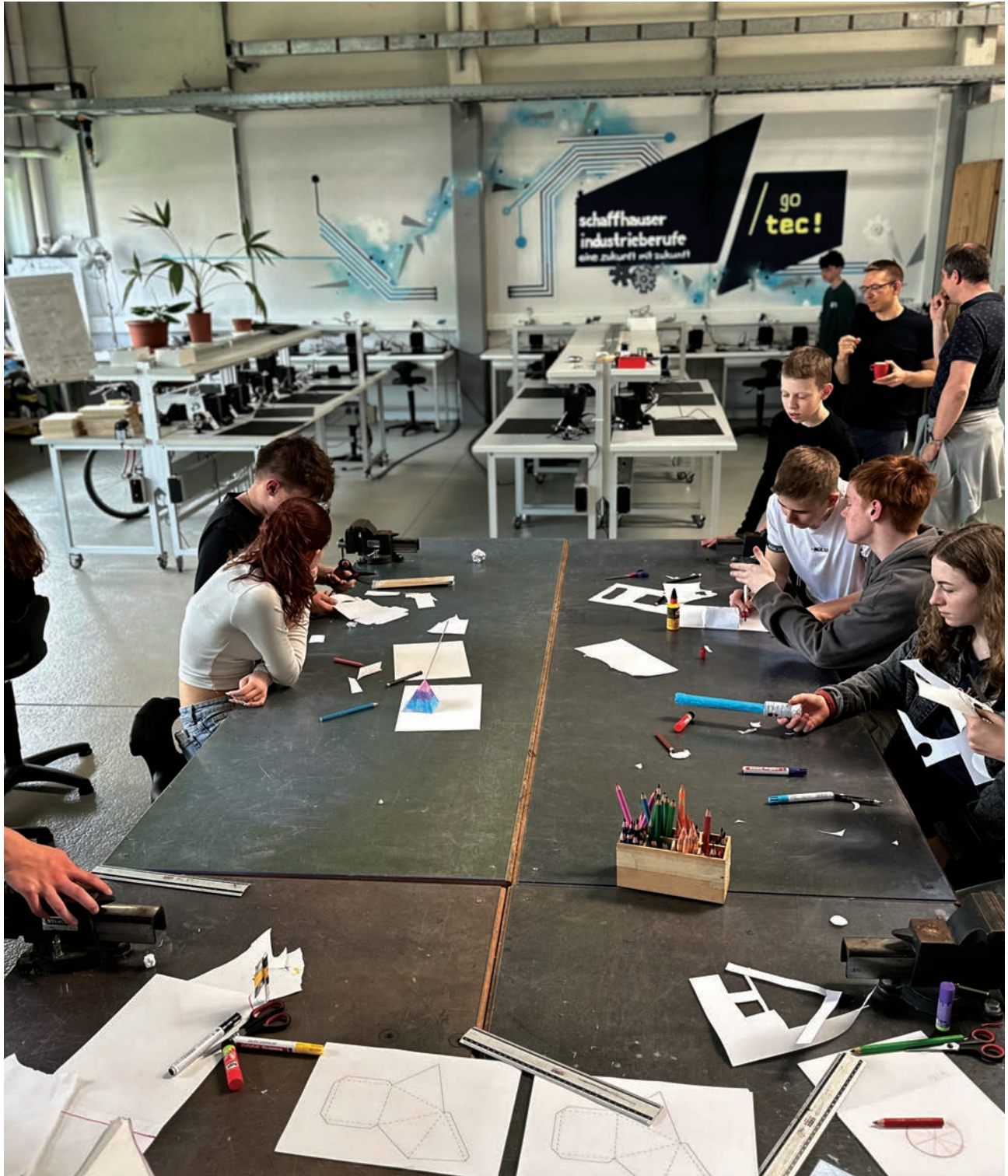


Figure 93 Workshop go-tec 1, authors work, 2024



Figure 94 Workshop go-tec 1, authors work, 2024

Conceptualization Workshop 2

Basis:

01. 16 Participants
02. Age: 15-16
03. 3.5h
04. Material:
05. Reality Composer on iPad (no LiDAR)
06. iPad
07. Predefined Paper patterns of simple geometric forms
08. Scissors
09. Loose paper
10. Adhesive Tape
11. Glue

We had observed in the first workshop that some of the pupils had just built one of the predefined patterns and then colored it with pencils. From this we decided to not include the colored pencils anymore, as this was not the intended outcome.

The main findings and assumptions that we wanted to check:

Assumptions:

01. *The flow that we had created works with our target group. (See figure 73)*

Workshop 2

Schedule:

01. Introduction
02. Who are we and what are we doing today?
03. What is Design Thinking and how can we use it in design.
04. Think of some problems in your everyday life, that could be solved with design thinking and discuss them in groups.
05. Collect ideas on Edupad.
06. Break
07. Presentation of the goal
08. What is a paper prototype.
09. Paper prototyping a simple bowling game.
10. Break
11. Introduction to Reality Composer
12. Translation of the paper prototype into AR.
13. Review and discussion.
14. Thank you.

In the theory part we gave them an input to reflect about their routine and how the theory about Design Thinking could be implemented there. By including this, we wanted them to reflect in the process of learning and think how this could affect them in a positive way.

This does not have a direct correlation with the application flow, but the implementation of this aspect could give a higher and more present engagement. This was implemented from the feedback that was received from the teachers.

We presented them a clear concept of the goal that we wanted to achieve together. The concept of bowling was chosen, as it utilized some simple functionalities that were present in Reality Composer. It is an easy game to effectively prototype with paper. The pupils could prototype and

assemble their bowling game in paper and test it right there. With testing and prototyping in paper, they would realize the limitations of paper. These limitations could then be addressed in the Augmented Reality prototype. This system would suppose as an effective way to teach the concepts at hand.

This correlates to the Reference screen, that we were planning to implement in the build mode of the application. We had the idea from the findings of our first workshop with go tec! Giving the user a clear objective was the plan. The other parts of the workshop would still reference the same parts that were already present in the previous workshop.

We used the breaks again for letting the participants test the Apple Vision Pro. We did not expect to have a big difference in wear-time. That's the observation of the pupils, looking at the person wearing the device, would be our focus. It would be important to investigate, what set up would work best when translating what the user in the application sees, to bystanders.

Implementation

The implementation of the second workshop was very similar to the first one. Only the notable details will be mentioned. There were no technical issues to report on. In comparison to the previous workshop we were accustomed to most aspects of the workshop and knew our ways around the facility of go tec! The pupils were much livelier to the other class. This might be attributed to the different personalities, or that it was Friday afternoon.

Edupad seemed to be a popular tool, and it made interacting for some pupils smoother and easier. The input that was received from the group session, were valuable and it heightened the interest of the pupils in the matter. They seemed to be skeptical about the proposal of building a bowling game. But as soon as we started with the paper prototypes, the initial skepticism seemed to disappear. There were not many questions about what they should do, and organically a small contest seemed to arise. The communication about what Reality Composer is capable of was better. They understood that there was no possibility to scan the objects. But that they had to rebuild their assets from the paper prototype. This time we had preinstalled a scene, that would show the basics in how it works. Having an example seemed to solve the problem of the never-ending questions. The participants seemed to have the confidence, that they could solve problems that arose by themselves. There was a great output of scenes, and the functionalities were impressive. The pupils seemed to explore most of the facets of Reality Composer and seemed to get it. The testing and demonstration of the vision pro were similar, yet we still could identify some findings, especially from the way the pupils reacted from the outer way in. finished the workshop half an hour late, but nobody seemed to complain about the overtime.

Findings

Immediately after the second workshop we had a much better feeling than the after first workshop. Looking at the outcomes it seemed that they had had a much better experience with this workshop. We saw a much wider variety of problem-solving aspect, and from the mood, in the workshop, also much more fun. With a clear goal the pupils were behaving more interested and better understood what there was to do. The feedback from the teachers was much more positive. They asked us to come back in the summer and do the workshop again. When testing the Apple Vision Pro with the pupils we learned that it was important for the bystanders to see what was happening in the device. The assumption was, that this would be important so more people could profit from the demonstration of the device, but it would also be important, as the vision pro is filming its surroundings. It inspires a level of confidence in the bystanders if they know when they are being filmed.

Assumptions:

01. *“The flow that we had created works with our target group. (See figure 76)*

Looking at the results and the quality of the results, we are assuming, that this flow works. The results had a greater variety in interactions and interesting ideas. The process from paper prototype to Augmented Reality was better implemented and on average we saw better quality in outcome, from an Interaction Designers perspective.



Figure 95 Workshop 1 go-tec. authors work, 2024.

One notable mention is one group that built a bowling game with a space rocket as a ball. The bowling game had an anchor, that made it only playable when the camera was pointed to an image of a galaxy. In a unique way they had identified the limitations of their prototype and translated it into Augmented Reality, with an aspect of Virtual Reality.

The impressive aspect of this prototype was, that we had not explained how you could anchor your scene to a real-life object or image. Neither of us had showed them how to do it, and neither of us helped them with the anchoring. Through experimentation and a fast understanding of the topic and the tools they had figured this out by themselves.

