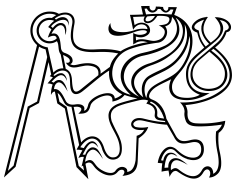
Master Thesis



Czech Technical University in Prague

F3

Faculty of Electrical Engineering
Department of Computer Graphics and Interaction

Educational application in Virtual Reality

VR educational application for teaching astronomy

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Supervisor: Ing. David Sedláček, Ph.D.
Field of study: Open Informatics
Subfield: Computer Graphics
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ZADÁNÍ DIPLOMOVÉ PRÁCE

I. OSOBNÍ A STUDIJNÍ ÚDAJE

Příjmení: **Moravenov** Jméno: **Jordan** Osobní číslo: **434963**

Fakulta/ústav: **Fakulta elektrotechnická**

Zadávající katedra/ústav: **Katedra počítačové grafiky a interakce**

Studijní program: **Otevřená informatika**

Specializace: **Počítačová grafika**

II. ÚDAJE K DIPLOMOVÉ PRÁCI

Název diplomové práce:

Výuková aplikace ve Virtuální Realitě

Název diplomové práce anglicky:

Educational application in Virtual Reality

Pokyny pro vypracování:

Prostudujte způsoby, mechaniky a herní prvky, které se používají pro výklad a ověření znalostí v aplikacích pro virtuální realitu (např. výukové aplikace, tutoriály her a programů, tzv. serious games).
Navrhněte využití těchto poznatků pro návrh a implementaci výukové aplikace, která bude uživateli umožňovat získání teoretické informace s následným praktickým procvičením dané problematiky, za kterou bude ohodnocen. Uživatel bude moci sledovat, která témata aplikace již prošel, případně za ně byl ohodnocen. Hlavní výukovou logiku aplikace implementujte jako knihovnu, která umožní jednoduché rozšiřování aplikace o další výuková témata. Sepište detailní postup pro přidání dalších témat. Při návrhu aplikace postupujte dle metodiky UCD (User Center Design).
Ve splupráci s vedoucím práce vyberte a navrhněte 5 výukových témat, která realizujete. Finální aplikaci otestujte s cílovou skupinou uživatelů.

Seznam doporučené literatury:

Jason Jerald. 2015. The VR Book: Human-Centered Design for Virtual Reality. Association for Computing Machinery and Morgan & Claypool, New York, NY, USA.
Steven M. LaValle - Virtual Reality, Cambridge University Press 2016
Virtual Reality & Augmented Reality in primary education: Robin De Lange, Maarten Lodewijk, Nesse van der Meer, 2017

Jméno a pracoviště vedoucí(ho) diplomové práce:

Ing. David Sedláček, Ph.D., katedra počítačové grafiky a interakce FEL

Jméno a pracoviště druhé(ho) vedoucí(ho) nebo konzultanta(ky) diplomové práce:

Datum zadání diplomové práce: **12.02.2020** Termín odevzdání diplomové práce: _____

Platnost zadání diplomové práce: **30.09.2021**

Ing. David Sedláček, Ph.D.
podpis vedoucí(ho) práce

III. PŘEVZETÍ ZADÁNÍ

Diplomant bere na vědomí, že je povinen vypracovat diplomovou práci samostatně, bez cizí pomoci, s výjimkou poskytnutých konzultací. Seznam použité literatury, jiných pramenů a jmen konzultantů je třeba uvést v diplomové práci.

Datum převzetí zadání Podpis studenta

Acknowledgements

I wish to express my deepest gratitude to my supervisor for that he supported me on the path to finish this project.

Declaration

I declare that this work is all my own work and I have cited all sources I have used in the bibliography.

Prague, February 8, 2020

Prohlašuji, že jsem předloženou práci vypracoval samostatně, a že jsem uvedl veškerou použitou literaturu.

V Praze, 8. února 2020

Abstract

The popularity of the VR technology is growing rapidly and so is the number of VR games. However, only a small fraction of them is educational. When we have a look at the current state of serious game development not only for VR we see that it is turning away from *gamification* towards *game-based learning*. Also the modern pedagogy is trying to shift drastically from the traditional ways of education towards *constructivist* approach to teaching. Based on that this thesis provides some guidance on how a good educational application might look like.

Another part of this thesis is a package for *Unity* game engine that makes it easy for game developers to add interactive educational content to their virtual worlds.

Keywords: VR, CGI, HCI, astronomy, Unity, Blender, 3D, education, game, serious game, constructivist, pedagogy

Supervisor: Ing. David Sedláček, Ph.D.

Abstrakt

Popularita VR technologie rapidně roste a taktéž i počet her pro VR. Nicméně pouze malý zlomek z nich je výukových. Když se podíváme na aktuální stav vývoje tzv. *vážných her*, tak vidímě tendenci odvracet se od *gamifikace* a používat nový přístup, kterým je *game-based learning*. Také moderní pedagogika se pokouší drasticky odtrhnout od tradičních vyučovacích metod a využívat *konstruktivistický* přístup k výuce. Na základě toho tato diplomová práce předkládá vhled do toho, jak by dobrá výuková aplikace mohla vypadat.

Další částní této diplomové práce je balíček pro Unity pro herní vývojáře, který jim umožní snadno přidávat interaktivní výukový obsah do jejich virtuálních světů.

Klíčová slova: VR, CGI, HCI, astronomie, Unity, Blender, 3D, výuka, hra, vážná hra, konstruktivistický, pedagogika

Překlad názvu: Výuková aplikace ve Virtuální Realitě — VR výuková aplikace pro výuku astronomie

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Chapter 1

Introduction

Virtual reality (VR) is nowadays a rapidly growing technology which gives us incredibly immersive platform for an entirely new multimedia kind of content and does not only open door for creating many exciting games and experiences but also gives us the responsibility to search for possible serious applications in the field of education, therapy etc. of this relatively new technology.

Especially the educational potential of VR intrigues me so the objective of this thesis in it's very core is to find good techniques for teaching in a fun way that will make people enjoy the learning process and be eager to proceed with the learning due to a fascination by the taught subject itself enhanced by interactive VR world that waits to be explored.

To tighten the subject of education I will stick to what fascinates me personally – astronomy. I attended the astronomy course on the Stefanik's observatory in Prague and the follow-up demonstrator course and after that I started to guide the visitors of the observatory, use the observatory telescopes to show them far breathtaking objects on the sky as well as lecturing about various astronomy subjects.

To bring education of astronomy into VR I created an application called *Guide to the Solar System* which I introduced in my bachelor thesis. This android application runs on smartphones and uses gazing selection technique as well as experimental head shaking techniques.

In my opinion 6-DOF[1] VR is where the real immersion comes in so I decided to target my master thesis educational VR application on VR headsets with 6-DOF and controllers (such as HTC Vive, Microsoft Mixed Reality etc.). Moreover Oculust Quest brought 6-DOF and controllers also to the lower end of the market so it is likely that soon, everyone will afford to use 6-DOF VR for education if there happen to be good educational applications.

[1] DOF or "degrees of freedom" of a system is the number of parameters of the system that may vary independently.

Concerning VR we most often address the DOF of head tracking. If we only track head rotation (in 3 dimensions so in 3 axes) we have 3-DOF. If we also track the head position in space (in 3 axes) we have 6-DOF.

Chapter 2

Research

2.1 General VR applications analysis

Since I had not much experience being in VR I decided to try out various VR applications to grasp the different techniques used for education and also for VR interaction in general.

2.1.1 Methodology

I looked up as many free-to-play VR applications as I could and after playing every single one of them I took notes. During this period of trying applications I was periodically making a conclusion from the notes. I played some of the applications several times and observed the shift in my impression from the application. At the end of this period I made a usability test with two participants testing 3 different types of applications and then compared the results of the testing with my own observations on the applications.

2.1.2 Applications

Before showing you the final conclusions and findings let me introduce to you several of the tried applications, since I will be often referring to them in the text.

Non-educational applications

Gnomes & Goblins
: This game with gorgeous graphics puts the user in a forest full of fantastic creatures. In the demo, you try to make friendship with a little gnome (See Figure 2.1.)which invites you in his world.

Figure 2.1: The official logo of the game *Gnomes & Goblins*.
Source: https://store.steampowered.com/app/490840/Gnomes___Goblins_preview
Accessed: 2020-05-11

The Lab: Secret shop

This location (See Figure 2.2.) in the *The Lab* application is full of mysterious objects for you to discover. Right after you enter the location a well animated character introduces you this experience. Even with low-poly meshes the graphics are beautiful and the vibe of the room is immersive.

Figure 2.2: A screenshot of the Secret shop which is accessible from the *The Lab* VR application

Allumette

This is a short VR animated movie that everyone having a VR headset should watch. Even without any possibility to interact with the world, it is a great whole new way of watching animated movies. It is a story about a girl (See Figure 2.3.) living in a city floating in the clouds.

Figure 2.3: The official logo of the VR movie *Allumette*.
Source: https://store.steampowered.com/app/460850/Allumette/
Accessed: 2020-07-31

Disney Movies VR: Disney: Trust in Me

An extremely short experience where you get approached by the snake

Kaa from the 2016 Disney movie *The Jungle Book* (See Figure 2.4.) standing on a tree branch.

Figure 2.4: The movie scene which is represented by the VR experience *Disney: Trust in Me* from the application *Disney Movies VR*.
Source: https://www.awn.com/news/disney-launches-jungle-book-vr-experience
Accessed: 2020-07-31

Waltz of the Wizard

Fun game where you invent various magic spells that allows you for example to levitate objects and more. (See Figure 2.5.) This application also enables the user to enter other worlds. For example to enter a labyrinth escape game where you need to fight your way through an army of dark knights.

Figure 2.5: The official logo of the game *Waltz of the Wizard*.
Source: https://store.steampowered.com/app/436820/Waltz_of_the_Wizard
Accessed: 2020-04-02

Job Simulator

This game puts you in a funny and surreal way in the role of several professions like shop assistant etc.

Figure 2.6: A screenshot from the game *Job Simulator*.
Source: https://newatlas.com/job-simulator-vr-game/41698/
Accessed: 2020-07-31

Educational applications

VersaillesVR | The Palace is yours

This application allows you to walk through the Palace of Versailles and to admire the art and learn about it. (See Figure 2.7.)

Figure 2.7: A screenshot from the game *VersaillesVR | The Palace is yours*.
Source: https://www.experenti.eu/chateau-versailles-e1569931763473-2/?lang=en
Accessed: 2020-07-31

Perspectives: Paradise

This is an educationally propagational application which goal is to present how much damage was caused to the Enewetak Atoll (See Figure 2.8.) by the U.S. hydrogen bomb tests. The application starts with an experience that puts you on the atoll during the bomb explosion. Then after a short mandatory lecture it unlocks different 360° views or 2D video interviews etc. related to the topic.

Figure 2.8: The official logo of the game *Perspectives: Paradise*.
Source: https://store.steampowered.com/app/1016390/Perspectives_Paradise
Accessed: 2020-07-31

Nefertari: Journey to Eternity

An educational application which places you in an Egyptian tomb where you can learn about ancient Egyptian culture by hearing lectures connected to the wall paintings.

Figure 2.9: A screenshot from the game *Nefertari: Journey to Eternity.*
Source: https://store.steampowered.com/app/861400/Nefertari_Journey_to_Eternity
Accessed: 2020-07-31

Smithsonian American Art Museum – Beyond The Walls

One of two good museum VR application I have found. It allows the user to freely move around the museum and to learn about the art pieces. (See Figure 2.10.)

The other one is *The VR Museum of Fine Art* which has stunningly detailed graphics even when looking on a painting from few centimeters.

Figure 2.10: A screenshot from the game *Smithsonian American Art Museum – Beyond The Wallsx.*
Source: https://store.steampowered.com/app/1087320/Smithsonian_American_Art_Museum_Beyond_The_Walls/
Accessed: 2020-07-31

CAPCOM GO! Apollo VR Planetarium

This game allows you to watch a 3DOF 180° movie but what is more interesting it features a nice way to observe large objects by putting small models of the object in a scanner device which creates a large hologram of the object floating.

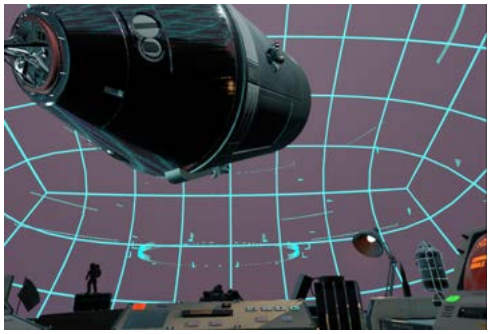


Figure 2.11: A screenshot from the game *CAPCOM GO! Apollo VR Planetarium* showing a large floating model of a capsule.

2.1.3 Observations

Here are the main observations that I concluded from my experiences.

Environment

There is no surprise that the environment should be **beautiful** to look at so it is a pleasant place to be at. The reason to start my conclusions with something so obvious is that it is really important. Moreover it turned out that the appearance of the environment influences the perception of *realism*. For example one of the participants in my test found the day scene from Allumette much more realistic then the night one. When the graphics are beautiful the user feels more immersed and the "realism" of the surrounding world fascinates him. Even sketchy graphics can feel realistic when they are beautiful.

In general there are maybe some situations when this does not hold. However we will not discuss these since concerning education, we want to transfer the knowledge to the user together with positive emotions.

Another thing to consider is how the application reacts to **collision** of the user with the environment.

In standard video-games it is enough to stop the player's avatar if it collides with an obstacle. However in VR nothing can stop the player from shoving his head into a virtual wall. To handle this kind of problem I see two possible solutions that are appropriate for two different situations.

The environment surrounds myself: In this most common situation, it is appropriate instead of allowing the user to observe the inside of the meshes to dim the lights and to hide our virtual world from the user. It might interrupt the user's immersion, however since the user wants to be immersed into our world it will effectively force him to move his body so it is inside of the boundaries that allow him to be part of our virtual world.

A good example of this technique is the educational application *Nefertari* where everything gets black when the user's head collides with the walls. In a hall with significantly low ceiling it was necessary for me to crouch in order to move around without being disrupted by the dimming. And actually exactly this was the moment I felt most immersed in the game when I was almost crawling around the ancient Egyptian pyramid halls.

Another good example of this technique is the Oculus Quest guardian system that, using the headset cameras, teleports the user from the VR world into the physical world while showing the guardian area so the user knows where to move in order to get back into VR.

So it is a good practice to dim the lights but also to provide the user with some kind of guidance back into VR since otherwise he might lost himself in the darkness.

The environment surrounds observed little-people: Let's take Allumette as a great example of an application where observing of the inside of mashes can actually be an interesting way of interaction. Since the player is in the role of a passive transcendent observer of someone else's world, colliding with objects, which is unnatural in general, is no such a big issue. In Allumette the diameters of mashes are too small to be able to put the head inside the actual mesh but we can observe what is happening inside of a flying sailing ship or potentially inside of buildings etc.

The **interactivity** of the environment is another factor that increases the immersion a lot. Of course our VR could be full of interactive objects thats fun to play with, however it takes the immersion to a whole new level if we can interact with **animated** objects that are not important to the actual game.

To give specific examples, it might be some plants that bend on collision with our hand (i.e. controller). There are beautiful plants in the experience from *Disney Movies VR* called *Trust in Me*. It adds a lot to the appealing factor that we talked about earlier but the interaction on collision is missing.

Another example are the curtains from the *Secret shop* in *The lab*. I even had not realized how drastically low-poly[1] the curtains were until I saw my own screenshot on the screen. Despite the low-poly mesh the immersion was great because I could push the curtain aside with my hand.

A whole new level of environment interactivity might be the brand new VR game *Half-Life: Alyx* that, according to trailers, provides ability to interact with everything you see just like in real life. Until we achieve this level of environment interaction we are forced to use object highlighting to indicate interactive objects that are crucial for the gameplay. Beside that, in my opinion, we should also add not highlighted interactive objects to the scene such as moving curtains or bending plants which increases the immersion.

[1] a low-poly mesh is a mesh constituted by a low number of polygons

When talking about interaction with the environment, there are many things to cover. One of them is **animation** which we just talked about. Another thing is **sound**. Of course it will be more immersive if a mound of dry leaves we rake through makes the corresponding sound. The appropriate sound corresponding to the objects we are touching contributes to the enjoyment of the interaction.

The next thing concerning environment interaction that we will discuss more is the **vibration** of the controllers during the interaction. When manipulating with an object, for example while we draw a line in the dust on the ground with a wooden stick, we want to feel the feedback from the friction. And controller vibrations are a great way how to simulate this.

I have experienced this technique for example while turning the wheel in *The lab* loading scene, while poking gnomes' suspension bridge (*Gnomes and Goblins*) or while pulling a bowstring (*The lab*). The application where the usage of this technique really stands out is *Waltz of the Wizard* – specifically the game where the player fights knights in a labyrinth which is accessible from within the main application. (See Figure 2.12.) In this game the friction simulated by vibration was giving my brain enough feedback to feel entirely in control of holding objects.

Figure 2.12: Waltz of the Wizard: the knights fighting game

This game also features handling of another problem that occurs on collision of the objects we hold with the environment. The problem is: What to do with the **position of the objects** on such collision? The common solution is to stop the object and show a ghost object showing the real position of the user's controller. Even though *Waltz of the Wizard* does no show this ghosty controller it does a good job with estimating the appropriate object position. The object should remain (if possible) fixed in the users hand in the point he is holding it and the rest should rotate around this point accordingly the same way the object would bend our wrist in real life.[2] And the feedback from the resistance of our wrist

[2] I am not sure about the exact point position which the object should be fixed to. It might be the point where the user holds the controller or the pivot of rotation of the users wrist. It might also depend on the object type since a sword handle is held in our palm but a xylophone stick is held between our fingers. It is a problem worth further study and user testing. However, the main idea here is, that it should feel natural like the real life objects rotate on collision. Even fixing the rotation to any of the suggested points is better then unnatural sudden changes of the object position and rotation. If this is not possible,

can be simulated by *vibrotactile simulation* [Jer16, page 37] even though the proprioceptive haptics are missing.[3] In my experience *Waltz of the Wizard* does that well enough so that we are aware of the collisions of the object we are holding with the environment even if we are not looking.

This behavior forces you to pay attention to how you hold a large object. For example when I crouched hiding behind an obstacle it was not possible to hold the long sword pointed down how I first tried. I found a suitable position with the controller pointed up behind my back where the sword didn't collide with the environment and in my brain, there was a real large sword behind my back and I was aware of it's position leading to better immersion.

While I personally found this controller vibration a great way to provide sort of a haptic feedback, after I tried some VR applications with other users, they complained a lot about the vibrations since they had found it extremely disturbing. I tried most of the applications on HTC Vive and the complains occurred while using Microsoft Mixed Reality. I myself found a prominent difference between Vive, where the vibrations were subtle, and Mixed Reality, where the controller was vibrating heavily even on a slight touch of a VR object. Now I don't say this to compare these two headsets, it is the application we are talking about. So to make a point, we should pay attention to how we use controller vibrations in our applications and set the vibration power accordingly to the amount of friction we want to simulate while taking in account the real maximum vibration power of different controllers which might become a calibrated factor in the future. And also have in mind that sometimes less is more.

Characters

One very special topic about interaction is the interaction with a character. We are social creatures and so we are extremely sensitive to getting information from small changes in the other person's facial expression and body language. Also when when immersed in a certain situation we keen to use these communication channels subconsciously. Let's have a look at my experience with interaction with virtual characters on few examples.

We mentioned *The Lab: Secret shop* in connection with environment interaction, specifically we talked about the interactive curtains. There are also two characters that worth mentioning concerning user-character interaction. The first one is a little dragon (See Figure 2.13a.) that maintain eye contact with your controller when you are near him. In the screenshot, there is the controller model rendered, however in the actual experience, the user sees a floating light in his hand which is used to explore this interesting scene. The dragon gets curious about this light and follows it with his eyes, head and by turning and leaning the whole body. This way of animated

it might be better to drop the object instead of suddenly snapping it to user's hand.

[3] For proprioceptive haptics that gives the user muscle resistance you need to restrict the movement by special hardware or by using real objects tracked in VR.

(a) : The dragon following the light in your hand.

(b) : The shop owner welcoming you in his shop.

Figure 2.13: Screenshots from the experience *Secret Shop* in the game *The Lab*.

reaction of the character to the user's hand movement has big impact on the user's immersion in the virtual world. Another similar example of eye contact is the *Disney Movies VR: Trust in Me* experience where you are approached by the big snake Kaa who maintain an eye contact with you while hypnotizing you.

The other animated character of *The Lab: Secret shop*, actually the main one, is the owner of the shop – really charming nice guy who, besides maintaining an eye contact with you, gesticulates extensively and his whole monologue is very live. (Figure 2.13b) After finishing speaking to you he turns away from you to leave the shop but suddenly turns his head back to you and waves to say goodbye. As an reaction I instinctively raised my hand as well. This is the power of a good character animation.

Of course it would raise the interactivity to a whole new level if the application could also process user's interaction inputs like speech or the waving gesture. When the person knows there is no point in communicating he probably won't. Just remember how we laugh when we are with a friend and we barely smile when we are amused while instant messaging. Our brain just uses other communication channels like emoticons to directly express emotions to others. A good animation performance of the character is the main step to activate the user's instincts to communicate. The next step would be to support this user's behavior by implementing real communication.

Another good example of this user's tendency to communicate is the VR application *Becoming Homeless: A Human Experience*. This application features various ways of immersing the user in the story. One of them is that the user needs to sit on a physical chair before entering the VR. Sitting behind a desk or sitting in a car feels much more real this way. Another immersion technique that is very simple but had a great impact on me is that

at the beginning the storyteller told me that I will be put in the position of a person's life story of becoming a homeless and to try to imagine I am now in this financially bad life situation and that this is my apartment. So I did so and became much more immersed in the story that in storytelling experiences without such an introduction that gives me a role in the story. The scene of this game I want to mention concerning the communication tendency of the user is the one where you are sitting in a car and a police officer approaches you and you know you are in trouble. He knocks at the window covered with raindrops and the window goes down. In this moment I tended to smile and I was mentally prepared to politely argue with the officer. However the scene was cut immediately even before I had a chance to see the officer's face. (Probably the model of the officer was not sufficient for that.)

Besides the communication with the main characters there might be many virtual creatures in our application and every single one of them in the user's proximity should have an animation prepared for situations of interaction with the user. For example bird following users hand with a look, spider running away when the user tries to kill it, a gnome stopping for a moment and having a brief look at the user to acknowledge his presence etc.

Transportation

The vast majority of VR applications use a transportation ray from the controller to transport to distances longer then it is comfortable or possible to walk to. This is in deed a great technique to teleport on rather shorter distances but might fail for really longer ones.

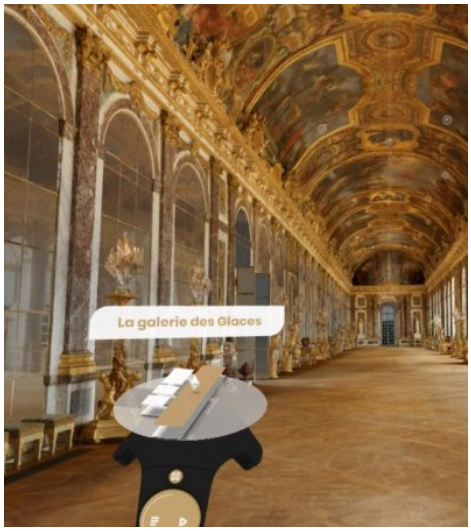
The *VersaillesVR* application introduces three ways of teleportation. For shorter distances it gets use of the classical **teleportation ray**.

On middle range distances it uses an **icon of an eye** (See Figure 2.14a.) which can be clicked by the laser pointer of the controller. As you can see in the figure it is useful for example when you are in the base level of the church and you want to jump on the terrace where it would be hard to reach with the curved teleportation ray. It might be also useful to land on a precise location (e.g. the top of an outlook tower) or places far away but on sight (e.g. an island visible from a boat).

If we want to teleport on even longer distances or to places that are not on sight from us (let's say to another room) a great and intuitive way is to use a **map**. In the *VersaillesVR* it is possible to display a map above your left controller and choose a spot to teleport to with the other hand. (See Figure 2.14b.)

