Virtual and Augmented Reality Applications. Winter Term 2022/23

supervisors: Prof. Dr. Munrir Georges, Andreas Löcken

Documentation of work

team locispace

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1. Metadata

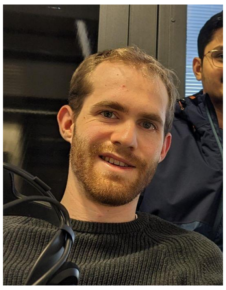
Tanmesh Shah - tas7664@thi.de

Tanmesh has a bachelor's degree in computer science and engineering and three years of experience working as a software engineer professionally. He had an advantage over the team in terms of coding and OOPS concepts.
Hence, he took on the task of developing the project. He had some knowledge of C# but no prior experience with Unity. Since this was his first project involving VR technology, it helped him learn a lot about Unity and VR. He also assisted the group with concept development and usability testing.

Tilak Kamkar - ti.9057@thi.de

Having a bachelor's degree in Computer Science and Engineering and more than four years of working as a Frontend engineer and a UI/UX engineer in the industry, tilak has more inclination towards visual design and the interface design. Thus, he worked on 3D modeling, Material, Visual and Interface Design aspects. In addition to this being a person of UX background he developed personas, design system, storyboards and also involved design thinking and concept Ideation. He also assisted in conducting and evaluating the usability testing.

Benedikt Schramm - bes0058@thi.de



As a former student in industrial design at Hochschule München Benedikt knows a thing or two about creating CAD models which he also did in this project. Besides this, he is also a conceptual thinker and was involved in creating and developing the basic idea into something that really makes sense.
From his experience as a UX research intern at Allianz he has a certain knowledge in research which he used in this project for example when planning and conducting the usability test.

Github:
link: https://github.com/Tanmesh4/ar-vr-thi-app
current branch name: main
how to use:

1. clone to your system and load project
2. Assets => Levels => Usability_test
3. run the unity file

2. Table of content

3. Overview

Resources

The project was conducted as part of the UXDM_AVR lecture and the associated practice courses. According to the module handbook these courses have 5 SWS and 175 hours of total workload during the semester respectively. This timeframe was used by the three team members to create what would become locispace.

Apart from this general timeframe, access to the VR laboratories ressources was very important for testing and development purposes. This place provided powerful Windows PCs as well as Oculus Rift 2 headsets and controllers that were used during the project by the locispace team. The private computers of the team members (two Windows and two Mac laptops) were used during the week to work on the project between laboratory timeslots. Here it was of great help that the place was often opened to coursemembers if requested specifically.

In terms of monetary dimension, this project was conducted completely without any need for funding. The used tools and assets were only taken from free sources.

Most notably:

- Unity
- Github: version control and sharing of the Unity project
- figjam: digital whiteboard for ideation, task distribution and content
- Pitch: presentation tool
- Google docs: writing texts in a collaborative manner
- Fusion 360 Student: 3D modeling
- Blender: 3D modeling

Project management

The work on the project was separated into individual sprints which consisted of the time during the lecture slots. Usually this was one week on the end of which the processed tasks were reviewed and the new tasks were discussed.

To keep track of milestones, tasks as well as the general project progression, the team made use of a figjam board with a corresponding planning section.

Problem

During the initial kickoff phase a brainstorming and clustering of ideas was conducted with all students from practical group 2. In this event we discovered that a big group that might need a learning VR application are students themselves. Often they have a limited attention span that can be extended by fun and game-like learning. Another thing they suffer from is the type of learning content. Oftentimes they have to work with complex, abstract and heavy-to-memorize subjects. One big improvement can be made by high quality learning material. But also, it was deemed impossible to build fitting solutions for all of them at the same time. This said, the team came to the conclusion that it might not be necessary to do so, because structuring and arranging the topics-to-learn already can be part of a learning experience. With this insight, it was agreed upon to try building such a system in order to help students cluster and learn their subjects in one single environment using the possibilities of a VR environment.

Objectives

Effectiveness - The project should lead to a concept that truly could work in the context of the chosen disciplines. This can be achieved using tried and tested learning styles or leaning into scientifically proven methods.
Adaptability - As stated earlier, it was a goal to find a solution that fits multiple subjects and learning styles at once. To achieve this, it needs to have a wide level of adaptability and customizability.
Learning in the process - as no team member had previous experience with Unity, gaining knowledge in the tool and game development in general was a great motivation.
Potential real world impact - with this project the team wanted to find out about better ways to learn - for themselves and potentially others.

4. Concept

User Stories / Personas

To understand the potential users further, the team created personas according to the expected target group. By doing this, the empathy towards them was increased and potential ideas of how to solve their problems started appearing.
Two personas were created in order to have a broad view on the user base. You can find and review them in the appendix.

Ideation

The ideation phase was based on the initial session in the large team. From there the team took direction and thought of various possibilities to solve the given problem. In the appendix -> ideation a lot of the material from this phase can be viewed.