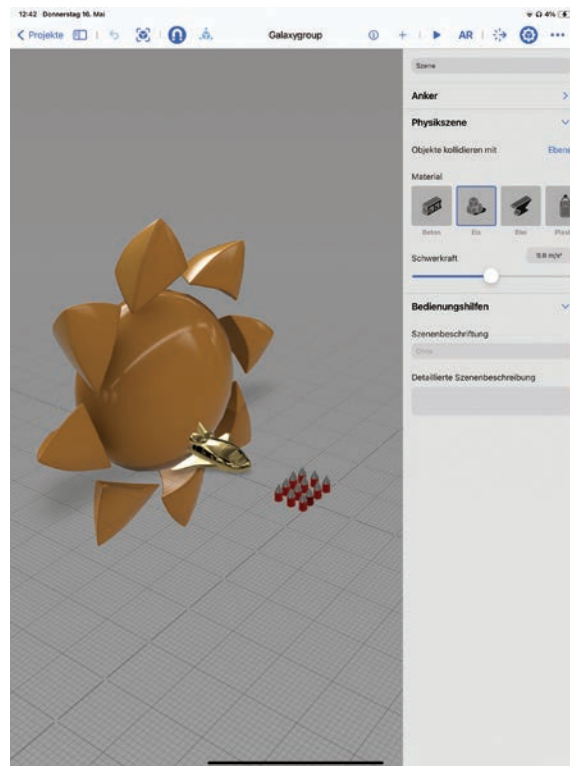


Figure 96 AR prototype workshop 2, students work, 2024

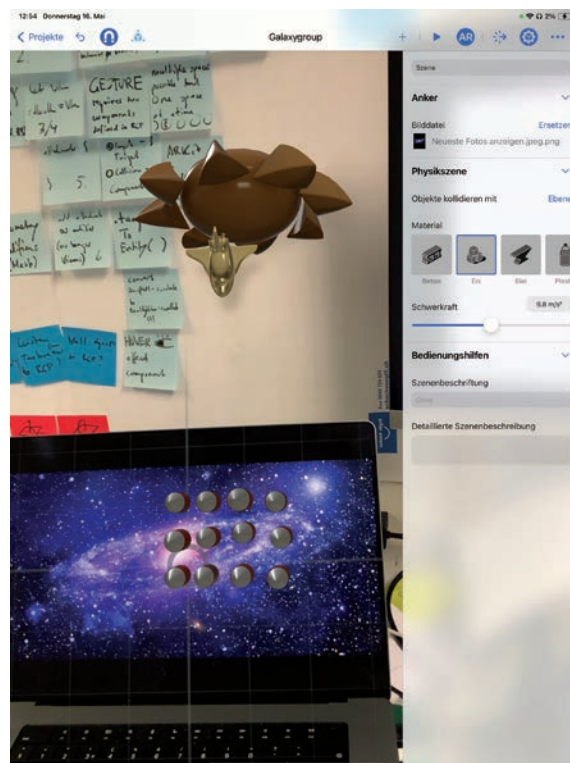


Figure 97 AR prototype workshop 2, students work, 2024



Figure 98 Workshop 2 gotec, authors work, 2024



Figure 99 Workshop 2 gotec paper prototype, authors work, 2024



Figure 100 Workshop 2 gotec paper prototype to AR, authors work, 2024.



Figure 101 Workshop 2 gotec paper prototype to AR, authors work, 2024v

Science Pavilion UZH museum

We involved five staff members from the Science Pavilion UZH museum in an early technical prototype session on the Apple Vision Pro.

The early prototype differs from the final one in terms of looks in virtual content. The focus that time was the actual app's user flow that has shaped from our initial, more general user tests earlier at go tec!

Findings.

01. *Reduction of misuse.*

We limited the number of placed 3d objects to four in total, each representing exactly one of the four total components that make up a whole radiotracer in our app. This discrete restriction helped us minimize unnecessary placement of virtual objects. It guides the user flow effectively: For instance, if a user has previously selected and placed an antibody, selecting another antibody would prompt them to either confirm replacing the current with the new one or cancel the action. Preventing placements of multiple objects is an additional suggestion from the staff, especially for the younger demographics, as they've observed creative (mis-)uses in interfaces that provide any sorts of combination or selection options.

02. *Onboarding- and Interaction Challenges.*

We found that users figure out gestures and inputs based on analogies they are familiar with, but not all mental models align when interacting with the app's user interface. For example, scrolling through the grid of placeable components on the left side were successfully performed with a lasso-like hand movement. Selecting a placeable component, however, was interpreted as a drag-and-drop

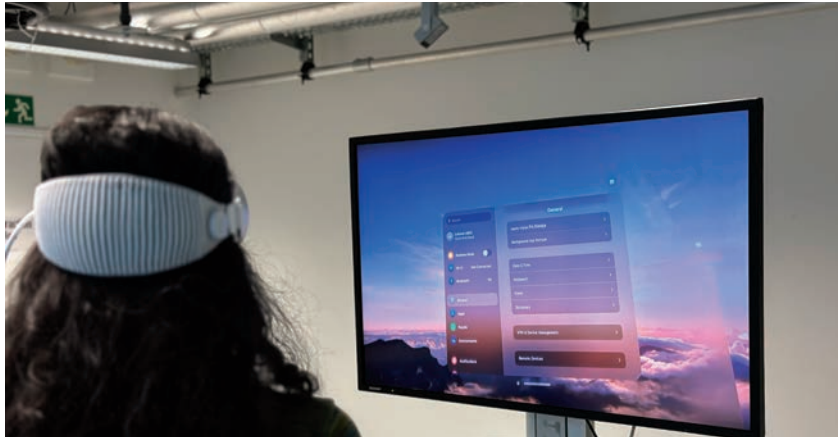


Figure 102 Image user testing science pavilion, authors work, 2024.

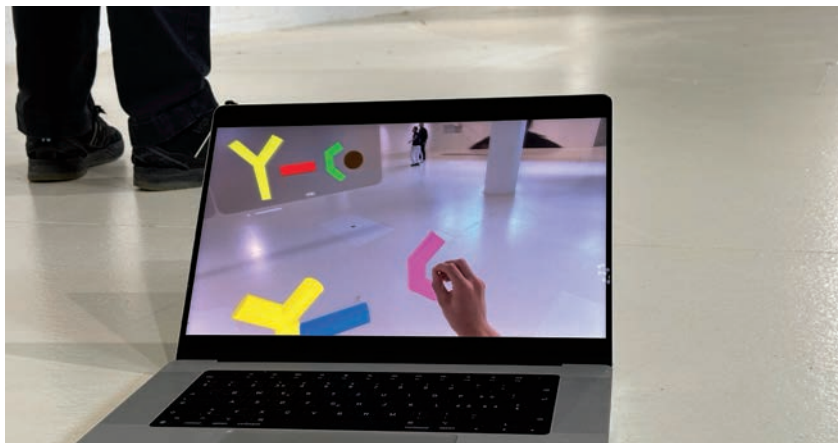


Figure 103 Image user testing science pavilion, authors work, 2024.



Figure 104 User test Science Pavillillion, 2024, authors work

interaction where three out of five users directly grabbed the thumbnail, reaching their arm to touch the virtual window, to then pinch and drag it into space. This did not initiate a placement. Our assumption instead was to look at the placeable component on the grid, then perform a tap with finger and thumb while the hand rests at the thigh.

While it was understandable enough for the members to build a radiotracer based on the reference view on the right side, having more than two components placed in space started obscuring the window. Users either walked around the virtual content to directly interact with the building view, or they repositioned the window with the grabber. A new suggestion is to anchor the selected 3d objects on a physical table or to lower the initial placing position in space.

03. Onboarding methods.

Three potential possibilities to address the interaction challenges we identified, for which the Apple Vision Pro at its current state, necessitates a more generous integration of onboarding methods, with new spatial interactions to get familiar with.

Regardless of any of the following methods used, having an additional supporting person available at all times turned to a strong consensus among all of us.

04. Poster on podium.

A poster placed at the podium providing users with quick visual bullet points on how to interact with the app and the Apple Vision Pro.

05. *Video on podium.*

A video played on an iPad placed on the podium guiding visitors through interaction steps.

06. *Tool tips in app.*

Integrating onboarding within the app assists the user during each step of interaction within the app in form of short text labels, informing what actions to take.

The main findings suggest assumption of no prior knowledge from the visitor at this stage. Clear explanations and instructions of gesture and input need to be provided during the whole exhibition. Having a.) a helping hand during the exhibition for immediate support and b.) providing visual reference material available at immediate reach will help the museum staff and the visitors make the best out of the immersive experience.

Our rule of thumb were always three minutes for the visitor to explore our app as standalone. As we've seen with in the first hardware- and user tests with the museum staff, it remains a challenge to familiarize the user with a new technology at start. Beyond the scope of this project, we would have further investigated how other methods of onboarding could be integrated, replaced, or improved. It does not happen often in times like these that a new product line gets introduced. Augmented reality and virtual environment systems have existed for a while, but new interaction paradigms are constantly on the change. We see great opportunity and an immense importance in the introduction of a new product with its interactions to onboard with.

Scientific Check

HollandLab

We went to test our advanced technical prototype with two of HollandLab's fellow researchers to test the app regarding its scientific accuracy.

01. *General.*

The synthesis of a radiotracer is a complex process involving knowledge stemming from many different disciplines. To narrow the building of a radiotracer down into four main blocks to choose and put together from, is confirmed to be just enough from the researchers. (Lamb et al., 2020) characterisation and application of radiolabelled compounds for use in diagnostic and therapeutic medicine requires a diverse skill set. This article highlights a selection of our ongoing projects that aim to provide new synthetic methods and radiochemical tools for building molecular imaging agents with various radionuclides. (Lamb et al., 2020) There was already a resonance when we presented our scenario during the concept phase and all in all they are happy with what we will show to the museum public.