The map is, however, rather small and flat. There is a big model of the Palace of Versailles in the main hall where you are located after launching the application. (See Figure 2.15.) There you can see interesting places and parts of the building that you would like to visit. The model doesn't provide any interactivity, however it would be a nice alternative for the to the abstract

(a) : The eye icon on the right terrace is used to teleport the user up there.



(b) : A small map on your controller helps you with orientation and also enables you to teleport to different places in the palace.

Figure 2.14: Screenshots from the game *VersaillesVR | The Palace is Yours.*

map for teleportation on the left controller. The 3D model is not only more attractive to look at and examine than the flat map, but also it gives you an overview of the whole world of the application.

Another example of a nice 3D map is in the application *Perspectives: Paradise*. You are on the shore of the atoll and you can see a model of the whole atoll floating above the ground. (see Figure 2.16) In the application this model is used for visualization and playing videos and not for transportation, but it is a nice example of how a clear teleportation map might look like.

Also the application *Deadly Hunter VR* has a 3D map of the game world and it is used there for level selection. (See Figure 2.17.)

Form of VR content

As we already mentioned in the introduction chapter of this thesis, there are various degrees of freedom (DOF) concerning the head movement. We won't encounter 3 DOF only in smartphone VR. There are also experiences with only 3 DOF that you can watch on your PC headset which is capable of 6 DOF. For example the vast majority of experiences in the *Disney Movies* application are only 3 DOF. Without the extra freedom obtained by the tracking of head movement (6 DOF) the experience is not so immersive and moreover it causes sickness. If possible 3 DOF experiences should be avoided. However, we can have some really valuable content, for example 360° video footage of walk through an African tribe village that would be nice to share with the users. In such case I would suggest to indicate what form of content

Figure 2.15: A 3D model of the Palace of Versailles.

Figure 2.16: A 3D model of the whole atoll of which shore you are actually standing on in the VR.

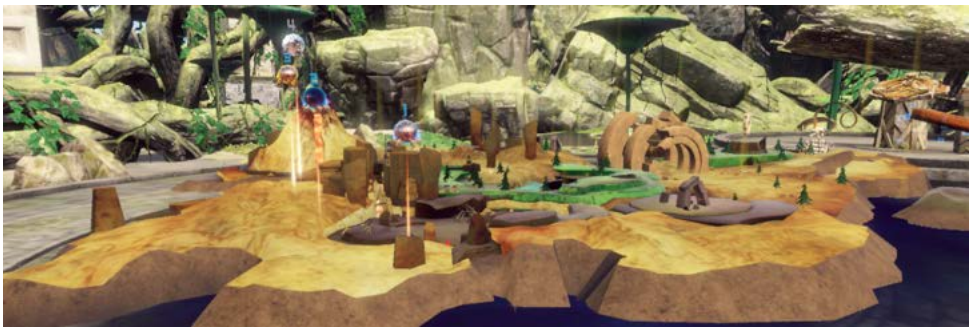


Figure 2.17: A screenshot from the game *Deadly Hunter VR* showing the level selection 3D map.

it is in terms of DOF so the user knows what to expect before jumping into the experience.

There are actually more significantly different forms of content that all fall in the 3-DOF category that provide considerably different experience. We can have 360° panorama image or 360° video. The lack of depth is really noticeable. Because of that it is even more disorienting and it also leads to extremely low immersion. It rather feels like watching 2D movie. However unlike classical 2D or even 3D movies on screen, here the filmmaker has no control over where the user is looking so it is easy for the user to miss interesting parts of the video. VR reveals its' strength in more immersive and interactive applications.

If the scene is 3D modeled we can have the perception of depth. However the only 3 DOF still ruins the immersion and the sickness is still a factor.

Interestingly, everything changes when we move not only from flat to 3D but also from CG to real footage. I talk about 3D movies such as in *Amaze VR*. The quality of content in this application is rather poor, however, the experience of these videos is very immersive due to the fact that there is 100% real footage with depth so with combination of VR headset the user is placed

right in the action. Here the content creators, in my opinion, are trying to get the maximum of this technology so the action is often taking place too close to the spectator. It places the actors and objects inside the spectator's personal space who have no opportunity to move and moreover due to wrongly set pupillary distance in the headset and headset imperfections the videos made my eyes literally pain when having to focus so close. Due to the realism the immersion is high despite the lack of DOF but the sickness is still an issue.

The *Smithsonian American Art Museum* features a hologram of a person that you meet in the virtual museum. The 3D model has motion capture animation and video texture of the actor speaking so the hologram feels really realistic and it is nice demonstration of blending CG world with real content.

This approach is taken on a whole new level in the movie *7 Miracles*. Besides regular movie sequences (TODO zjistit jestli jsou jen 2D nebo s hloubkou) there are scenes where you have 6 DOF and you see the actors in 3D.[Vrm, at time 0:58] (TODO: skouknout ten film a napsat toho o nem vic)

Game tasks

Linearity and mandatoriness: Non linear sequence of the game tasks is important for the sense of freedom. The opportunity to choose an objective together with the openness of the virtual world is essential for this. But not only the freedom is the reason. In every game there might be some tasks that you don't want to do and if there is no other way of proceeding in the game except making something we don't want to, the game is becoming a tempter. If we buy a FPS[4] game we will not be surprised that the game wants us to kill people. However in an educational game we want to be more careful not to create situations where the user has some moral or other problems with our virtual world being caused by cultural, religious or other reasons that we cannot predict. Therefor it is a good idea to compose the story graph in a way that abandoning of some single objective does not prevent the user from playing or ideally making several different scenarios for solving particular task. For example if we play a shop assistant simulation game we might consider giving the player an option not to serve some rude customer which can cause some in game financial loss of the shop and so gives the player freedom of expressing his will.

Realism of assignment: The level of realism of the way we assign some task to the user have impact on the immersion. Take for an example *The Lab: Secret Shop* where the character of the shop owner tells us to look around his shop. The way the game gives us this task through this very believable character (how we discussed earlier) is very immersive. (See Figure 2.13b.) In contrary to that in the game *Job Simulator* the tasks given by the virtual customers were very unclear and sometimes the only way to understand what the customer wants is by looking at the floating big screen visualizing clearly

[4]First person shooter

what we need to sell. (See Figure 2.6.) This way the user stops paying attention to the virtual customers with whom we cannot interact anyway and the game mechanics degenerates only to looking at the virtual screen and throwing shown objects on the desk.

Education

From the educational perspective we want to get advantage of the potential of VR where we can experience thing, not only hear or see. While searching for educational games I often bumped into this Confucius' quote: *"I Hear and I Forget, I See and I Remember, I Do and I Understand."* By an audio lecture we can often struggle to explain something and then some good visualization is handy. It is like comparing audio only lecture to a vivid documentary movie. Then of course there is the "to do" part of the quote that tells us that when we take some action and do something actively by applying the acquired knowledge we truly understands the main idea and move the knowledge to the long-term memory.

The vast majority of educational applications I have tried were some kind of "trigger a lecture" applications just like my bachelor project *Guide to the Solar System* (more about it in section 2.3.1). Among others of that kind of applications are the virtual museums like *Smithsonian American Art Museum* where you choose an art piece to hear something about it and also *Perspectives: Paradise* which also let us choose lectures to play after the storytelling beginning.

When the lecture is in form of an audio unless it is very short it is a good idea to support it visually for example with a presentation **slides** where we can follow the important facts. Another observation that I have made is that it is useful to have the option to give the user a break from listening by giving him something to **read in a silence**. For that it is very tiring to read from hand especially when the resolution and frame rate are not ideal in nowadays headsets. Instead, even with a low-resolution headset it is pleasure to read something from an object anchored to the virtual world, e.g. from an iron plate on the wall in *Nefertari: Journey to Eternity* or from a large screen with big letters. When the object we are reading from is standing still in the virtual world it is easier to read compared to a piece of paper which corner is anchored to the tip of the controller in our shaking hand.

Concerning the situation when the user wants to interrupt the lecture, it is important to give him this ability otherwise the user gets very frustrated, however, it is also frustrating when you interrupt some lecture accidentally. In the *Smithsonian American Art Museum* the lecture gets interrupted automatically when you go a little far away from the art piece the lecture is about. Several times I was listening to the lecture with interest and I was admiring the museum walking and suddenly the lecture stopped. It is better to play the lecture to the end unless the user takes an action with his controller. Another interesting approach is used in the *Nefertari: Journey to Eternity*

where the lecture cannot be stopped but the sound fades out accordingly to the distance from the wall painting. So you can just walk to some other room and you only hear the lecture in the background coming from far away which is not disturbing at all.

Astronomy

The tested applications were mostly not astronomical but there are few observations that might be useful for an application about astronomy.

First of all it is quite uncomfortable to float in the space. It is a good idea to provide something to stand on being a futuristic floating platform or a cloud.

Another thing is that a linear motion with constant velocity does not cause so much sickness as acceleration or deceleration of the camera.

The application *CAPCOM GO! Apollo VR Planetarium* featured a great way of visualization of large objects as rockets etc. You have a small maquettes of the actual object that you can hold and examine carefully in you hand. Then there is a device where when you put the model into, a large version of the object appears floating. It would be also nice to give the user the possibility to rotate this object.

2.1.4 Educational application idea

After studying all these VR application I started to realize what kind of a VR application I would like to create.

First of all I must say that storytelling always amazed me. I love animation movies which motivated me to study Computer Graphics in the first place. Being part of a story like *Allumette* or *Google Spotlight Stories: Age of Sail* is an amazing experience. Another required aspect of my VR application is that the player learns by having to apply the acquired knowledge. If he learns and learns without ever having to actively remembering any of those information he will soon forget.

This two aspects led to the idea of *two phase learning* where in the first phase the user is preparing for a mission. In this phase he is learning from various lectures of different forms that he can find on the location. In the second phase the actual mission comes. He needs to test his new knowledge and even though we are talking about learning in the first phase and about testing in the second phase, the actual learning takes place here, where the information get burned into the memory.

The first phase is more about the user exploring the virtual environment and finding interesting lectures to watch. Then in the second phase the user should be immersed in some exciting story and to become the main character responsible for reaching the given goal which is impossible without

the knowledge which can be acquired in the first phase.

The reward for successfully accomplishing a mission might be for example unlocking a new location with more lectures to explore, getting a new technology (for example a rocket) or an object that can be used in the game or a short VR experience that the user can play at any time.

2.2 Pedagogy

If we truly want to figure out the essence of a good educational game, we need to also dig into the field of pedagogy besides the game designers' research which will follow in the section *Related work*.

2.2.1 Transmissive vs. Constructivist Approach to Education

In modern didactics we recognize two types of approaches to education: **transmissive** and **constructivist**.

The **transmissive** approach is also known as *traditional* education. The student takes a passive role while the teacher actively teaches the subject to transmit the knowledge to the student. This approach is appropriate for teaching rules, axioms etc. and for materials that are hard to comprehend or that are abstract so the presentation of already well structured knowledge is the best way for the student to understand. The downside of this approach is the lack of preparation of an individual for real-life situations where the knowledge needs to be applied.

The **constructivist** approach is about the construction of knowledge by the student himself. It is active and preferably social approach where through discussion and collecting of pieces of information the person is gradually enhancing the knowledge structure already present in his head by new connections and editing his current knowledge structure in the light of the new findings.

It is worth to have a look again at the famous Confucius quote: *"I Hear and I Forget, I See and I Remember, I Do and I Understand"* which I mentioned earlier. The quote is well known among the educational game designers and it is used to emphasize how the active interaction in games helps with education in contrary to only listening to the teacher or in the better case of seeing illustrative demonstrations. I have also previously used that quote to show the potential of the VR technology for education. Interestingly enough, all these three methods mentioned in the quote (listening, seeing, doing) correspond to the three categories of methods beneath the transmissive (traditional) approach.

- Education methods of the *transmissive* approach

- verbal
  - storytelling
  - explanation
  - lecture
  - text reading
  - discussion
- illustratively demonstrative
  - demonstration and observation
  - images
  - instructing
- practical skills
  - imitation
  - manipulation
  - skill creation
  - production

The reason for this is that even in the third category of the transmissive methods, the activity that the student does is taught rather than letting the student to figure out the knowledge by himself by trial and error to make him **construct** his own structure of understanding.

The constructivist methods were used widely in classical antiquity. The *Socrates' method* consisted of bringing the students to new knowledge by the teacher's leading questions and students' discussion.

Later, in the Middle Age in west Europe we encountered the dark extreme of transmissive education that consisted of memorization of texts without the proper understanding.

Nowadays in modern didactics there is heavy emphasis on the *constructivist* approach. More and more new elementary and secondary schools are created that abandons the traditional (i.d. transmissive) approach to education and really heavily on individuality and freedom of children. Many of those new schools however suffer from the lack of discipline of their students and their inability to fit seamlessly in the hierarchical system of our today society. (TODO: najit k tomu zdroje a pripadne prepsat)

Hopefully we will create a better educational system for the next generations taking in account all the positive and also negative findings gained from these first attempts to rip from the traditional education system.

2.2.2 The Problematic Method

Using this method we give the students a problem to solve. The problem might have one or more solutions and according to the constructivist approach

we don't provide the students with any ready to grasp knowledge by teaching them the methods of solving this kind of problems but we lead them to derive the new knowledge by their own mental activity.

- Conditions that the given task must met so we can use the *problematic method*:
  - the task is solvable by logical consequences of the already known material;
  - the task is adequate to the students' age, knowledge and skills;
  - the task has so called *problematic content* (the new piece of knowledge) – i.e. the task is harder then what the student is already prepared for;
  - the task raise the students' attention and the desire to learn;
  - the teacher directs the students' actions in the problem solving (e.g. recapitulate what the students already know, asks the other students what they think when seeing a wrong approach, leads students' attention to the mistake).

An example of a *problematic task* might be: "Assign every chair around a circle table with 7 chairs to 7 people so the following conditions are met...". Here children encountering this kind of problem for the first time don't know how to solve it or how to approach it but we might provide them with a picture of the table and so after a while when they are moving the names around the table and finally menage to find the solution they learned some knowledge and their own solving methodology that will help them to solve similar task much quicker next time.

Even though it is slower then teaching them the most efficient approach right away, this way they become able to apply the acquired knowledge in different real life problems that are seemingly not similar to this one.

2.2.3 Hejný's Method (Hejného metoda)

Milan Hejný is responsible for creating a method of teaching mathematics to children that is nowadays being taught in many so called alternative schools in Czechia and Slovakia and interest for this method is beginning to raise also in other European countries and Canada. It is based upon over 50 years of experiments and studying the whole history of education. The consequence of using Hejný's method is supposed to be that the children learn math by themselves and with joy.

The method consists of 12 principles but can be briefly explained by these three main principles: 1) we have schemes in our head, 2) schemes are created by different environments, 3) the teacher is only a manager.

Schemes

When I ask you a question: *"How many wall sockets do you have home?"* Can you answer? *"Sure!"* You would probably say, "Just give me a minute!" The American psychologist J. R. Geric (TODO: jak se to pise?) asks: *"When did you learn it?"* You were never taught that information but you can still retrieve it from your knowledge because you have the *scheme* of your home in your mind. So from the perspective of real life you know the answer to this question even though you don't know it as a fact.

Environments

In elementary school we were taught to multiply by memorizing multiplication charts, however, Hejný's method aspires to the creation of this schemes that are naturally applicable to all kind of situations. This require us to use different **environments** for the teaching process. One environment for learning the addition of number might be a game where two children are standing next to each other on a staircase, one child is walking on the stairs on teacher's command e.g. 2 stair up and 3 stairs down. The class is asked to tell the other child on the stairs how many stairs to take to be again at the same stair as the first child. This is an example of one *environment* that is set to teach addition and you need to use several different environments for teaching one concept (in our example the abstract idea of negative numbers and addition). Hejný's teacher's book contains different environments and how they are related.

Hejný also stresses that the discussion among children is crucial. The effectiveness of the whole method drops significantly while used at home environment instead of among other children.

Teacher's role

During these games the teacher's role is strictly restricted to maintenance of joyful atmosphere among the children and guiding them and managing their activities without giving them any knowledge or even confirmation of the correctness of their solutions.

The Hejný's method teaches less material in a single session than if we use the traditional transmissive approach however the children are supposed to learn more. This is due to the fact that they are gaining more knowledge caused by deeper understanding of the problem as well as gaining more social skills.

You can watch the usage of this method in action (in Czech) in this video: [Mat]

2.2.4 Conclusion

In our application instead of using only traditional teaching methods as reading or listening to information, watching information or even doing tasks according to a manual we might consider using the modern *constructivist* approach where we set an environment that allows the users to acquire knowledge themselves by playing in the environment while given a goal to reach.

Multi-player mode is required for this method to be effective. Furthermore the user's mistakes must lead to visible consequences in the virtual environment so the user sees when he needs to self-correct his reasoning especially if using single-player mode where there is no group where the users can correct each other.

2.3 Related work

2.3.1 Guide to the Solar System

Guide to the Solar System – VR educational application introducing objects of the Solar System is my bachelor thesis [Mor18] for which I developed a VR educational application for android smartphones. The application *Guide to the Solar System* uses gaze interaction only and allows the user to visit various locations (planets and their moons on the surface and on the orbit) on which the user can trigger short audio lectures.

The target group of the application was very general since it was meant for nearly anybody who is interested to learn about astronomy without having any prerequisite knowledge. I had done a usability testing with 6 participants which led to some findings relevant also for my master thesis.

The ability of interrupting the lectures was of great importance and participants who struggled to perform the head shaking gesture for lecture interruption got frustrated. Concerning the length of the so called lectures, I determined the ideal **length of a single lecture** to be around 30 seconds. 1 minute long lectures were short enough for the participant not to interrupt them. However, the participants enjoyed most those lectures containing a single interesting fact that were around 30 seconds long and remembered information from those most. The lectures that were 2 minutes long were carefully listened only by participants for which the lecture content matched their field of interest. For the vast majority of participants the 2 minute lectures were too long and they lost interest and interrupted them.

The first level of the game is a tutorial that teaches the user how to use the application step by step. In the next levels the participants had some problems due to the fact they had not remembered everything from the tutorial and they were rather discovering the game mechanics by the trial and

failure method by their own. Here the application should have given some hints on how the game works in several first levels instead of relying only on the tutorial at the beginning. Also for the tutorial it is important that the user can hear the same information again if he struggles and he needs to take an action in order to apply the audio-visually given information. The whole tutorial principle where the user have no other choice what to do except for the task the tutorial is demanding is, however, boring and it is better for the user to have freedom with hints instead or to make the tutorial very short.

Another observation is that the participants firstly paid attention to the objects that are close around them. After inspecting them visually they paid quite a lot attention to the sky and small imperfections in the skybox were disturbing.

It is also useful to visually distinguish active objects which trigger lectures that have already been triggered and lectures that are waiting to be heard.

My bachelor thesis and also [PB+17] suggest that it might be a good idea that the user have a safe home place where he can feel like owning it and being home there where he can for example visualize his achievements more immersively. However I had not read any articles that seriously study this concept.

2.3.2 Actors in VR storytelling

This paper [Riz+19] presented in the VS-Games conference[5] 2019 concentrates on the usage of real actors footage in the VR world for educational storytelling. According to what I have learned at various HCI courses at my faculty I remain unconvinced by the quantitative research which questioned only 23 participants. However there are several qualitative findings that are really interesting.

The participants found unnecessary to be able to change the storyline. In contrast to existing storytelling games which are distinguished from a regular movie exactly by the possibility to drive the story by the player's own decisions in this work the participants did not have such a desire. This is highly relevant, because the tested application is educational. The focus of the whole paper is at edutainment (educational entertainment). When the player's mindset is to learn about facts, e.g. about history, he has usually no need to interfere with the story. Instead he is willing to be immersed in the real story in order to learn. Another explanation of this finding could be that we are too used to educational materials being passive and non-interactive.

The participants however did have a demand to be able to **pause** the story and to **fast-forward/backward** the story. I also missed that functionality in *Allumete* and *Age of Sail*[6] and it is necessary for longer lectures in any

[5] International Conference on Virtual Worlds and Games for Serious Applications.
[6] A movie from the series *Google spotlight stories*

form (2D movie, VR story etc.).

Concerning the interactivity we need to also mention the study *Exploring Effects of Interactivity on Learning with Interactive Storytelling in Immersive Virtual Reality* [ZBJ19] comparing three versions of an educational storytelling application with three different levels of interactivity with the goal to find how much interactivity leads to higher learning gain. According to the study the difference of interactivity level had no effect on the participants' learning gain.

In conclusion, the interactivity of the educational storytelling game seems to have no large impact on the learning gain. An arbitrary interactivity may add to the fun factor of the game as something additional but is not the key aspect of a good educational application when talking about learning by storytelling.

2.3.3 Comparison of a Gamified and Non-Gamified Virtual Reality Training Assembly Task

This paper investigates whether gamification can improve the learning curve for VR training applications. Since our goal is to investigate the educational aspect of VR, we can think of a training applications as a subset of our problems. Some taught topics might be entirely theoretical however some might require effort to train some practical skill. (E.g. how to use a sextant.) In the paper the tested application was teaching how to assembly a drum set. Half of the participants were trained on a gamified and half on a non-gamified version of the application after which they all had to assembly a real drum set for first time in their life.

The participants from the gamified group finished the training process faster, however the distribution of times spent assembling the real drum set afterwards was rather uniform. To quote from the results of the paper: *"Gamification does not seem to impact the overall number of mistakes made by the participants in general during the practical real-world test"*. So their conclusion is that despite the fact that based on this research we cannot see a difference between the educational impact of the gamified and non-gemified versions of the applications, we can tell that gamification affects the behavior of the user during the training process itself.

The paper also mentions other related works comparing gamified and non-gamified training applications for different fields, however, without success in favor of the gamified versions.

Gamification could be a good tool for making educational applications more attractive or addictive for some people which would eventually lead to more time willingly spent in the game and thus learning more. However regarding the efficiency of the training process itself in its' gamified and non-gamified versions it seems to be no difference.

2.3.4 Secrets to Effective Serious Games and Gamification Approaches

A presentation *Secrets to Effective Serious Games and Gamification Approaches* [Ser] at *Learning Solutions Conference 2018* by Andrew Hughes[7] covers the topic about how a *good serious game* should look like that is pretty close to my topic about how a *good educational game* should look like. The presentation is covering the topic generally but the examples are all from the realm of training applications specific for certain companies and the training serious games are compared to the standard e-learning questioners. (It worths mentioning that such e-learning materials are now on many universities being considered as the modern way of education but in the light of serious games we will show it to be "the bad way")

Serious Game vs. Gamification

Andrew Hughes stresses a lot the importance of understanding the difference between serious games and gamified applications. [Ser, at 2:20]

Serious game
: A game that makes me better at something which is applicable in the real life.

Gamification
: The process of taking something boring and adding elements such as badges, points etc. in order to keep me doing the boring tasks outside of the actual game.

In that sense Hughes is seeing gamification as *the bad practice* for creating games for serious applications and does not think gamification is the right tool for creating serious games. He is actually talking about *gamification* and *serious games* as about something disjunctive where we have the real *serious game* on the one side and a *gamified application* on the other side which is only a failed attempt to create something that we can truly consider to be a serious game.

Let's take a look at the definition of gamification given by Yu-kai Chou who is the pioneer of gamification and according to his words in his TEDx speech called *Gamification to improve our world* he sees gamification as the tool that can takes us closer to the utopian vision where there is nothing you *have to do* and only what you *want to do*. I personally find this vision rather anti-utopian since going after such a vision is not seeking a really better future but seeking more pleasant future which are two strongly different things. However, the point I want to make is to show that even that Yu-kai Chou sees gamification

[7] The president of Designing Digitally, Inc.; a professor at University of Cincinnati.

as something, as you saw, extremely positive his definition is almost the same as Hughes'.

Gamification
The process of taking fun elements of games and pouring them into boring non-game context.

Yu-kai Chou immediately gives the same point as Hughes when he says that the true gamification should not lay in using elements such as badges, points and leader-boards but rather in taking the *core drive* of the games. So he seems in agreement with Hughes in general but I see this in contrary with his definition of gamification since the definition talks about *"pouring game elements"* and not the *"core drive"* and also pouring them into some *"boring context"* instead of making the context fun since the taught subject is not boring from its nature. It is why I agree more with Hughes' distinguishing between *gamification* and *serious games* instead of talking about world changing *gamification* and then *true gamification* that violates the definition of *gamification*.

