Feasibility of a Virtual Reality training supporting pre-service teachers performing music education in primary school

Technology supported music education

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Abstract

Within this research, an attempt was made to tackle the lack of confidence of pre-service teachers. Via the design of a supportive Virtual Reality training, the aim was to train their listening skills. With the use of spatializer software inside a 3D game environment, spatial audio was implemented in a virtual music class to localize inconsistencies of students. In this virtual music class eight students are playing the chord notes of the song “The lion sleeps tonight”. The pre-service teacher has to hear and identify three common inconsistencies in a music class: playing too early, playing too late and playing along with a different chord. When the pre-service teacher has found some inconsistency, he directs his feedback to the individual student to improve his or her playing.

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Chapter 1 - Introduction

The last few years, music education in Dutch primary schools has been an increase of interest. A reason for this switch could be recent studies about the importance of music for the younger brains. One of these studies was conducted by Jaschke, Honing, and Scherder (2018), where they followed for 2.5 years 147 primary school children to research the effect of a structured music education. From their results they concluded that there was a transfer effect visible on the academic performance of the children, who played music over a longer period of time. This means that similar areas in the brain were activated since the moment a child would solve an arithmetic problem (Jaschke, Honing, & Scherder, 2018). Furthermore, the study showed that music education enhances the ability to plan and control over one's actions. As a response to these recent publications, the Dutch government decided to provide subsidies over the years to improve the quality of music education (Van Essen, Termorshuizen, & Van den Broek, 2019). Moreover, initiatives were taken by other parties, such as the non-profit organisation “Méér muziek in de Klas”.

To organise structured music education in the Netherlands, a standard curriculum is provided by the Dutch organisation “Stichting Leerplanontwikkeling” (“Leerplankader kunstzinnige oriëntatie”, 2019). However, it is expected that not only in-service teachers, but also pre-service teachers have to follow these guidelines to maintain qualitative music education. Already known through research is that pre-service music teachers in primary schools experience a lack of confidence (Biasutti, Hennesy, & De Vugt-Jansen, 2015). According to Hennesy (as cited in Biasutti, Hennessy, and de Vugt-Jansen, 2015) possible factors that have an influence on the level of confidence are “prior personal experience, the opportunities and support for teaching music during school-based training and the nature of the university-taught courses” (p. 144). Even before standing in front of a classroom, these pre-service teachers have the idea that they have to master music to teach it to students in primary school (Biasutti et al., 2015). Mastering music certainly helps with analysing the quality of the music. However, being a musical analyst is not the only role the teacher has to fulfill. Additional roles are for instance to provide feedback on the musical quality of the students, to direct the class (which was in 2018 on average 23 children per classroom (“Hoe is de groep van mijn kind op de basisschool samengesteld?”, n.d.)), be a pedagoge, and be a developmental psychologist (Spieker, 2019). Hence, measures are taken and budgets are available for music education, but pre-service teachers still feel overwhelmed.

An approach to make the pre-service teachers feel more confident is to use technology to train their skills. Ideally, an in-service teacher presents common real-life scenarios of a music class to a pre-service teacher and examines its behaviour. A kind of technology that can contribute to this representation is based on Virtual Reality (VR). Virtual reality is defined by Mikropoulos and Natsis (2011) “synthetic, highly interactive three dimensional (3D) spatial environments that represent real or non-real situations” (p. 769). As the VR environment should be based on learning principles and tries to achieve specific learning outcomes, it can be described as an Educational Virtual Environment (EVE). With respect to the effectiveness of a VR environment, Mikropoulos and Natsis (2011) conclude in their literature review that VR is applicable in the context of pedagogical use.

The purpose of this thesis is to research how a Virtual Reality training can be designed to support pre-service teachers in primary school to increase their level of confidence and to design such a Virtual Reality training with the focus on music education. To be able to answer if it is a viable option for pre-service teachers, a few additional questions have to be answered with respect to audio and visual design.

- What musical cues do (in)experienced pre-service teachers most likely miss during a music class?
- What is the added value of simulating a music class in VR for the pre-service teachers?

- How can a primary school music class be simulated in a VR application with audio and visuals of a classroom environment?

This VR training is meant to support pre-service teachers next to music lessons provided by the music pedagogy teacher, rather than receiving feedback on their actions during a real music class. The aim is to prepare the pre-service teachers before teaching music to primary school students. This way the pre-service teacher will be able to detect problems in the musical quality of the students and will be able to provide accurate feedback to them. On the one hand, this might lead to more experienced teachers and thus setting a step in improving music education. On the other hand, it might increase the self-confidence of the teachers, as they will be more prepared based on real-life situations.

At the end of this research, a virtual music class in VR has been designed. Eight virtual students are playing the chord notes of the song “The lion sleeps tonight”. The pre-service teacher is being asked to localize the virtual student, who repeatedly makes a mistake. As can be seen in Figure 1, the student with the purple boomwhacker plays repeatedly too early. If the pre-service teacher clicks the button of the incorrect student, he gets the chance to perform the exercise again. And if the pre-service teacher clicks the button of the correct student, he can provide feedback to the individual student to help him or her improve his or her playing.

Figure 1: A screenshot of the virtual music class, where the virtual student with the purple boomwhacker (note Bb) plays too early.

Chapter 2 - Background Research

Within this chapter, multiple topics will be addressed. For the first two sections, an interview was conducted with Benno Spieker. In the first section the role of the music pedagogy teacher, who educates the pre-service teacher, will be addressed. Secondly, the role of the pre-service teacher is explained. Thirdly, an overview of existing VR applications in (music) education is provided. In the fourth section, four audio approaches for VR are described. The fifth section highlights an educational instruction for VR and the influence of Cognitive Load on a user. At last, a conclusion is provided to set a base for the ideation phase.

2.1 The role of the music teacher

To get more insight in the current music education at the teacher academy (PABO), an interview was conducted with Benno Spieker, who works as a teacher at a conservatorium and researches the possibilities of using technology to support music education. He is also a former music pedagogy teacher at a teacher academy (PABO). On average, a music pedagogy teacher in the Netherlands will educate around 20 to 30 pre-service teachers, i.e. PABO-students. These PABO-students are being taught didactics and music pedagogy. Through activities, which they call “domains” in music education, the PABO-students need to learn music skills. These skills help the PABO-students to create a proper music lesson on their own. Through these domains, the music pedagogy teacher hopes that the PABO-students gained sufficient knowledge to get them started on teaching music in their own primary school classes and trying to get them to notice deviations in tones, chords etcetera.

2.2 The role of the pre-service teacher

The music pedagogy teacher at the teacher academy (PABO) educates 20 to 30 PABO-students. As Benno Spieker points out, the pre-service teachers studying at the PABO will also educate 20 to 30 students. However, these students are in primary school. If the pre-service teacher has time to provide a music lesson, it will often take place in his own classroom. Otherwise, the music lesson takes place in a gym at the school or a room with more space. During a common music lesson, a pre-service teacher makes use of instruments such as their own body; materials that are being used on a daily basis (e.g. a glass); or real musical instruments such as a xylophone, triangle, drums. An instrument that also is being used is the boomwhacker. A boomwhacker is an affordable percussion instrument that can be used to play chords, rhythms and melodies. Based on its length, a boomwhacker produces a different tone. To indicate the difference in tone, they are colour notated (Ruardi, 2019).

Depending on the musical background of the pre-service teacher, they might not recognize a certain rhythm or sound. They are entrained to understand what kind of discrepancies there are within a group of students. However, if there is a student that deviates for example from the pitch, the pre-service teacher finds it hard to provide feedback. In general, common deviations in a music class are students starting too early or too late; playing too loud or too soft; playing too quick or too slow. When a pre-service teacher has had sufficient training, it becomes easier for the pre-service teacher to provide students in primary school with activities.

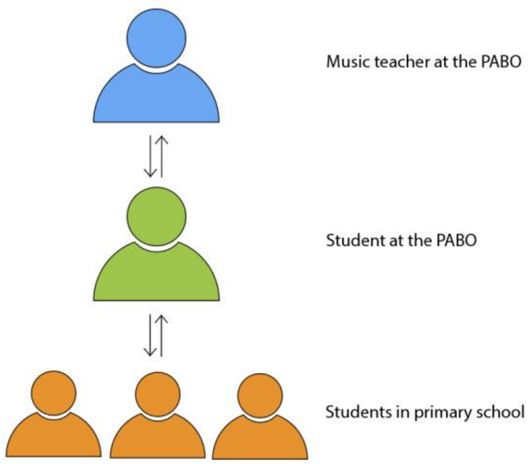

Figure 2: A picture of the flow of education, featuring in the centre the pre-service teacher.

2.3 Existing virtual environments for trainings in (music) education

2.3.1 State of the art

To the best of our knowledge, a VR training that is specifically designed for pre-service teachers, who teach music in primary schools, has not yet been developed. However, there already exist mixed reality and VR applications for (music) education. First of all, there is a VR Music Room on Steam (Serafin, Adjorlu, Nilsson, Thomsen, & Nordahl, 2017), in which the user can play virtual instruments, for example the drums.

With respect to primary school children, Innocenti et al. (2019) evaluated the VR application VR4EDU on its effectiveness. In the experiment, there were eight different rooms where the children had to learn about music genres. Afterwards, they received on paper questions they had to fill out. The VR test group resulted in an increase in the number of correct answers (Innocenti et al., 2019).

When focusing on virtual applications for pre-service teachers, there exist several trainings. Some of these training research the performance of a pre-service standing in front of a class. Mixed reality simulations, such as Mursion, provide pre-service teachers with real time feedback from virtual avatars. It's a mixed reality experience as the pre-service teacher asks questions in the physical space, while the questions are being answered by a person via a skype-connection (Dalinger, Thomas, Stansberry, & Xiu, 2020).

An alternative approach to simulating with mixed reality, is to make a simulation of a class in Virtual Reality. In a study conducted by Remacle, Bouchard, Etienne, Rivard, and Morsomme (2021) they researched the speech of teachers in real-life and in Virtual Reality training. Different from Dalinger, Thomas, Stansberry, and Xiu (2020), the teacher could not interact with the children sitting in the classroom. The aim of this study was to investigate whether VR could be an approach to train teachers' vocal skills (Remacle, Bouchard, Etienne, Rivard, & Morsomme, 2021). Their results showed that VR could elicit the teachers' speech.