Research

Because one of the project goals was to build a truly working solution, the team also went and did a small research phase on different learning styles and methods that can be applied to the given problem. This way, they learned about the so called method of loci and mind palaces:

“The Method of Loci is an effective mnemonic device, or a trick to aid in memory storage and retrieval. The effectiveness of the Method of Loci relies on visualizing mental images to associate with the material that needs to be remembered.“

- *definition from study.com -*

(https://study.com/academy/lesson/method-of-loci-definition-example-quiz.html)

This method has clear advantages for the given scenario, in that it is very flexible, powerful and is already proven to work.

Further Research showed that VR mind palaces were tried before and working in various research projects. This also led the team to the conclusion that it was worth transferring this concept into a user-focused potential product.

Storyboards

Because a VR application is not just about screens but a 3D environment, Storyboards were created to show in simple sketches how the application might eventually look like.

On one occasion, a digital tool that was used to create a professional looking storyboard in an easy way. Another set of drawings was created with figjam.

These two storyboards gave a good indication on which operations will be performed by the user and what kind of controls could work to achieve the desired effect.

Moodboard & design guide

A simple mood board and design guide were created in order to give guidance when creating the user interface. Primary and secondary colors were defined here, as well as font types for different functions.

UI click prototype

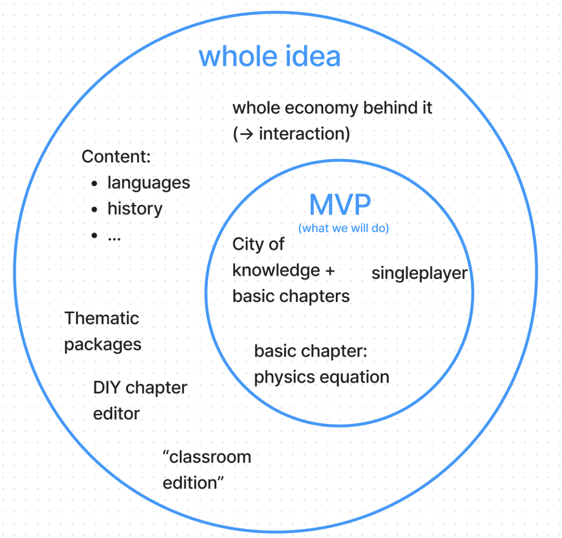
Before implementing it in Unity, the team created a figma prototype of the UI. This was used to develop a workable way of guiding the user through the process of building his mind palace. Some quick tests within the team were performed to clarify that this was a sensible way. It then served as a base for developing the real UI in Unity.

Concept

The core idea behind the project is to create a space in VR - the locispace - in which the user can build his own mind palaces for different topics.
By using a large city landscape, topics can be separated from each other by distance. For example, city quarters, roads, houses and rooms can be used to cluster. In one Room, there will be only one mind palace regarding one tiny fragment of knowledge. But because the VR city will be able to grow, the amount of storable information is effectively limitless.
The mind palaces will be built out of so-called assets which will be digital objects. To not limit the user's imagination, basically everything can become an asset - 3D objects from our database, models from the internet, pictures or even drawings. The user gets the maximum of freedom in this regard.
To build a mind palace in a room, the user will use a virtual wall canvas as a UI. In there, he or she selects the knowledge fragment to learn and subsequently the assets by clicking on it.
After successfully building a mind palace, the user has the chance to test and deepen his knowledge by playing small minigames and quizzes. These can also be used in order to refresh it after some time.