One often used game element used in gamification are **badges**. According to Andrew Hughes the problem with badges is that it only works for so called *high-achievers* that are only a small part of our target group and thus they have no effect on the motivation of the majority to do the "boring stuff". It still can be a useful element of the game to enhance the motivation of thous high-achievers however it is something additional. The serious game should not depend on such additional motivators and the core game itself should be fun.

Concerning the badges, Hughes' tip is to bind the arbitrary badges with an actual reward that we can touch or we can use. For example getting some special ability in the game for one hour or in case of a company training application giving a real T-shirt to the employees.

Another often used game element used in gamification are **leader boards**. Again, Andre Hughes says the leader boards of the top players only matter for the high-achievers but this time also only for the top players that can see themselves in the top positions. Thus he advise to use rank boards comparing us to the equally skilled people so we compete with them to go higher.

This approach to leader boards is used for example in *Duolingo*, an application for learning languages, and truly seems to be an efficient motivation for high-achievers. However, I have seen people belonging to the high-achievers group where the leader board had a negative educational impact on them since the number of points earned is directly proportional to the number of completed lectures weighted by the number of the mistakes but in *Duolingo* doing a lecture fast and without mistakes does not teach you anything. Instead, you need to pay close attention to the lecture questions which requires already having an outside-of-the-game motivation to learn the language.

In Hughes' opinion, the educational applications with multiple choice questions gamified by badges etc. might still work sometimes but only for few years from now[8]. However, when the millennials[9] get over our target audience this boring applications pretending to be fun would not work for them.

Game Theme vs. Game Mechanics

You see that the definition of serious games above said *"applicable in the real life"*. It is an important part of the definition because every game (not only intentionally educational) teaches us "something" and so the teaching itself does not make the game serious. We can say that at least the playing of the game teaches as how to play the game better and so it is the goal of a serious game (not gamification) to make a fun gameplay where "getting better" at the game actually means getting better at something valuable that we want to teach. Andrew Hughes takes for an example the first person shooter game Call of Duty. When we think about what children learn from this game it might be for example what type of sniper rifle is the best for certain kind of environment. Is the detailed knowladge of all the guns used in the U.S. military the think we want our children to learn? - Hughes asks. But the children playing the game learn it because it is needed to obtain this knowledge in order to be better at the game which is fun itself.

Here come in place two aspects that makes a game: *game mechanics* and *game theme*. For example when you have different versions of Assassin's creed you get the same game mechanics but with different themes such as the American civil war or the ancient Egypt. This way we can use fun to play game mechanics (driving our parkour capable character and fighting) with an educational theme. This way you learn about those historical periods without intending to. Here I have to stress that this way of learning is more about seeing then experiencing. We have no need to pay attention to the story that is set in a historical theme in order to go trough the game or to get better at the game at least at this action game example. Watching a historical

Figure 2.18: A screenshot from the game *Where in the World is Carmen Sandiego* showing the world map.
Source: https://www.emuparadise.me/Super_Nintendo_Entertainment_System_(SNES)_ROMs/Where_in_the_World_is_Carmen_Sandiego_(Europe)_(En,Fr,De,Es,It)/36284
Accessed: 2020-08-08

[8] Being said by Hughes in 2018 when the speech was held.
[9] The generation Y.

drama movie will have higher educational impact since the entertainment factor of the movie is paying attention to the story while the story in action games has only supportive function. This is why the example game is not called a serious game. However, we can see that the *theme* of any game might have an educational impact if the theme's content is educationally valuable. Another example that Hughes gives is the detective game from 1985 *Where in the World is Carmen Sandiego* where the investigation can take place at different locations. The whole game could easily have been designed so that it takes place for example only in a kitchen, however, the game designers located the investigation in large cities all over the world so the player is constantly exposed to the world's map (See Figure 2.18) with the city locations shown so he is unwillingly exposed to those educational information.

To sum it up, the theme is what gets us interested at the beginning and the mechanics are what makes the game fun. [Ser, at 1:02:37]

Elements of a good serious game

Andrew Hughes calls the time that we live in today the time of *instant gratification*. We are living in a time of impatience where we are used to instant messages and we are irritated that our emails are not delivered instantly. We are used to want something and getting it immediately being something valuable like instant access to information that can highly improve our efficiency or something dangerous like instant rewarding of our brain with dopamine by pornography which decrease the urgency of real social contact. The instant gratification that occupies this century is, according to Hughes, the reason why we need to reward small steps in our game. We humans in general are not good at motivating ourselves with long-term goals for a long period of time without separating the process to smaller achievements. For example while working on a plan to colonize Mars the motivation of the team would soon fade out without smaller victories like reusable rockets. The generation of people addicted to instant gratification and the growing popularity of nano-learning might suggest we need even shorter iterations of activity → reward that we might think. Every **small achievement** should be **acknowledged** and the goals the user have should be short-term. The length of the goals will be also affected by the expected continuous play time of our target audience. For example if we are making an application for someone who would not spent a whole hour playing, we should take in account that he will play 10 minutes a day and choose the tempo of the game accordingly.

The **first levels** should be really easy to use the instant-gratification trap to make the player feel good about him doing well and be interested in the game and then we can start to increase the difficulty to sustain this interest. So the actual learning in a serious game does not take place in the first several levels.

We should also take an advantage of the natural **curiosity** of people. When

we are given some tools and some open environment where we can use the tools we can get very creative and enjoy the process of discovery of new things. This curiosity can be used to teach the *game mechanics* instead of read-or-skip tutorials that explains how to interact with the game in very linear way. For example: click here to build this specific building and build it at this specific place. Instead, according to Hughes we should get the players the freedom to discover the mechanics on their own by trial end error in the game itself in the first easy levels. So instead of separating the story of the **tutorial** from the story of the game itself, the first levels of the game itself within the main story should be used to teach the mechanics of the game in a way that does not restrict the user's freedom and creativity.

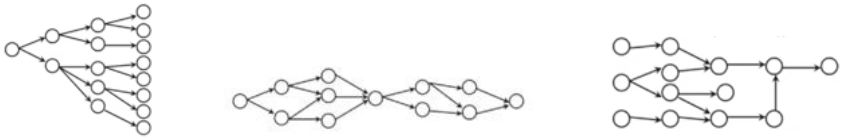
The **back-story**[10] of the characters is another aspect of a good game. According to Hughes, we need to add the personality to our characters. Just remember the shop owner from *The Lab* that we talked about earlier in section 2.1.3. Even without back-story the animation and speech gave him strong **personality**. Also remember the *Becoming Homeless: A Human Experience* where we were set to some specific life situation which, as we mentioned, enhanced the immersion. According to Hughes, the characters' story and personality triggers our emotions and bounds us emotionally to the characters.

Multi-player is also an important factor of a good educational game, mainly the cooperative mode and in general all aspects of the game that allows socialization with others.

When we consider *non-linearity* of a story there are several different ways of **branching** or rather several types of gameplay. What branching actually is is one of the gameplay types which has a tree like structure of the story (see figure 2.19a). It mimics the real world but it is not used since the number of alternatives is exponential. It is not feasible to implement such an amount of different stories. What many game developers refers to when saying *branching* is actually *parallel gameplay* or *parallel branching* (see figure 2.19b). It is widely used. It gives the user the sense of control and gives him alternative stories which, however, end the same way or merges in certain points which makes it feasible to implement. Another type of gameplay is *threaded* (see figure 2.19c) which starts at several points with gradually merges instead of spreading by choices. It is used for example when choosing from multiple characters at the beginning who have different stories before they met for example.

The choosing of an alternative path in the game should be based on the player's actions, however, according to Hughes we should not use the multichoice option interaction technique for that. For example *Walking death* is a game with multichoice gameplay and it was the most popular game in 2012, however, the reason, according to Hughes, is not the poor interactivity

[10] Background story – the known history of the game world and characters preceding the main story.



(a) : Branching gameplay.

(b) : Parallel gameplay.

(c) : Threaded gameplay.

Figure 2.19: Non-linear storyline structure.
Source: Slides of the *Secrets to Effective Serious Games and Gamification Approaches* presentation. [Ser]
Accessed: 2020-07-15

of the game but the great character personalities and back-stories that we talked about in previous paragraphs. There should not be a visible pause of the game in order to make the player choose a story branch but we should create the illusion that every action might affect the way the story evolves.

Concerning **realism**, one might think that educational game should be as realistic as possible. The exaggeration is however an important technique in teaching. For example some company once asked Hughes if he can make a training game that won't allow the user to fail since in real life you don't want the employees to fail due to the fatal consequences. However we learn exactly by our failures and when we fail in the game we might consider burning in a big fireball even if this would not happen in the real life. The mechanics of the trained skill should be of course realistic, however, we can support the educational impact by some non-realism.

The last relevant tip given in the speech takes place outside of the game design and it touches the way we use the game to teach our students. We should avoid saying things like: *"Go play the game for an hour at Friday afternoon in order to learn!"*[11] With this attitude we only put gaming as such in position of something mandatory and annoying where is nowadays our whole educational system instead of being something fun. Instead, for motivation to play we should establish a system of rewards. Internal in-game rewards or external rewards, but never money even if our target audience are our employees using the game for skill training.

2.3.5 Piloting Two Educational Games in Five European Countries

In this paper [TG18a] two Educational games by Triseum were heavily tested with secondary school students (857 students from 5 different cities). The test was managed by their teachers by integrating the game into their classes. Let's first have a look at the games itself and then discuss the conclusion of the paper.

[11] Later in the Results subsection of the section 2.3.5 in the paragraph about *Behavioral engagement* we will show the fixed play time to be productive when it is voluntary.

Variant: Limits – game description

Variant: Limits is a 3D third-person RPG that is supposed to teach calculus.

When I searched on the web what is the essence of learning physics I came into a conclusion that studying physics is on high level based on studying math. Simon Clark[12] suggests [How] that the only way to truly dive into physics is to be drilling and drilling our math skills. Where VR can be found extremely helpful is, however, understanding of the abstract concepts behind the algebraic procedures. From my experience, without understanding the core concepts even student highly skilled in algebra might found his skills inapplicable in real life problems. That is why for example the video series *Essence of linear algebra* is so popular and recommended by teachers on our faculty. It teaches to understand the core concept by visualization. In this game the abstract ideas of limits are taught rather then drilling algebra.

In the game you walk with your character and solve puzzles in order to unlock doors, create bridges etc. so you can move forward. In the puzzles your task is to select some value of the given function, determine a limit to set a correct input and so on. Some puzzles are well visualized in the virtual world, for example when you deal with an angular functions and you see big stone door rotating while you move the function input slider in order to solve the task.

Figure 2.20: A screenshot from the game *Variant: Limits*.
Source: [TG18a]

ARTé: Mecenas

This game is, according to the trailer, promising to teach us about art history not only by looking at pictures of art in books but by exploring the artists'

[12] A physics professor at the University of Exeter.

world. The game mechanics are very different from *Variant: Limits*. This is a strategy game where we choose a quest on the map and we are clicking to trade. The *game mechanics* (See section 2.3.4.) are mostly about trading and from time to time we are exposed to art in form of a question where we have to choose the right answer from three options. For example we have this type of questions: *"Which of these statues is suitable for the mentioned building facade?"* And we have to use our knowledge to answer in order to get more reputation in the game.

Figure 2.21: A screenshot from the game ARTé: Mecenas.
Source: [TG18a]

Results

Both games are obviously made carefully to use the *constructivist* (See section 2.2.1.) approach to teaching. The game encourages the players to use other sources to spend time and energy to find the answer by their own. In the game *ARTé: Mecenas* the student can need to open some books or to search on the Internet to be able to answer. In the paper it is called *classroom engagement*. [TG18a, at section IV. B.]

Also **collaboration** is of great importance. The tested students played together in a computer lab in their school. This caused the students help each other and the discussions about why some solutions work and other don't were sometimes very heated. In the paper it is called an *agentic engagement*. [TG18a, at V. D.]

The paper also stress **variability** where the game is not the only teaching method used but is combined with a traditional classes.

Concerning game mechanics there were problems with the game *ARTé: Mecenas*. There was a lot of text reading required which was demotivating for a lot of the children. Also the game mechanics based heavily on trading were

hard to understand by everybody – here students who like maths and/or are already gamers had an advantage.

The *Behavioral engagement* was high because the game had a fixed time when the students were playing it. They played for 60 min in class. We are used to attend lectures because we have to and we are trying to be concentrated the whole time even if we find the lecture boring. Attending the class where the children were supposed to play the game was not mandatory and some children refused to attend. However those who voluntarily attended where highly concentrated because of the 60 min time given by the teacher and they enjoyed the playing. The other children that previously refused to attend came to play next time after a possitive review from their classmates. [TG18a, at V. A.]

The *cognitive engagement* was very high for the game *Variant: Limits*. The children were talking a lot and discussing the problems in both games but in this game they shared more the ideas of how to solve some type of puzzle instead of sharing which configuration of orbs leads to opening the door in a single puzzle. *"[In other learning formats,] they do share ideas, but mostly it's, 'What did you get on that one?' 'Oh, I didn't get that.' So, they're mostly comparing answers, and not solutions, or not ideas. When we work with this [game], they share ideas more than they share answers, and that is something that I think is working well. [. . .] Somehow I feel that sharing ideas is the main strength of this."* [TG18a, at V.C.]

Another important observation is the distribution of motivation according to the current knowledge/skill level of the children. In the *ARTé: Mecenas* the students that are already well educated in art history are good in the game and the trading goes well which motivates them to play. When their knowledge is bad they struggle a lot and that demotivates them. This is bad because we want to encourage mostly the ones that still need to learn more. In *Variant: Limits* however the poorer students were more satisfied by playing than the better ones even thou they were slower. The students that already have the needed knowledge were faster in the game but the game didn't intrigue them so much.

The paper states: *"A more general conclusion from these observations is that in* ***game-based learning*** *scenarios, it seems advantageous for teachers to be familiar with the student group and to be aware of individual differences and requirements on parts of the students in order to anticipate certain developments and to take actions which facilitate a successful game use for all kinds of students."*

The paper also stress that these results cannot be awarded only to the tested game or to the pedagogical concept (i.e. the presence of a professional teacher, group collaboration at school environment etc.). The game together with the pedagogical concept created one whole which was tested.

Game-Based Learning

As we talked much about gamification and it's drawbacks let's see what Triseum says on their web page [Gbl] about gamification as they are the creators of both educational games we just discussed and they acknowledge themselves as the leaders of the *game-based learning revolution*:

GBL stands for Game-Based Learning. There is some confusion around what GBL is in the field of education, and it's often mistaken for gamification. Whereas gamification aims to incentivize an activity that a person might otherwise choose not to do (often through points or other awards), GBL helps students achieve measurable educational goals like developing critical thinking skills or knowledge mastery of a subject. GBL is a more effective way to learn not only because it's immersive and engaging but also because it's fun to play and leads to better performance than the traditional curriculum and methodologies.

That being said, gamification is not something bad. It is a tool for making something boring that needs to be done fun. It might help children with injured arms to do their painful rehabilitation etc. However we seek forward making learning fun since learning is not a boring or unpleasant activity in its core.

Other games

Beside these first two games Triseum have made two more ARTé games.

ARTé: Lumiere covers art from the revolutionary era and seems to immerse the player more in this historical period due to being able to move in the virtual world (unlike ARTé: Mecenas) and talk to the in game characters.

ARTé: Hemut Features very different gameplay since it is a card game which gaming board is a 3D model of an ancient Egyptian city.

2.3.6 Enhancing Progressive Education through the Use of Serious Games

This [RB18] is another paper that concludes that even thou the tested games had a positive emotional impact on both children and teachers, still the real impact of the selected games on learning needs to be deeply examined and that more research is needed that is focused on the effectiveness of games for education.

2.3.7 A Serious Game for Understanding Ancient Seafaring in the Mediterranean Sea

This paper [PB+17] describes the development of an educational VR game that should teach the user about the seaborne trade mechanisms and seafaring practices in the Mediterranean sea during the Classical and Hellenistic periods.

The game objective is to gather wealth by trading. Here we need to note that it is not an arbitrary game mechanics since one of the educational goals of the game is to teach about the trading mechanisms of that era.

To get better at the trading the application relies on extensive storytelling. Using the tool **Twine** for non-linear storytelling the user can dive into a classical multi-choice driven interactive storytelling.

The goal of the paper is to present development approaches for creating such a game.

Chapter 3

Design

3.1 Navigation

According to a consultation with my supervisor I started first with designing the main navigation that will allow the user to track his progress and to move between lectures. The navigation should be then prototyped using some VR prototyping tool such as Microsoft Maquette or Storyboard VR.

One passed lecture can open access to another. In addition to this my supervisor suggested that the graph of these dependencies should not be a tree but that it should be possible to open access to a new lecture by passing several different lectures - either mandatory all of them or at least one.

My first thought was that now my task is to design clever visualization of the graph of lecture dependencies so that the user can easily choose a scene to enter. This turned out to be really hard since the application should be able to handle a huge number of lectures and topics. Not only the large number of lectures is problematic but also the possibility to have complicated dependency connections between the lectures.

However when we think about it, the visualization of the whole tree is not needed. Since the user will explore the world gradually he will always have already passed lectures that he is familiar with and lectures that need to be passed to open new lectures. Based on that I decided to visualize only a single lecture node with its description and with lecture dependencies (parent nodes) and lectures that can be unlocked by passing this lecture (children nodes). This lecture view can then be accessed by a folder-like logical structure of lectures enhanced by filtering.

3.1.1 Basic elements

During the process of navigation designing I came up with several main elements of the application that I need to explain carefully because its understanding is important for the whole educational concept of the game.

These are *locations* (in Czech: *lokace*), *lectures* (cz: *lekce*) and *adventures* (cz: *dobrodružství*).[1]

Location

A location (cz: lokace) is a virtual place that you can walk around and explore various interactive objects that allows us to trigger a *lecture* or an *adventure*. A location could be for example Brahe's observatory, a place on the Moon etc.

Lecture

A lecture (cz: lekce) is the source of knowledge in the game. It is triggered by an object found in a *location* and it can take various forms: 2D video, text, 3D instructional animation etc.

Adventure

An adventure (cz: dobrodružství) is an interactive game, which can be found on a *location*. The game will test the user's knowledge acquired from *lectures*. Successful completion of an adventure will unlock new *locations*.

Concerning representation of locations in Unity, a location could correspond to one scene in Unity. It can be however implemented using several scenes. For example *The Lab: Secret Shop* would be one *location* even thou you can use a spell to become tiny and walk on the shelf which could be done by a new scene containing more detailed versions of the meshes on the shelf.

An adventure could also take place in a single scene or it could take advantages of several different scenes if the story of the adventure is long enough to take the user to different places. The adventure could also have no scene at all. It could be an interactive game that takes place in the scene of its location.

You will see specific examples of locations, lectures and adventures in the section **??**.

To sum things up: The user explores *locations* and learn from *lectures* to be successful in exciting *adventures* which unlock more *locations*.

[1] I will always include the Czech translation of terms, that occur in the game since the game content is in Czech language.

3.2 Menu prototype

The reason to create a prototype is not only to present it to my supervisor to consult if my suggested solution is appropriate. The process of prototype creating itself is really crucial for the design process. What is a seemingly clear design in our head can turn out to be only a vague idea after trying to sketch it on a paper. In this process we figure out what can and cannot work and we are forced to answer many questions concerning the whole concept of our product – in this case the menu.

After the main idea was created on a paper I started creating the prototype with an appearance not necessarily equal to the final menu but close enough to get the same feeling and to answer the main design questions about the placement and look of particular pieces of the menu.

Even though concerning the visual aspect this stage could have been done in Photoshop as well, it was important to have the prototype in 3D and to be able to experience it in VR. Moreover the possibility of prototyping for VR from VR itself creates an instant feedback for the creator.

3.2.1 Microsoft Maquette

After exploring the possibilities of prototyping tools for VR I have chosen to use Microsoft Maquette which seemed to have all the needed functionality and after using it I must confirm that it is really a good software.

The creation of new objects and its editing was really fluent and intuitive. The toggling of different object editing modes was a little tricky and required more time to learn.

A big problem was was the unexpected change of local coordinate system of a group of objects that should in my opinion rotate around axis of the group however the group rotated around seemingly arbitrary axis which was preventing me to be precise and forced me to use free transformations.

However, the biggest pain was to write text. The input method in Maquette is to select characters with a laser pointer in your right hand on a virtual keyboard fixed to my left controller. It was not only incredibly frustrating to type but it was literally painful.

Except the writing of text it was pleasant to create things in Maquette. The library of available 3D objects is large and there are many useful options such as virtual camera for taking screenshots.

3.2.2 Sketching

The main navigation designing process took place on a paper using a pen. In figure 3.1 you can see the idea of displaying several menus at once around

the user. On the left: the folder-like structure of topics / categories with the option to select (at the bottom) whether we want to browse locations, lectures or adventures. In the middle: the actual list of items (i.e. locations, lectures or adventures) with the ability to filter (at the bottom). On the right: the details of the selected item.[2]

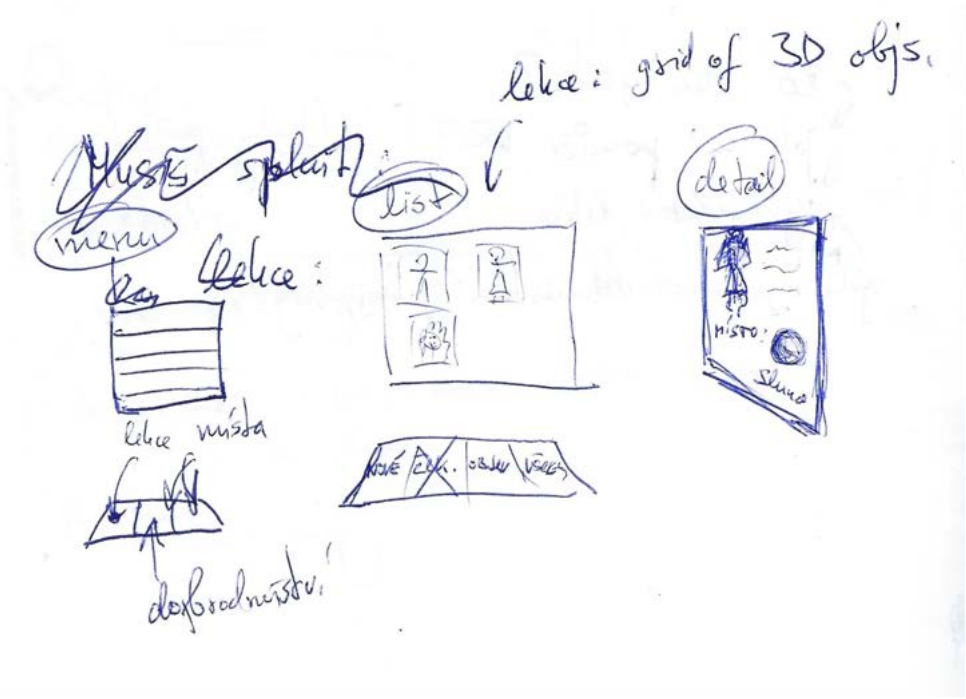


Figure 3.1: A sketch of the three main menus used together.

All the sketches are included in the Appendix B. I will explain the menu more in-depth on screenshots of the finished Maquette prototype.

3.2.3 The prototype

The individual windows of the prototype were created according to my sketches. Then I took advantage of the Microsoft Maquette option to create multiple scenes to create an animation sequence of the navigation process. I also added numbered hand models that indicates the order of clicks of the user during the navigation.

Let's now go through the menu step by step.

How I mentioned earlier, there are several 2D windows floating in the 3D space surrounding the user or rather creating a curve in front of the user. (Figure 3.2) Instead of switching between the windows how you would

[2] In the sketches there can occur the term *místo* which I used instead of *lokace* to address *locations* in Czech.

probably do it for example in a smartphone application, here the user focuses the particular window simply by facing it.

Figure 3.2: The menu prototype

It might look a little overwhelming but figure 3.2 is just to show you the feel of the menu. It won't be so overwhelming for the user since he will be the one opening all those windows according to his actions.