2.3.2 Affordances of simulations

An affordance of simulating for teacher education is that it is possible to reconstruct real-life events of a class. During such a simulation, the environment and the training are controlled to let the pre-service or in-service teacher practice with these situations (Dalinger et al., 2020). Having a controlled environment is an approach to achieve certain outcomes of the simulation (Dieker, Rodriguez, Kraft, Hynes, & Hughes, 2014). In a simulation, the teacher can make mistakes while practicing scenarios (Dalinger et al., 2020;

Dieker et al., 2014). The difference between a real classroom and a simulated classroom is that the teacher can re-enter, if he makes a mistake (Dieker et al., 2014). Developing a simulation for teacher education is not to replace going to a real school to gain experience. On the contrary, it is meant to practice with real-life situations before the teacher stands in front of a real classroom (Dalinger et al., 2020).

2.4 Audio possibilities in VR

2.4.1 The essence of audio in Virtual Reality

Having proper audio in VR contributes to the experience of the users. First of all, the amount of audio equipment, such as microphones and loudspeakers, that are used to record, influences how accurately the sound of a real environment is reproduced (Au et al., 2021). Normally, more equipment leads to a more accurate reproduction. In combination with VR, the reconstruction of audio can let the users experience auralisation: thinking they are in a different acoustic setting (Au et al., 2021; Ballestero, Robinson, & Dance, 2017). The goal to create auralisation is to let the users be immersed in the virtual environment. Therefore, Ballestero, Robinson, & Dance (2017) state that it is necessary to deceive the human senses by recreating the sounds as accurately as possible.

Additionally, the quality of audio determines how precisely users can point to sound sources in the environment, which is being regarded as sound localization. Still, according to a study conducted by Haustein and Schirmer (as cited in Wu and Roginska, 2019) people suffer from a localization blur, which is “the smallest angle difference needed for the person to detect a position-change of sound source” (p. 2). They concluded that humans perceived the sound the best in front of them. Humans suffer the most from this blur at 90 degrees. Concerning sound localization, humans also confuse the back with the front and vice versa. Visuals in VR help to overcome this confusion (Valzolgher et al., 2020; Wu & Roginska, 2019). Next to visuals to overcome confusion, a study by Strelnikov et al. (as cited in Valzolgher et al., 2020) proved that audio-visual training results in a better performance of localizing sound than just an auditory explanation. Meaning both components in designing a virtual environment support each other (Valzolgher et al., 2020).

In conclusion, users are immersed in a virtual environment, when sounds from the initial environment are reproduced as accurately as possible and when audio is accompanied by visuals to accurately localize the position of a sound source.

2.4.2 Mono sound

The first audio approach that could be used in a virtual environment, is a sound recording that is being perceived as coming from only one position. This is called mono sound. The mono sound is recorded through one microphone, while the playback of the recording is not limited to one speaker (Hoffman, 2020). To the human ears, the mono sound can be perceived as spatial by using head trackers to make head and body movements possible (Orman, Price, & Russel, 2017).

Orman, Price, and Russel (2017) researched if they could train undergraduate music conductors with the use of a head tracking virtual reality system. Before the simulation, they audio recorded an ensemble of 19 wind and percussion players from one position. During the simulation, the audio recording was played via 5 loudspeakers and a red box appeared surrounding one of the 4 ensemble sections, to let the user shift his focus to this place. After the experiments, Orman et al. (2017) concluded that this setup enhanced the non-verbal conducting skills of music conductors. A different approach for creating spatial audio with the use of mono sounds is to let one of the experimenters move a loudspeaker along with a predetermined position in the virtual environment. Valzolgher et al. (2020) created a virtual environment, in which 17 speakers were aligned in a semicircle in front of the users' eyes. Through one of the virtual loudspeakers, a mono sound was produced, which the user had to indicate. To create monaural listening, the user put an earplug in his ear. Valzolgher et al. (2020) concluded that over time the users were able to adapt to monaural listening through the localization of the correct sound source in the virtual environment.

Concluding, mono sound, which is played back from either a static or a dynamic sound source, can be used to create three-dimensional audio as long as the user can move his head.

2.4.3 Binaural Sound Reproduction

The second audio approach records sound as if it came directly from the ears and it uses headphones to playback the sounds. To be able to hear the variations between left and right, the sound is recorded or rendered by a method called Head-Related Transfer Function (HRTF). This method records audio via a dummy head or measurements to reconstruct the audio both ears would perceive in a room (Au et al, 2021). However, taking measurements is more labour and time-intensive (Sikström et al., 2018). As described by Plinge et al. (2018), the convenience of binaural sound reproduction is that the users are more immersed in the environment as they experience the sound coming from the scene rather than the sound coming from the inside of their heads.

A study by Pedersen, Hulusic, Ameldis, and Slattery (2020) created ear training to distinguish musical intervals in VR. Therefore, they used HRTF to create spatial audio renderings. In a semicircle, 13 virtual piano keys were visualized, of which the sounds were perceived via headphones. Their findings of the experiment were that the VR training provided the necessary spatial information to recognize the intervals instead of stereo sound and the users would more rely on the spatial cue (Pedersen, Hulusic, Ameldis, & Slattery, 2020).

In conclusion, spatial audio can be accurately designed for both ears via HRTF, which is a method that records audio via a dummy head or taking measurements.

2.4.4 Ambisonics

The last approach is recording audio in multiple directions, while multiple microphone channels are being faced away from each other. At the moment of recording, the microphone records from a static point in an environment (Droste, Letellier, & Sieck, 2018). As the sound is being captured from multiple angles, a user with head tracking VR can experience 360 degrees of sound. When the sound is captured by the microphones, audio files are created in four raw audio formats (Ballestero et al., 2017). Via encoding, it is possible to convert the channels into binaural audio to replay the sound via headphones (Droste et al., 2018; Plinge et al., 2018; Ballestero et al., 2017), but also to channel it via an array of loudspeakers (Au et al., 2021). In an array of loudspeakers, multiple loudspeakers surround a participant, where neither HRTF nor headphones are being required. Via channels of the loudspeakers, the audio is distributed (Ahrens, Marschall, & Dau, 2019).

As opposed to the previously mentioned research, Plinge et al. (2018) researched how they could let the user walk and rotate their body in a 6 degree of freedom (6 DoF) virtual environment while adapting the audio to their positioning. In this study, three sound sources were spread in a room of 3,5 x 4.5 meters, which were recorded with one ambisonic microphone. To decode the B-format audio file, they used the Directional Audio Coding (DirAC) encoder. In the 6 DoF setup, distance information to the sound sources was calculated while recording. With this distance information, the researchers concluded that it improved the experience instead of approaches without the distance information (Plinge et al., 2018). Nonetheless, Au et al. (2021) routed the ambisonic sound recordings over 16 loudspeakers attached to a sphere-formed aluminium frame, i.e. a loudspeaker array. An inconvenience of a loudspeaker array is that it has to be used in an anechoic chamber, and thus can't be easily moved to different places.

There can be concluded that in the case of ambisonics spatial audio can be best recorded with an ambisonics microphone that converts with the help of decoder the recording into binaural audio, i.e. sound via headphones rather than a loudspeaker array.

2.4.5 Spatializer plug-ins

When advanced recording equipment is not available, spatializer plug-ins can be used to design 3D audio within Unity, and even through additional middleware such as FMOD (Beig, Kapralos, Collins, & Mirza-Babaei, 2019). For instance, mono sound that has been recorded can be perceived as spatial via a plug-in ("Oculus Audio Spatializer Features", n.d.). Currently, there are multiple spatializer plug-ins available. As the game engine "Unity" is used, the spatializer plug-ins Resonance, Steam Audio and Oculus Spatializer are most applicable. The Oculus Spatializer in particular creates audio spatialization through Head-Related transfer functions (HRTFs) from a presambled database ("Oculus Audio Spatializer Features", n.d.). In combination with the head tracking of an Oculus VR headset and the Oculus Spatializer plug-in, the audio sources are being mapped to localize their position.

2.5 Learning in VR

In section 2.2 there was elaborated on the performance of the pre-service teacher, when standing in front of a music class. As was explained, even the smallest change in pitch might not be recognized. Learning can be encouraged by the Cognitive Affective Model of Immersive Learning (CAMIL) (Makransky & Petersen, 2021). This model provides a framework for the effectiveness of learning through immersive virtual reality. According to this Makransky and Petersen (2021), a high presence (i.e. the realness of the environment) and high agency (i.e. control over the variables, control over one's own actions) positively affect the learning, as it encourages "interest, intrinsic motivation, self-efficacy, and embodiment" (p. 15). However, self-regulation and extraneous cognitive load should be taken into account. In VR there is a possibility to create an information overload through visuals or text. This causes a cognitive overload and it might lead to an obstacle for the users' their learning (Albus, Vogt, & Seufert, 2021). When a user learns in a VR training, multiple cognitive processes are involved. By identifying these cognitive processes, it can help to design a proper pedagogical learning environment. In the literature review of Albus, Vogt, and Seufert (2021), three types of cognitive load were identified. The intrinsic cognitive learning (ICL) is the load from the difficulty of the tasks in the training. Secondly, the extraneous cognitive learning (ECL) is the redundant visuals etcetera in the virtual environment that does not have an influence on the learning outcomes. At last, the germane cognitive load (GCL) is the understanding of the tasks while making efforts in the virtual environment. If the extraneous cognitive load is diminished and self-regulated activities are present, it can, together with the other four affordances such as interest and intrinsic motivation, elicit factual, conceptual and procedural knowledge and transfer of learning (Makransky & Petersen, 2021).

With respect to simulations of a classroom in virtual reality, Dieker et al. (2014) identified three key elements. The first element is to let the teachers feel physically and cognitively present in the virtual environment. The second element is to fit the simulation to the teacher's personal needs. The third element is to engage the teachers in a cyclical process, in which they first state the objective of the simulation, then they execute the tasks in the simulation and at last they review their actions (Dieker et al., 2014).

2.6 Feedback

The users will receive feedback in the VR training to have information about their performance. Schell (2015) defines the following feedback loops: “judgment, reward, instruction, encouragement and challenge” (p. 262). To ensure the users experience the VR training as expected, Schell (2015) points out that the feedback should provide information the user needs and wants to know, and provide information that helps the user achieve the intended goal.