MVP

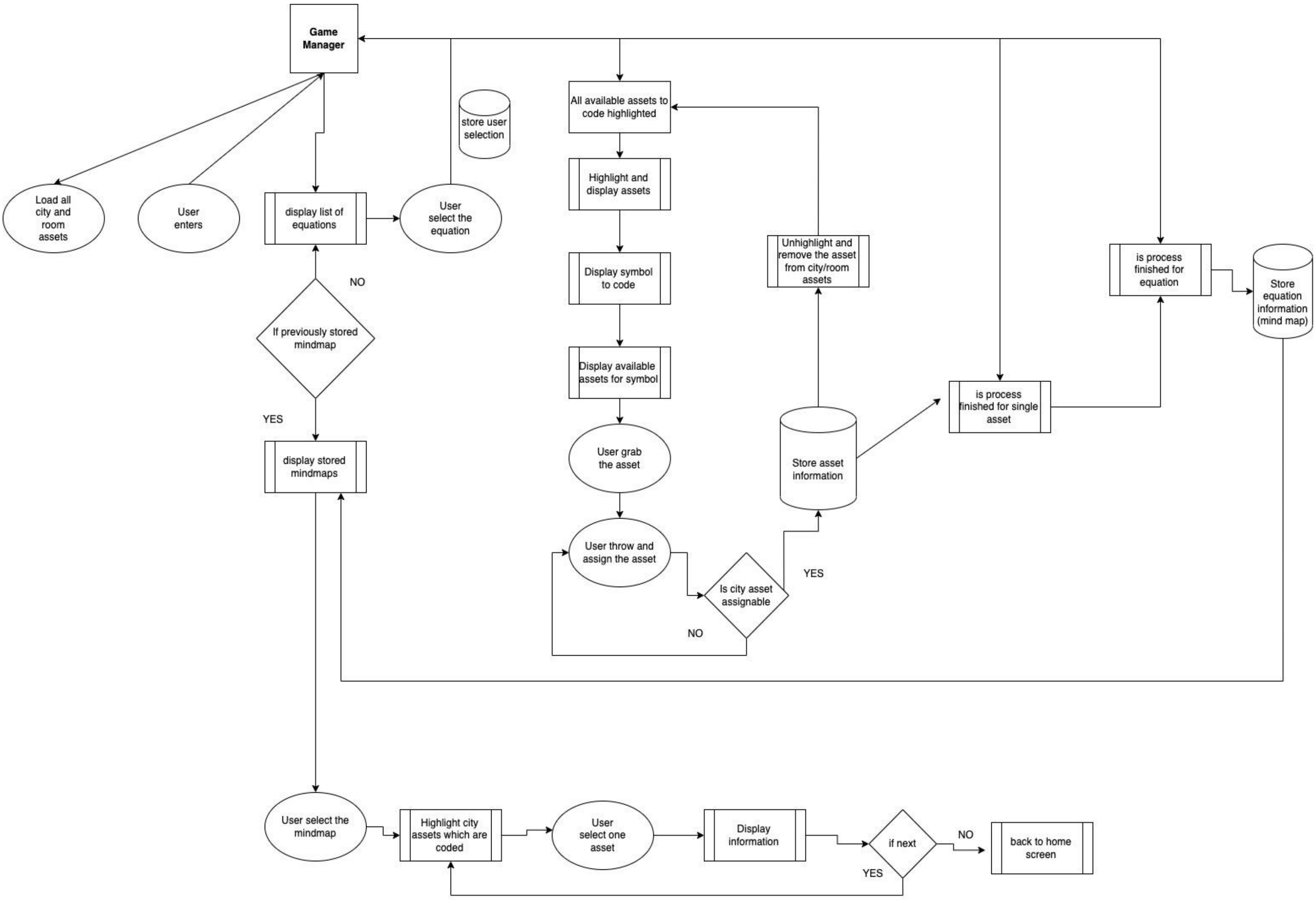
Because of the timeframe, the team decided to set focus on just the most important elements of the concept. These contained: Building and editing a simple mind palace about one specific topic in a building with 2-3 rooms. Testing the knowledge was also seen as mandatory but later dropped when it became visible that multiplayer interaction was more important.
The content was agreed on to be basic physics formulas, as they are sufficiently abstract and clearly separable enough to serve as examples for this project.



5. Activities and Interactions

Based on the basic idea, the team developed the UI click prototype and storyboard mentioned above. From this point they thought further about the activities and interactions of the user with the VR environment.

For the implementation of the flow and activities, Prof. Joed suggested sketching an architecture diagram.



architecture diagram

Setup

Before the user enters the environment to create the mind palace, all the city assets, and environment prefab are loaded. The environment and assets are created in prefabs so that it is reusable.

Initial Interaction

When the user enters the environment, on the wall he can see the list of equations that can be mind mapped in the locispace. With the controllers, the user can select the equation that he wants to study.

Interaction with Assets

On proceeding with the equation selection, the user is given the choice of assets that he relates to the term. For example in a force equation, on selecting the term half (½) user is given the option of assets - half-filled cup, dwarf, sliced pizza. On selecting any one of the options a GameObject asset falls on the table. Users can grab, hold and pick up the asset and place it inside the room wherever the user feels it is suitable and map it with their chain of thoughts.

Final Interaction

The user continues to collect the assets for each term in the equation. In the final phase, the user can move and place the assets as he desires. Even if the user forgets the symbolism of the asset, he can hover over the asset to get the tooltip of information. For eg: the user hovers over the dwarf asset to learn “Half-> ½ Dwarf”.
Once he is satisfied with the positioning and placement of the asset, he then memorizes and saves the progress.

6. Development

Through the development of their own software snippets the team was able to create meaningful interactions and achieve functionality according to the concept.

Classes and Functions

sceneChanger	a class that is used to change the canvas scene depending upon the user's action.
changeScene()	move to next requested UI Canvas
loadRequiredAsset()	activate an asset that the user wants to interact with

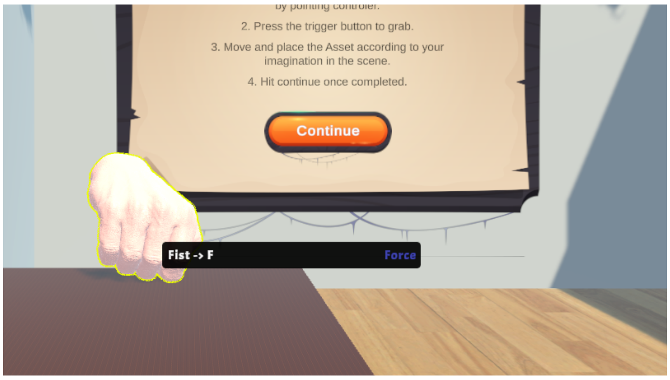
Grabbable	this class helps the user to interact with the selected asset. The user can grab and drop the asset in the mind palace
createGrabber()	when raycast ins interacts with the object it creates a grab and gives the point of interaction of raycast with the asset

DestroyGrabber()	when the user wants to stop the interaction and unclick the button this method allows the object to be released.
interface IEnumerator DragUpdate()	when the interaction is still in progress, it updates the point of interaction and position of the asset. It records and keep the track of the movement done until the asset is released.