Let's first have a look at the left most window (Figure 3.3) which carries the title *Categories* (cz: *Kategorie*). On the bottom you can see three buttons: Lectures, Adventures and Locations.[3] These buttons enables you to choose what items you will see. Under the title "Categories" there is the hierarchic structure of topics. For example you have topics such as history, physics, objects etc. And under objects you might have stars, planets, galaxies. Lets choose to browse the locations and then imagine that you click at Stars (cz: Hvězdy) under Objects (cz: Tělesa) just like how it is visualized on the screenshot by the semi-transparent blue hand.

[3]See section 3.1.1 for the definition of these terms in context of the game.

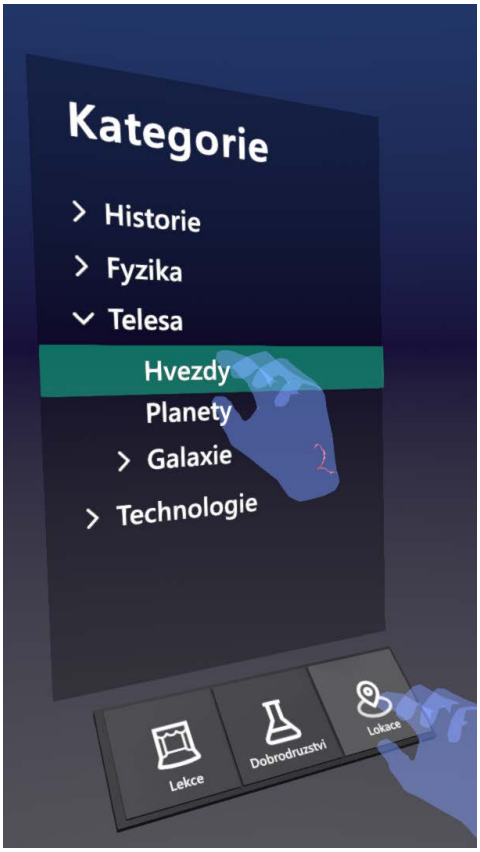


Figure 3.3: Menu – Categories

The next window (Figure 3.4) is titled *Locations* since we have just chosen to browse locations. The first location on the list is the Sun (cz: Slunce). As you can see the text is gray and it has a lock icon which means that the location is not yet open for the user to visit it. But despite that, we can still click it to see for example what are we required to do in order to unlock this location.

After selecting the locked *Sun* location a new window appears on the

Figure 3.4: Menu – Locations

right (Figure 3.5) (You can see all the screenshots of the prototype in bigger size in Appendix C.) In the top left corner, there is a small header showing that this window is the description of a location. In the right top corner you can see that the location is locked. Under the large title of the location there is a brief description to get the user interested. Underneath there are three sections:

- **Dependencies** (cz: Prerekvizity) – a list of adventures of other locations that need to be finished to unlock this location. On the example in the screenshot there are three dependencies. The first one is already successfully finished which is signalized by the green tick in the corner. The second adventure waits to be taken and the third one is not yet available.
- **Lectures** (cz: Lekce) – a list of lectures that the user has found in this lecture. Notice that you can see the number of lectures at the location by seeing the number of question marks, however the lectures are not accessible until the user finds them at the location. This is impossible until the location itself is unlock and so every lecture in the list is represented only by a question mark.

Figure 3.5: Menu – Locked location

Figure 3.6: Menu – Adventure

- **Adventures** (cz: Dobrodružství) – a list of adventures that are accessible from this location.

Note that the adventures are visualized by an image of the adventure. Another possibility is to add depth by replacing the image by an empty window, a hole in the VR scene, through which the user sees the adventures world in 3D. It can of course be just a background image but placed far away and large enough to create the effect of the adventure world being behind this rectangular hole. As we will see, the lectures on the other hand are visualized by a 3D model. This way, when the adventures and lectures looks differently, the user can easily tell if an item in the menu represents an adventure or a lecture.

Since we need to absolve several adventures to unlock this location let's click on one of the dependencies to see what needs to be done. Figure 3.6 shows an example of an adventure details window. On the screenshot there happens to be an already finished adventure so it has a green tick in the corner. The adventure is sort of a quest so it should give the user a goal to finish. Let's see what I mean on an example. Imagine that in the Brahe's office (a location) there is an sextant laying on the desk which triggers a lecture that teaches the user about how to use a sextant. It is required that the user has this knowledge in order to be able to finish the sailing adventure. The adventure description however don't say: *"Let's examine if you know how to use a sextant"*. The description says: *"Become a navigator on a 18th century cargo ship and deliver the cargo on time."*

Below the description there is a list of rewards user can get by successfully

finishing the adventure. The first one is the most important – unlocking of a new location. The other rewards in the list are only illustrative.

Below the list of rewards there is the location where this adventure can be found.

Now let's say we have passed all adventures needed to unlock the Sun location.

Figure 3.7: Menu – Unlocked locations

Figure 3.8: Menu – Adventure

In figure 3.7 you can see that the lock icon is replaced by the icon of the location (3D model of the Sun) and mainly there is a globe (see where the blue hand is on the screenshot) for entering the location by putting the globe on your head.[4] We can also see that now all the dependencies are fulfilled. Below we can see that there are 4 lectures already discovered by the user thus there are 4 little models in the Lectures section instead of gray question marks (see figure 3.8). Also the adventure accessible from within this location is unlocked.

[4]The way of entering other worlds in VR used in *The Lab* and other applications.

Figure 3.9: Menu – List of lectures

The window with the list of browsed items (figure 3.4) was titled *Locations* and there were list of locations beneath. If we chose to browse lectures instead (from window on figure 3.3) the content of the list of browsed items would change accordingly (Figure 3.9). Now we see the list of lectures. (This window should also have a filtering option common for all three types of items to enable the user to see only unlocked locations etc.) When we click at the third lecture *The life of a photon* (cz: *Život fotonu*) instead of the details of a location we will see a window with the details of the selected lecture (figure 3.10).

Figure 3.10: Menu – Details of a lecture.

When we compare it with the details of a location (figure 3.5 or figure 3.7) and the details of an adventure (figure 3.6) we can see several similarities. In the top left corner there is the type of item (lecture, location or adventure). Below the title there is a description and below the description there are different sections unique for every item type.

In case of a lecture in the description there is an interesting fact that could bring the user's desire to learn more about it. In the given example of a lecture details in the screenshot (figure 3.10) the description says: *"Did you know that despite its speed it could take over a million years for a photon to get from the core to the surface of the Sun? In this video we will take a look of the life cycle of a photon from its birth in the solar core to its end in our eye."* The user can get excited to learn more by this quick fact that is not further explained. After that, the description said what will the video be about.

The user can tell that this lecture is a video mainly by the lecture type annotation below the main title. And of course there is the location on which the lecture was found and a teleportation globe to jump to that location.

To conclude everything, one window is to select the category/topic of interest and the type of browsed items (locations, lectures, adventures); the second window shows the browsing results – the list of items, there you can also use some filtering; and the third kind of windows is to show *details* about certain item and there can be more of them opened at once because you can for example open the details of a lecture by clicking on a lecture in the details of a location.

3.2.4 How to run the prototype

To load the prototype into Maquette, copy the project files from `/maquette` to their corresponding locations according to the information bellow.

If the given example directory paths don't work for you, try to open the correct destination folder from maquette VR menu.

Also note that if Maquette freezes on the loading screen, it is probably because of an error that is shown on the desktop screen. For example: `X Controller tracking` if you don't turn on both controllers.

Copy the project

`/maquette/dp_menu/` is the folder containing the maquette project itself. Copy the folder to:
`C:\Users\<username>\Documents\Maquette\Projects`
It is the folder where Maquette saves your projects. It can be opened from withing Maquette as shown in figure 3.11

Figure 3.11: How to open the projects folder.

Copy the images

The folder `/maquette/My Pictures/` contains images used in the scene.
Copy the folder to:
`C:\Program Files (x86)\Steam\steamapps\common\Microsoft Maquette\MaquetteContent\MaquetteLibrary\Images`
It is the folder where Maquette searches for images that can be included. If it is not at the given address you can found it's location by opening it from within Maquette, when you click on the "load images" button located in the left hand palette how it is shown in figure 3.12.

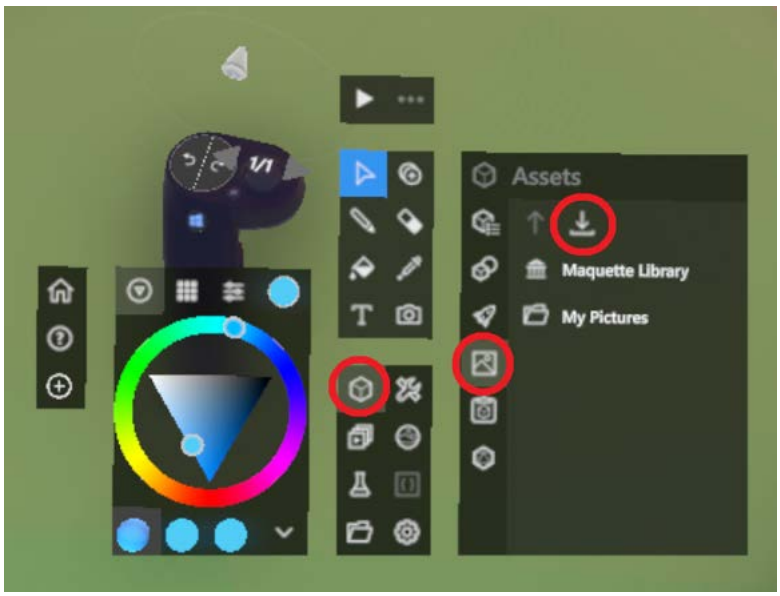


Figure 3.12: How to open the images folder in Maquette

Load the project

After launching Maquette you won't see the project in the recently opened projects section. In order to open it, open any existing project provided by Microsoft. Then click on the folder icon in the menu on your left controller as shown at figure 3.13.

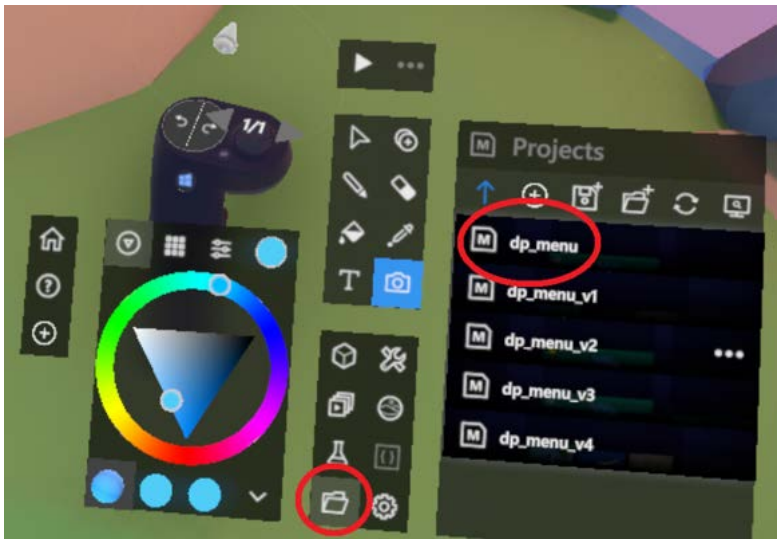


Figure 3.13: How to open the project in Maquette

Chapter 4

Implementation

4.1 EduVR library

The task was to program the application scripts in a way that it is easy to import and to use to add new educational content.

I have created several prefabs and scripts that makes it easy to add new lectures to the scene or to be used in a new scene.

See Figure 4.1 for an overview of the all classes in *EduVR*.

4.2 Application Creating

To test the implemented library an application was created. I decided to locate the education in a sci-fi environment. For that I used the asset *Sci-Fi Styled Modular Pack* that contained prefabs for floors, walls etc. that allows the user of the prefab to create all sort of sci-fi buildings. I used the example scene where a simple space station was build. Another environment that I find suitable for astronomy education is a historical one where people can get familiar with more historical topics about famous astronomers and their discoveries. For that I used the asset *Free Medieval Room*.

I connected these two interiors by a tunnel from the *Sci-Fi Styled Modular Pack* and added a terrace to the medieval room in order to allow people see the space station from outside and see the skybox better but to also test how would they feel being on an planetary orbit on an open terrace. A better way of connecting those two locations in future larger scale application would be via some kind of teleport or portal and then we can locate the historical room at Earth with a regular skybox.

In the sci-fi part of the location I created several lectures about Venus and in the historical part I created one lecture about history. For screenshots from the game see Appendix D.

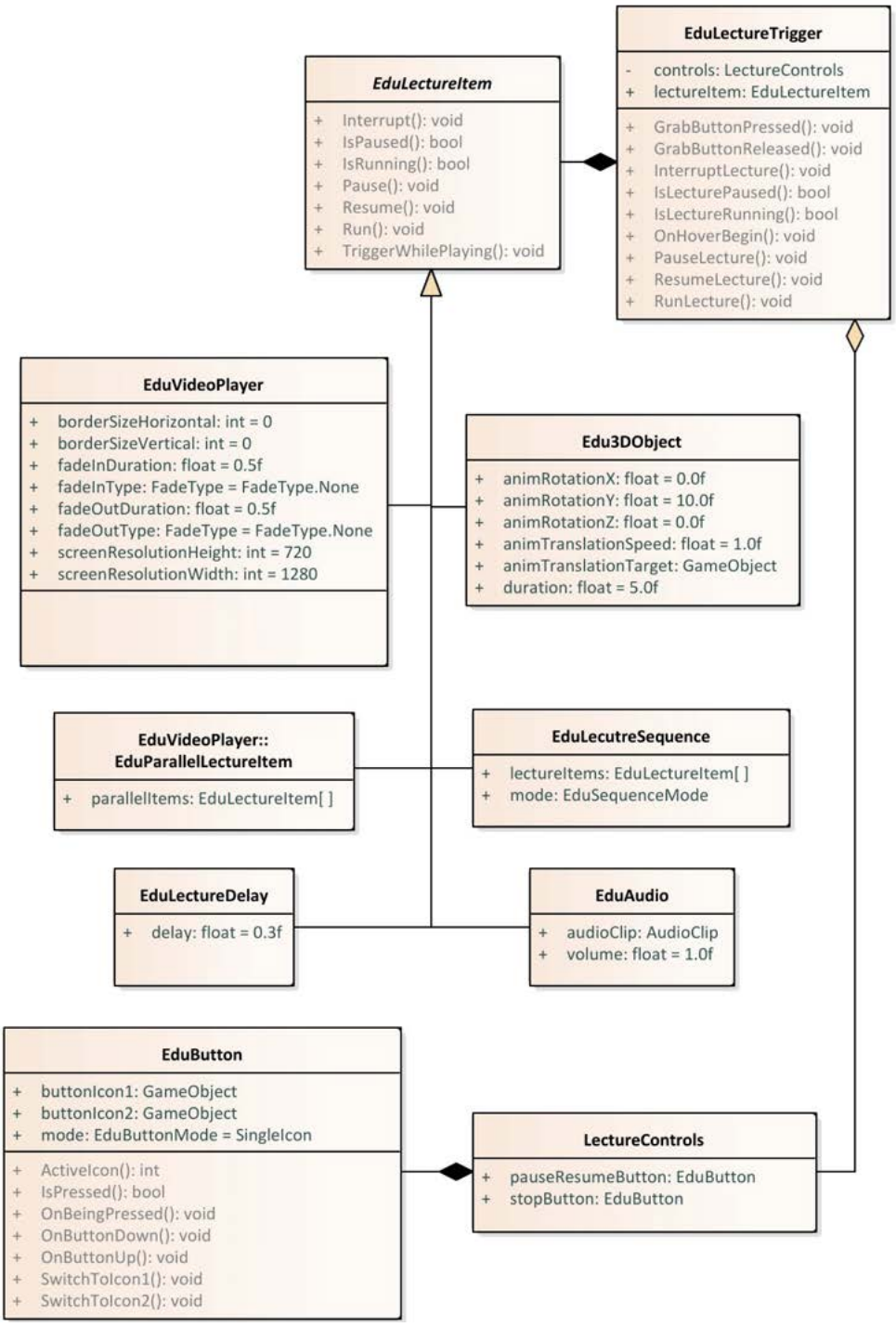


Figure 4.1: UML diagram of the classes in *EduVR*.

Chapter 5

Manual

This unity tutorial shows how to use the *EduVR* library.

5.1 VR Scene Creation

Before using the *EduVR* library we will need to import the *SteamVR* library. (See Figure 5.1)

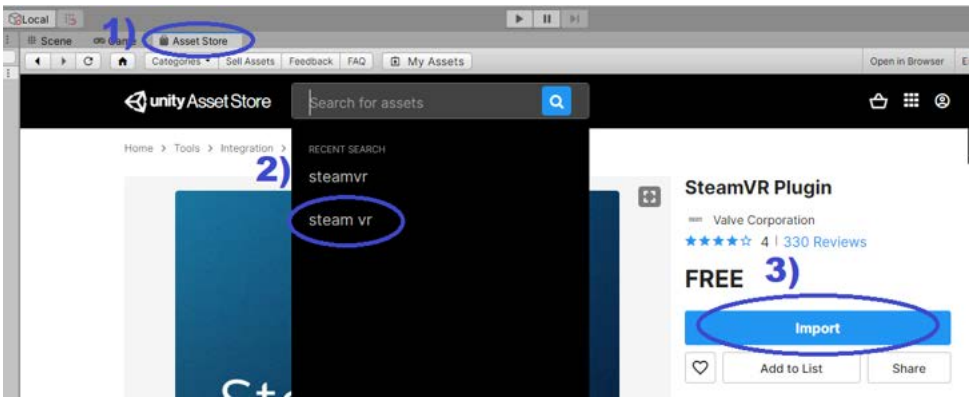


Figure 5.1: Screenshot showing how to import the *SteamVR* plugin in Unity.

In order to create a scene ready for VR create a new unity scene, remove the camera from the scene and then add the *Player* and *Teleporting* prefabs from *SteamVR* into the scene.

Add some ground object, e.g. a plane.

Add a plane that will define the area that the player can teleport to and move the plane so it is slightly above the ground so the ground does not collide with it and add the *TeleportArea* script to it.

Now when playing the game it should work with our headset and controllers and we should be able to teleport around the TeleportArea that we have created.

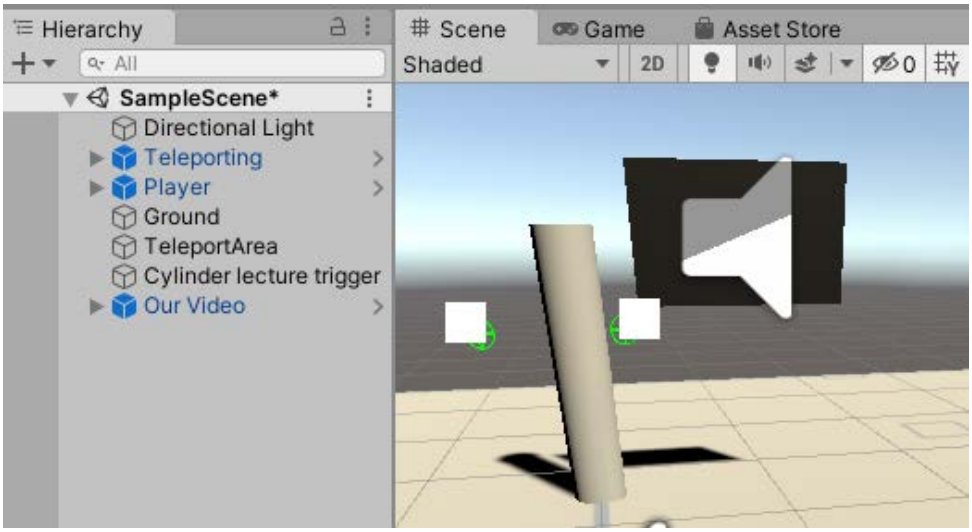


Figure 5.2: A scene with a cylinder for triggering a video lecture.

Now import the *EduVR* package from file `EduVR.unitypackage`.

5.2 Edu Video Player

In order to use the video player prefab we will need another object in the scene that will trigger the video. Let's create for example a cylinder for that purpose and attach ***EduLectureTrigger*** script to it. Then drag the *EduVideoPlayer* prefab into the scene. Figure 5.2 shows what we have so far.

Now let's add a video clip to our player. Drag the video from you asset folder onto the *VideoClip* attribute of the *VideoPlayer* component (I.e. the unity component, not my *EduVideoPlayer* script.) and in the *Audio Source* attribute of the same component choose the video player object itself as shown on Figure 5.3.

The next step is to attach the video player to the lecture trigger object by dragging the video player onto the *LectureItem* attribute of the *EduLecture-Trigger* component of our cylinder. (See Figure 5.4)

Try to play the game now. When you touch the cylinder, the video plays.

Have a look at Figure 5.5 in order to see the attributes of the EduVideo-Player how they appear in Unity. The attributes are as follows.

Screen Resolution Width/Height
: These two attributes determines the texture size in pixels which will be used as target for rendering the video. The aspect ratio of the resolution should match the aspect ratio of the video to have optimal performance, however, more importantly it should match the aspect ratio of the video player prefab object in order not to stretch the image. For example if

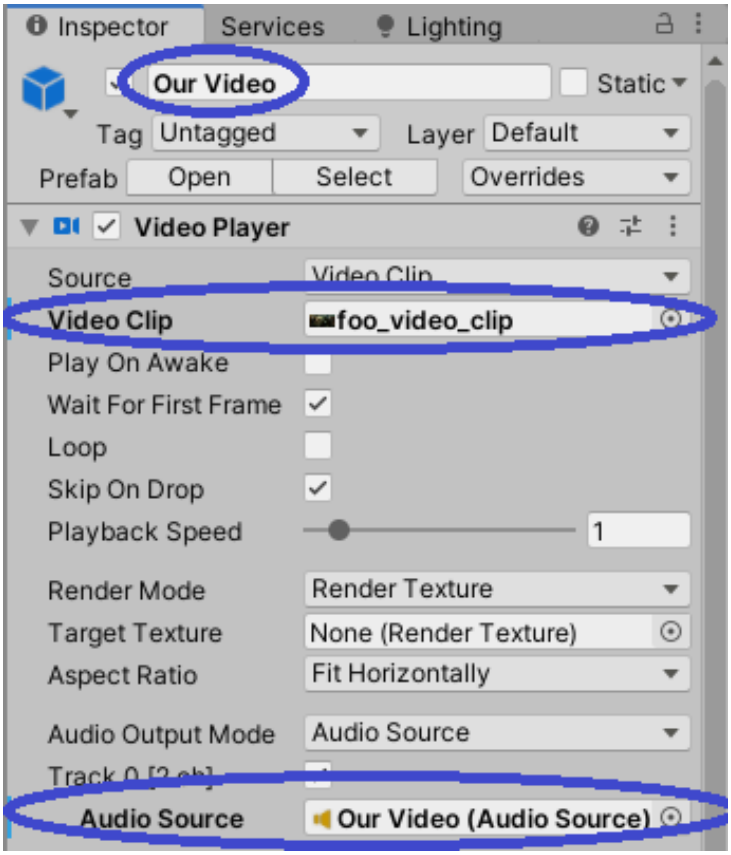


Figure 5.3: A screenshot showing how to attach a video clip to the EduVideoPlayer game object.

we scale the video player prefab so that it is a square and we set the resolution to be 100 x 100px the video will be rendered with the correct ratio so it will have black bars on the top and bottom of the player.

Border Size Horizontal/Vertical
Adds a padding to the video.

Fade In/Out Duration
How long (in seconds) will be the fade in/out animation.

Fade In/Out Type
What animation of the player will be used at the beginning/end of the video.

5.3 Edu 3D Object

Edu3DObject script makes every Unity object a lecture item just like our video so it can be attached to our cylinder to be triggered as a lecture.

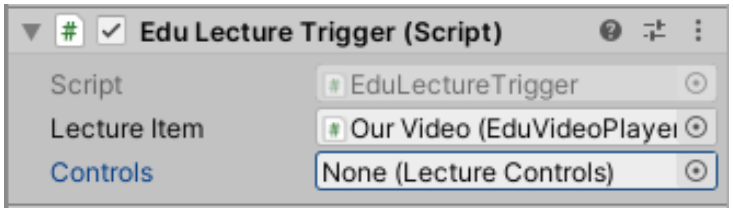


Figure 5.4: The public attributes of *EduLectureTrigger*.