2.7 Conclusion state of the art

At the PABO, a music teacher educates on average between 20 to 30 students. Within their limited amount of time, they teach their students didactics and music pedagogy. The exercises they practice during their music lessons are to provide the students with as much knowledge as possible to encourage them to create their own music lesson. With this knowledge, a PABO-student, i.e. a pre-service teacher, provides a music lesson mostly in a classroom, a gym or a spacious room at a primary school. To make the experience as real as possible in virtual reality, these three rooms can be taken into account. Within a music lesson at primary school, the pre-service teachers make use of daily used objects or real instruments. However, when it comes to detecting flaws in the musical quality of the students, it depends on the background of the pre-service teacher, if he is able to perceive this.

Currently, there does not yet exist a VR training for pre-service teachers in music education teaching at a primary school. Nonetheless, there already exists a VR application to practice with instruments, a VR application for primary school children to practice with musical genres and simulations to let teachers practice standing in front of a classroom. Simulations are particularly interesting as the preservice teachers can make mistakes, while standing in front of the virtual music class; the situations are controlled; and simulations won’t replace real-life experience, but rather real-life situations are reconstructed for practice purposes.

To immerse the user in the virtual training and to accurately localize sound discrepancies, three audio approaches have been identified: mono sound, binaural sound reproduction, ambisonics and spatializers. In the ideation phase, one of these approaches can be chosen to design a virtual reality training.

As the purpose of this virtual reality training is to be educational, an instruction model has been identified. The CAMIL model can be used as a framework to promote learning in an immersive virtual environment. The feedback that will be provided in a virtual reality training should be as clear as possible by providing information that improves the user to reach his own objective.

Chapter 3 - Ideation phase

Within this ideation phase, there will be elaborated upon four ideas for a supportive Virtual Reality Training application. This step can be regarded as the first step towards the design of a VR training. This section will be concluded with defining the concept that will be further developed.

3.1 Idea 1: Virtual listening application

Within this VR training, pre-service teachers are listening to a virtual music class. One of the students will repeatedly make a mistake. A common mistake is for instance, the student in primary school repeatedly starting too early or too late, repeatedly too fast or too slow, repeatedly too loud or too soft.

With the use of 3D audio and the visual elements of VR, the pre-service teacher has to localize the position of the virtual student, who plays a musical note incorrectly. After localizing the virtual student, the pre-service teacher can either via a User Interface menu indicate what the virtual student played incorrectly, or provide feedback directed at this virtual student. This step is to check whether the pre-service teacher understood the event.

For this concept, there can be songs recorded of only one instrument (e.g. boomwhacker), several instruments (e.g. simulation of an orchestra) or a group of singing children (e.g. an orchestra).

The aim for this application is that the pre-service teachers can practice with common mistakes in a music class, next to the music lessons at the PABO. It is meant as a supportive tool for the pre-service teachers. Furthermore, the PABO teacher, who educates the pre-service teacher, can advise the pre-service teacher to practice with a certain listening exercise.

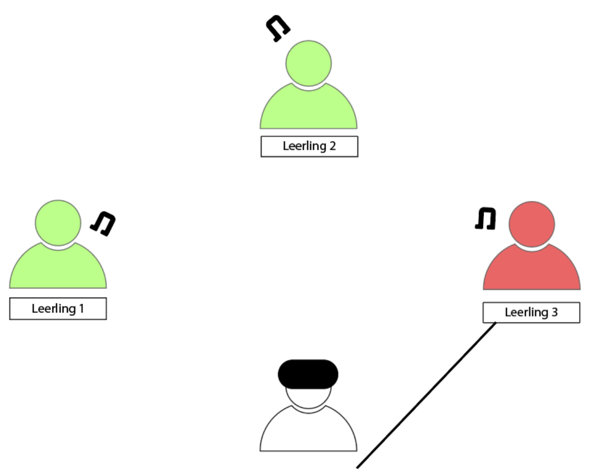

Figure 3: A representation of a pre-service teacher localizing a student who makes a mistake in music class. The line represents the pre-service teacher reaching the virtual student in VR.

3.2 Idea 2: Virtual conducting application

Within this Virtual Conducting application, the pre-service teacher will specify what musical instruments the virtual students have to play. For instance, this could be based on a song or a rhythm. During this training, the pre-service teacher guides the virtual students in playing a song or a rhythm.

The following steps might be taken into account in such a training. First, the pre-service teacher will specify what kind of instrument(s) the students will play. The next step is to let the students know in what order they have to play. Additionally, the pre-service teacher could instruct some of the children more by writing down instructions on the virtual whiteboard.

3.3 Idea 3: Virtual application for testing prototypes

This research is conducted as part of the PhD project of Benno Spieker. Last year, other projects were developed on behalf of this overarching project. However, due to the COVID-19 pandemic, they were not able to test their products with users. Instead, they had a remote user study. Henceforth, the question remained how the pre-service teachers would use the prototypes in a physical setting and how they would respond to using these technological prototypes. For instance, afterwards could be evaluated if further research would be conducted on developing the product.

One of the projects was carried out by Jasmijn Kruijshaar, who designed a metronome that can visualize the pitch, the timing and the volume of a primary school student playing music (Kruijshaar, 2020). In the virtual environment, the students could have metronomes in front of them and the pre-service teachers could experience if this would help them to recognize inconsistencies in music (see Figure 4).

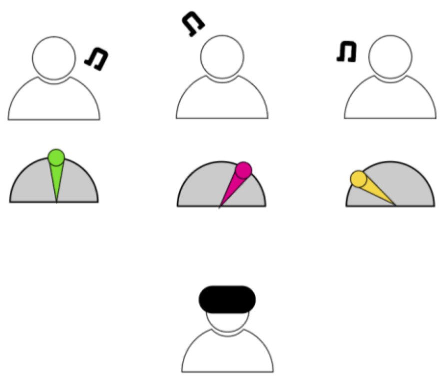

Figure 4: A formation of a music class with a pre-service teacher in VR listening to students making music.

3.4 Idea 4: Collaborative Virtual Reality Music Class

The fourth idea is to create a collaborative VR music class, where the pre-service teacher and the teacher at the PABO are present in one virtual environment. This concept is an addition to one of the three previously mentioned ideas. In the case of the VR listening application, the pre-service teacher listens to virtual characters of whom one is repeatedly making a mistake, e.g. starting too early, too late, etcetera. The teacher at the PABO is then able to track where the pre-service teacher is looking during the exercise. If the pre-service teacher should look in a particular direction, the teacher at the PABO can provide real time feedback.

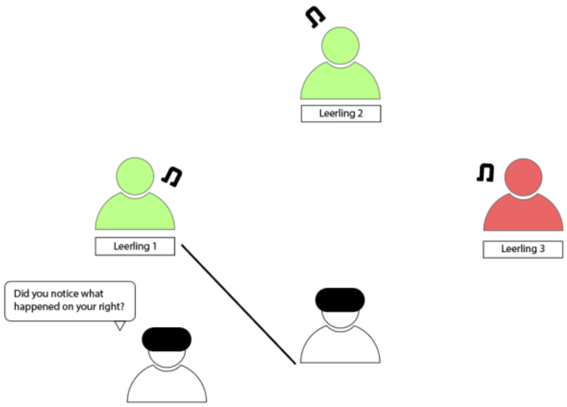

Figure 5: The teacher at the PABO provides real time verbal feedback to the pre-service teacher.

3.5 Conclusion

The concept that was interesting to further develop was the virtual listening application. We have noticed that pre-service teachers lack confidence in their music teaching. There already exist virtual applications, in which classes of primary school are simulated. We can adopt this concept and shape it into a simulation of a music class. With the VR listening application, the vision is to let the pre-service teacher listen to common mistakes that happen in a music class.

In this virtual listening application, the pre-service teacher will be able to use it as a supportive training next to the music lessons at the PABO. Furthermore, if the teacher at the PABO senses a pre-service teacher might benefit from listening to these common mistakes in music class, he can recommend the pre-service teacher to use the proposed VR training.

Chapter 4 - Requirements and specifications

To define the requirements for the virtual listening application, a meeting was scheduled with Benno Spieker. During this meeting, his wishes were discussed. Afterwards, the wishes have been converged into requirements based on the MoSCoW prioritising.

MoSCoW prioritising

Must have

- At least one song is recorded with a mono microphone.
- To synthetically produce 360 degrees of sound, there will be made use of a spatial sound technique: the Oculus Spatializer.
- At least one listening exercise
    - There is a focus on rhythmic music education.
        - The instrument that is used for the first listening exercise is the boomwhacker.
    - The listening exercise can be divided into three parts:
        - The pre-service teacher can hear a flaw in the musical quality of one of the virtual characters;
        - The pre-service teacher is able to localize the position;
        - The pre-service teacher can identify the type of flaw. The identification is based on providing feedback to the virtual character.
- There will be one virtual environment designed.
    - The first virtual environment will be a reconstruction of a classroom in primary school.
    - The virtual students will be arranged in the shape of a U (see Figure 6).
- The primary school students are cartoon characters.
- Teleport from one position in the virtual room to another position in the room to prevent motion sickness (see Figure 6).

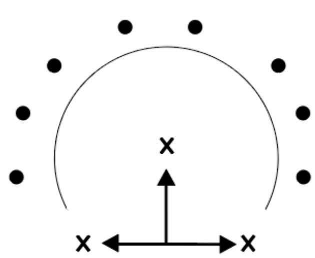

Figure 6: This figure represents a formation for a music class, where the students are indicated by the dots and the positions of the pre-service teacher by the X's. The teleport function should position the pre-service teacher to these three desired locations.

Should have

- Giving feedback to the child, that repeatedly makes a mistake.
- 3 additional listening exercises.
    - A clapping exercise.

    - A singing exercise.
    - A boomwhacker exercise.
- The pre-service teacher can choose the number of students that are playing in the virtual music class.
- Two additional virtual environments: a spacious room at a primary school and a small gym.
- Teacher can choose his own avatar; an avatar which the teacher identifies himself with.

Could have

- Instead of a U-shaped virtual music class, the children could be spread around the classroom. This variation can be chosen by the pre-service teacher, when choosing a listening exercise.
- Listening exercises designed based on a level of complexity. The pre-service teacher is able to choose a listening exercise based on a level system from simple, medium, or hard. Otherwise, the pre-service teacher is able to choose a listening exercise based on the education levels in the Dutch primary school.
- The virtual characters play multiple musical instruments at once. Rhythmic instruments could be a tambourine, woodblock, cymbals etcetera.
- There will be an animation of the virtual students to indicate when a student is playing.