02. *User Flow.*

When it comes to building the radiotracer, not every order makes sense, especially when selecting the very first component. We got advised that the visitor should not start with the radionuclide. This is supported by our findings from the workshop where attaching the radionuclide happens at the end of the process. The three other components, namely antibody, linker and chelate can be initially placed by choice. The recommended start would be the linker as the visitor could attach the rest of the pieces to the respective sides. characterisation and application of radiolabelled compounds for use in diagnostic and therapeutic medicine requires a

(Lamb et al., 2020)

diverse skill set. This article highlights a selection of our on-going projects that aim to provide new synthetic methods and radiochemical tools for building molecular imaging agents with various radionuclides.

(Lamb et al., 2020)

03. *Color Coordination.*

We should avoid color green for our particle emitters that virtually display around the physical round flasks. With them we wanted to show feedback while the user builds the radiotracers to highlight if the set combination is correct or needs adjustments. Instead of green, they advised us to use blue, red and orange.

04. *Formulas.*

We should leave out any forms of formula as they bring complexities with them. Antibodies, the Y-shaped forms in our app do not really have a formula. We therefore should omit the usage of any more abstract visualizations.



Figure 105 Usertesting HollandLab, authors work, 2024



Figure 106 Usertesting HollandLab, authors work, 2024



Figure 107 Exhibition concept, authors work, 2024.

Project Communication

Exhibition Concept

To exhibit our work, we wanted to have the user immediately immersed in the topic. The visitor should find a minimalist representation of the lab. This lab would come to life as soon as the glasses are out on and activated. It would as well be of importance, that other visitors could always see what the person wearing the Apple Vision Pro could see.

The cameras of the Apple Vision Pro do record people around them. The recordings are not stored, but it would be better to show the bystanders what is getting recorded.

(Apple, Inc., 2024a)



Figure 108 Exhibition concept, authors work, 2024.

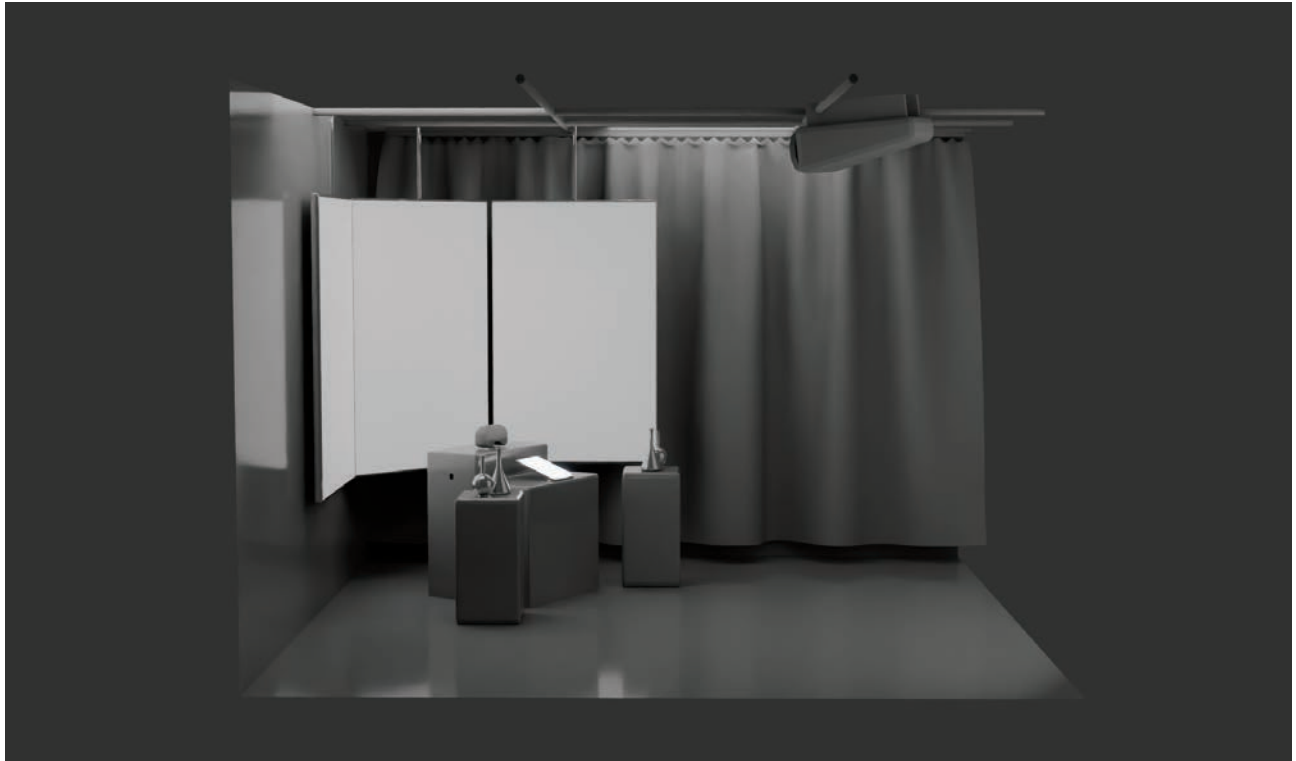


Figure 109 Exhibition concept, authors work, 2024.

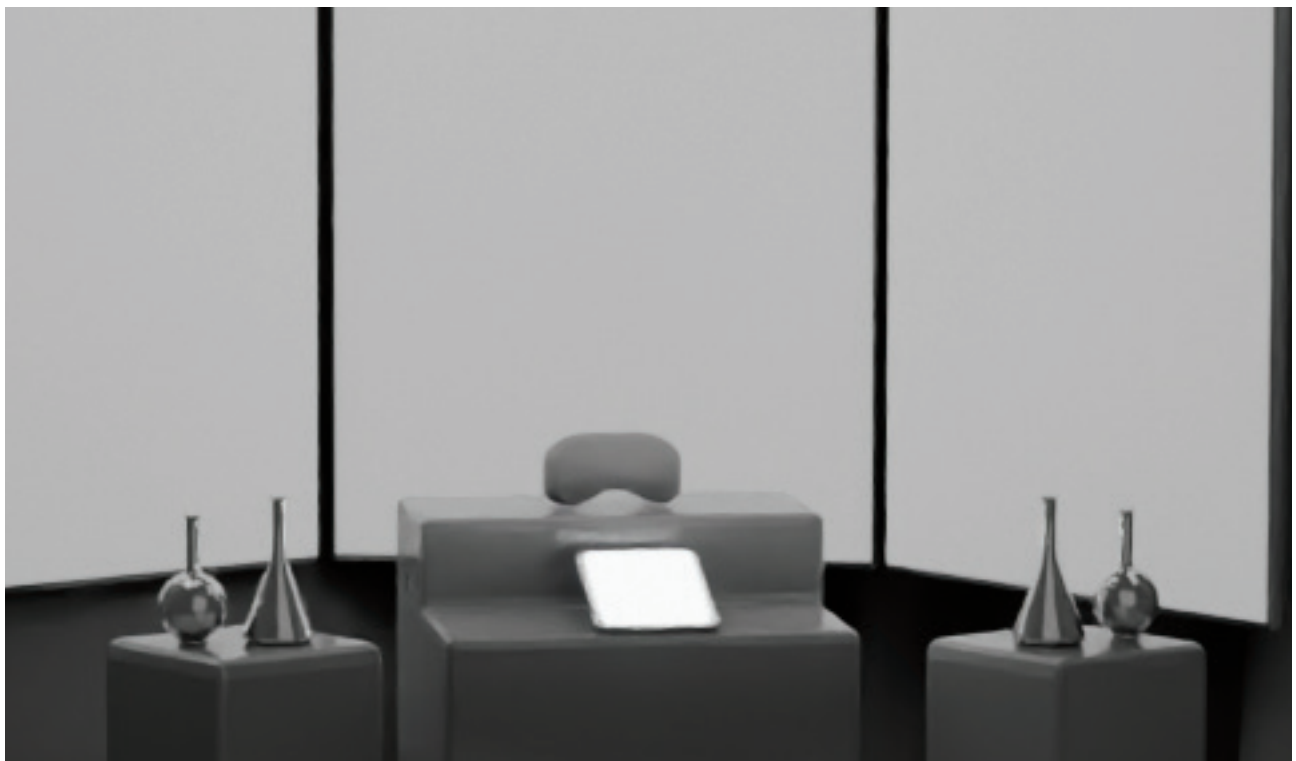


Figure 110 Exhibition concept, authors work, 2024.



Figure 111 Exhibition concept, authors work, 2024.



Figure 112 Exhibition concept, authors work, 2024.

Video

The video for the project would be a showcase of the application and how it could be used. The core functions are shown and how they explain the science of radiotracers. In a simple step by step video. Jonas Genz and Eda Nisli give context on the science. The setting is a simple interview setting. The idea is to include the target group as well, but at the writing of this text, we have not yet found willing participants.