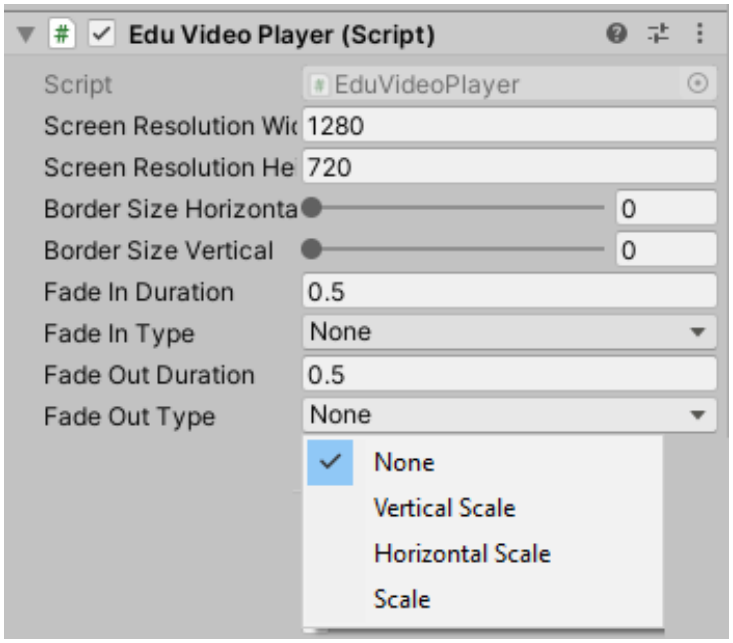


Figure 5.5: The public attributes of *EduVideoPlayer*.

Create a small cube and attach the *Edu3DObject* script to it. Now attach the cube itself to the *LectureItem* attribute of the *EduLectureTrigger* object which is our cylinder. Try to play the game and you will see that after the cylinder is touched the cube appears and rotates for 5 seconds end then disappears.

To control the behavior of the object let's have a look at the *Edu3DObject* attributes. (See Figure 5.6 to see the attributes in Unity.)

Duration
The length of the lecture item. I.e. for how long the object will be visible before it disappears.

Anim Rotation X/Y/Z
The speed of rotation animation around the axis X/Y/Z.

Anim Translation Target
When a game object is attached to this attribute the Edu3DObject will move towards it's position.

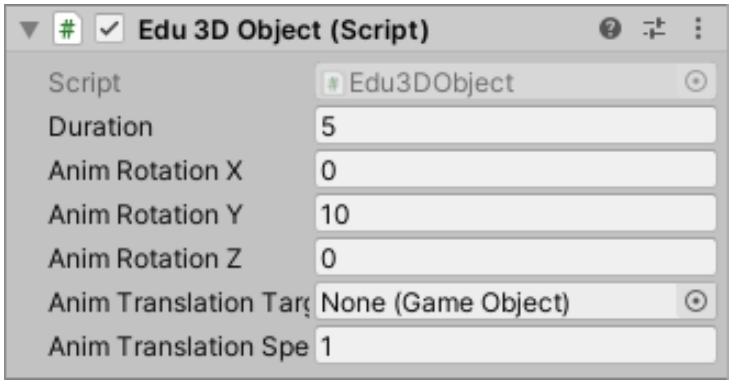


Figure 5.6: The public attributes of *Edu3DObject*.

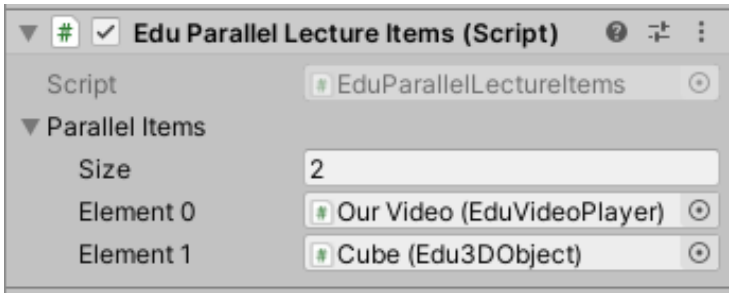


Figure 5.7: The public attributes of *EduParallelLectureItems*.

Anim Translation Speed
The speed of the translation animation if *Anim Translation Target* is set.

5.4 Edu Parallel Lecture Items

Let's combine these two lecture items together into one lecture. For that we will use the *EduParallelLectureItems* which is a *lecture item* just like the *EduPlayer* and *Edu3DObject* so it can be attached to the lecture trigger and it allows multiple other lecture items to be attached to it and it plays them simultaneously.

Create an empty object that will represent our parallel lecture item. Add the *EduParallelLectureItems* script component to it. It has one public attribute *ParallelItems* (See Figure 5.7.) which is an array of *lecture items*. Set the *Size* of the array to 2 which will create two slots onto which drag and drop our video player and our rotating cube. Now attach the parallel lecture item to our lecture trigger cylinder.

You have maybe already noticed that the trigger runs the lecture only if the lecture is not currently running. In case of the parallel lecture item it is considered running as long as any of it's children lecture items are still running.

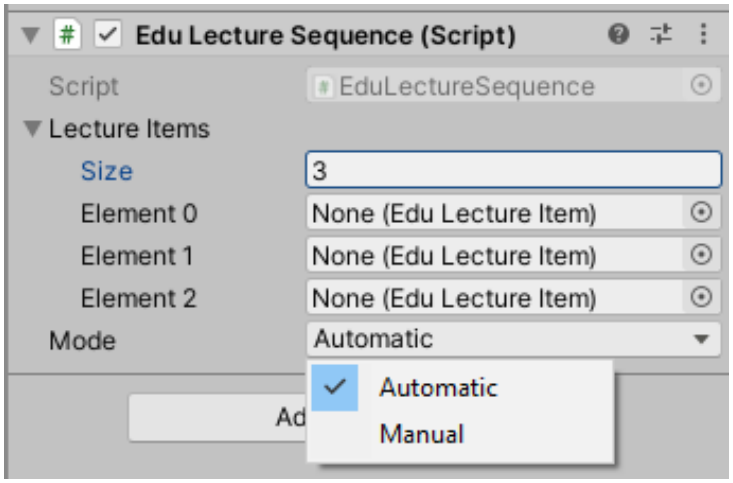


Figure 5.8: The public attributes of *EduLectureSequence*.

5.5 Edu Lecture Sequence

The *EduLectureSequence* script is similar to the *EduParallelLectureItems* in a sense that it can hold another children lecture items. In contrary to *EduParallelLectureItems*, however, *EduLectureSequence* plays the children item sequentially and the sequence is considered running until the end of the last lecture item in the sequence.

In addition to the parallel lecture item it has *Mode* attribute with two possible values: *Automatic* and *Manual*. When the mode is set to automatic the script waits until the currently running children lecture item ends and then proceeds to the next one. When the mode is set to manual the same applies but additionally the touch of the lecture trigger skips to the next lecture item in the sequence. (See Figure 5.8.)

5.6 Edu Lecture Delay

This lecture item does nothing but waits for a certain period of time during which it is considered running and then it ends.

It has a public attribute *Delay* that is the waiting time in seconds.

Now let's take these two lecture items that we just learned to create a lecture where video plays and after a while the rotating cube appears.

Create an empty object that will represent our delay lecture item and add the *EduLectureDelay* script to it. Set the delay time accordingly to at what time in the video the cube should appear. Let's say that we want the cube to appear 10 seconds after the start of the video so set the *Delay* attribute to 10.

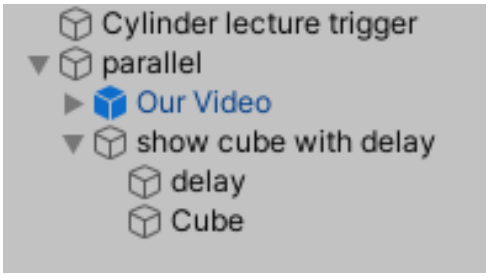


Figure 5.9: The game objects required for the complex lecture containing a video and a 3D object with a delay.

Create another empty object and name it *show cube with delay* and add the *EduLectureSequence* script to it. Set the size of the children array to 2 and attach the delay lecture item as the first child and the cube as the second child.

Now drag and drop the sequence object to the children slot of the parallel lecture item where the cube was attached just next to the video player. To see the whole structure have a look at Figure 5.9. Note though, that the hierarchic structure of the objects does not matter. It is only important that everything is attached accordingly so the sequence has the delay and the cube attached to its lecture items array attribute, the parallel lecture item has the video and the sequence attached and that the parallel lecture item is attached to the lecture trigger.

5.7 Edu Audio

For playing an audio track you create an empty object representing the source of the audio and add the *EduAudio* script. It has two public attributes *AudioClip* and *Volume*. Onto the *AudioClip* drag and drop your audio asset and adjust your volume by the *Volume* that takes values from 0 to 1.

5.8 Lecture Controls

You have probably noticed that beside the *LectureItem* public attribute the *EduLectureTrigger* has another one that was empty until now - *LectureControls*.

There is a prefab named *LectureControls* which is constituted from two buttons. One is for stopping the lecture and the other one is for pausing or resuming it.

The controls are controlling only the lecture that it is connected to so you can pause a lecture, go to play and pause another one and come back to resume the first one.

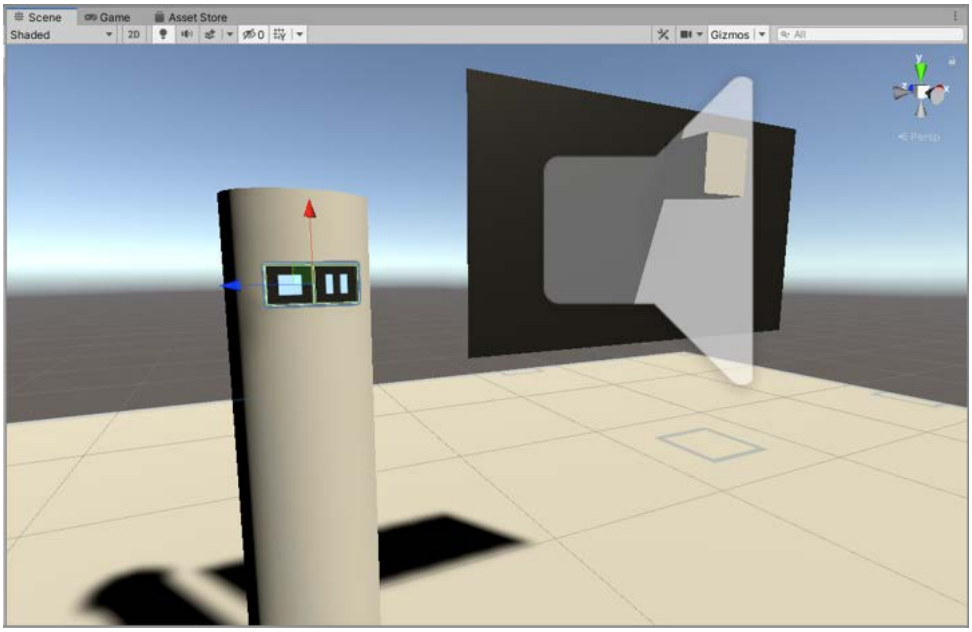


Figure 5.10: The *LectureControls* prefab for stopping, pausing and resuming the ongoing lecture.

Let's bring this prefab to our scene and position the controls object so it is on our cylinder lecture trigger. (See Figure 5.10.) Then drag and drop the controls object onto the *LectureControls* attribute of our lecture trigger.

Then play the game. The controls are not shown until you hold the grip button. I.e. when you form a pointing index finger gesture. Then you can pause or stop the lecture by pushing the corresponding button. (See Figure 5.11.)

5.9 Edu Button

The lecture controls itself are created from two instances of *EduButton*. When it is in *SingleIcon* mode it ignores the *Button Icon 2* child object. So you need to only care about the *Button Icon 1* plane object under the button prefab. Drag and drop an image from you assets on the Button Icon 1. Then in the SteamVR *HoverButton* component you can set the corresponding action on button down, button up and button being pressed events.

When the mode is set to *ToggleIcons* than you need to choose an image also for *Button Icon 2* and then every press of the button toggles between those two icons. In your event handler code you can check which icon is active by calling *ActiveIcon* button method that returns an integer 1 or 2 and see if the button is currently pressed by calling the *IsPressed* method.

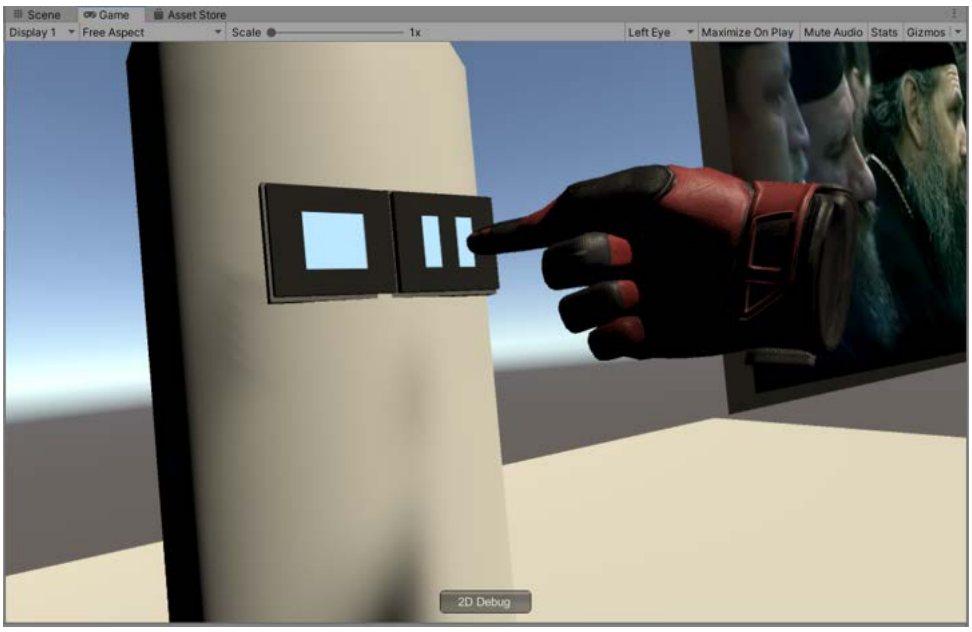


Figure 5.11: The index finger pointing hand gesture, that is done by holding the grip button on the right hand controller, reveals the lecture controls.

Chapter 6

Usability Testing

Since the goal of the application was to test the implemented *EduVR* package for education rather then creating a polished final product I already knew about many usability issues such as limited interactivity etc. So the test was intended to see how people react on the composed lecture consisting from two videos, audio and 3D model in contrary to lectures containing only one media such as video or image. One lecture is a long documentary video to test when will the participants start to be eager to stop the video.

The test was held with four participants. For testing logs see Appendix E.

Half of the participants were female and half male. Their age was: 25, 26, 26, 50. Their previous experience with VR were: none, smartphone VR only and two participants have played Vive few times.

Let's proceed to the findings.

The participants went immediately for the medieval room after seeing it from a distance or they at least were very excited when they discovered the room after exploring the space station first. They found this kind of place familiar, calming and relaxing. They also very much liked the glowing Venus in the projection machine at the space station but here in the medieval library the location itself was very appealing to them.

The participants wanted to open the book and to sit on a sofa or a chair. I.e. they expected from every object the interaction they are used to from the real world even if they know they cannot do this interaction in VR such as sitting in a chair. Another example of this is that every participant wanted to use the candle flame to burn something. The models that has no usage in VR such as keyboards should not be there unless we find a meaningful reason for having them there.

The participants expected the painting to be interactive even though paintings are not interactive in the real world but we are used for some kind of interaction with painting for example from movies.

Everyone had some further expectations from the skybox but very different ones. One participant missed wind blowing because of the strong association

from being on a terrace, another wanted to see flying atmospheric meteors because of the association from observing night sky from Earth. These were the ideas of the female. Both male however didn't have such thoughts but wanted to teleport themselves from the terrace to the planet on the skybox.

The participants got interested about the table with many plants in a grid on it which looked like we are growing some plants for some purpose and they got curious about what kind of plant it is and tried to guess it by themselves. The single plants used for decoration had not triggered such questions.

Every participant was excited about the composite lecture and since it is short enough, they played it several times. The lecture was 45 seconds long.

I expected that the participants won't be so excited about the single media lectures but interesting is how much they literally disliked it. They tried hard to trigger some additional interaction during the video and also while looking at pictures. The screens are associated with tablets and computers and since the image and video was displayed on a screen the participant expected an interactivity similar to smartphone applications. Moreover these virtual tablets are no power consumptive so they can be turned on by default not waiting for a user to make them show something interesting.

In a sci-fi themed location it is appropriate to have and object that looks like screen but an interactive more sophisticated 2D application is needed to run on such virtual devices. Such an interface can be used for a variety of things such as starship control, lecture triggering, navigation, teleportation, learning. For that it is insufficient to create all these applications directly in Unity. A better approach will be a screen prefab that can run standalone 2D applications either implemented in C# using a unity library created specially for this UI task or a HTML5 and JS interpreter supporting at least a small subset of HTML and JS allowing the programmer to easily create interactive screens. The advantage of the first approach is that there can be one library for 2D and 3D virtual interfaces. The advantage of the second approach is that HTML and JS are more sufficient and expressive for creating interfaces easily than C# and that there is already a large code base for that.

One participant showed the desire to switch off the lights in the room while playing videos.

All the participants got interested in the empty shelves that could be used for storing interactive objects which number might increase over time as the user explores more of the virtual world.

From the throwable decoration objects every participant choose one that he or she liked most and interacted with it a lot even thou it is no more interactive than being throwable. For one participant it was a flower, for another one it was the bag or the little octagonal sculpture. They carried the object with them for a long time and moved it from place to place all over the location. They also started to feel possessive about the specific instance of the object even thou the model has more instances in the scene. So the

user should be able to utilize his choice of favorite object in the game. For example attaching a certain ability to his chosen object. Also some harder to find interactions might be hidden in the objects. Interactions that are not crucial for the game but that can be discovered randomly.

For the space station location it is a good idea to provide rooms where there is a good view at the planet which the station orbits around and another room where parts of the space station are observable from the outside. Also there should be a room with no view at all so the user won't get agoraphobic.

The participants especially liked the blue glowing vertical lamp.

The lecture trigger object should provide more complex interactivity such as showing the play/pause controls or showing a menu to choose from several lectures etc.

The participants found teleportation in VR very intuitive and pleasant but they obviously sometimes struggled with orientation when they teleported themselves too close to some wall or a large object. When they teleport near a wall their head is in the better case too close to the wall which is disorienting. Also when teleporting too close to the projection machine, which is narrower at the bottom, their body occurs right inside the projection machine mesh. To fix that the teleportation areas should have some slight padding (e.g. half a meter) from the walls and large static objects and users can then move closer towards the walls and the objects by regular motion after the teleportation itself.

When holding SteamVR throwable object the user is unable to teleport which is an unnecessary limitation since we can use the teleportation button while holding some object by holding the trigger button.

One participant approached the rotationally symmetrical projection machine from the wrong side so the lecture would start to play with video facing in the wrong direction away from the user. We cannot always avoid that lectures should be observed only from one direction. So we should either position the content in the 3D scene dynamically with respect to the participant's current position and head orientation or restricting the participant's movement by placing the lecture trigger in a way that it cannot be approached from the back.

Chapter 7

Conclusion

I examined the current situation in pedagogy and educational game development and came with some ideas of a good educational VR game. Then I created a Unity library called *EduVR* that allows the game developers to easily add educational content to their virtual worlds. Then I created a VR application using *EduVR* and tested it with a target group.

7.1 Assignment fulfilment

Here is the assignment of my thesis restructured from plain text to a list.

- Examine the techniques for education in VR.
  - Done. See Chapter 2.
- By using knowledge from the task above and UCD design an application that will teach the user and test his knowledge.
  - Partially done. I describe the idea of such application in Section 2.1.4 and Section 2.2.4. And than described in more detail part of the design in Chapter 3.
- Implement a Unity library
  - Done. See `EduVR.unitypackage` file.
- Create a manual for using the library.
  - Done. See Chapter 5.
- Create 5 educational topics.
  - Partially done. I created 2: Venus and History. See `/unity/LocationDemo` application.
- Test the application with a target group.

- Done. See Chapter 6.

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Appendix A

Project directory structure

This tree represents the directory structure of this project. Note that this tree does not contain every single directory nor file (e.g. .idea/, .gitignore etc.). It's purpose is to help you to get oriented in the files.

ROOT

- B4MSVP *files for "Software or Research Project" subject*
- ctuthesis *LaTeX source files for the master thesis*
  - bibliography
  - images *images included in the master thesis text*
  - src *tex files for every chapter*
  - moravjor_DP.tex *main tex source files used to generate thesis PDF*
  - moravjor_DP.pdf *the thesis in pdf*
- maquette *maquette VR prototypes*
- photoshop *Adobe Photoshop project files*
- sources *PDF fulltexts*
- unity *Unity project of the VR application*
- EduVR.unitypackage *the final library for Unity*

Appendix B

Menu sketches

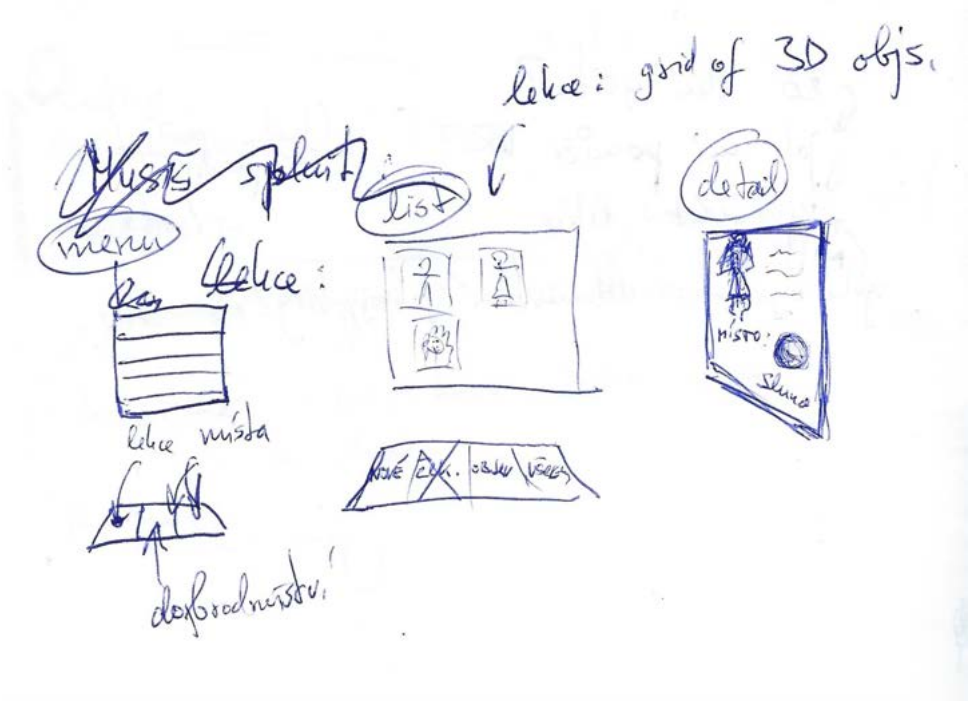

Figure B.1: The first idea of the navigation.