Simple Tooltip	this class as the name suggest is used to show a tooltip when hovered over the gameObject or Asset. Singleton Pattern is used in this script to make sure only one tooltip is visible at a time.
simpleTooltipstyle()	In this method, it defines the style, visualization, and aesthetic of the tooltip.
onPointerEnter()	this tells that raycast is entered on the asset and the tooltip can be displayed
onPointerExit()	this tells that raycast is exited and hide the tooltip

The tooltip works on the principle of hovering. The hovering effect is achieved by using two event methods of pointerEventData.
InfoLeft and Info Right. In this project, we use InfoLeft i.e. information on the left-hand side for addressing the term for which the asset is used.
InfoRight i.e. information on the right-hand side for addressing the name of the asset.

Outline	this class is used to attach an outline to a selected asset. This helps the user to understand that the requested asset is available.
Outline Mode	which tells the mode to apply for a particular asset
Outline Color	allows selecting the color for the outline
Width	allows the thickness of the outline to increase or decrease



implementation of the tooltip and outline in the real application

- UICanvas Manager: It acts as a GameManager GameObject for the whole process. It dictates the user's action and contacts the sceneChanger to indicate the action to perform. It keeps an eye on the action performed on the UI and decides the next appropriate stage. Once the process is finished it tells sceneChanger to load the final scene.
  The main function of this GameManager is it not only tracks the whole overarching process, or the user is in which phase but also keeps track of a particular action phase until it is completed.

- AudioSource: As the user is oftenly interacting with UI, audio source is added to give feedback of appropriate selection.

Multi User Interaction

As suggested, the team used PUN Photon - Unity Networking to implement a multi user functionality. This allows multiple users to interact in one loci space and also includes voice chat.

Setup

We have created an account on Photon. For this project, we required 2 channels. Once for networking and the other for voice. We activated both channels and assigned our app ID.

Initial interaction

Two or more users can join the room simultaneously. They can move around and take a look at the environment. The voice channel helps them to discuss. The first player who joins is the host and all others who join are participants.

Interaction with assets

When multiple users are interacting in an environment, the host can interact with the UI. On discussing with fellow users they can request an asset resembling the term they want to code. Any one of the users can pick up the asset and place it as per his choice. The asset will move and position all other users as well. They can put forth their view and come to a conclusion about the final placement of the asset.

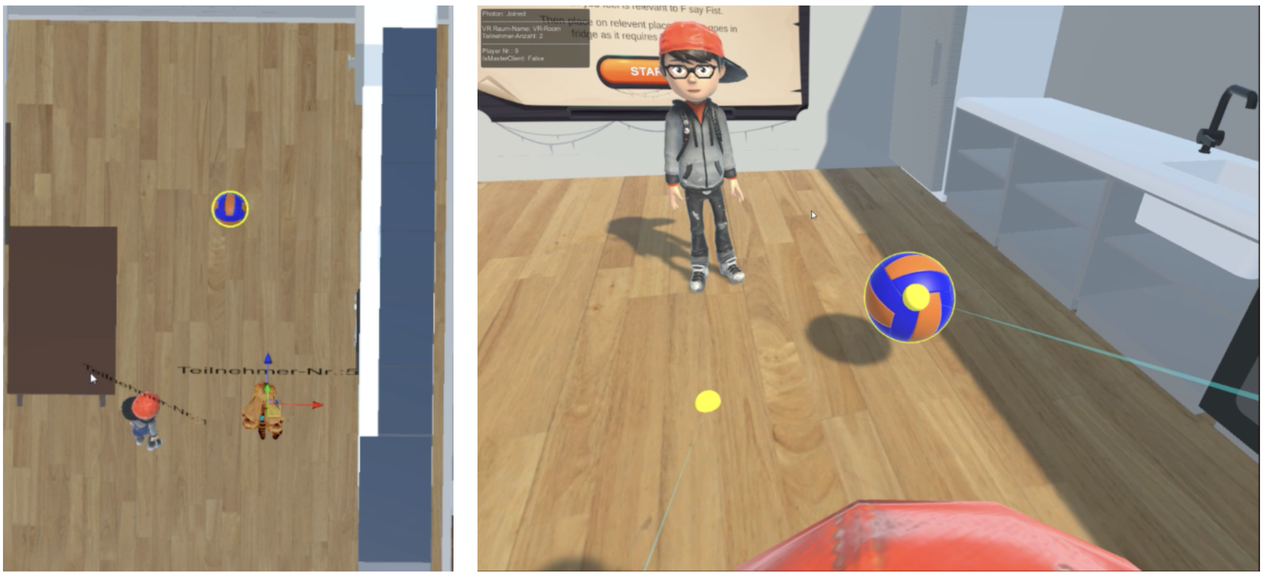
Development of Interaction

NetworkManager - It is a game object which is used to synchronize the particular node with photon status.