Won't have

- The graduation project will be focused on a spatializer, therefore recording techniques such as Binaural Sound Reproduction and Ambisonics will not be addressed in the design of the Virtual Reality training.
- The pre-service teacher will not be able to walk around the virtual classroom.
- The virtual characters will not be designed to be real students from a music class.
- There will not be a recording of a real music class of students in primary school.

Chapter 5 - Realisation and evaluation

In the realisation phase, the concept was developed based on its criteria of chapter 4 “Requirements and specification”. The development of the Virtual Reality training is divided into several iterations, which makes it for instance possible to change direction, when something unexpected has happened. This Creative Technology Design Process makes the process of designing flexible and helps to evaluate if the goals are achieved (Mader & Eggink, 2014).

First, each iteration is defined with the goal. This goal explains what is expected to find out at the end of the iterations. Secondly, the process defines what is realised within the iteration. At last, the evaluation discusses results of testing with the prototype. In case an element needs to be adjusted or improved, the following iteration will integrate this point of feedback.

For the evaluation of the third iteration, the Virtual Listening application was user tested with 25 pre-service teachers.

5.1 First iteration

5.1.1 Goals

The goal of the first iteration is to get acquainted with the Oculus Rift S and to try out the Oculus Spatializer. At the end of this iteration, it should be decided whether the Oculus Spatializer can be used for simulating a virtual music class or a different method for producing 3D sound should be chosen.

5.1.2 Process of development

To test the Oculus Spatializer, a simple scene with three cubes was created within Unity (see Figure 7). This setup was created to make a clear distinction between the three cubes. When the user looks to the left (see Figure 8), it is expected that he hears the pink cube in front of him, the orange cube from his right and the green cube from behind. In case the user looks to his right, it is expected that he hears the green cube in front of him, the orange cube on his left and the pink cube from behind (see Figure 9).

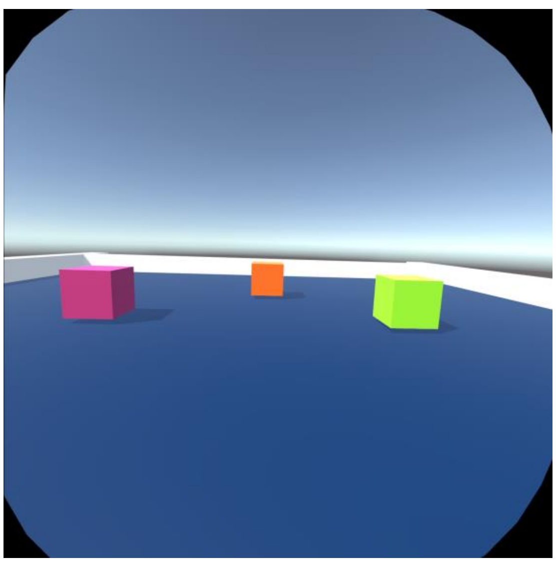

Figure 7: A screenshot of the scene within Unity, where the user looks straight forward via the VR headset.

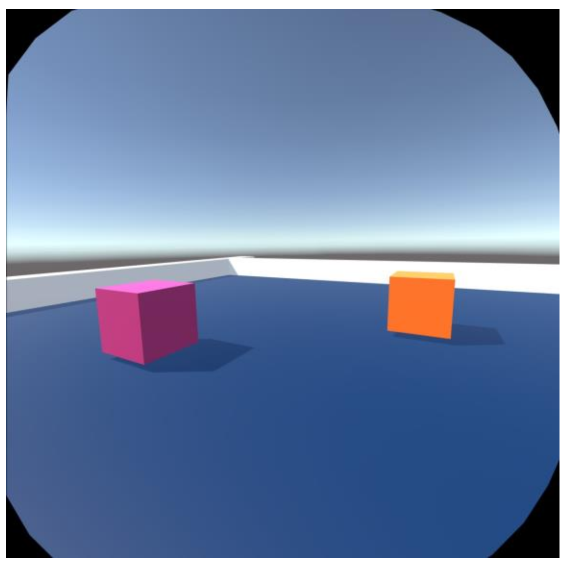

Figure 8: A screenshot of the scene within Unity, where the user looks to his left via the VR headset.

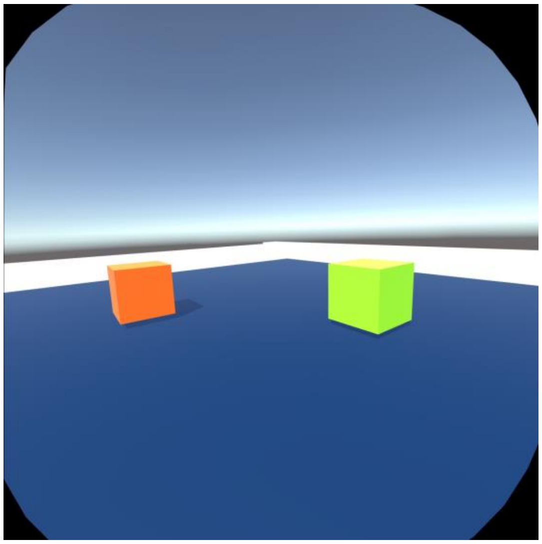

Figure 9: A screenshot of the scene within Unity, where the user looks to his right via the VR headset.

After creating the aforementioned setup in Unity, sounds were added to the three cubes. The sounds are played through the middleware FMOD. First, three 3D events were created to assign one sound to each cube. A 3D event was created instead of a 2D event, as the sound depends on the position of the player (FMOD, 2021). For instance, the sound is played soft when the user stands far away from the cube and loud when the user stands right in front of the sound source. The next step was to drag a song onto the timeline. For testing purposes, free available sounds were used (Bennstir, 2009; JarredGibb, 2015; Juskiddink, 2008). Each sound file had a duration of less than 20 seconds. Therefore, a loop region was added (see Figure 10). For setting up the FMOD project with an Oculus Spatializer, a step-by-step guideline can be found in Appendix A. Within this iteration, the most important elements are briefly touched upon. As previously mentioned, the Oculus Spatializer transforms a monophonic sound into a spatial sound through Head-Related Transfer Functions (HRTFs). This had to be specified by clicking the Master Track, and then clicking on “Mono” in the input signal. The default spatializer could be removed, as the Oculus Spatializer also had to be added to the Master Track (“How to use the Oculus Spatializer in FMOD Studio”, n.d.); see for detailed steps this documentation by Oculus. If all the steps have been performed, it results in a FMOD project that can be seen in Figure 10.

The last step was to integrate the FMOD project with Unity and import the Oculus Spatializer for Unity. These steps can also be found in Appendix A. When these steps are completed, an FMOD studio listener was attached to the player in Unity (i.e. the VR headset) to hear sound relative to its position and a FMOD Studio Event Emitter was attached to each cube (see Figure 11). At this point it was not yet necessary to specify at what moment the sound had to be played. Hence, the integrated function “Play Event” was set to “Object Start”. Meaning that the three sounds were played at the moment the user pressed play in Unity.

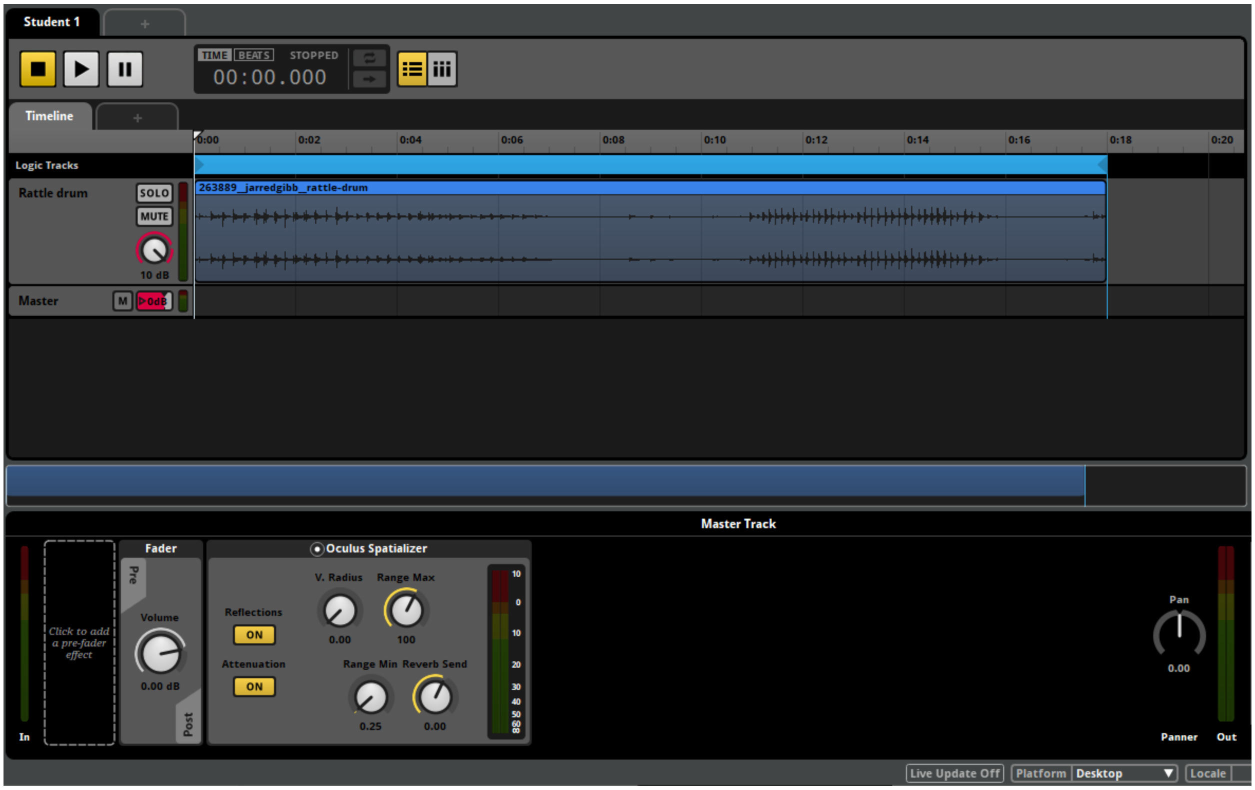

Figure 10: A screenshot of the FMOD project with the integrated Oculus Spatializer.