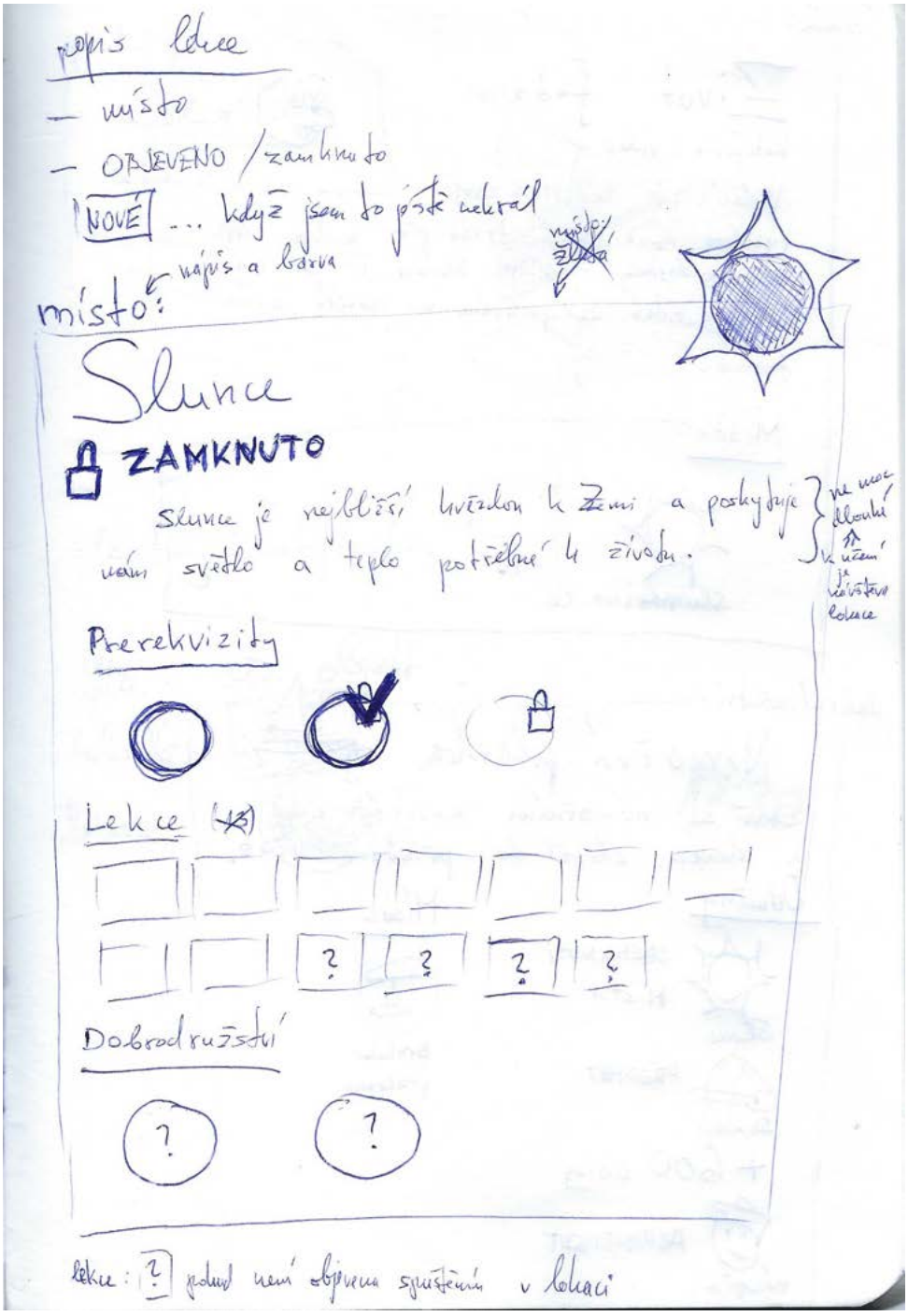

Figure B.2: A sketch of the *location* window.

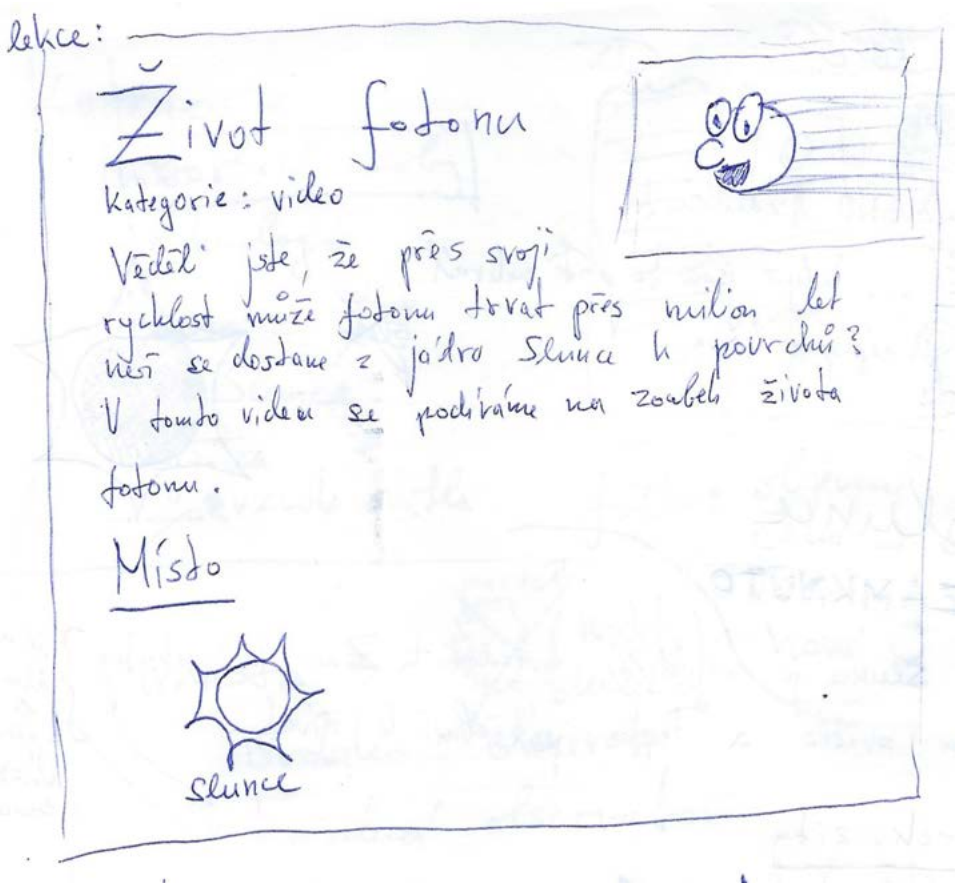

Figure B.3: A sketch of the *lecture* window.

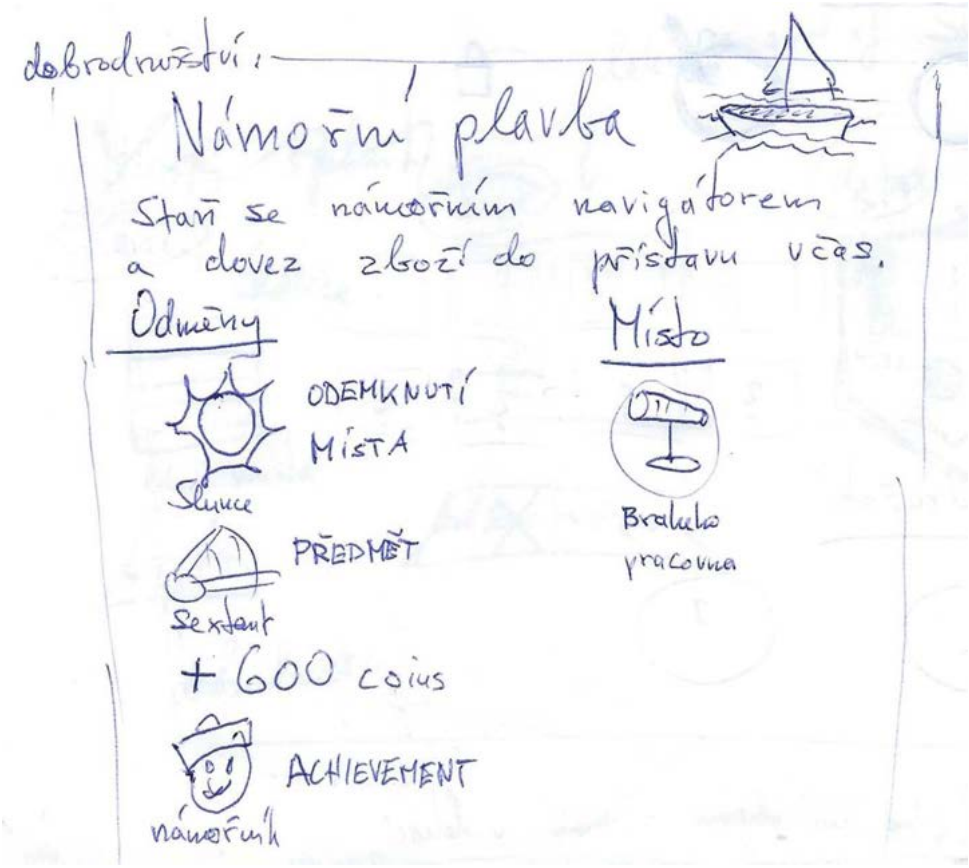

Figure B.4: A sketch of the *adventure* window.

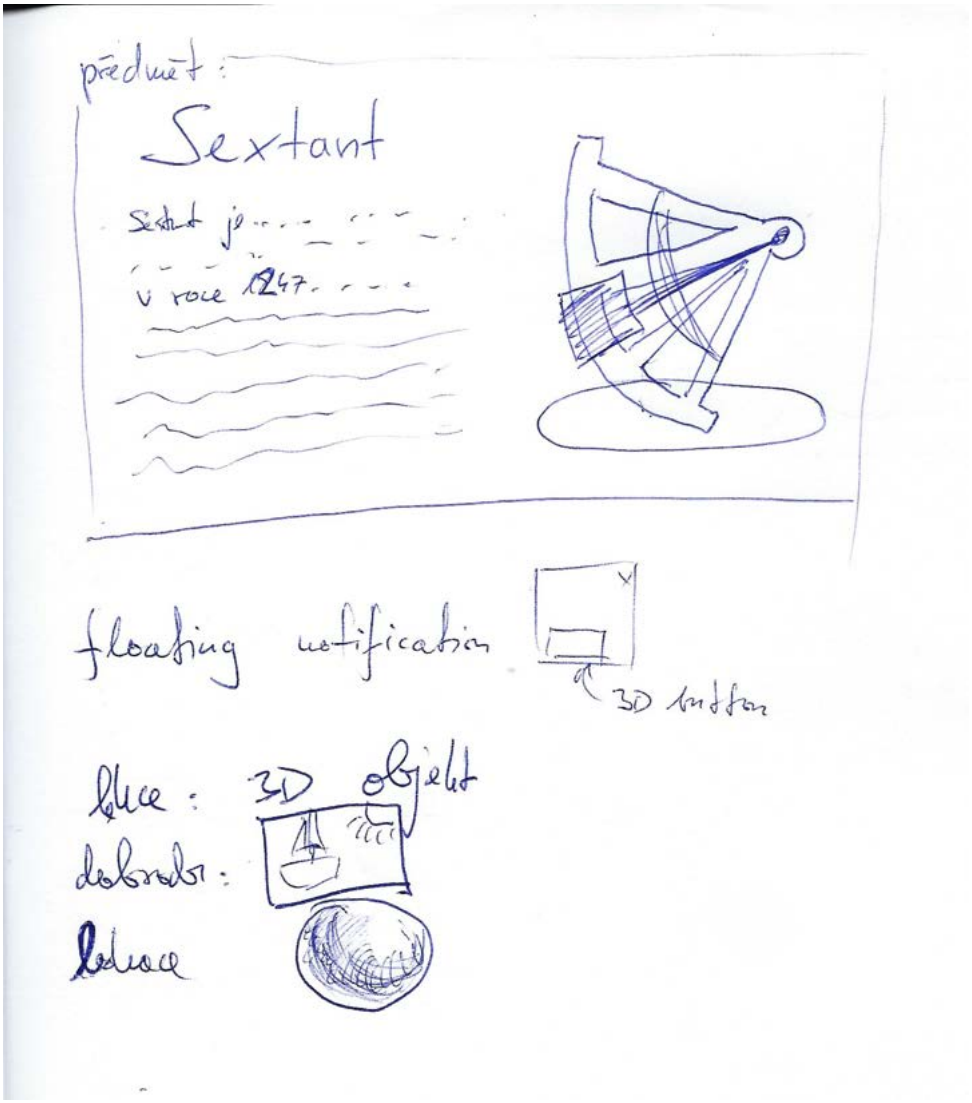

Figure B.5: A sketch of an award object (top) and different icon types (bottom).

Appendix C

Menu Maquette prototype

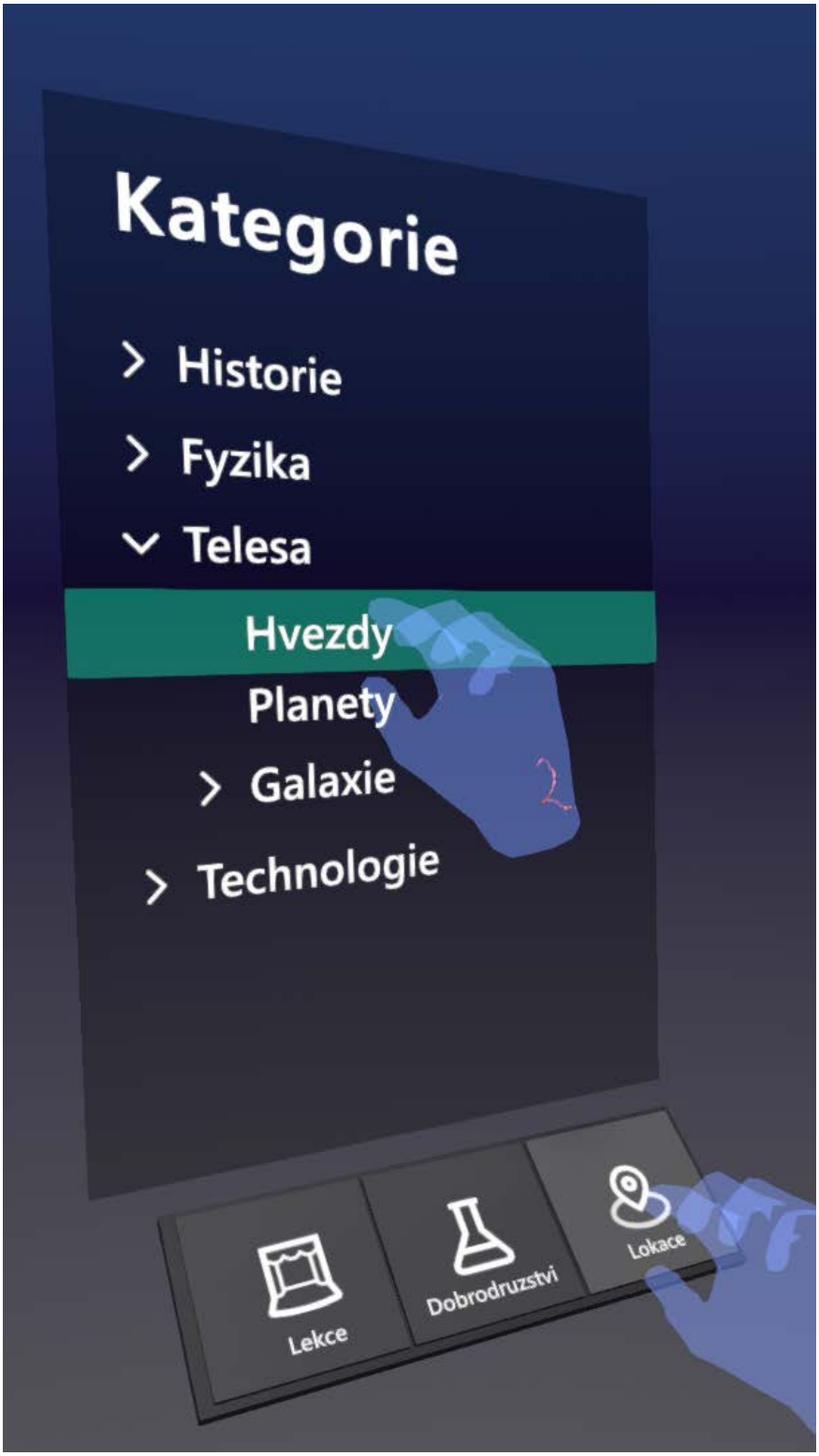

Figure C.1: The list of categories with the 3 buttons at the bottom for selecting the type of items to be browsed.

Figure C.2: List of locations according to the selected category with Sun location locked.

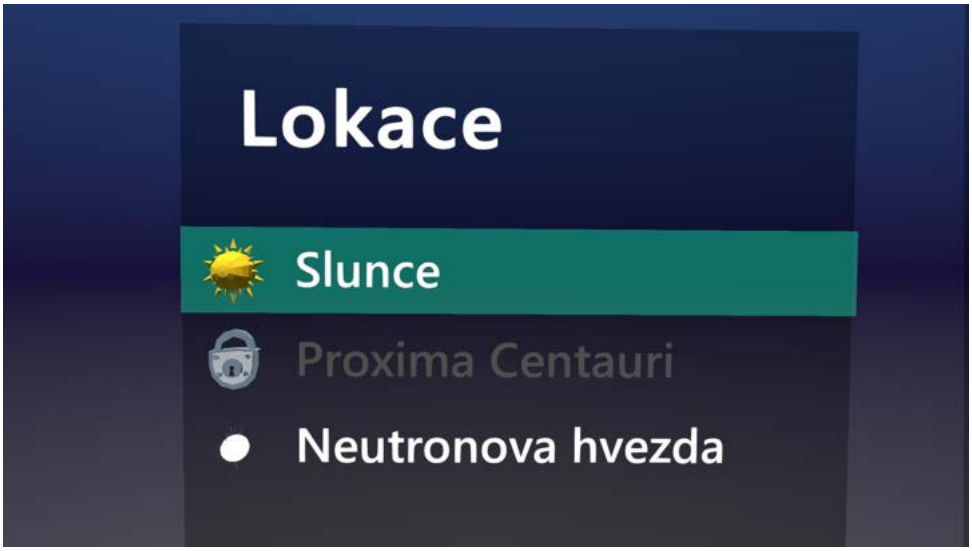

Figure C.3: List of locations according to the selected category with Sun location unlocked.

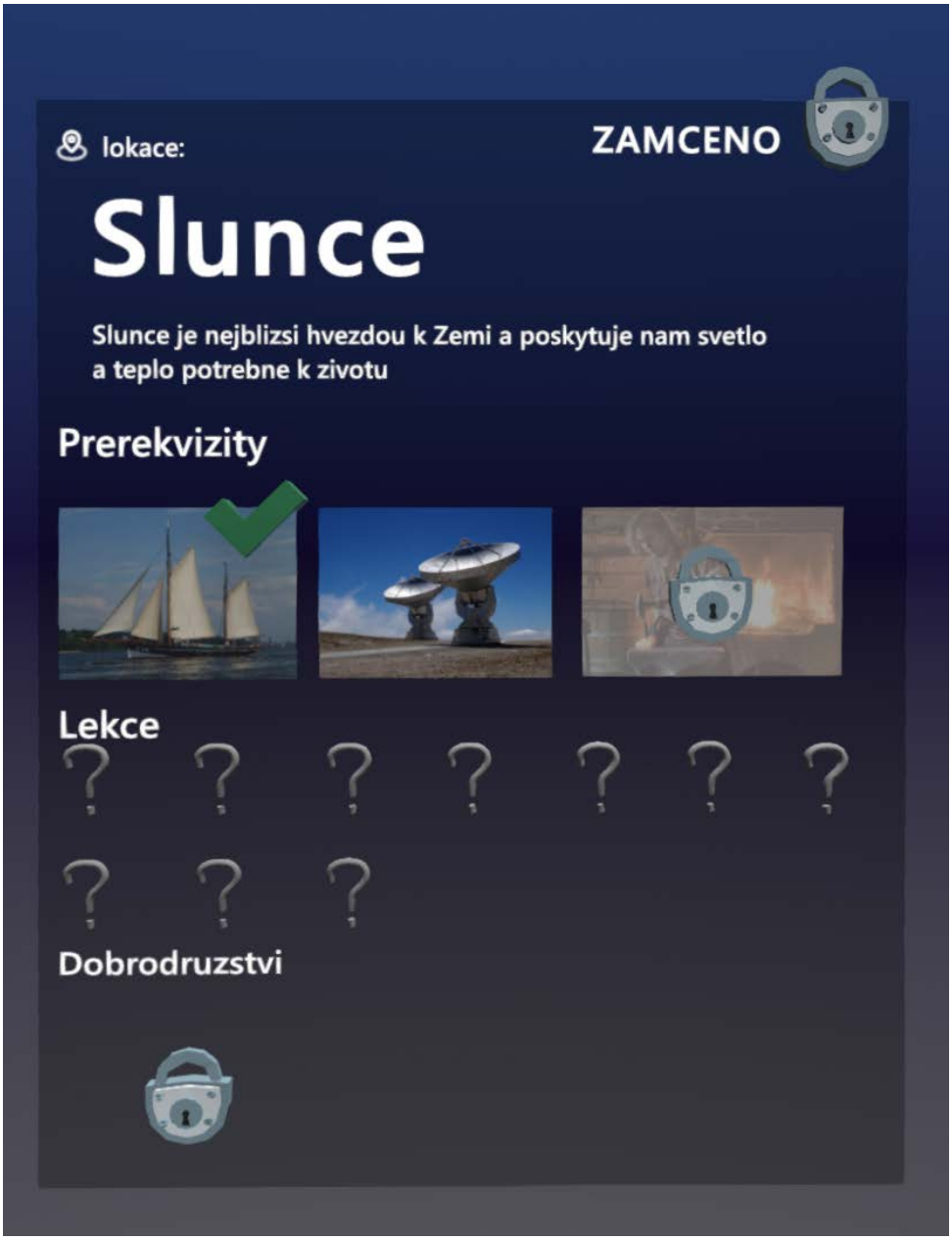

Figure C.4: Details of the locked Sun location.

Figure C.5: Details of the unlocked Sun location with the list of location on the left.

Figure C.6: Wide angle view of all the three introduced windows.

Figure C.8: The details of an adventure.

Figure C.9: List of lectures.

Figure C.10: A lecture details.

Figure C.7: Wide angle view including the adventure details window.

Appendix D

Screenshots from the Application

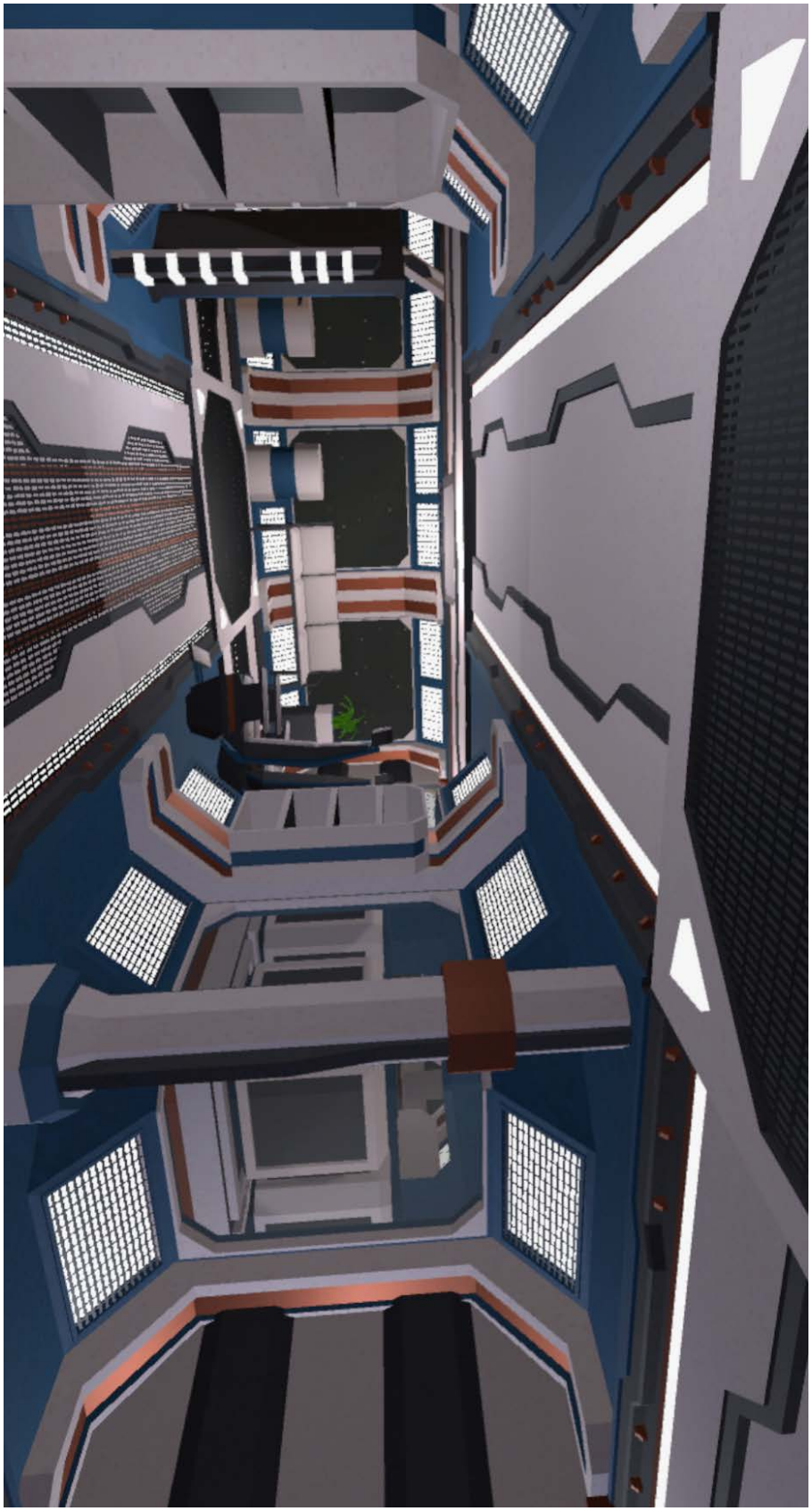

Figure D.1: The space station.