NetworkVoice - It is a game Object which accesses the photon voice network and has a recorder to store and signal the user's voice.

Photon as a package provides different libraries. For the Interaction, the classes used are

- Photon View() - it acts as a container to observe the different actions like transform or movement.
- Photon Transform View() - it is used to synchronize the position, rotation, and scaling of an object.
- Photon Rigidbody View() - it is used to synchronize the velocity of the asset moved.



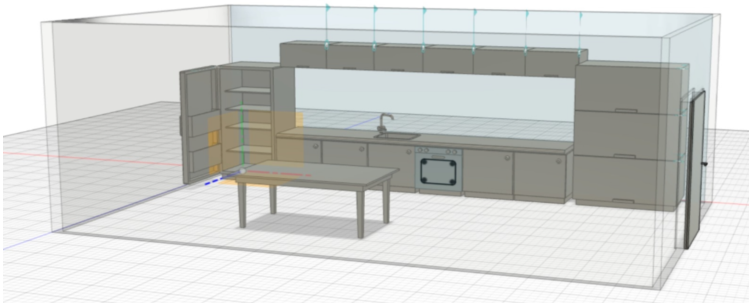
demonstration of multiple users interacting using our application and Photon

7. Content creation

A lot of the application's content was created by the team themselves. This was beneficial for the goal to learn about the whole game development process. The environment, a large part of the assets and almost all UI elements were created by them.

Environment

The environment contains a ground plane, a house with four rooms and furniture within it. Using Fusion 360, various versions of the house shell and detailed kitchen furniture were created.



These were then imported into Unity as FBX and in the later stages of the project enhanced with textures for the floor and surfaces. In order to improve the immersive effect,a few wall decorations were also added in the kitchen environment.

before (left) and after (right) material design in comparison

Later after usability testing, the ground structure (a floating rock) and a lot of the bedroom furniture were added from free online asset libraries because the team wanted to work more efficiently now. Few came with a fitting texture, others were completed by adding one in Unity.

Assets

The objects used by users as visual cues to remember a term is called “Lociassets”. After analyzing the target group it was decided to move forward with Multicolor 3D lociassets, as it iss more relevant to users.

Ideation and research phase

Each physics formula we broke down into terms, arithmetic operators, and coefficients. For each of these values, approximately 9 relevant objects of the real world were selected. Some of them were more true to the meaning, some were fun and some matched by their starting letter and function.

F = Force
- Fist
- Darth Vader helmet

- **Finger**
- **Punching glove(Pow)**
- **Fan**

- pushing a wall or a box
- weightlifter

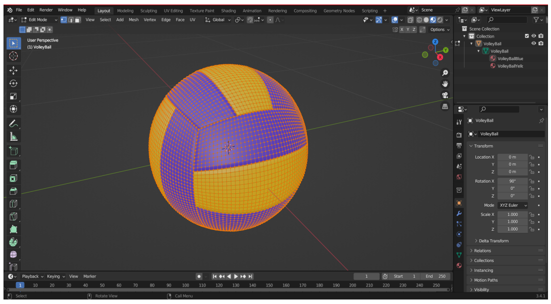
brainstormed ideas for “force”

Assets survey

To narrow down which assets to build as 3D objects the team created a quantitative survey among potential users.. There were 13 participants in the study who were asked to choose the top 3 most relevant loci assets per term. The results of this survey are attached in the appendix.

Modeling

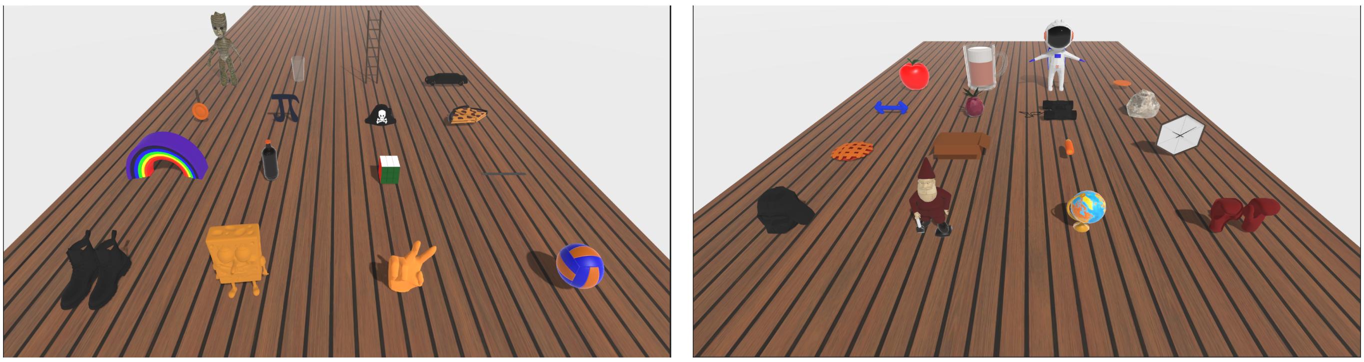
Blender was used to newly model 20 lociassets and tweak 16 pre-built models, and then define materials for them. Although limited basic knowledge of Blender was present, more proficient ways of modeling, shading, meshing, and material designing were learned and incorporated.. Models include single-material models, multi-mesh models, and photo-realistic models.