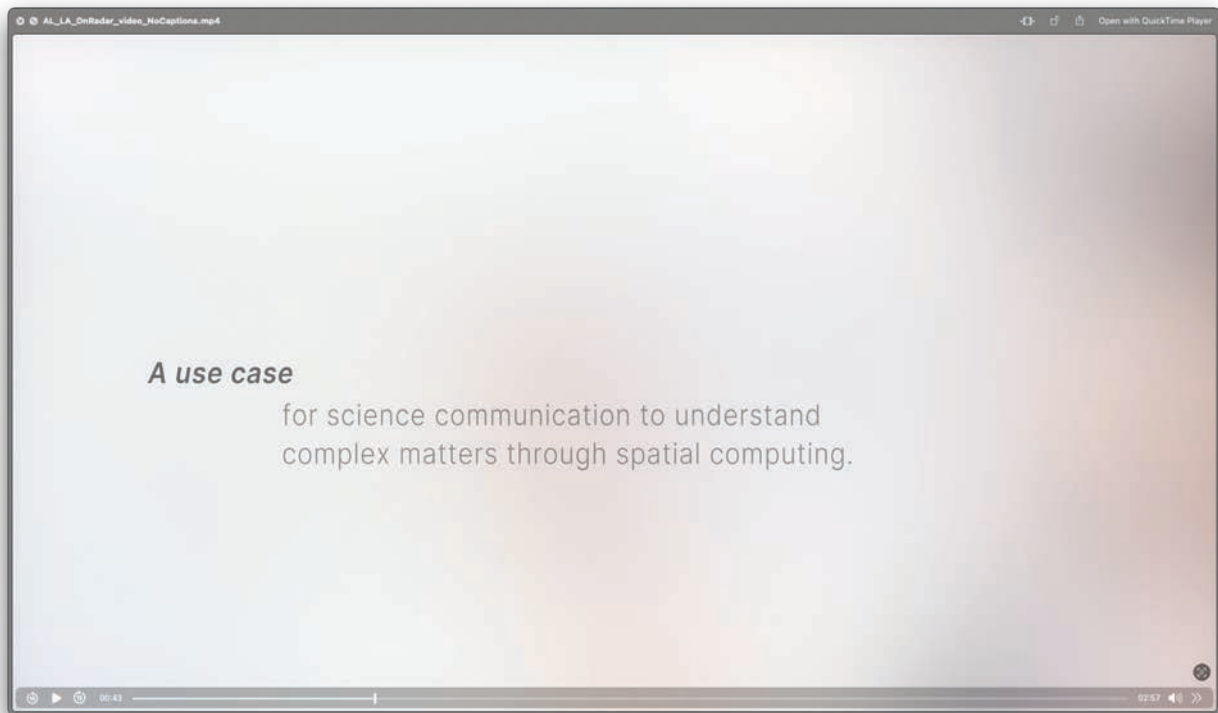


Figure 113 Screenshot video, authors work, 2024

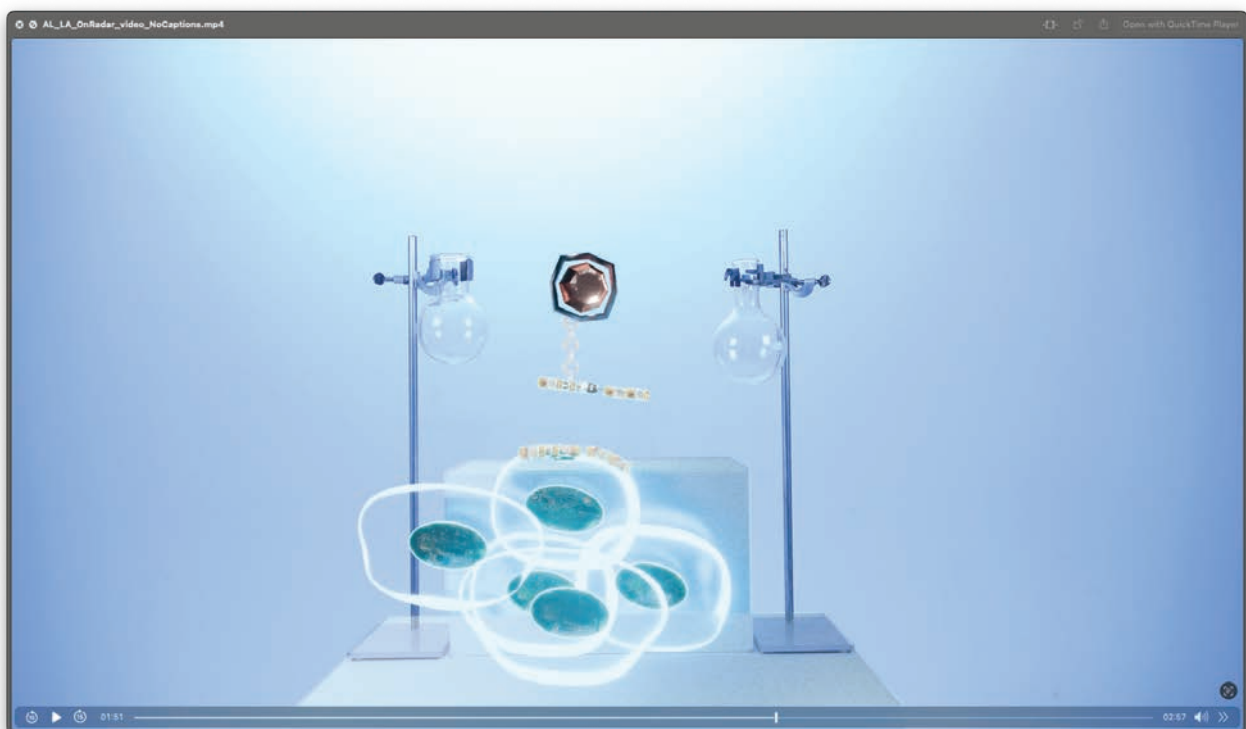


Figure 114 Screenshot video, authors work, 2024

Result

With our app, we have laid the groundwork on the three pillars that make up an app for the Apple Vision Pro: We started with Immersive Spaces to design the view users could build radiotracers. Upon induction, they see a three-dimensional representation of a mouse animated inside a Volume. They navigate with windows we still know from the Mac and iPad.

The outcome of our project is a spatial computing app designed in a museal context that is tailored for young visitors to explore the field of medicinal radiochemistry. Upon entering the app, they get assisted with getting familiar of new spatial interaction gestures. By following along short frames of onboarding steps, they intuitively select and place virtual 3D representations of radiotracer content in the real space.

The following pages showcase our final screens.

Antibody



Figure 115 Antibodywithlabel,authorswork,2024.

Create

Antibody Linker Chelate Nuclide

161 Tb 89 Zr

177 Lu 99m Tc

68 Ga 188 Re

Test Induce





Figure 116 Final Result, authors work, 2024



Like a key to a lock, the antibody of the radiotracer docks to the matching cancer cell.