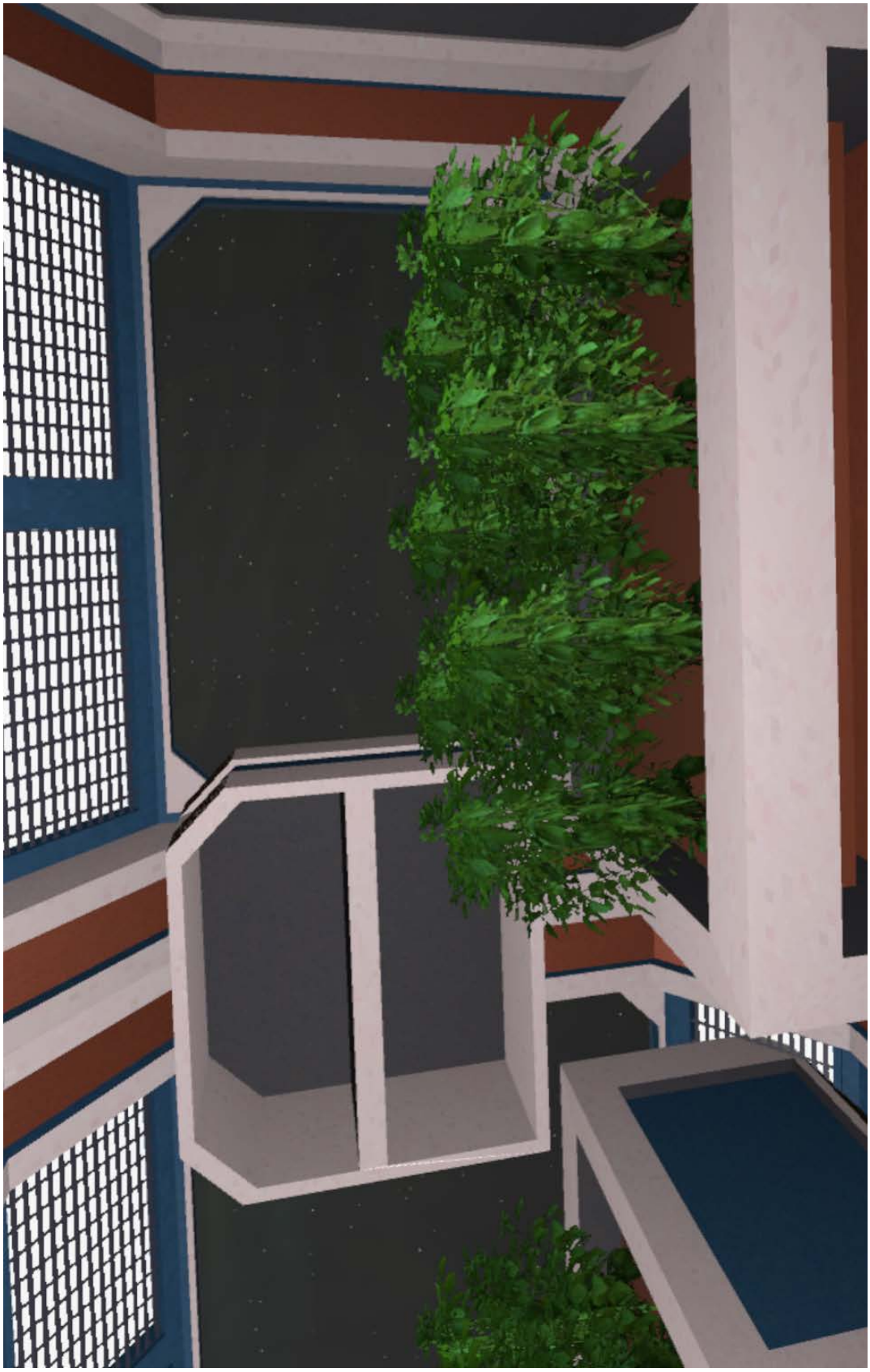

Figure D.2: The garden that all participants were curious about.

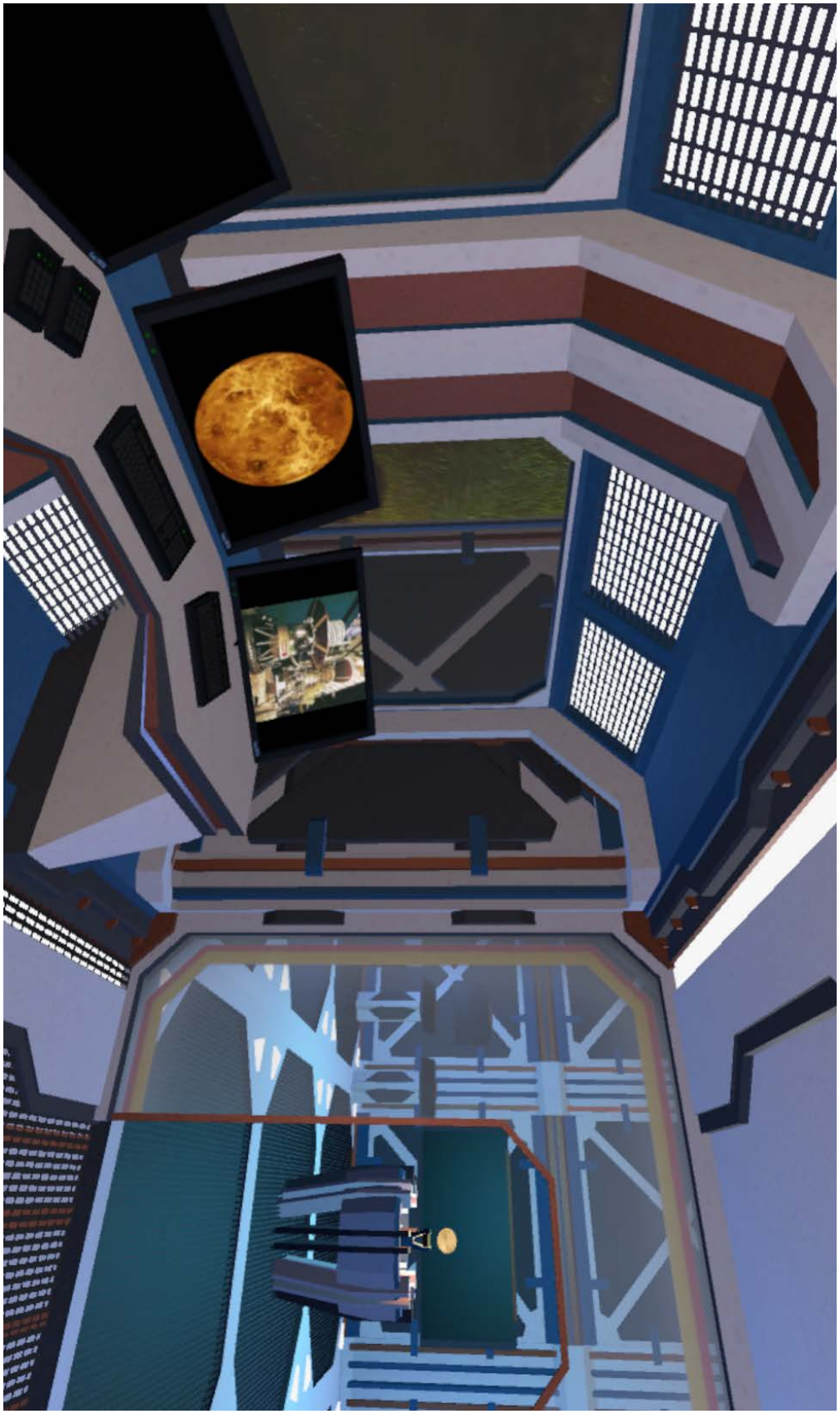

Figure D.3: The screens in the corridor with the entrance to the projection room visible.

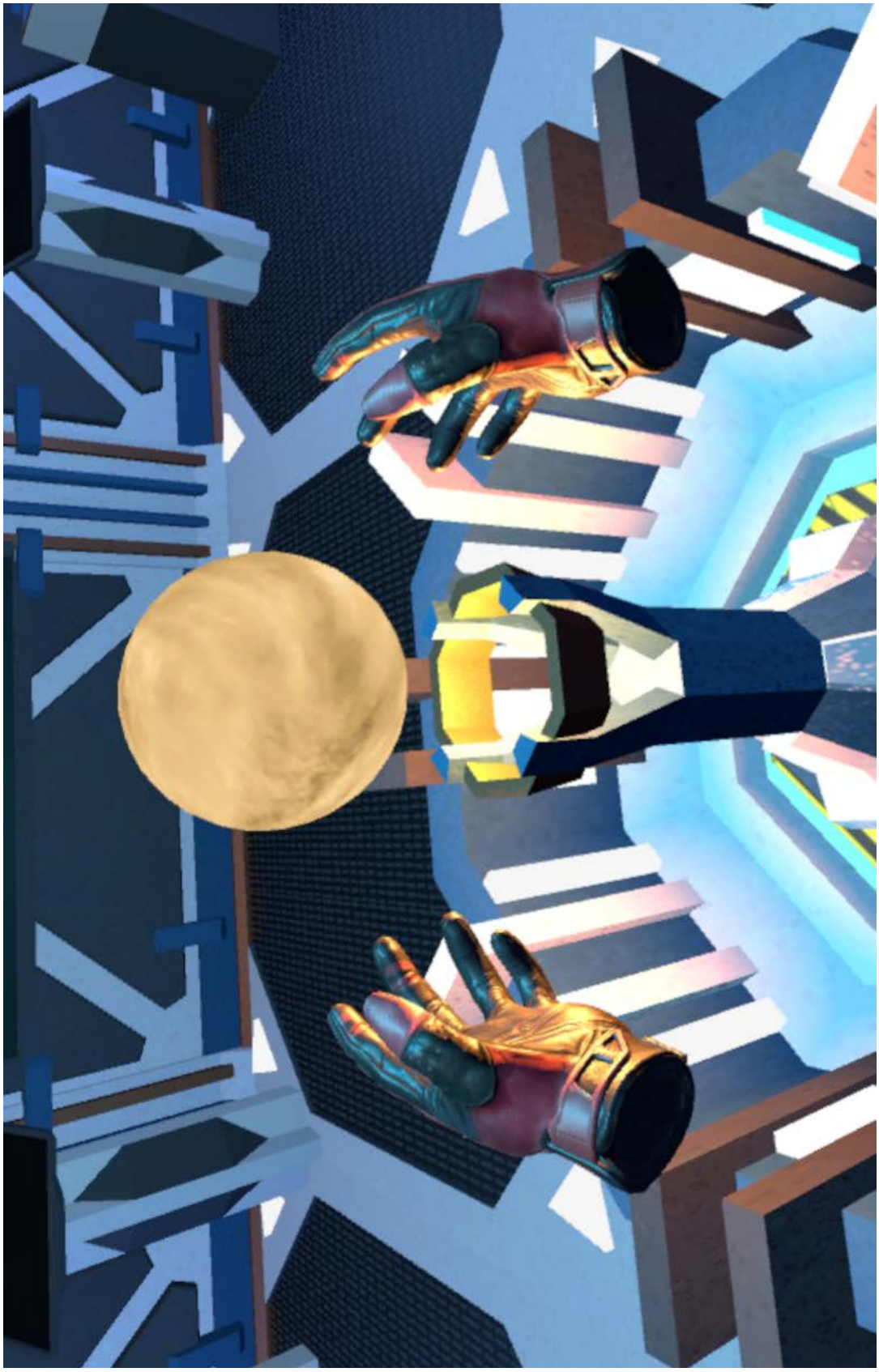

Figure D.4: The projector machine with Venus.

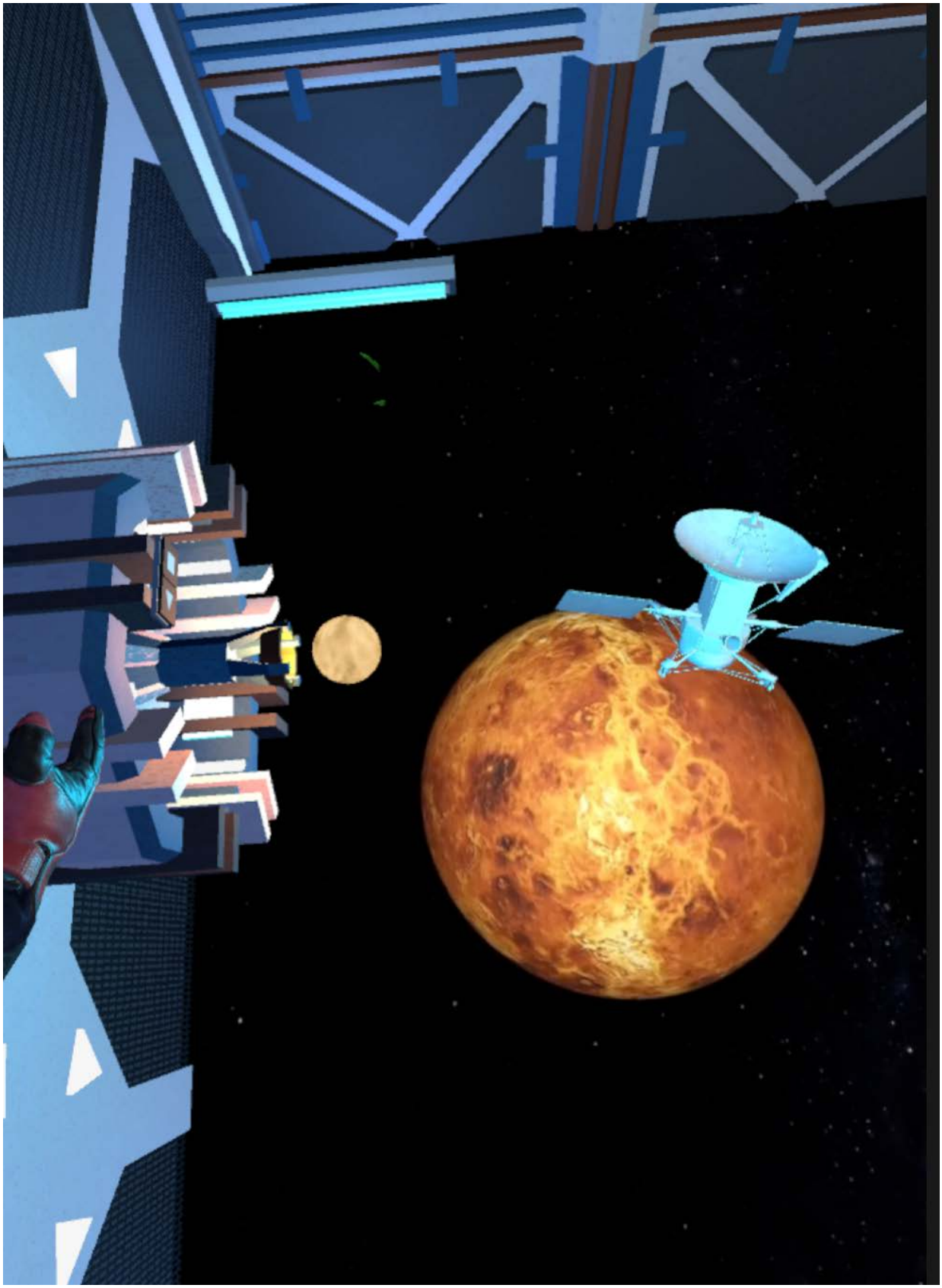

Figure D.5: The lecture with a probe model in front of a video and the lecture controls visible on the projection machine.

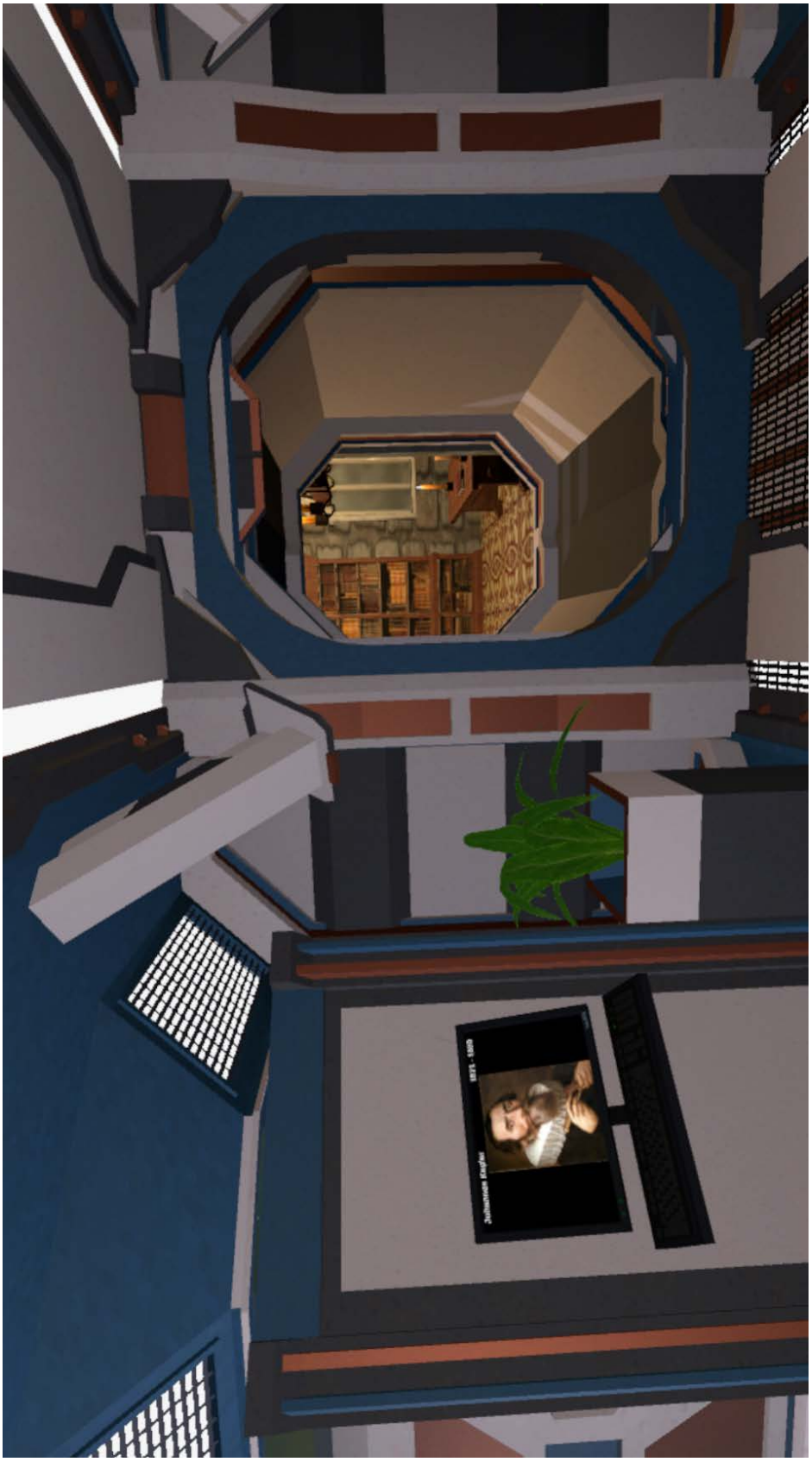

Figure D.6: The corridor to the historical section.

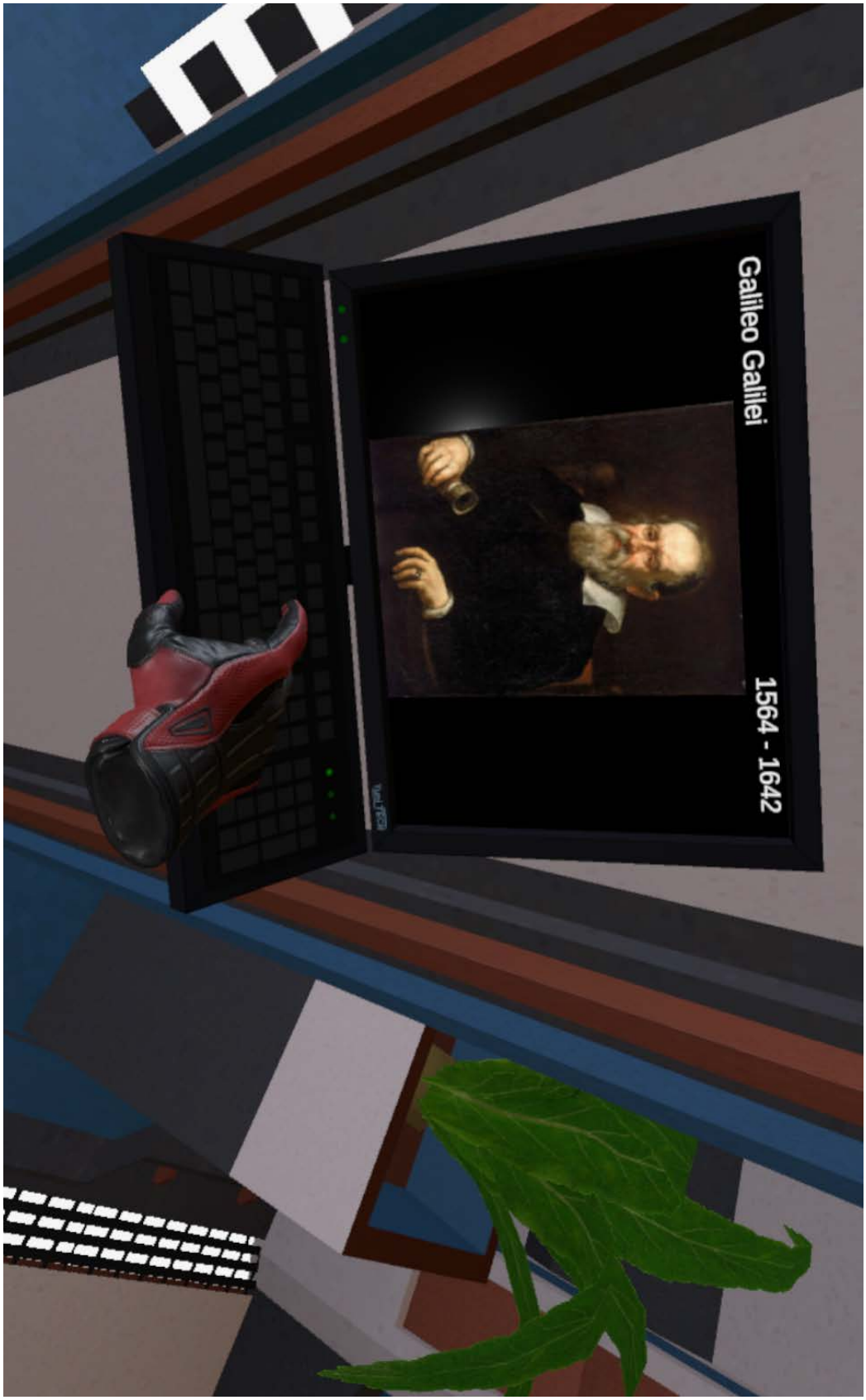

Figure D.7: A lecture consisted from images and text.

Figure D.8: The historical section.

Figure D.9: The telescope on the terrace of the historical section.