the “volleyball” asset in Blender 3D

Asset migration to Unity

All the lociassets were bundled together as a package and imported to Unity. There multi-mesh loci assets such as glass, clock, and many more materials were created accordingly and applied. For photorealistic loci assets such as a boulder, a Groot figurine, and globe materials, textures were imported and defined. As except principle shader some other complex materials were not supported while importing to Unity and redone again for a few material parts.



an overview over all the assets

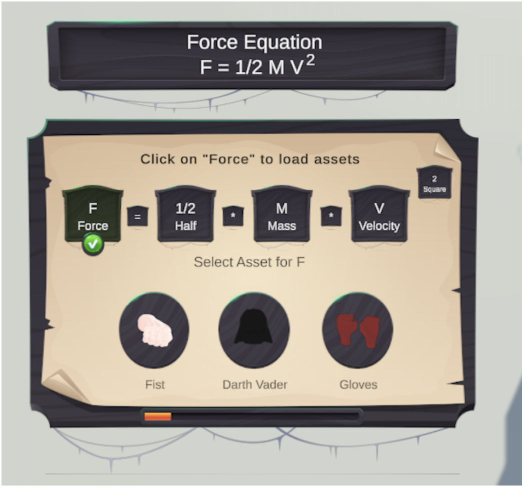
In Unity, all of the assets were relevantly resized according to real-world environments.Following this, every asset was positioned to fall on the kitchen table while spawning on selection.

Additionally, colliders were defined:

1. Box colliders for lociassets and a few kitchen instances.
2. Mesh Colliders for floor and Kitchen slab.
3. The rigid body component for lociassets and Table.
4. User Interactable components were linked with respective scripts.

UI

A 3D UI canvas with UI components was used for user guidance throughout the mind palace building process. This structure contained buttons and text. Then the team added a board 3D model as a background, applied textures, and designed different UI canvases according to the state of the process. The TextMeshPro library is used for the compatibility of text with 3D objects.



a screen of the final UI (after user test improvements)

8. Usability Tests

Goals

When preparing the usability tests, the team had the following goals in mind:

1. Collect **direct feedback** and opinions on what to improve in the application
2. Identify potential **weak points** in the usability and user guidance
3. Get an indication on the **performance** of this learning method
4. Gain ideas on the **further development**

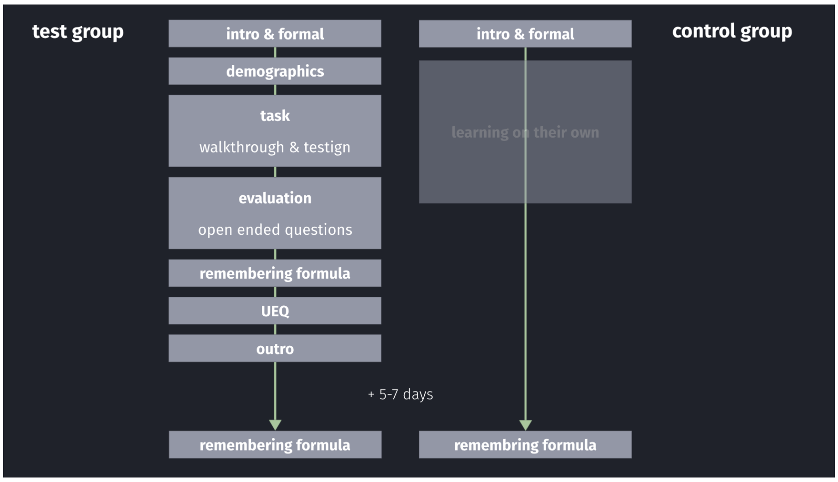
Preparation

In order to test how well the learning application works against standard methods, it was decided to use a between group design with one group testing locispace and a controlgroup. An extensive test guide was created in order to ensure a consistent and professional conduction across the individual tests. This document consisted of the following points:

- introduction

- consent agreement (to be on the safe side legally)
- demographic/base questions
- intro to locispace and the task
- walkthrough of the complete mindpalace building process in VR. The participant was saying his/her thoughts out loud. This tied in with the above mentioned goal 2.
- evaluative interview questions were used to collect feedback (goal 1)
- questions about the learnt formula served the purpose of goal 3
- short UEQ questionnaire
- outro

- after 5-7 days, the participants of both groups were questioned about their respective formulas in order to validate the remembering effect.



scheme of the usability test progression in both groups

Conduction

Because of the extensive preparations, testing went well.
On 3 separate days the team was able to conduct testing with 5 participants using locispace and 4 as a control group. All tests were moderated by Benedikt, with Tanmesh and Tilak protocoling the statements and taking care of the technical preparations. The individual sessions took between 25 and 60 min, due to participants' variation.