Chelate  

Nuclide  

Tap with index finger and thumb and hold to drag



Figure 117 Build window applicarion, authors work, 2024

On Radar

Bachelor Interaction Design

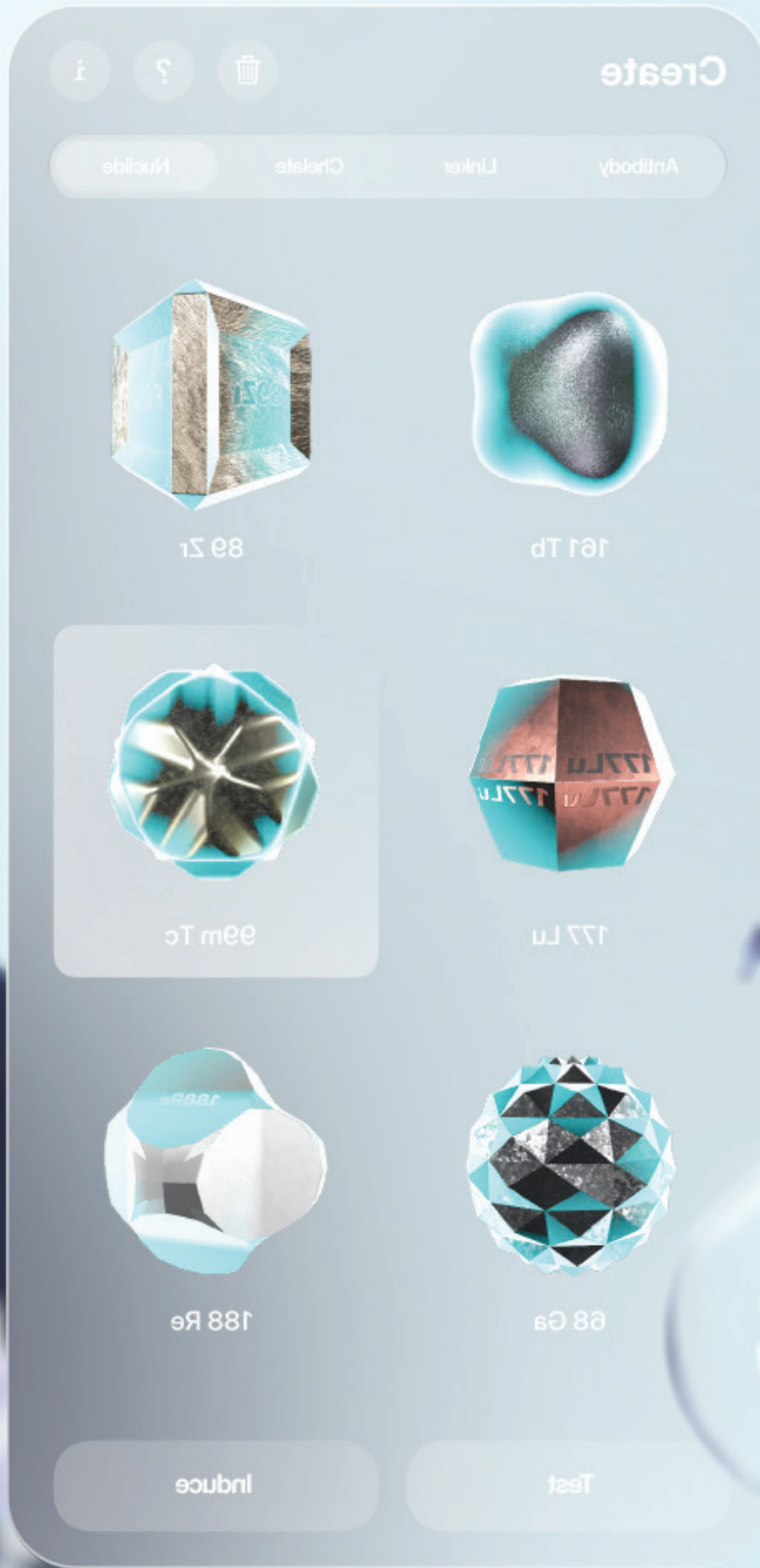
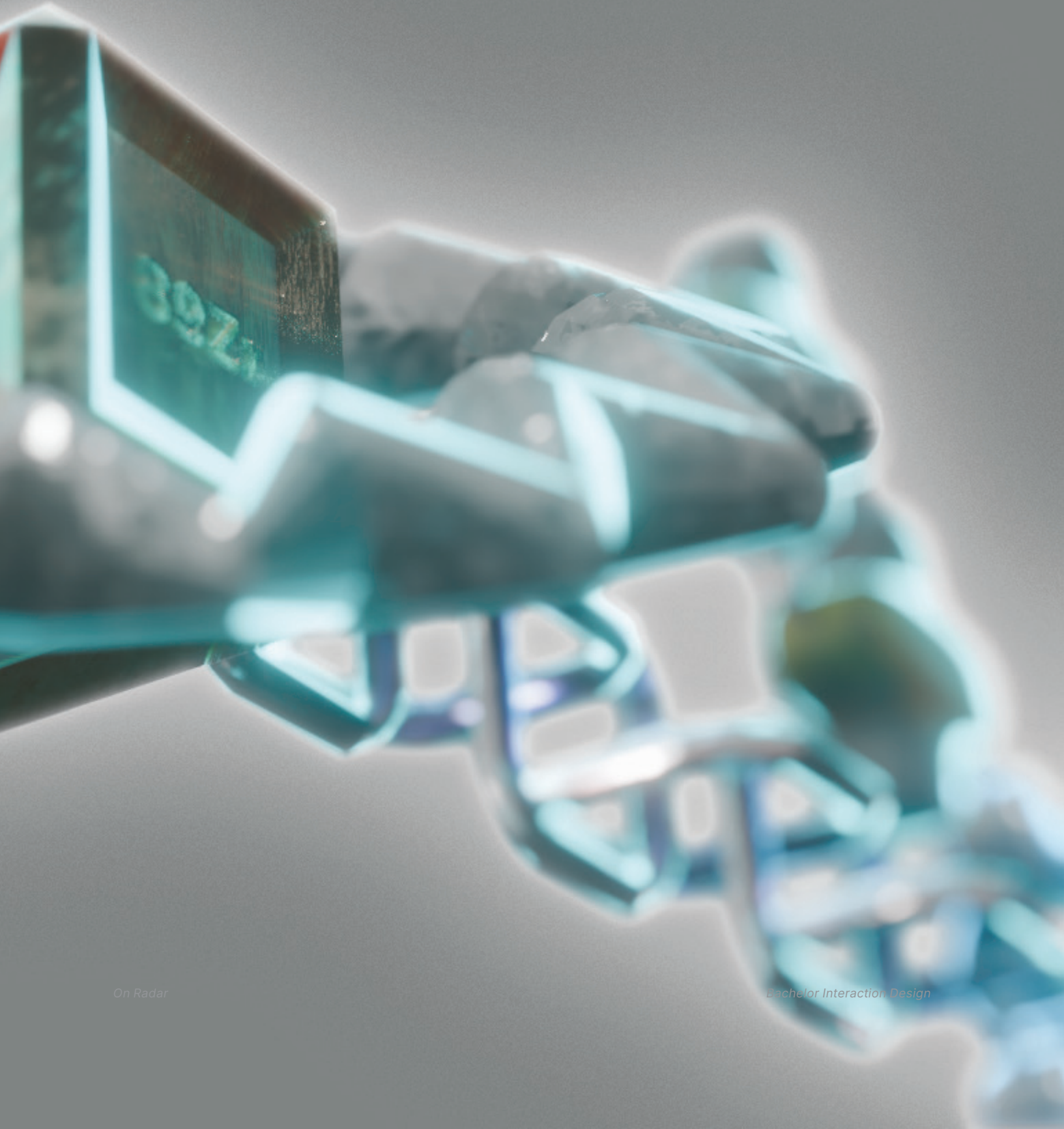




Figure 118 Complete Tracer, authors work, 2024.



Conclusion and Reflection

Reflection

Process

The process was unlike any other we have had in the previous undergraduate courses. Last year, we settled on choice of platform and topic earlier than the regular schedule. This decision changed the nature of our project during which the research, conceptualization and development always led back to the initial idea at the start.

We were surprised how much the topic of animal testing has gained attention as our concept progressed. From the beginning we knew that a three-dimensional representation of the mouse would be an integral part of our research process to display in our app.

Experiments on animals in Switzerland are, under strictest of laws, permitted for the development of drugs and therapies that offer better treatment for human and animal diseases. Observing the debate on the political landscape, one could say that the incorporation of the mouse in our app has indeed set a statement. As designers, we recognize the relevance of this debate and support the development of research under these terms. Certainly, at the same time we see the importance of animal experiments in our app to transparently showcase so, also as a way of showing that animal testing is an integral part in the researcher's process as well.

(The Federal Council, 2022)

Up until the middle of the project, we did not have Apple Vision Pro yet. This challenged us to distribute the work of modelling and development. However, hardware is not everything. Staying true to the concept meant 1.) sticking to the plan and 2.) not hitting directly towards all devices' capabilities. First comes the concept, followed by hardware. We are happy and proud what we could have technically achieved in the second half of the project course.

We want to address our instincts as Interaction Designers. Having planned the workshop at go tec! With regard that our technical prototype was not yet at an advanced stage meant that we had to adapt aspects that made up our final app. In those situations where things are not finished the way we planned for, we valued how much we adapted the workshop to still bring as many learnings from it as possible. This has evolved and confirmed especially after the second user test iteration in the workshop setting.

Methodologically, we felt most confident with the workshops and field visits when intervening in an unknown field. The workshop with researchers of HollandLab and the visits at the laboratory proved for us to be of most important value. We were able to extract the needed information to validate or invalidate our assumptions. We recommend expanding this combination of methodology in any further research domain designers want to investigate in.

Partners & Team

We look back at a time-dense time. Parallel to our design meetings, we were in regular exchange with our cooperation and collaboration partners. Carrying a project with many stakeholders involved demanded regular exchange and communication. This infrastructure was not to underestimate.

We would argue that a clear and regular communication is what held this project together during all times. The amount of time it takes to arrange meetings, presentations, workshops, electronic mails, instant messages, voice- or video calls and user tests has once again reinforced that communication was among the most important structures of our Bachelor's project.

Overall, we received good responsiveness from all partners. Our monthly conversations had already started in June last year and with every internal progress session, we kept each other updated. This assured all involved people knew what the process was and how far along it has progressed.

Apple Vision Pro

It comes without denying that a device worth 3500 dollars is taken for granted as part our Bachelor's project. We welcome to take one step back and acknowledge that this project would have been possible on other platforms, if not on even another constellation leveraging augmented reality as well. We therefore do not expect an audience for the mass at this stage.

The decision of platform is a parameter that regulates the efficiency of user testing. Its effectiveness, its finances, its development environment, its user interface design, its story and should therefore not be underestimated. However, the decision of technological stack is what influences the decision of platform vastly and thus makes design and development for the Apple Vision Pro suitable and distinguished from others. An Interaction Designer familiar in the engineering and design field knows what trade-offs make the greatest difference in creating it – most of the processes which would not have been seen by the end user anyways, even if we decided to develop and design for Meta Quest: The same questions would have come up in any regard, concerning development environment, use of frameworks, programming language and the user interface design system.

In the end, what has beaten alternative platforms in favor of visionOS was the environment we could develop and design for. The contents of our app would not only be shared across the spatial computing platforms, but across all existing ones thanks to the modularity of SwiftUI and RealityKit Apple has invested in. These frameworks are also optimized to the Swift programming language. We run code natively on devices that are optimized for its own processors. Ultimately, question of platform choice for us came to the technological stack, but also with what professional backgrounds we possessed before. We estimated it to be of a great challenge if we had to learn the stack from the beginning.