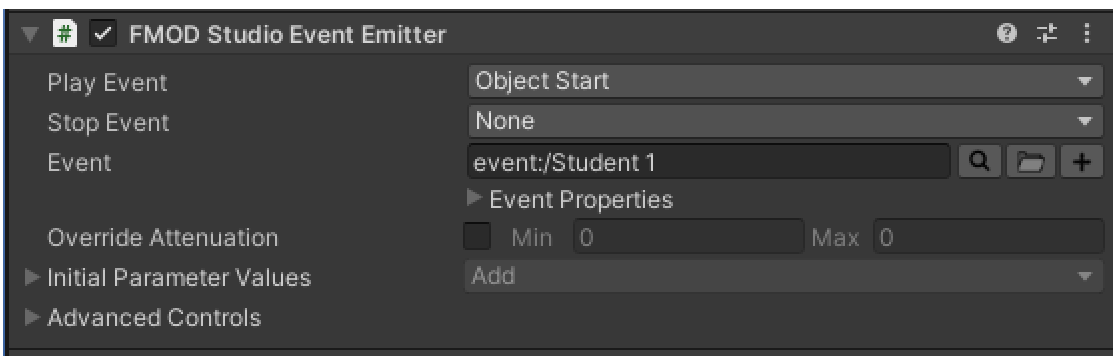

Figure 11: A screenshot of a FMOD Studio Event Emitter.

5.1.3 Evaluation

Due to the COVID-19 pandemic, a remote session was scheduled with the supervisor and the critical observer rather than a physical meeting. To test this first iteration, the Unity scene was recorded with OBS studio. As the sound was transformed through the Oculus Spatializer, the supervisor and the critical observer were asked to put on a headset. Via this approach, they could also experience and evaluate the music and the spatializer.

The evaluation resulted in experiencing the spatial sound as described in goals for this first iteration. All three of us heard a difference when moving our head towards a different cube and a difference that was relative to our position. Henceforth, it was decided to try to develop a more advanced scene with more realistic sounds in the second iteration. However, the sounds did not match, which was distracting. This was a design issue, as the three sounds were randomly picked. For the next iteration, the sound should be more consistent.

5.2 Second iteration

5.2.1 Goals

For the second iteration, the following goals were defined. The first goal was to develop a context for the Unity environment. The context is one of the three most common spaces a pre-service teacher educates music in primary school: a classroom. Furthermore, boomwhackers needed to be created as assets for the environment. In addition, virtual characters should be positioned in the virtual classroom that represent students in primary school. These are the characters to whom the pre-service teacher is going to listen to in the VR listening training. For the listening exercise, a song needed to be recorded with boomwhackers. At last,

5.2.2 Process of development

In the first place, a virtual classroom needed to be designed. To model the assets for the virtual environment, the software Maya was used. When the outline of the classroom was designed (see Figure 12), interior elements were developed to make the classroom more realistic. As the pre-service teacher provides the music lesson in the classroom, tables and chairs should be stacked to create space in the virtual environment (see Figure 13). Other elements are a beamer and a whiteboard (see Figure 14). On the whiteboard, the pre-service teacher can write something down about a musical exercise. The other purpose of the beamer and the wall is that from this point in the virtual classroom, the melody of a boomwhacker song could be played. In this case, the beamer projects the rhythm of the song and produces the sound, and the students follow the instructions.

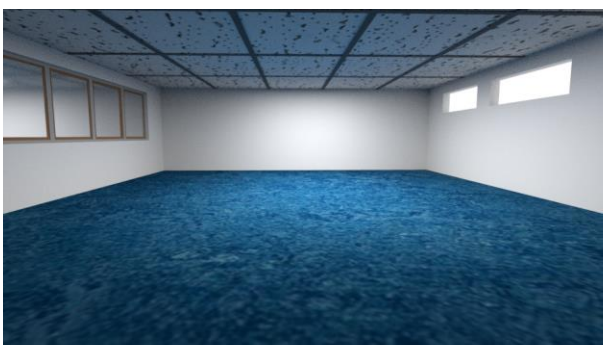

Figure 12: A screenshot of the outline of the classroom modelled in Maya.

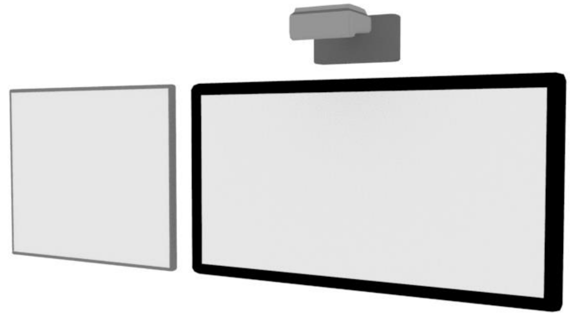

Figure 13: A screenshot of the chair and table modelled in Maya.

Figure 14: A screenshot of the beamer and whiteboard modelled in Maya.

Based on the song “The lion sleeps tonight” published by Musication on YouTube (Vink, 2020) each note of the melody has been recorded separately: C - F - G - A - Bb - C’. Within FMOD, six 3D events have been created, as each note will be played by one virtual character. One setup of the sound files in FMOD is depicted in Figure 15.

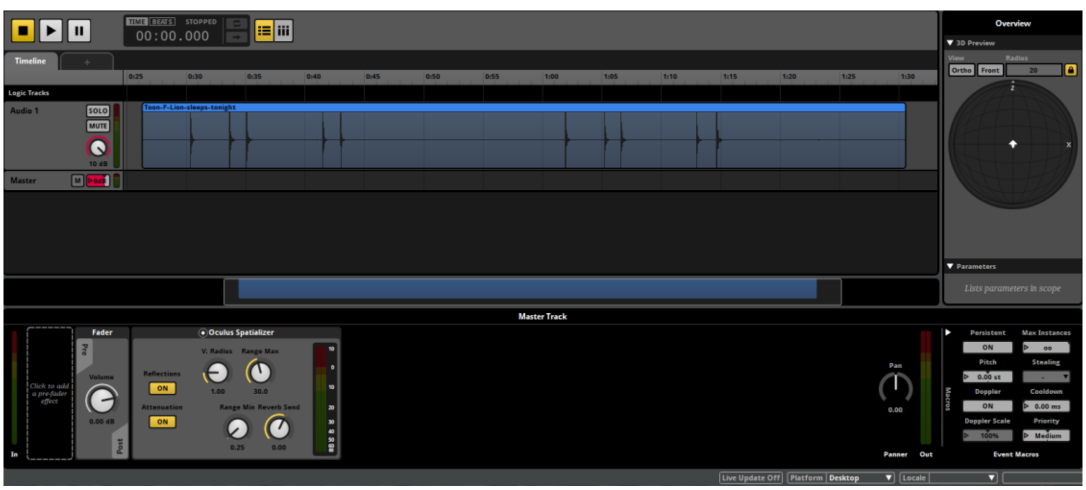

Figure 15: A screenshot of the setup of the full sound file in FMOD.

To visualize the students in primary school, the assets “Timmy” and “Amy” have been downloaded from Mixamo (“Characters”, n.d.). Mixamo offers characters with a rig. The rig is the skeleton of the character. It is necessary to have a rig, if the character needs to be animated.

After modelling, recording and importing the assets into Unity, they were positioned in the virtual environment. Just as described in Chapter 4, Requirements and specifications, the virtual characters were placed in a circle (see Figures 16 and 17). With this setup, the pre-service teacher is able to teleport forwards, backwards and to both right and left to focus on one or more virtual students playing the tone of the boomwhacker. From left to right, the virtual students played the tones: F - G - A - Bb - C' - C. The virtual students played the tones in order of the song. For the listening exercise, the virtual student playing tone F was repeatedly making a mistake, as he started too early.

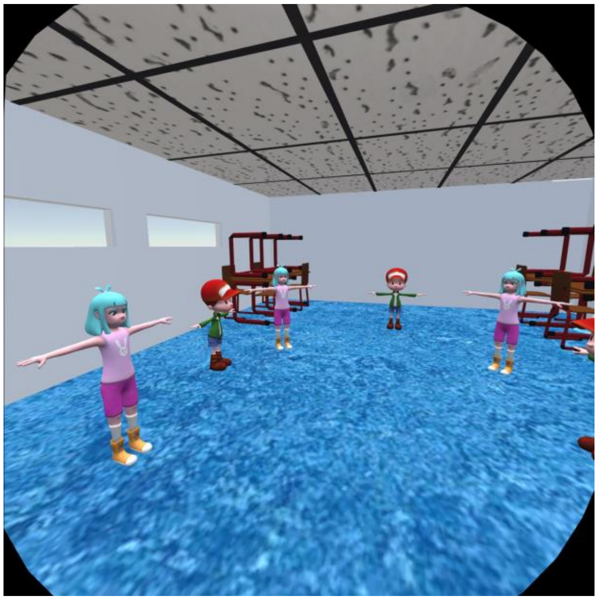

Figure 16: A screenshot of virtual students in the virtual music classroom positioned in a circle.

Figure 17: A screenshot of the beamer and whiteboard in the virtual classroom.

5.2.3 Evaluation

For this evaluation, a physical meeting with the supervisor and critical observer was scheduled. First of all, it was hard to localize the virtual student. Not only was it distracting that they had to look quickly from left to right, as the tones quickly followed up each other, but there were also no animations of the students. At this point, it was expected that the animations would visually support the pre-service where they have to look and what student is playing the tone with the boomwhacker. Hence, having an animation of the virtual student became a "Must have" in the MoSCoW priority list. This is in compliance with the statement in section 2.4.1 that audio and visuals complement each other.

An alternative to playing the melody of the song "The lion sleeps tonight", together with the supervisor and critical observer we agreed to play the chords of the song. The chords of this song can be divided into three groups: Group F, Group Bb, Group C. The chord notes are F - A - C' for Group F; D - F - Bb for Group Bb; C - E - G for Group C. In the third iteration, there will be elaborated how this has been implemented in the virtual environment.

Furthermore, the volume was too soft and with the current settings of the Oculus Spatializer, it seemed that the music was coming from the ceiling rather than from the virtual students. Both the volume and the settings had to be adjusted in the third iteration.