Results

During the tests, more than 100 individual notes were created, as well as the UEQs and basic data. To get meaningful to results, all of this was clustered and sorted by topic. This allowed the team to evaluate the initial goals:

1. Direct feedback on multiple topics was gained and can be viewed in the attached link to the according figjam board.
2. Some misunderstandings and improvements were collected and are also visible in the above mentioned clustering.
3. The learning method seems to be more effective as all locispace users were in large parts able to reproduce in contrast to only 1 traditional learner
4. Some vague ideas for future improvement were found

Insights

The most important insight is, that the main task of building a mind palace in acceptable time is already possible and was quite easy to achieve for the testers. There is some criticism related to the limited possibilities of the MVP which will disappear on its own with further iterations.
Also, a lot of smaller problems with the UI, environment and controls were found that were mostly ironed out in the remaining time. These are too numerous to name, so please take a look at the appendix for further information. Green boxes in the respective presentation are positive, red ones stand for current dealbreakers and grey ones are opportunity areas for further improvement.

Just to name a few of them:

- size of some assets need adjustment
- assets for operator signs should be added
- assets should have a label to look up what they stand for
- clicked buttons should be grayed out
- building progress should be visible

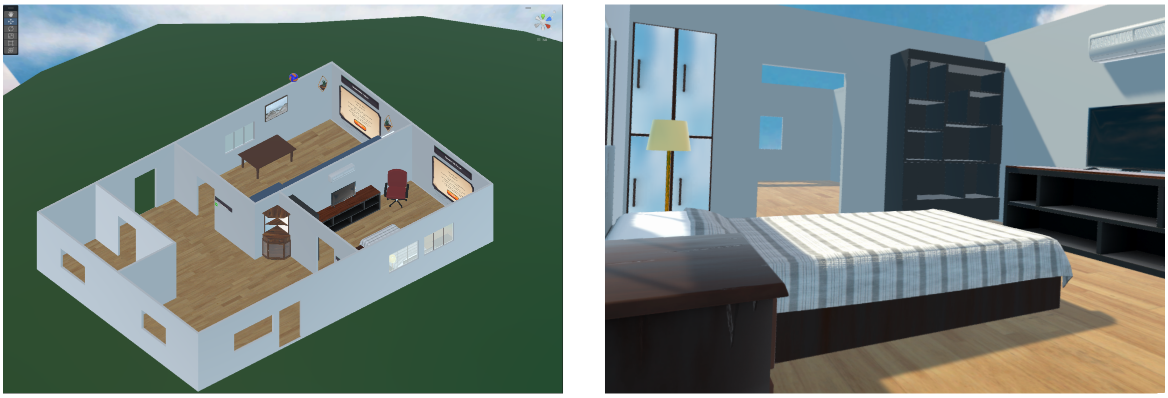
9. Subsequent improvements

The usability study showed some room for improvement in details. In order to improve usability, the team worked on these insights. The following progress could be made in the individual areas of the application:

Room

1. Moved the table as users felt restricted to walk or move.
2. Added wall decoration to make the aesthetic more pleasing.

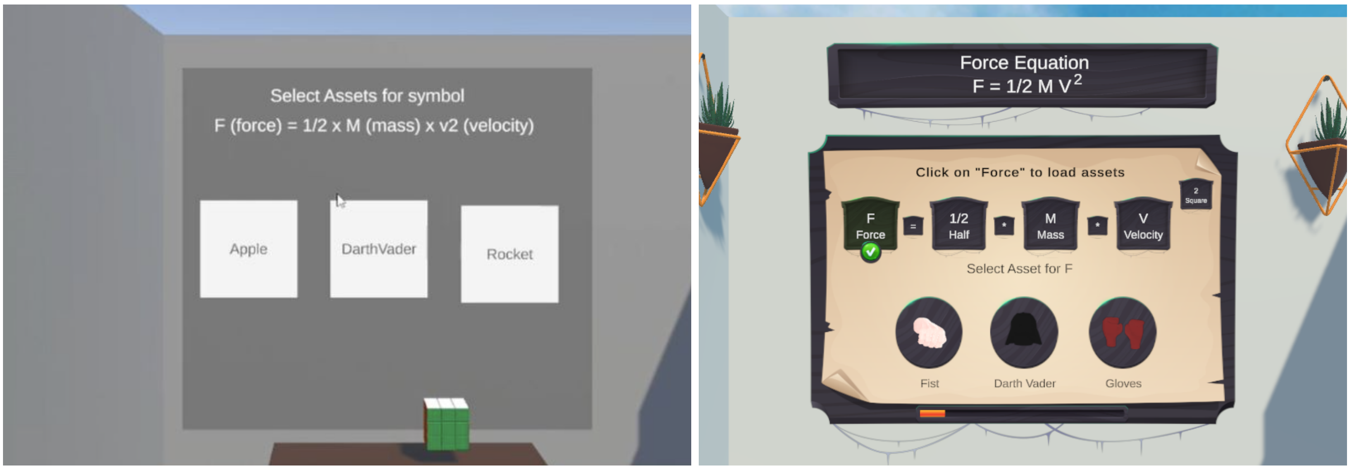
3. Created a larger environment that also includes the kitchen, a bedroom, a hallway and assets like an AC, bed, chair, etc.
4. Added (potentially interactive in the future) labels for the individual loci spaces (rooms)