Apart from the platform decision lies our one wish for improvement should the Apple Vision Pro be used in a museum exhibition context. Eyesight is, as our first observations showed, of greatest challenge. We may lose users if we provide only one device that does not have ZEISS lenses at hand, but we must also uphold an optimal user experience that provides precise user input. Before our actual application comes into play, there lie pain points that must be kept in mind throughout the whole service for it to be put in use: onboarding the visitors with the new interaction methods. As of now, the headset is still a personalized device, with its eye- and hand setup calibrated for one individual person.

(Kuss, 2023)

From a developer's perspective, it can be described as a dream come true. To use the same tools and frameworks we usually develop apps on iOS, made building for visionOS an instantly familiar experience. The resources provided were crucial for getting started with all the new API's that were introduced at WWDC 2023. Regarding the programming of our Bachelor's project, we found the documented articles, SDKs, and complementary videos from that year as well as from the previous years to be of helpful guidance.

From a designer's perspective, the environment around visionOS is amazing to build for. Tools such as Reality Converter and Reality Composer Pro make it easy to create stunning visuals in little time. It takes some adjustments to work in a completely Apple-based environment. Yet, the tools borrow aspects from other 3D programs that make it easy and fast to adjust.

On another note, the documentation provided by Apple lacks depth and completeness. It seems that this documentation is catered to developers. However, in an environment like visionOS that is dependent on both designers and artists who create assets, it would've been advantageous to find some more resources about this aspect of the process of developing an application for Apple Vision Pro.

Learnings

As our project neared towards its finish line, we began to recognize some things we would have done differently from the start.

Looking back, would have liked to work with the Apple Vision Pro right off the start, noting that we had the device for a total of only two months to physically test and develop with. The timeframe of this project was too short, for which we underestimated the amount of workload it took developing an app for the Apple Vision Pro after conceptualization. Since officially obtaining it in March with many efforts of organizing one before, we realized we could no longer fully leverage all the many aspects this platform offers, including spatial audio. It was time to put the full focus on the core aspect of our concept instead. Having had the device from the beginning would have better distributed the development- and 3D modelling time over this period, while still iterating on the concept.

Most importantly, the visionOS simulator on Xcode would have not allowed us to test features that required build-in sensors for our use case. A colleague who visited the Apple Developer Centre in Munich to test his app on the Apple Vision Pro for one day in February, told us that the difference between working with the simulator and a physical device were two completely different experiences. A month later, we could confirm this. But because we were aware of the risks, we made sure to have a backup plan ready to fall back on iPad in any case, hence the storyboard flexibility. And of course, it is a dilemma to question the decision on platform in the middle of the process, but that was part of it, and we were ready to adapt to this.

One of the shortcomings we most importantly take note from is that we did not have the chance to obtain and thus validate the pre-knowledge of our target users. We take this

task with us in anticipation of LONG NIGHT on September 2nd. There, our app project will be exhibited as part of this ceremony we look forward to and can draw the needed findings from our last puzzle pieces.

On a last broader note, we should be reminded of the scope an undergraduate project entails as with the current pressure in development and time, we realized to keep our ambitions and goals down-to-earth, especially since the Concept Seminar in January.

Conclusion

Looking back at our research question “Is the Apple Vision Pro a valid use case in this project?”, we must split our findings into the hardware and software aspect.

Before obtaining the Apple Vision Pro in March, we assumed that eye- and hand tracking would not require the person not having it initially set up to redo it completely. This was an important premise for us as the device would be exhibited in a museum. After using the hardware and testing it with people from the design department, the Science Pavilion UZH museum staff, high school students at go tec! and group members from HollandLab, in all cases we had to manually redo eye- and hand tracking for their inputs to respond accurately. While there is a shortcut to quickly go through the process of redoing it, we had to give this step a hard pass as it will slow down user retention, disrupt the user flow and results in being an important leverage point in the user journey.

(Meadows, 1999)

If there is one feature of the Apple Vision Pro we would like to see improved in a future generation, it is the approach in enabling multi-user support without having to manually redo eye- and hand setup.

From the software aspect – everything involving using visionOS in an ideally setup state – has proven to be of great potential. Our project as a standalone app functions well with the innate stationary characteristic of the Apple Vision Pro. It offers the visitor to explore matters that go further than the traditional screen. However, there was an underestimation concerning onboarding from our side. Only when we went user testing our app with the museum staff, did we realize at how many aspects they pointed us to potential interaction barriers this device currently brings. The good thing is that we can do something about the onboarding. The tracking aspect concluded in the hardware is a concern outside our power.

If we look at our second research question “Is the research around radiotracers suited to be used in an explanatory spatial computing application?” through the context of the museum, we must answer it with yes and we will see. As taken from our learnings, we must yet test the level of difficulty of our in-app content to evaluate which pre-knowledge is best suited.

Despite that, the use of spatial computing technology for explaining the field of medicinal radiochemistry has proven to be valid as it enables visitors outside this field to encounter radiotracer that are otherwise either researched behind closed doors, are too small for the eye to see or emit radioactivity. The most inspiring aspect of this project we conclude from our background research: we have hope to save the lives of humans.

Contribution

By bridging the sciences with interaction design, we combined Science Visualization-, Interaction Design- and Game Design methods in a spatial computing application on the Apple Vision Pro.

We hope we shed more light on a yet unknown field as we introduce a streamlined app to young visitors that explains the research of radiotracers in a graspable form and serves as a promising showcase for the museum.

Future Steps

There were yet so many features and aspects of spatial computing to take full advantage of, either not making it to our final app project or not being further explored. For the future we could see our project continued in the following aspects.

Because we addressed the importance of evaluating the pre-knowledge of our target users, the first step in further improving this project would be to conduct further user tests in the museum context.

Beyond the platform scope of visionOS and the Apple Vision Pro, we would love to see the project expanded outside the range of the hardware and software we focused on, by making a physical artefact, installation, or a combination out of it.

On a bigger picture, we see great potential for creating a collection of similar apps that address single topics on science. How could a spatial computing app in anthropology, biology or physics look like?

We have built the foundation for a multi-platform app in the future. Next to the Apple Vision Pro, our codebase can be adapted to expand to iPhone and iPad. This requires additional work but half of it is already done with the provided 3D assets.

Lastly, we would love to see our app published as a potential App Store release on visionOS. We did have corresponding plans for doing so. But until the App Store for Apple Vision Pro is available in Switzerland, we would first keep our young visitors during the Science Pavilion's one-year pilot phase of this application on the radar.

Bibliography References

Aliaga, D. G. (1997). Virtual objects in the real world. *Communications of the ACM*, 40(3), 49–54. <https://doi.org/10.1145/245108.245120>

Apple, Inc. (2017). Apple Park Visitor Center für die Öffentlichkeit zugänglich. *Apple Newsroom (Schweiz)*. <https://www.apple.com/chde/newsroom/2017/11/apple-park-visitor-center-opens-to-the-public/>

Apple, Inc. (2023a). Introducing Apple Vision Pro: Apple's first spatial computer—Apple. <https://www.apple.com/newsroom/2023/06/introducing-apple-vision-pro/>

Apple, Inc. (2023b). Keynote—WWDC23—Videos. *Apple Developer*. <https://developer.apple.com/videos/play/wwdc2023/101/>

Apple, Inc. (2024a). Apple Vision Pro Privacy Overview.

Apple, Inc. (2024b). Apple Vision Pro—Technical Specifications. *Apple*. <https://www.apple.com/apple-vision-pro/specs/>

Apple, Inc. (2024c). AR Creation Tools—Augmented Reality. *Apple Developer*. <https://developer.apple.com/augmented-reality/reality-composer/>

Apple, Inc. (2024d). ARKit 6—Augmented Reality. *Apple Developer*. <https://developer.apple.com/augmented-reality/arkit/>

Apple, Inc. (2024e). Capture and edit your Persona (beta) on Apple Vision Pro. Apple Support. <https://support.apple.com/guide/apple-vision-pro/capture-your-persona-beta-dev-934d40a17/1.0/visionos/1.0>

Apple Inc. (2024). Create ML - Machine Learning. Apple Developer. <https://developer.apple.com/machine-learning/create-ml/>

Apple, Inc. (2024f). Designing for visionOS. Apple Developer Documentation. <https://developer.apple.com/design/human-interface-guidelines/designing-for-visionos>

Apple, Inc. (2024g). Designing for visionOS. Apple Developer Documentation. <https://developer.apple.com/design/human-interface-guidelines/designing-for-visionos/>

Apple, Inc. (2024h). Designing RealityKit content with Reality Composer Pro. Apple Developer Documentation. <https://developer.apple.com/documentation/visionos/designing-reality-kit-content-with-reality-composer-pro>

Apple, Inc. (2024i). Devices and Simulator. Apple Developer Documentation. <https://developer.apple.com/documentation/xcode/devices-and-simulator>

Apple, Inc. (2024j). Immersive experiences. Apple Developer Documentation. <https://developer.apple.com/design/human-interface-guidelines/immersive-experiences>

Apple, Inc. (2024k). Model3D. Apple Developer Documentation. <https://developer.apple.com/documentation/realitykit/model3d/>

Apple, Inc. (2024l). Move, resize, and close app windows on Apple Vision Pro—Apple Support (AM). <https://support.apple.com/en-am/guide/apple-vision-pro/dev009366408/visionos>

Apple, Inc. (2024m). RealityKit Overview—Augmented Reality. Apple Developer. <https://developer.apple.com/augmented-reality/realitykit/>

Apple, Inc. (2024n). RealityView. Apple Developer Documentation. <https://developer.apple.com/documentation/realitykit/realityview>

Apple, Inc. (2024o). Swift. Apple. <http://www.apple.com/lae/swift/>

Apple, Inc. (2024p). SwiftUI Overview—Xcode—Apple Developer. <https://developer.apple.com/xcode/swiftui/>

Apple, Inc. (2024q). UIKit. Apple Developer Documentation. <https://developer.apple.com/documentation/uikit>

Apple, Inc. (2024r). visionOS Overview. Apple Developer. <https://developer.apple.com/visionos/>

Apple, Inc. (2024s). What does EyeSight show? Apple Support. <https://support.apple.com/guide/apple-vision-pro/about-eyesight-tan5162eaaec/visionos>

Apple, Inc. (2024t). Xcode 15. Apple Developer. <https://developer.apple.com/xcode/>

Apple, Inc. (2024u, May 13). Xcode. Mac App Store. <https://apps.apple.com/ch/app/xcode/id497799835?mt=12>

Artivive GmbH. (2023). BringArtToLife—Artivive. <https://artivive.com/>

Artivive GmbH. (2024). About. Artivive. <https://artivive.com/>

about/

Brodie, K. W., Carpenter, L. A., Earnshaw, R. A., Gallop, J. R., Hubbold, R. J., Mumford, A. M., Osland, C. D., & Quarendon, P. (2012). *Scientific Visualization: Techniques and Applications*. Springer Science & Business Media.