5.3 Third iteration

5.3.1 Goals

As stated in the evaluation of the second evaluation, it was a priority to animate the characters. Moreover, the goal was to adjust the sound tracks in FMOD to note chords instead of the notes of the melody. After adjusting the sound tracks in FMOD, the listening exercise could be developed.

During the first iteration, the virtual characters were not yet designed to be inclusive. Meaning that the virtual characters had one type of skin colour. The skin colour will be altered to make it a more inclusive training.

Finally, the aim was to user test the VR training with participants to understand if the design of this project was headed in the right direction and to get insight into the reactions of the pre-service teachers while interacting with the virtual environment.

5.3.2 Process of development

For designing the animation, the position of the following elements had to be altered: the position of the boomwhacker, one of the wrists of the virtual character and one of the elbows of the character. The other arm of the character was positioned to be static at one position. In Figure 18, the animation of the boomwhacker is visualized. For each separate virtual character, an animation timeline was created. At this point in the process of development, there was not yet taken a look at the automation of the animations. The positions, when the virtual character should hit the hand with the boomwhacker, were calculated accordingly. Depending on the song "The lion sleeps tonight", a note was played. Figure 18 shows the animation for chord notes C - E - G, as this animation for this note of the chord is going to be played at the same time.

Figure 19 shows the original soundtrack ("Audio 1") and the trimmed soundtrack ("Audio 2"). The chord notes almost start at 31 seconds. If the song was played from the start, the pre-service teacher had to wait throughout the melody before the animations would be triggered. Thus, according to the song "The lion sleeps tonight", the tones C - E - G are played at 52 seconds. To make a natural animation, the frames per second were set to 30 fps. At 52 seconds, the animation hits the hand of the virtual character, which can be calculated as follows: 30 frames x (52-31) seconds = frame 630. This process of calculation continued over the entire soundtrack and the other chords F and Bb.

When each single animation of hitting the hand with a boomwhacker was assigned to the correct position on the track editor, the notes in FMOD could be set on the 3D event timeline. In Figure 20, the 3D event timeline of note G is depicted. Note G starts at 52-31 = 21 seconds.

After the design of the animations and the soundtracks of each virtual student, the listening exercise was created. In the chord notes, there is a C and a C'. The virtual student, who is playing note C, mistakes himself with C'. Henceforth, he is playing at the same moment note C' does. Figure 21 shows the adjusted soundtrack in FMOD. For the listening exercise during the user test, the participants have to localize this virtual student.

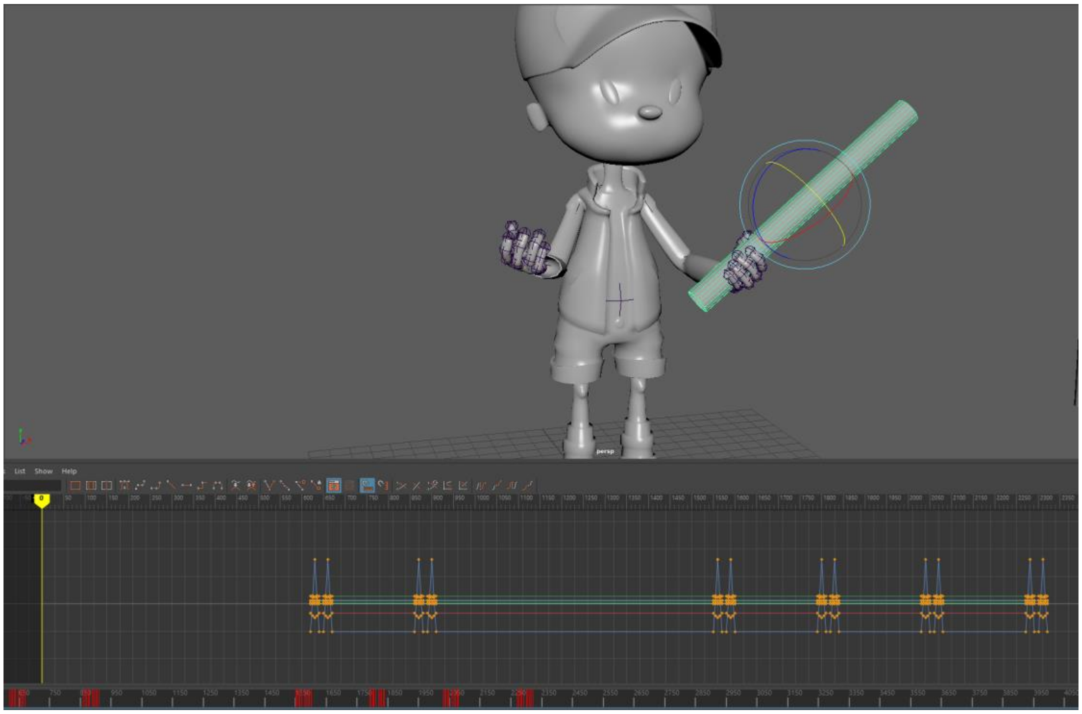

Figure 18: A screenshot of the animation in Maya.

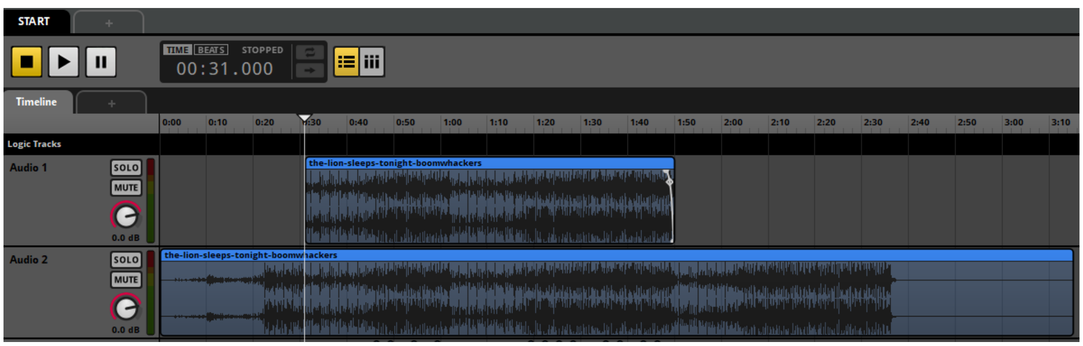

Figure 19: A screenshot of FMOD, where the song starts after 31 seconds.

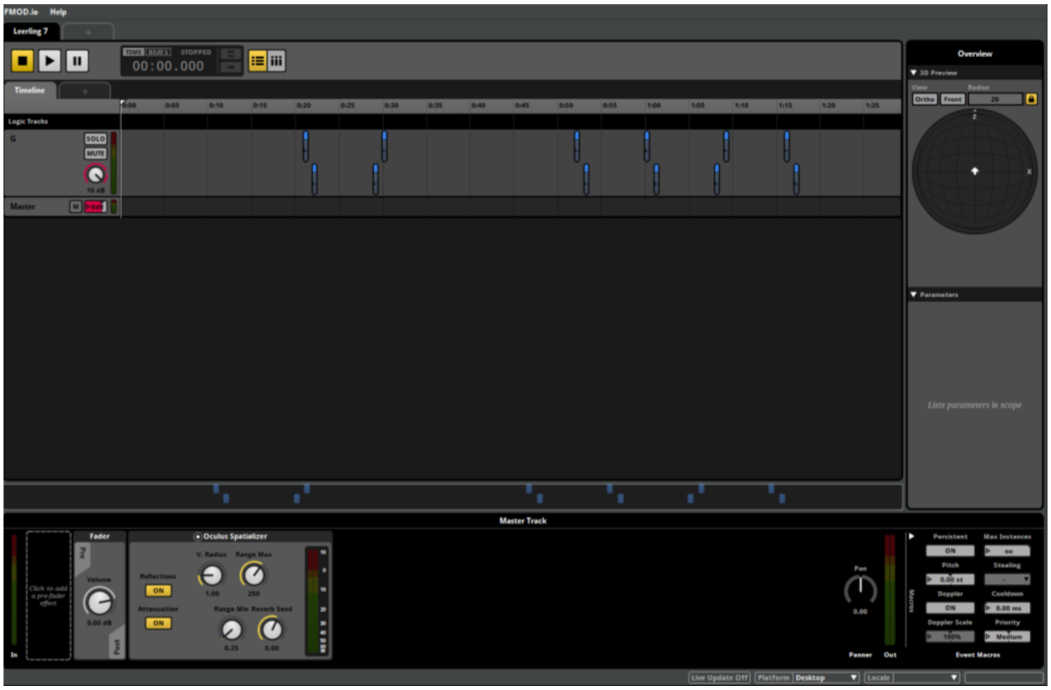

Figure 20: A screenshot of the FMOD event of the note G.

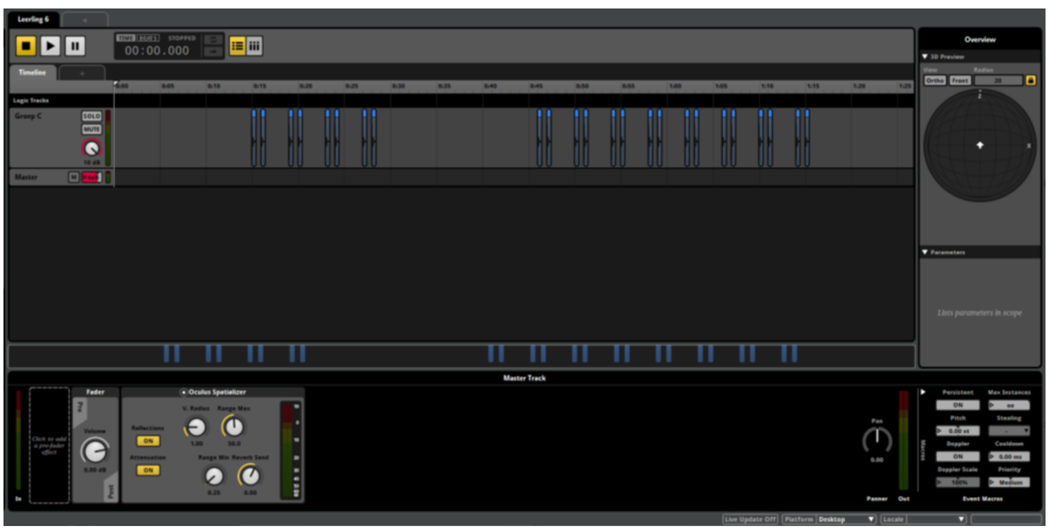

Figure 21: A screenshot of the FMOD event of the note C, that is adjusted to play along with chord notes C' - A – F.