Figure D.10: The space station sci-fi section visible from the historical section terrace.

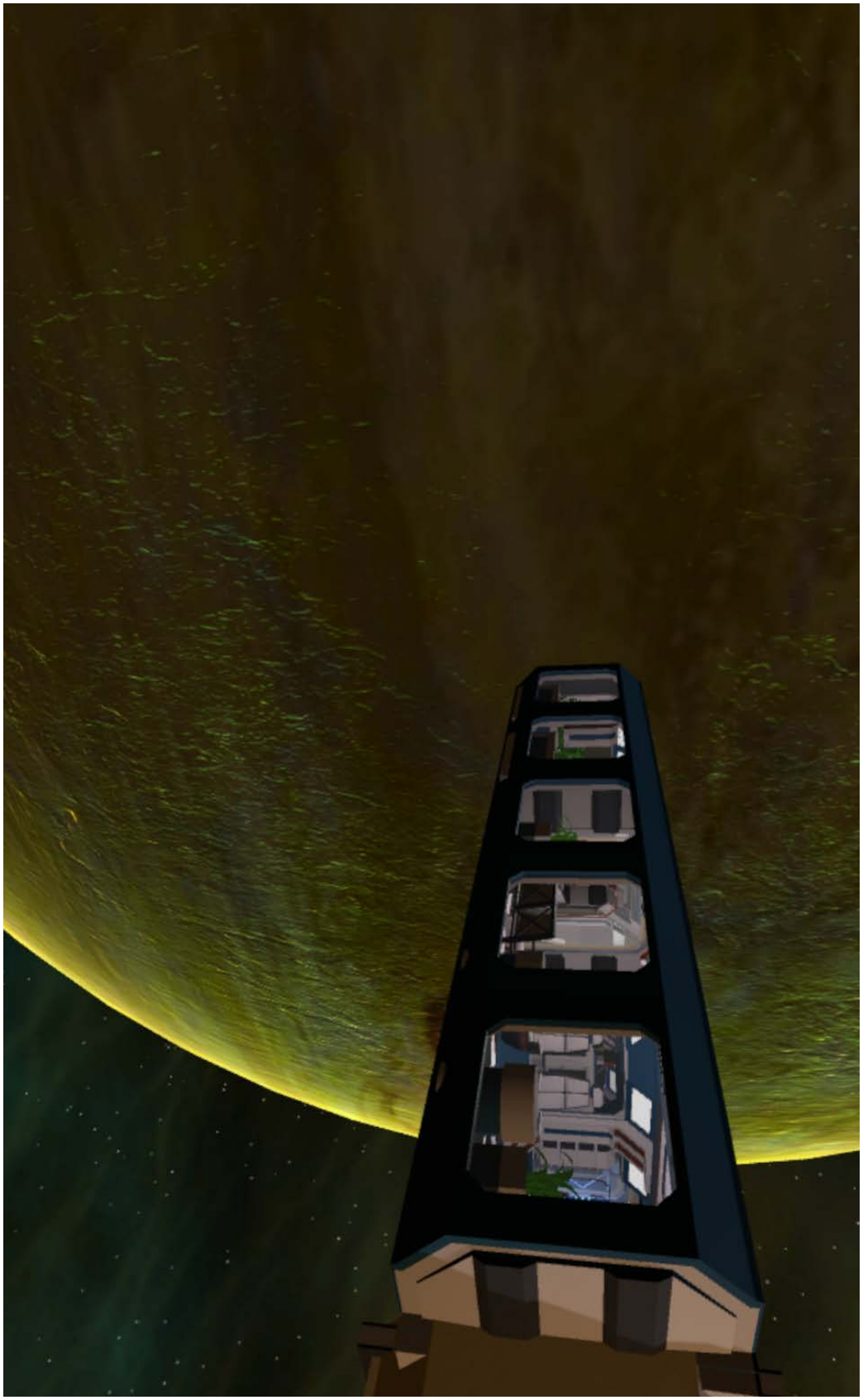

Figure D.11: The space station visible from outside with the planet on the background.

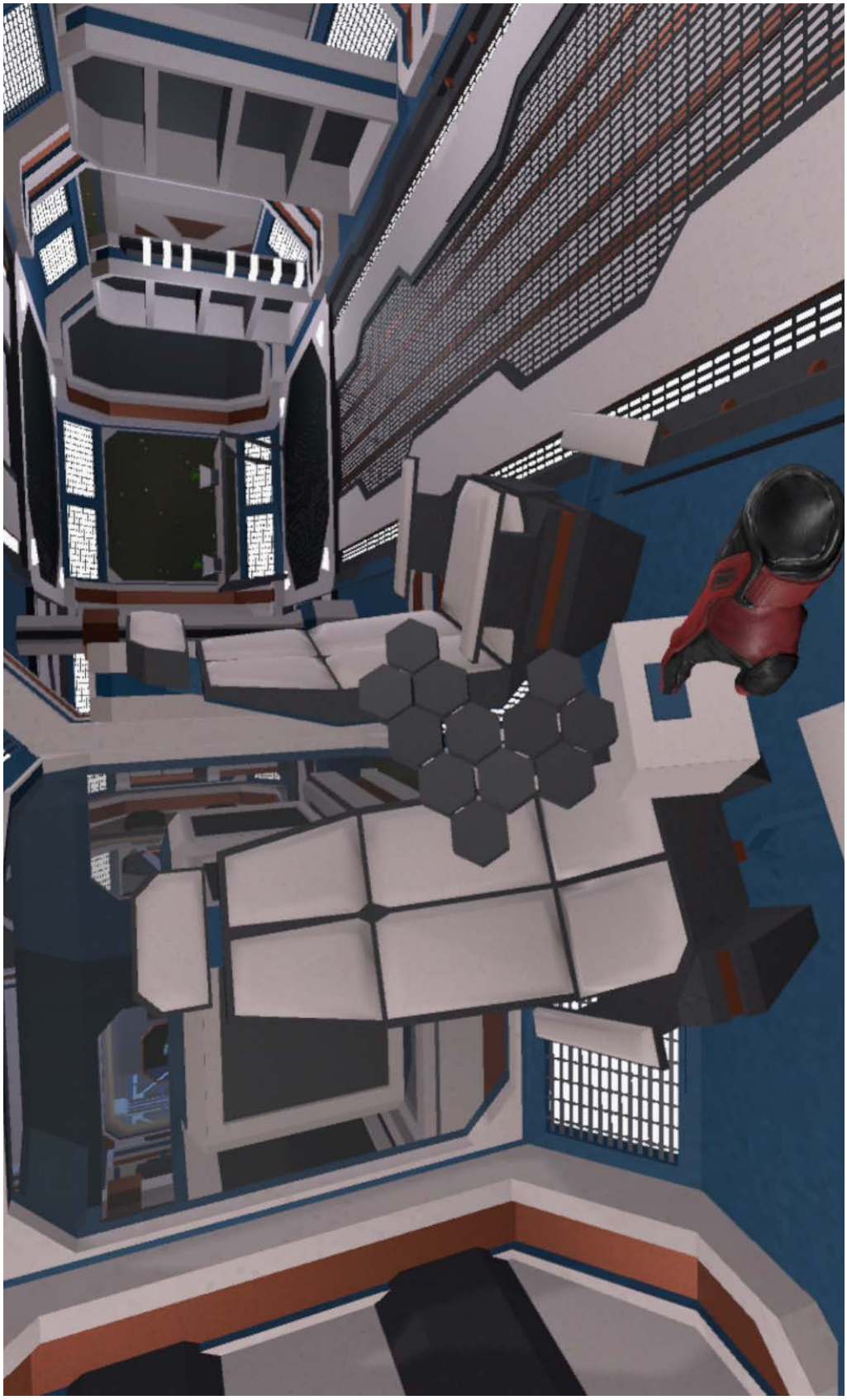

Figure D.12: A participant trying to interact with an object that she decided to carry around.

Appendix E

Usability Testing Logs

E.1 Participant č. 1

E.1.1 Pretest

muž, 26 let, žádné zkušenosti s vr

E.1.2 Test

ihned zamířil k historické sekci, když ji viděl - "tam je to obytnější" útulné

vidí východ na terasu: tady můžu pozorovat hvězdy

vidí základnu z venku a konstatuje porozumění lokace: takže toto je vesmírná základna, jasně

chci si číst! - ???

sahá rukou na plamen

sahá na obraz na zdi

pokouší se znovu otevřít knihu

bere jednu knihu za druhou z poličky a hází je na zem na sebe s tím, že staví věž

po pár knihách jednou knihou v ruce shodil všechny ostaní na zem

jde zkoumat vesmírnou základnu a bere si z historické sekce s sebou pytel

spustil klávesnicí slidshow s fotkami astronomů a hned začal sahat na obraz očekávaje interaktivitu; čekal, že fotka ne colou obrazovku je spořič a zmizí a zobrazí se mu něco jiného

shodil kytku kytkou což ho příjemně překvapilo, že jde

teď je na zemi po dním ona kytka a jeho pytel; ptá se zda si může vzít obě -> vybírírá si, že si dále ponese pytel

vidí velkou halu a říká, že tam vidí nějakou řídící místnost

když vstupuje říká, že to je nějaká svatyně

spuští přednášku o Venuši a vzápětí říká: tak projekční místnost...

podivuje se informaci o atmosféře a povrchu a po skončení přednášky komentuje: jsem slyšel, že ta atmosféra je nějaká jedovatá

osahává celý projektor nad kterým je Venuše ve snaze změnit planetu a říká, že chce přepnout na Mars

podivuje se že ovládání přednášky se zobrazí jen když přednáška běží

"počítač je k ničemu?" (sahá na ten který spuští dokument)

"něco se děje" (všiml jsi dokumentu)

po chvilce řekl, že ho to zas tak nezajímá, ale že počká na konec

když se konec neblížil, šel a bez problému přednášku vypl

řekl, že by rád místo vypnutí dokumentu vybral, které tam zaslechl, o kterém by zjistil více

"to je pěkná barva!" okomentoval vertikální zářivku

bere znovu s sebou pytel než jde ven z projekční místnosti

užívá si zvedání objektů

spouští slidshow s obrázky sondy a komentuje, že slyšel, že tam ta sonda zůstala

spustil obrázky venuše a swipuje přes obrazovku s tím, že chce s venuší rotovat

zkoumá těžítka

chce trhat rostliny a jíst je

dostal se znovu do historické sekce

chce se teleportovat na planetu skyboxu

"dobrý, že ta svíčka svítí"

napadlo ho, že by si tou svíčkou mohl svítit do knížky "chci si číst"

shodil svíčku a ptá se, zda nezačne hořit stůl. když byl ujistěn, že ne, vklidu ji tak nechal

nevšiml si zhasnutých svíček

"ZASE JSEM ZTRATIL PYTEL!!!!" vyřkl

zjistil, že si svíčku může přendat z ruky do ruky a ptá se zda může žonglova a pokouší se o to

tahle je nějaká divná (bez plamene) svítí? příjde mu že ano, kvůli textuře která je na vršku svíčky osvětlená. až když viděl, že neosvětluje okolí konstatoval, že nesvítí a zapálil ji

"můžu ji i zhasnout?"

shodil druhý pytel z terasy a zdůraznil, že to je ten druhý, ne ten jeho.

šel znovu do vesmírné stanice

dají se židle otáčet? vidí že to nejde a konstatuje, že je tato židle otočná co do typu židle

E.1.3 Posttest

čekal větší lokaci a přepínatelnost lokací

interaktivnější počítače - že tam může něco i napsat

nečekal to ale přišlo by mu přirozené, aby tam někdo byl s ním. buďto jiní návštěvníci nebo robot, který by ho provedl

čekal by ochoz v mísnosti s vysokým stropem

snadno se zvyká na teleportaci, škoda že mám jen ruce

myslí, že ho na začátku přilákalo na historické sekci to, že to vypadá úplně jinak, než kde začal

E.2 Participant č. 2

E.2.1 Pretest

žena, 25 let, malé zkušenosti s VR

E.2.2 Test

mám hustý rukavice

je to tam jiné, jdu tam (o historické místnosti)

"středověká místnost"

chce otevřít knížku

zapálila svíčku. (shodila jednu na zem a myslela, že ji tím zhasla, protože po zvednutí neměla plamínek)

postavila svíčku na stůl

sahá na obraz - očekávala teleportaci

"ooo, dalekohled. líbí se mi"

osahává dalekohled

"wow" - reakce na skybox

čekala bych nějaký pohyb. alespoň meteority nebo tak

opět osahává dalekohled. když se nic nestalo, koukne do něj a vidí galaxii

kouká z balkónu doů

sebere pytel - "to je fajn."

napadlo ji zapálit pytel ale místo toho ho vyhazuje z balkónu a druhý pytel nechává být

zouší vzít svíčku ze stěny - "to je trapné!"

chce vytáhnout knížku

vrací se do vesmírné lodi

intenzivně mačká pohovku - neví co se stane (vybrat, sednout si, něco najít?)

rostlina - hýbání by bylo fajn

to jsou rajčata?

jé, co to je? (vidí projekční místnost)

jů

šmatá intenzivně na venuši

o 3D satelitu: "hustý"

pozoruje s nadšením satelit

"o! :-(" (satelit zmizel)

ŘEŠENÍ TECHNICKÝCH PROBLÉMŮ - ZVUK BYL TICHÝ (nešel do sluchátek, ale do VivePro sluchátka)

2. si spustila přednášku, tentokrát se zesíleným zvukem

říká, že se jí líbí

chce zhasnout světla

3. spouští přednášku po naučení grip button controls

intenzivně objímá Venuši

kontr. jí rychle mizí (kliká místo držení)

říká, že se jí líbí Venuše

myslela, že si ji může vzít

zase tahá za kytky

sahá na velkou obrazovku

"áá" - spustila po nápovědě

po chvilce opět sahá na veklou obrazovku - neví co chce, cokoli, co by ji zabavilo

chce přinejmenším tmu, když už by měla koukat na delší film

chce mít rozsvícené mini obrazovky, aby bylo vidět že jsou aktivní

má tlačítka na přerušení filmu asociovaná, že je to součást obrazovky a nechápe proč je pak obrazovka zhasnutá

prohlíží poličky a říká, že je to taky prázdný

shýbá se k malé kytce na zemi: "AHÁÁ!!! já to věděla" komentuje úspěch nad objevením interaktivní kytky

spuští obrázky klávesnicí: "Je to spořič!" "ne! interaguju... asi"

ukazováčkem šťouchá logo monitoru

spuští druhý monitor druhou klávesnicí a říká, že k tomu chce zvuk

óó - viděla těžítka na stole

"a ten výhled!"

vadí ji ve výhledu z okna projekční místnost

komentuje těžítko s osmiúhelníky: "to chci"

drží těžítko a ukazováčkem šťouchá do cedulky těžítka

bere si ho s sebou

snaží se ho položit na vroubky sloupu

spuští obrazovku s astronomy

chce aby obrazovka už svítila, aby bylo vidět, že je spuštěná

DOSTALA ZA ÚKOL JÍT DO KNIHOVNY, pochopila to tak, že je tam dostupná nějaká další místnost, kam jde jít a proto chvíli rychle chodí se tam a říká, že je ztracená

zkoumá zase své těžítko a říká, že by čekala jakokoli interakci, že se alespoň rozsvítí, nebo něco hustšího, že se z něj rozvine mapa

opět jde hledat a zase říká, že je ztracená

ŘEKLI JSME SI, ŽE MÁ JÍT DO TÉ HISTORICKÉ MÍSTNOSTI, KDE UŽ BYLA, NE HLEDAT NOVOU

obrázky Tychona by hledala spíše v knížce, "je to víc staré" "plus kecy k tomu" (rozuměj: v té knížce k obrázku)

chtěla by i atlasy s obrázky

nebo nějaké staré výkresy

jde na terasu

bojí se, že spadne

"paraalx mapping, OMG" komentuje texturu terasy

říká, že by přidala padající meteory než= jenonom skybox

říká, že se jí nejvíc líbí soška (myslí těžítko s osmiúhelníky) a ???

pokládá sošky na sebe vzhůru nohama a je nadšená že se vzepřela gravitaci

E.2.3 Posttest

lokace je moc uzavřená: hned je vidět okno a vede to jen dokola

líbí se jí, že je to dobře osvětlené

chce si vzít Venuši do ruky a mít nějaké stavy na té kouli, aby bylo vypínání tam

"líbí se mi to" - komentuje celkový dojem

chce aby svítili všechny aktivní obrazovky, se kterými lze interagovat

aby zhasínala světla, při projekci

moc se jí líbí video, kde je vidět přednášející

E.3 Participant č. 3

E.3.1 Pretest

muž, 26 let, žádné zkušenosti s 3DOF VR, jen jednou smartphone VR

E.3.2 Test

"Ha! planeta" vidí Venuši v projekční místnosti

teleportuje se blíž - přímo do středu projektoru, udělal ale kroky vzad

spuští přednášku a na mojí otázku říká "to bude Venuše"

"ó, můžu ji hladit" - komentuje steamvr interakci s koulí

stojí uprostřed projektoru a hladí ji

KRÁSNÝ

pozastavil přednášku a jde zkoumat. překáží mu však velké video v prozkoumání místnosti

můžu se ???

krásná zářivka

vypadá kosmicky

blbne s teleportem

"Á" (u velkého videa s dokumentem)

"nějaká neuronová sít" (komentuje první záběr)

kouká na to video - "proč to neříká Jordan?"

začal si prohlížet ruce

vidí, že je video dlouhé tak se teleportuje před ně s tím, že alespoň lépe uvidí

vzápětí se teleportuje dál a zkoumá další obrazovky

chce na to ale ticho, chce zastavit video. stiskl grip a hned si všiml kontrolek tak jde zpátky k levé obrazovce a bez problému pozastavuje video a jde zase zkoumat další obrazovky

je zklamaný, z dokumentu s tím, že to může i na televizi

ó, počítače, podívám se ven

zkoumá planetu na skyboxu "tam je něco zeleného" ukazuje na detaily na povrchu

jde tedy k počítači, s tím, že tím zjistí více o planetě co je vidět z okna

mačká klávesnici ukazovákem

"aha, tady na obrázku"

"a! sověti, dobrý"

"to vypadá jako mars"

"chci si sednout do křesla"

jde ke kytkám: "nejsme na vesmírné stanici???"

po chvilce: "to je hustý, že umíme pěstovat kytky na vesmírné stanici"

"to je asi bazalka"

vidí prázné police: "docela velké. můžu si sem odložit ovladače " - směje se

zkouší ukazovákem na tablet

"hm... další sedačky"

"ó, tycho" - swipuje obrazovku ukazovákem

zjistil, že se to přepíná klávesnicí a iteruje

"necháme tam galilea"

"tak jdeme do knihovny ... SE SVÍČKAMI!!!!! (řekl překvapeně) schválně jestli se můžu spálit"

"nepálí to"

bere knihu ze stolu - bere ji však oběma rukam z boku bez interakčních tlačítek

naučil se po chvilce jak brát do ruky věci

položil knihu na stůl

"ta kniha je fakt na nic asi"

hraje si s knihami

jde do knihovny

snaží se zapílit knihu: "je to sranda!"

jde k dalekohledu. vidí pytle: "AMFORY!!"

schválně jestli můžu ???

podivuje se nad balkonem

chce teleport na planetu na skyboxu

všiml si galaxie v dalekohledu

hned na to zkoumá, kterým směrem na obloze míří dalekohled

zklamaný z knihovničky co není 3D

zkouší se spálit o svíčku

květinu oběma rukama z boku

pak jednou a odhazuje ji

bere si ji s sebou

odhazuje ji

další kytky, přetahuje je

staví věž z kytek

chce vzít do ruky křeslo, pak klávesnici

jde do projekční místnosi, kde spuští mou přednášku -> pauze -> stop

resume video dokumentu

E.3.3 Posttest

z toho, že je na kosmické stanici měl na začátku hned jasno, že se bude učit o vesmíru

nejdříve se snažil zkoumat naučné prvky

dobrá venuše

škoda, že jsem pak nemohl na venuši

teleportace steamvr promakaná

grip button po pochopení bez problému

dlouhé video zklamalo

mohl proklikávat obrázky: nevěděl, zda je tam více interakce a jen on neví jak to udělat

knihovna dobrá, že to bylo Tychona Brahe (to si vymyslel on)

E.4 Participant č. 4

E.4.1 Pretest

žena, 50 let, malé zkušenosti s VR

E.4.2 Test

kouká z okna

s nadšením kouká na venkovní část vesmírné lodě

"nejsou tu žádné nápisy? nevím pak kde je mé místo" - hledá kapitánské křeslo

teleportovala se k projektoru ze špatné (zadní) strany a na můj pokyn obchází zepředu

spustila přednášku dotykem poté co chváli mačkala na ovladači tlačítka venuše: "Věděla jsem to!"

"můžu znovu?" zase z dálky míří na venuši a mačká tlačítka.

"poprvé jsem nedávala pozor"

VYSVĚTLUJI JÍ GRIP BUTTON

viděla tlačítka kontrolek, přišla na to, jak se to ovládá

"Je to super!!" (enjoyment z interakce)

"spíš bych ale mlátila do koule" (tj. kontrolky by hledala dotýkáním venuše)

jde k levé malé obrazovce a kliká dole na tablet

říká že je to chyták, že nefunguje zrovna ten, kde je nad ním malá obrazovka

sleduje dlouhé video

je to hustý, tak velká obrazovka

"to jsem nečekala" - příjemné překvapení

zastavuje video: "Ha ha, už mám zkušenost"

kouká, vyšla ven, je u PC

"to je díra nebo sklo??" znepokojeně kouká z okna a příjde jí, že tam chybí sklo

"tamty počítače s židlí budou fungovat"

kliká na obrazovku místo klávesnice

zkouší ???: znova

zkouší oba najednou: "jdou spustis oba najednou?"

proč nefunguje? (klikala opět na obrazovku)

"mění se to samo... ne, ja to měním"

"můžu sem? ne." (prosklená stěna)

"byla jsem tu? ne. botanická zahrada to asi je! mo pěkné, jako ve StarTrek"

"ó, ??? knihovna, ??? ?"

"tento počítač funguje!" (Tycho)

proklikává a čte text

rozhlíží se kolem sebe: "když tak koukám, zde nic víc není. jdu do knihovny. tam jsem chtěla"

vstoupila do knihovny: "WOOOOW"

"tady chci zůstat! udělejte mi kafe"

všima si knihy na stole

dotkla se jí: "ha, svítí. ó, posouvá se"

přišla jak brát věci triggrem do ruky

užívá si to velmi, bere střídavě obě svíčka

chce postavit hnihu na hranu (bere ji oběma rukama z boku)

staví svíčky na svá místa, dělá znovu pořádek

hraje si s knihou

dotýká se rukou stolu

míří na dálku ovladačem na svíčku

přemisťuje knížky na poličce

zkouší dosáhnout na knížky na horní poličce

zkouší obrázek - nic nedělá

(popoháním ji, aby se šla kouknout ven)

nepodařilo se jí to (není zvyklá se teleportovat tam kam chce) a tak myslí, že ven z místnosti nevede jiný východ (i když si předtím všimla dveří ven) a tak se vrací zpátky do lodi. já ji naviguji správným směrem ven na terasu

na terase: "woooow, to je třešnička na dortu"

"jen bych zapla větry" (zmiňuje skutečný vítr, který foukal na karlově mostě v Golem VR)

"ooo, vidím část vesmírné stanice" je nadšená z toho, že ji vidí z venku

prohlíží si stanici z terasy, vyklání se a je v šoku z toho jak hnusně vypadá z venku spojovací chotba mezi historickou sekcí a vesmírnou stanicí: "proč to není stejnou barvou jako zbytek stanice? to je dřevotříska??"

vidí pytel: "můžu to brát?"

"někdo to schodil" (komentuje, že je jeden pytel na ležato a narovnává ho)

"dělá něco teleskop? můžu s ním hýbat? ne. jde s ním něco dělat?" zkouší všechno možné rukama

až po nápovědě strká hlavu do okuláru a říká, že to prý zkoušela a nedařilo se

jde se ještě projít po stanici

E.4.3 Posttest

nejvíc se mi líbila knihovna a terasa a koule (rozuměj venuše) na začátku

nepřišla bych na kontrolky grip button bez rady

super, že jdou přednášky opakovat