Chacon, S., & Long, J. (2024). Git. <https://git-scm.com/>

Cloudinary. (2024). USDZ Format: How It Works, Use Cases, and Pros/Cons. Cloudinary. <https://cloudinary.com/guides/image-formats/usdz-format-how-it-works-use-cases-and-pros-cons>

DAQRI. (2014, January 6). Elements 4D Interactive Blocks. Kickstarter. <https://www.kickstarter.com/projects/daqri/elements-4d-interactive-blocks>

DAQRI. (2023). Augmented Reality Chemistry Blocks | DAQRI Elements 4D. <https://web.archive.org/web/20180209150252/http://elements4d.daqri.com/>

Diehl, A. (2019, January 1). Design Thinking Workshop–In 2 Stunden Design Thinking üben. #DNO. <https://digitaleneuordnung.de/blog/design-thinking-workshop/>

Falk, J. (n.d.). Understanding Museum Visitors' Motivations and Understanding.

Feiner, S., & Macintyre, B. (1993). Knowledge-based augmented reality.

go tec! (2024). Über uns. go tec! <https://go-tec.ch/ueber-uns/>

Gregory, S. A. (Ed.). (1966). *The Design Method*. Springer US. <https://doi.org/10.1007/978-1-4899-6331-4>

Ha, A. (2019). Daily Crunch: AR startup Daqri is shutting down | TechCrunch. https://techcrunch.com/2019/09/13/daily-crunch-ar-startup-daqri-is-shutting-down/?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLnVbS8&guce_referrer_sig=AQAAAKAYeaGLyirkdHFo0J9atob26m-6W9Ks-9k9SW81HFh24I-Ujow4nDyVYxDHA2UKQPnUz0x4qvG-puBcYTramBkxgXeVeGyHrhMZVIHZOmeafnp-35slq9UK-rU9r-W2xOGTljLpfRnFjoif0P6gTLUUM5c2FE9fZJOM_zaT64_4Z5C

Hall, W. A., Paulson, E., Li, X. A., Erickson, B., Schultz, C., Tree, A., Awan, M., Low, D. A., McDonald, B. A., Salzillo, T., Glide-Hurst, C. K., Kishan, A. U., & Fuller, C. D. (2022). Magnetic resonance linear accelerator technology and adaptive radiation therapy: An overview for clinicians. *CA: A Cancer Journal for Clinicians*, 72(1), 34–56. <https://doi.org/10.3322/caac.21707>

Hassan, A. (2023). What Is a Command Line Interface? (CLI Definition) | Built In. <https://builtin.com/software-engineering-perspectives/command-line-interface>

Hayward, V. (2008). A brief taxonomy of tactile illusions and demonstrations that can be done in a hardware store. *Brain Research Bulletin*, 75(6), 742–752. <https://doi.org/10.1016/j.brainresbull.2008.01.008>

Holland, J. P. (2024). HollandLab. [Hollandlab. https://www.hollandlab.org/research](https://www.hollandlab.org/research)

Katz, S. D. (1991). *Film Directing Shot by Shot: Visualizing from Concept to Screen*. Gulf Professional Publishing.

Kim, G. J. (2015). *Human-Computer Interaction: Fundamentals and Practice*. CRC Press.

Kuss, J. (2023). ZEISS Optical Inserts für Apple Vision Pro. <https://www.zeiss.de/corporate/ueber-zeiss/gegenwart/newsroom/pressemitteilungen/vision-care/zeiss-optical-inserts.html>

Lamb, J., Earley, D. F., Guillou, A., Behmaneshfar, S., Bühler, J., Pires, P., Klingler, S., Gut, M., Flores, J. E., Gribi, F., Fay, R., D'Orchymont, F., & Holland, J. P. (2020). Expanding the Chemistry Palette for Radiotracer Synthesis. *CHIMIA*, 74(12), 946. <https://doi.org/10.2533/chimia.2020.946>

LaValle, S. M. (2023). *Virtual Reality*. Cambridge University Press.

Meadows, D. (1999). *Leverage Points: Places to Intervene in a System*. Hartland: The Sustainability Institute, 19.

Merge Labs, Inc. (2023). Merge Cube | AR/VR Learning & Creation. <https://mergeedu.com/cube>

Merge Labs, Inc. (2024, January 10). Spatial computing used in today's classroom with an iPad and Merge EDU. Merge EDU. <https://mergeedu.blog/spatial-computing-used-in-todays-classroom-with-an-ipad-and-merge-edu/>

Moskvitch, K. (2017, February 15). The machines that learned to listen. <https://www.bbc.com/future/article/20170214-the-machines-that-learned-to-listen>

Müller, J., & Wiedemann, J. (2023). *The computer: A history from the 17th century to today*. Taschen.

Mynatt, E. D., Hudson, S. E., Fitzpatrick, G., Association for Computing Machinery, & SIGCHI (Group : U.S.) (Eds.). (2010). CHI Conference: We are HCI: conference proceedings, Atlanta, Ga, USA, April 10-15, 2010. Association for Computing Machinery.

National Academies of Sciences, Engineering, and Medicine. (2017). Communicating Science Effectively: A Research Agenda (p. 23674). National Academies Press. <https://doi.org/10.17226/23674>

Norman, D. A. (2013). The design of everyday things (Rev. and expanded edition). MIT press.

Reliance Digital. (2019). Wearable Technology – Then & Now | Resource Centre by Reliance Digital. <https://www.reliancedigital.in/solutionbox/the-amazing-evolution-of-wearable-technology/#>

Rodríguez, F. C., & Abriata, L. A. (2024). Molecularweb. <https://molecularweb.epfl.ch/index.html>

Rodríguez, F. C., Frattini, G., Krapp, L. F., Martinez-Hung, H., Moreno, D. M., Roldán, M., Salomón, J., Stemkoski, L., Traeger, S., Dal Peraro, M., & Abriata, L. A. (2021). Molecularweb: A Web Site for Chemistry and Structural Biology Education through Interactive Augmented Reality out of the Box in Commodity Devices. *Journal of Chemical Education*, 98(7), 2243–2255. <https://doi.org/10.1021/acs.jchemed.1c00179>

Schaffer, S., Schleicher, R., & Möller, S. (2011). A Model of Shortcut Usage in Multimodal Human-Computer Interaction. In V. G. Duffy (Ed.), *Digital Human Modeling* (pp. 337–346). Springer. https://doi.org/10.1007/978-3-642-21799-9_38

Science Pavilion UZH. (n.d.). Unsere Philosophie. Retrieved May 20, 2024, from <https://www.sciencepavilion.uzh.ch/de/ueber-uns/unsere-philosophie.html>

Science Pavilion UZH. (2024, May 15). Herzlich Willkommen. <https://www.sciencepavilion.uzh.ch/de.html>

Swift, R. (2023, October 7). Objave medijskog sadržaja korisnika/ce Rob Swift (@RobSwish) / X. X (formerly Twitter). <https://x.com/RobSwish>

The Federal Council. (2022). Popular initiative “Yes to the ban on animal and human experiments – Yes to research that brings safety and progress.” <https://www.admin.ch/gov/en/start/dokumentation/abstimmungen/20220213/iniziativa-si-al-divieto-degli-esperimenti-sugli-animali-e-sugli-esseri-umani.html>

usability.de GmbH & Co. KG. (2024). User Journey Mapping: Nutzererlebnisse ganzheitlich erfassen. usability.de. <https://www.usability.de/leistungen/methoden/user-journey-mapping.html>

Vermeeren, A. P. O. S., Calvi, L., Sabiescu, A., Trocchianesi, R., Stuedahl, D., Giaccardi, E., & Radice, S. (2018). Future Museum Experience Design: Crowds, Ecosystems and Novel Technologies. In A. Vermeeren, L. Calvi, & A. Sabiescu (Eds.), *Museum Experience Design* (pp. 1–16). Springer International Publishing. https://doi.org/10.1007/978-3-319-58550-5_1

Vida Systems. (2023). What are molecules? - Vida Systems. Google Arts & Culture. <https://artsandculture.google.com/asset/what-are-molecules-vida-systems/swH9DRTIX2Aypw>