A different goal was to make the design more inclusive. When downloading the virtual characters from Mixamo, there was only one type of skin colour available. Using the software Photoshop, the colour was altered. Figure 22 visualizes the updated virtual music class.

Next to the updated characters, the pre-service teachers need to choose a virtual student, who is playing the note C incorrectly. Therefore, UI buttons were positioned below the virtual students. When the pre-service teacher chooses the correct virtual student, the button turns "Green". In the case the pre-service teacher chooses the incorrect virtual student, the button turns "Red". UI buttons were added instead of colliding with the virtual student, as Oculus has an integrated feature, which is called "UI helpers". With these UI helpers, there is an integrated laser pointer, which makes it easy for the pre-service teacher to point towards a virtual student.

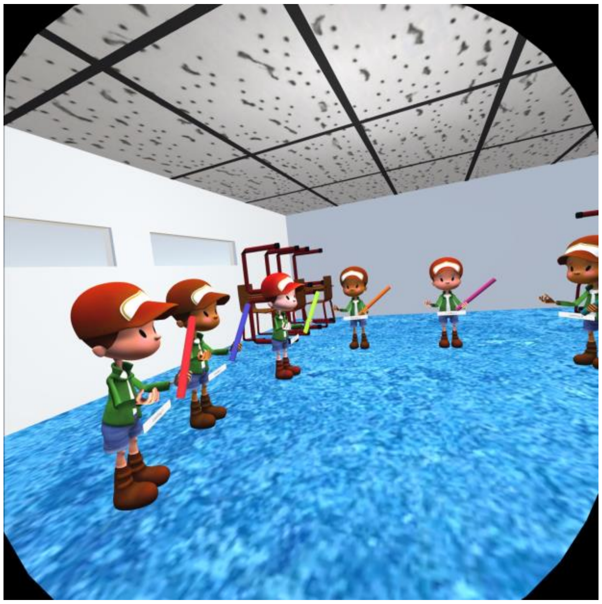

Figure 22: A screenshot of the virtual music class that was presented to participants in the User Test.

5.3.3 Evaluation

First, there is an evaluation of the progress that has been made during this iteration. Within Chapter 6, the evaluation of the participants is presented, with whom a user test has been conducted.

During this iteration, the boy “Timmy” has been animated. To be noted is that there was not yet an attempt made to automate the animations. It is relevant to research this, as it was time consuming and this approach might be seen as problematic, since later there will be more animations for different listening exercises. This will be a goal for the fourth iteration. Ideas to trigger the animation is to use Unity Event Instances (“Using Animation Events”, 2018). This also concerns the soundtracks attached to the virtual students. In the fourth iteration, different approaches will be elaborated upon to modify the soundtracks.

At this point, only virtual characters of the boy “Timmy” are in the virtual music class. The girl “Amy” will be animated in the fourth iteration and imported in the virtual music class.

Chapter 6 - Evaluation - User Test

6.1 Experiment and results

Participants and demographics

A total of 25 participants took part in the user test; all of the students are studying at a Dutch conservatory to become a music teacher. The participants were asked to participate in this user study via critical observer and their teacher, Benno Spieker.

However, due to COVID, the participants had to scan a QR code with their smartphone to fill in the questionnaire. Hence, seventeen out of the twenty-five participants responded. A possible explanation is that these participants forgot to fill in the questionnaire, when they walked out of the test room or forgot their phone, when they entered the test room.

Out of these seventeen participants, eight had never used VR. The remaining nine participants had used VR once or twice. Most of the participants reported that they were interested, excited or enthusiastic to use VR during this experiment. Only two of the participants reported that they didn't regard VR as special.

Procedure and materials

Due to the COVID pandemic, it is important to take precautions when testing with participants. Especially since the VR headset for a great part of the face of the participant. The following precautions were taken:

- The UV cleanbox of the University of Twente was brought to the location of the experiment. The UV cleanbox can be regarded as an additional disinfection method for the VR equipment (Davison, 2021). After an experiment with a participant, the VR headset was disinfected with the use of this UV cleanbox;
- The participants got a face mask to place between their face and the VR headset (see Figure 23);
- The researcher wore hand gloves to reduce the risk of infection via contact with the VR headset;
- The solid parts of the VR headset were disinfected with alcoholic wipes. The lenses were not disinfected with alcoholic wipes, as it affects the lenses;
- The participants were asked to disinfect their hands at the start of the experiment;
- Regularly, the keyboard, the mouse and other equipment were disinfected with alcoholic wipes;
- The researcher and the participants keep 1,5 meter distance at all times during the experiment;
- The participants and the researcher had to do the RIVM health checklist, before a participant would start with the experiment.

Figure 23: A photo of a facemask that would surround the eyes of the participants to prevent direct contact between the VR headset and the participants' skin.

At the start of the experiment, the participants had to read the information brochure written by critical observer Benno Spieker for his own research (see Appendix B). After reading the information brochure, the participants had to sign his Informed Consent (see Appendix C).

When all steps were completed, the researcher was able to conduct the user test with the participant. First, the participant experienced the virtual music class in VR. The participant was asked to find a virtual student, who could improve playing a note. As described in section 5.3.2, the listening exercise was the virtual student playing the note C' incorrectly. Each participant received the same task and had the same listening exercise. Afterwards, the participant had to fill in a questionnaire (see Appendix C). In total seventeen participants have completed the questionnaire (see explanation in section "Participants and demographics").

At the end of the experiment, the research thanked the participant for their participation and they left the room.

Listening exercise

Thirteen out of the twenty-five participants were able to execute the task correctly. They were able to select the virtual student, who had played the note C at the same moment the note C' played.

Design

All participants reported that they were excited after experiencing a virtual music class. One of the participants reported the following "Het was erg leuk om te doen en ik zie veel potentie in dit project hoewel de oefeningen nu nog niet te vergelijken zijn met een echte klas." (It was fun to do and I see much potential in this project. Although, the exercises can't yet be compared to a real class.). This participant recommended that it could be used as an addition to practice in real-life, for instance an internship, if the training is further developed. Via this VR training, the participant is not yet able to discover his or her own approach to teaching, as there normally are multiple ways to handle certain situations in a real music class.

One of the key elements of simulations is presence. The participants, who did feel as if they were in a music class, indicated that it was because of the music and the instruments; the realism of the virtual music class, such as the table of the teacher; the exercise, as one of the participants described that he would play this song in primary school; the positioning of the virtual characters.

The participants, who did not feel as if they were in a music class, indicated that it was because of the virtual characters playing too neatly, which does not correspond to the reality; the lack of interaction with the virtual students; the characters not being designed realistically; in real-life, the students require lots of attention, while in the virtual environment they were standing still and were only playing when programmed.

There have been a few suggestions to improve the design of the virtual music class. The first suggestion is to add more attractive elements. Another suggestion is to add more realistic looking students instead of cartoonish virtual students. One participant indicated that in a real music class the task is not only to listen to the quality of the music, but also to guide the students, to keep their attention, to direct them etc. Adding such elements to the VR training in combination with exercises that will increase in difficulty level, might improve the simulation. Additionally, there could be more exercises with different instruments or singing exercises.

Instruction

The participants thought both the instruction to choose an exercise and the instruction of the actual listening exercise were clear. As suggested by one of the participants, the buttons could be explained into more detail. One of these buttons involved choosing the number of students. During the experiment, the number was predefined: in total eight virtual students were playing a note. When the participant could choose between the number of students, to him “less” and “more” students was too vague. An improvement could be to specify the number of students. Also, one participant did not find it easy to read the instructions. The problem could be that the OVR Camera was too close to the beamer. In addition, the text of the instruction be adjusted to make it more compact or even a feature where it is read out loud. Furthermore, in the procedure of the experiment, there was not a trial session incorporated. This could be a future improvement of the experiment design.

Exercise

The melody of the song was in the virtual environment placed at the position of the beamer, which is above the ground and behind the user of the VR training. Most of the participants identified the sound source coming from behind or above their heads. However, some of the participants thought it came from the students or everywhere in the room. An explanation could be that the sound was played too softly from the VR headset. This could reduce the immersion of the virtual environment. Still, the participants understood that the sound of the virtual students was relative to their position.

When focussing on the virtual music class, the virtual students were positioned in a U-shape (see section 4). The participants confirmed that it worked well in VR. In a real music class in primary school, some of the participants would also position their students in a circle.

Even though the circle was comfortable and well-arranged, three participants found it hard that they were unable to see the virtual students in one glance. And due to a delay in animation and sound, participants were confused which student made the mistake.

On the other hand, other participants found it easy to localize the virtual student, who repeatedly made a mistake. They experienced it as easy, because they could hear which chord was played incorrectly, they could teleport in the music class, they could hear the 360 degrees of sound and they were helped by the visuals that showed which student was playing.

Localizing a virtual student is part of keeping track which chord group had to play. Most of the participants could follow the order of the chord groups. One participant preferred to have the video of the song in the virtual environment. In a real-life situation, the participant would look at this video, while instructing the music class. This leads to the question if there should be more for instance visual or auditory elements to support the pre-service teacher during the exercise.

Reflection

At this point in the development of the training, fourteen participants would use it: this could be now or in the near future. Two answers of participants stood out. The first response was that a participant would practice with the training before teaching immediately in front of a real music class. The second response was that a participant regards this training as the opportunity to practice in a safe environment with noticing discrepancies in the music class.

What is of equal importance are the explanations why participants would not want to use the VR training. Their explanations were that it is too distracting to train the hearing of pre-service teachers; during the experiment it was time consuming to make it ready for the participant to use the VR headset; real-life practice is more educational; people can get motion sick from VR; and sound can be improved to make the training more high quality.

If the participants would be the designers of the VR training, they would immediately change the delay in the animations of the virtual characters, spread the children over the classroom, perform various music exercises with multiple instruments, and let the pre-service teachers put on headphones.

In addition, the participants were asked what they would like to experience in the virtual music class. They would like to experience students, who do not sing at the right pitch; play with virtual instruments; train with intervals; train with solfege exercises; practice with classroom management; practice with choir exercises.