new floorplan and interior of the new bedroom

UI

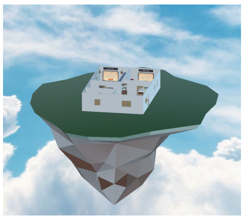
1. Revised the UI completely and made it more readable and appealing.
2. The user wanted the equation to be visible all the time, which is addressed by the bifurcation of Canvas into the equation panel.
3. Added thumbnail as a preview for each asset.
4. Added assets for arithmetic modifiers which were not present before.
5. Added a progress bar to visualize the progression of a mind palace.



old (left) and new (right) canvas UI in comparison

Exterior

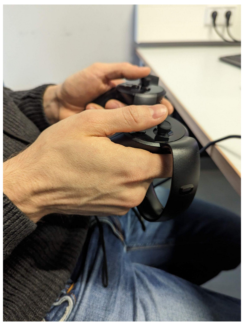
1. Visual adjustments of the sky.
2. Added a space island environment.



Space island environment

Control

1. Introduced locomotion using the controllers thumbsticks. This was made necessary because the users expressed the wish to move longer distances and the addition of a bigger environment.
2. Added thumbnails and a deletion possibility to the assets.
3. Resolved known controller bugs.



Navigation using Controllers

10. Results

Positive Practicability

It is indicated from our usability tests that participants who used locispace to memorize an equation tend to remember effectively, especially when compared to other learning techniques. Humans tend to remember content better that is interconnected or clustered spatially.
Creating mind palaces in the real world has some limitations like not enough memorable spaces or non-availability of relevant assets to build.
Locispace has practical implications from easy-to-memorize topics like language, and history to complex medical terms.

Limits

Locispace is mostly limited to memorizing knowledge and the underlying meaning of terms. It is not the perfect technique if users need to understand complex concepts instead of just being able to reproduce them. This is where other learning methods might be more useful.
Also, mind palaces take time to build and repeat. More so, getting used to this way of learning is also time consuming. And while it might have benefits for learning vast amounts of knowledge efficiently, it is questionable if there is a real world benefit for average students.

The existing concept also has shortcomings when it comes to usage of other mediums like music, vocal information or other more complex types. It is made specifically to remember words and their connection at this point.

Reflection on goals

Effectiveness - The team achieved this goal very much. Learning with locispace seems to work and a advanced application has been built.
Adaptability - This is also a core part of the concept. Due to time and skill, only one topic has been done but this can be changed easily.
Learning in the process - As it can be seen on the result and previous steps, a big learning success is visible.
Potential real world impact - still possible.

Furthermore, all the objectives that were set in the MVP and internal deadlines on our milestone plan have been completed on time. And last but not least developing a game in Unity also sparked interest and was a fun experience to the team members.

New goals & necessary improvements

Most important is the generation of more assets, both by the locispace team and the user himself. Also building the existing standalone space into a more connected and bigger experience according to the initial concept is still to do.
As it was noticed, that some guidance on the learning topics is necessary, the high-quality preparation of material and UI slides for these is important in the next phases of the project.

11. Conclusion

Key findings

1. We found out the project works and it has the potential to be used for learning other learning topics too. For example history or language learning.
2. There was an indication that the users using visual space to memorize concepts had a greater learning effect and were more aware of what they actually had memorized.
3. People not only remembered the equation terms but also the associated lociassets and positions where they placed them successfully.
4. Even users of non-science backgrounds were able to memorize the equation.

5. 5. User behavior towards memorizing something that's illogical changed as they felt it was fun using VR to learn.
6. 6. The multiuser implementation in the current version might not have an effective purpose, however as project progress in future it makes total sense.

Recommended future work

The future scope of the application can be used as a tool for students of medicine/language to really enhance their learning experience. With this app, we aim to make concepts memorable, and add fun to the learning experience.

Some of the future work planned in this application would be

1. Transforming this into a city of knowledge where users learn multiple subjects
2. Earn game points based on performance that double as in-game currency
3. Add an in -game shop for buying new assets or customizing their avatars.
4. Allow customizing mind palaces with individual themes such as pirate or medieval.
5. Co-learning but inviting other users to mind palaces and repeating the reason underlying mind palace design and competing with each other to play educational learning nuggets.

FInal Thoughts

Throughout this project we have gained valuable insights into the process of VR Unity development and the subsequent subtopics. We would like to thank all of our Professors, study participants and all other supporters of this project. They not only made it possible but also added to the success of the project.