Wikipedia contributors. (2023). Software Development Kit. In Wikipedia. https://de.wikipedia.org/w/index.php?title=Software_Development_Kit&oldid=237928656

Wikipedia contributors. (2024a). API. In Wikipedia. <https://en.wikipedia.org/w/index.php?title=API&oldid=1223842224>

Wikipedia contributors. (2024b). Artificial intelligence. In Wikipedia. https://en.wikipedia.org/w/index.php?title=Artificial_intelligence&oldid=1224349069

Wikipedia contributors. (2024c). Git. In Wikipedia. <https://de.wikipedia.org/w/index.php?title=Git&oldid=243787483>

Wikipedia contributors. (2024d). Swift (programming language). In Wikipedia. [https://en.wikipedia.org/w/index.php?title=Swift_\(programming_language\)&oldid=1224567082](https://en.wikipedia.org/w/index.php?title=Swift_(programming_language)&oldid=1224567082)

Wikipedia contributors. (2024e). Worldwide Developers Conference. In Wikipedia. https://de.wikipedia.org/w/index.php?title=Worldwide_Developers_Conference&oldid=242035988

Zürcher Museen. (2024). ZÜRICH'S LONG NIGHT OF MUSEUMS. Long Night. <https://langenacht-zuerich.ch/en>

Figures

Figure 01 The authors, Duy Bui, 2024	3
Figure 02 Additional teaser image, authors work, 2024	5
Figure 03 Apple vision pro headband, authors work, 2024	7
Figure 04 Close up antibody, authors work, 2024	15
Figure 05 Science Pavillion building, Michele Di Fede,	19
Figure 06 laboratory UZ I 5, Luca Zanier, 2021	21
Figure 07 Stakeholder map with all parties involved, authors work, 2024.	23
Figure 08 Apple Vision Pro at the Steve Jobs Theatre, author's work, 2023.	25
Figure 09 Apple CEO Tim Cook on stage, author's work, 2023.	25
Figure 10 Apple Park, author's work, 2023.	25
Figure 11 Window Apple Vision Pro, authors work, 2024	33
Figure 12 Volume Apple Vision Pro, authors work, 2024	33
Figure 13 Immersive space Apple Vision Pro, authors work, 2024	33
Figure 14 Laboratory HollandLab, authors work, 2024.	37
Figure 15 What are Molecules? (Vida Systems, 2023)	39
Figure 16 What are Molecules? (Vida Systems, 2023)	39
Figure 17 Merge Cube EDU (Merge Labs, Inc., 2023)	41
Figure 18 Elements 4D (DAQRI, 2014)	41
Figure 19 Figure Artivive (Artivive GmbH, 2023)	43
Figure 20 Figure Apple Park app (Swift, 2023)	43
Figure 21 Figure Apple Park app, authors work, 2023	43
Figure 22 Concept development, authors work, 2024	57
Figure 23 Image Science Pavilion, authors work, 2024	59
Figure 24 Laboratory HollandLab, authors work, 2024	63
Figure 25 Example of 1:1 translation at Technorama, authors work, 2024	65
Figure 26 Artefact Technorama, authors work, 2024	69
Figure 27 Flowchart research, authors work, 2024	76
Figure 28 Workshop HollandLab, authors work, 2024	

	78
Figure 29 Jonas Genz wearing the Apple Vision Pro, authors work, 2024	79
Figure 30 Workshop HollandLab, authors work, 2024	80
Figure 31 Creation of the user journey, authors work, 2024	81
Figure 32 Irchel campus university of zurich, authors work, 2024	85
Figure 33 User Journey visitor, authors work, 2024.	87
Figure 34 Paper Prototype for AR, authors work, 2023	91
Figure 35 Scenario 1, authors work, 2024.	93
Figure 36 Scenario 2, authors work, 2024.	94
Figure 37 Scenario 4, authors work, 2024.	95
Figure 38 Scenario 5, authors work, 2024.	96
Figure 39 Scenario 3, authors work, 2024.	97
Figure 40 Storyboard Version 1, sheet 1, authors work, 2024.	100
Figure 41 Storyboard Version 1, sheet 2, authors work, 2024.	101
Figure 42 Storyboard Version 1, sheet 3, authors work, 2024.	102
Figure 43 Storyboard Version 1, sheet 4, authors work, 2024.	103
Figure 44 Storyboard Version 2, sheet 1, authors work, 2024.	106
Figure 45 Storyboard Version 2, sheet 3, authors work, 2024.	106
Figure 46 Storyboard Version 2, sheet 2, authors work, 2024.	107
Figure 47 Storyboard Version 2, sheet 4, authors work, 2024	107
Figure 48 Storyboard Version 2, sheet 5, authors work, 2024.	108
Figure 49 Storyboard Version 2, sheet 5, authors work, 2024.	109
Figure 50 Storyboard Version 3, sheet 1, authors work, 2024	114
Figure 51 Storyboard Version 3, sheet 2, authors work, 2024	114
Figure 52 Storyboard Version 3, sheet 3, authors work, 2024	115
Figure 53 Storyboard Version 3, sheet 4, authors work, 2024	115
Figure 54 Storyboard Version 3, sheet 5, authors work, 2024	116
Figure 55 Storyboard Version 3, sheet 6, authors work, 2024	117
Figure 56 Home, authors work, 2023	121
Figure 57 Storyboard final, sheet 2, authors work, 2024.	122
Figure 58 Storyboard final, sheet 2, authors work, 2024	122
Figure 59 Storyboard final, sheet 3, authors work, 2024.	123
Figure 60 Storyboard final, sheet 4, authors work, 2024.	123
Figure 61 Storyboard final, sheet 5, authors work, 2024.	124
Figure 62 Storyboard final, sheet 6, authors work, 2024.	125
Figure 63 Storyboard Version 3, sheet 2, authors work, 2024	127

Figure 64	Preview of the blood cell mode, author's work, 2024.	129
Figure 65	bezel.it prototype, authors work, 2024.	131
Figure 66	Screenshot Video Prototype, authors work, 2024	131
Figure 67	Screenshot Video Prototype, authors work, 2024	131
Figure 68	Figma prototype start screen, authors work, 2024	133
Figure 69	Figma prototype test screen, authors work, 2024	134
Figure 70	Figma prototype end screen, authors work, 2024	135
Figure 71	Graph showing the permutation, author's work, 2024	137
Figure 72	Paper Prototype of the UI elements, authors work, 2024	138
Figure 73	Production Pipeline graph, authors work, 2024.	140
Figure 74	Screenshot Reality Composer pro, authors work, 2024	145
Figure 75	Screenshot Xcode, authors work, 2024.	145
Figure 76	Flow of the application, author work, 2024.	152
Figure 77	Visualization of a radiotracer, hollandlab.org, 2024	157
Figure 79	Lab mouse, wikipedia commons, 2014	159
Figure 78	Render of the mouse model, authors work, 2024	159
Figure 80	3D Model without modifier applied, authors work, 2024.	161
Figure 81	3D Model with modifier applied, authors work, 2024.	161
Figure 82	Mesh Linker 1, authors work, 2024.	162
Figure 83	Mesh Linker 2, authors work, 2024.	162
Figure 84	Mesh Linker 3, authors work, 2024.	163
Figure 85	Material linker 2 in Adobe Substance Painter 3D, authors work, 2024	163
Figure 86	Material element antibody 3 in Adobe Substance Painter 3D, authors work, 2024	164
Figure 87	Material element antibody 2 in Adobe Substance Painter 3D, authors work, 2024	164
Figure 88	Material nuklide element in Adobe Substance Painter 3D, authors work, 2024	165
Figure 89	Material chelate 1 in Adobe Substance Painter 3D, authors work, 2024	165
Figure 90	User Flow prototype, authors work, 2024.	170
Figure 91	Workshop go-tec 1, authors work, 2024	177
Figure 92	Workshop go-tec 1, authors work, 2024	178
Figure 93	Workshop go-tec 1, authors work, 2024	179

Figure 94 Workshop 1 go-tec. authors work, 2024.	185
Figure 95 AR prototype workshop 2, students work, 2024	187
Figure 96 AR prototype workshop 2, students work, 2024	187
Figure 97 Workshop 2 gotec, authors work, 2024	188
Figure 98 Workshop 2 gotec paper prototype, authors work, 2024	189
Figure 99 Workshop 2 gotec paper prototype to AR, authors work, 2024.	190
Figure 100 Workshop 2 gotec paper prototype to AR, authors work, 2024v	191
Figure 101 Image user testing science pavilion, authors work, 2024.	193
Figure 102 Image user testing science pavilion, authors work, 2024.	193
Figure 103 User test Science Pavillion, 2024, authors work	193
Figure 104 Usertesting HollandLab, authors work, 2024	198
Figure 105 Usertesting HollandLab, authors work, 2024	199
Figure 106 Exhibition concept, authors work, 2024.	200
Figure 107 Exhibition concept, authors work, 2024.	201
Figure 108 Exhibition concept, authors work, 2024.	202
Figure 109 Exhibition concept, authors work, 2024.	202
Figure 110 Exhibition concept, authors work, 2024.	203
Figure 111 Exhibition concept, authors work, 2024.	203
Figure 112 <No data from link>	207
Figure 113 Final Result, authors work, 2024	209
Figure 114 Build window applicarion, authors work, 2024	211