6.2 Final concept - fourth iteration

6.2.1 Goals

One of the most apparent elements that needed to be altered was the delay in sound and animation. Therefore, the question rose: who is guiding in the animation? Is it the sound or the animation? In the case of boomwhackers, the character is in the movement of hitting the boomwhacker on his hand, and at the moment the boomwhacker hits the hand, the sound needs to be played. This can be described as the goal to automate the animation and the sound track.

For the user test, the focus was set on one listening exercise to experiment with. Two additional listening exercises were developed. One listening exercise where the virtual student starts too early. And one listening exercise where the virtual student starts too late.

Up until now, we were able to establish the presence of the participants in the virtual environment. Moreover, there will be two additional exercises to try to fit the needs of the pre-service teachers in the training. At last, the goal is to design feedback menus; via these feedback menus, the pre-service teachers will be informed if they answered correctly or if they answered incorrectly.

6.2.2 Process of development

A proposed solution to automate the animations and the soundtracks, was to use Unity's Event Instances. This did indeed work for the soundtracks. First, a script was created to call a sound from FMOD (see Figure 24). This function passes a string to the Unity Track editor. In the Unity Track editor, the path to a sound in FMOD can be defined. However, before this path can be set, Animation Events first need to be positioned along the timeline (see Figure 25). As the script "playNote" is attached to the virtual student, we can find this function by clicking on the Animation Event (see Figure 26). In the string parameter, the path to the event in FMOD has to be set by writing down exactly how to find the sound in FMOD. Since the sound is triggered based on the Animation Events, there does not have to be a long timeline of sounds of the notes (see Figure 27).

A similar approach was attempted with animations. However, this did not work as planned, as calling the function "Animation.Play" is not available anymore ("Animation.play", n.d.). Therefore, calling the animation was not possible. To work around this problem, this will be regarded as future work.

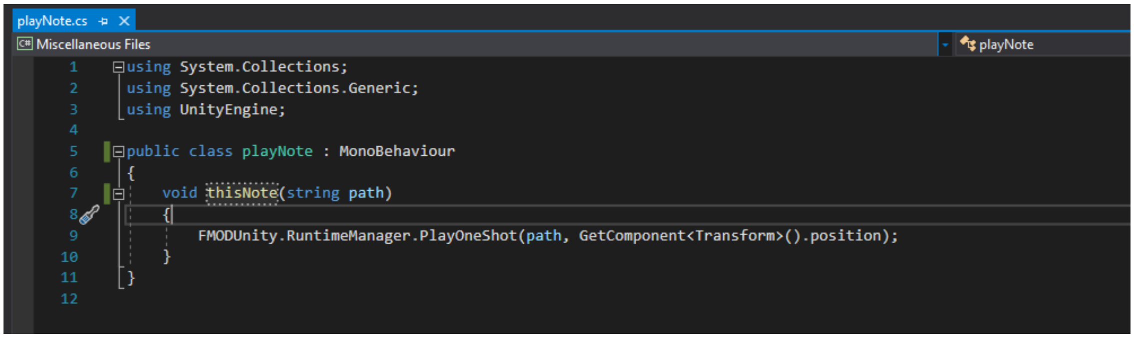

Figure 24: A screenshot of the Unity Script to set the path to a FMOD event and play this FMOD event.

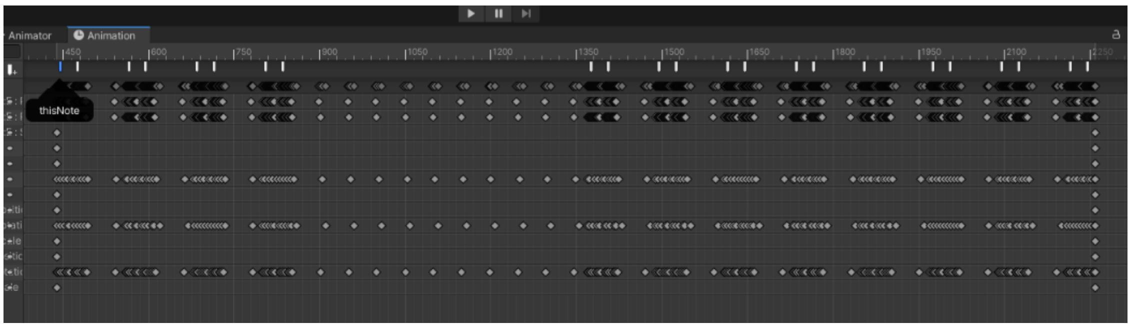

Figure 25: A screenshot of the Unity Track Editor. The Animation Event is highlighted on the left of the screenshot.

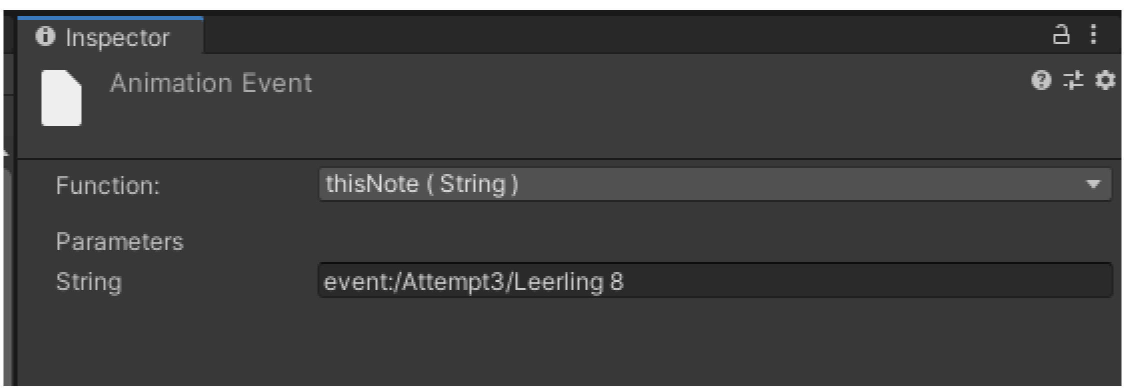

Figure 26: A screenshot of the Animation Event, where the function "thisNote" is being called and the path of the FMOD event is "event:/Attempt3/Leerling 8".

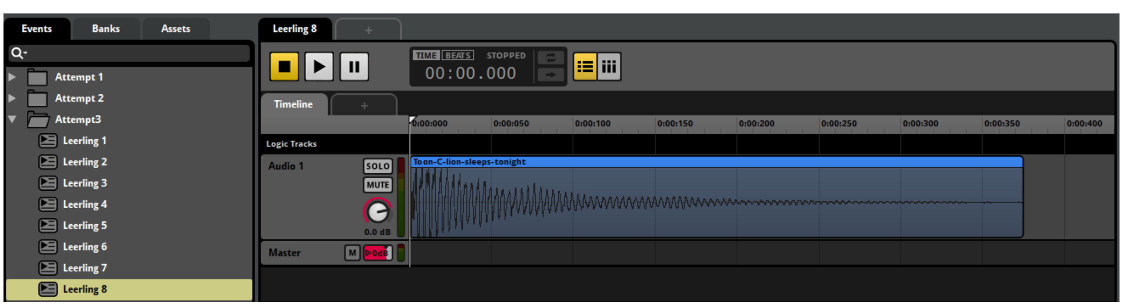

Figure 27: A screenshot of the soundtrack in FMOD.

One of the additional exercises is that virtual student 4 ("leerling 4") plays the note Bb too early. Through the animation this is noticeable as the animation has almost ended, while the animation of virtual student 5 and 6 just hit the boomwhacker (see Figure 28). A third listening exercise has been created, where virtual student 7 starts too late. This student plays the note A.

Figure 28: A screenshot of the virtual music class, where the virtual student with the purple boomwhacker (note Bb) plays too early.

At last, feedback has been added, when the pre-service teacher answered correctly or incorrectly. In case the pre-service teacher answers incorrectly, the panel in Figure 29 pops up. On this panel is written "There was another student who played less neatly. Do you want to try this exercise again?". This provides the pre-service teacher the opportunity to restart the exercise and listen another time to the same exercise. The feedback is based on the theory of Schell (2015), where the student is encouraged to listen another time to the exercise and is instructed that someone else in the virtual music class is playing less neatly. Nevertheless, when the pre-service teacher has answered correctly, the teacher himself can provide feedback to the student to improve his playing. After a walkthrough and a discussion with Benno Spieker, the following feedback items apply for the virtual student:

- Listen carefully when you have to play;
- I heard that you were playing a bit too early;
- Please play along with your neighbour;
- I heard that you were playing a bit too late.

These are general feedback statements and focused on providing only one student with feedback. In real-life, a pre-service teacher could also gather the entire music class and afterwards provide feedback. For instance, "class take a look at this example; at this point, this group will start to play, and at this point, that group will start to play".

Figure 29: A screenshot of the panel that indicates that the pre-service teacher answered incorrectly.

Figure 30: A screenshot of the feedback options that can be provided to the virtual student.

Chapter 7 - Conclusion

In the Netherlands, pre-service teachers in primary school lack confidence in teaching music. Having music education is important for the brains of the students. However, pre-service teachers have the idea they need to master their skills before they can teach music. Hence, pre-service teachers could be supported via training in Virtual Reality (VR), in which scenarios of a music class in primary school are being experienced. After this research there can be concluded that it is feasible to design a virtual music class in VR. It is not proven to reduce the lack of confidence of the pre-service teachers, but the intention was rather to support them with gaining skills in listening.

The method for simulating a music class was VR. The added value of VR in this context was the presence of the pre-service teacher in the environment, where exercises in the simulated music class can be repeated infinitely, re-entered, and is controlled to practice with real-life situations. This particular VR training did not yet exist, except for VR instruments, VR applications for primary school children to learn about music genres and simulations of a class in primary school.

Audio and visuals were two important elements in the quality and realness of the music class simulation. To localize a virtual student in VR, recording techniques for spatial audio were elaborated upon. There are several methods such as monophonic, Binaural Sound Reproduction and Ambisonics. Most interestingly, it is possible to synthetically create this spatial audio via a spatializer. In this research, the Oculus Spatializer Plug-in was used in combination with the middleware FMOD. Within FMOD, audio fragments were imported and adjusted with parameters to make it more soft or loud, and specifying the minimum and maximum distance from which the sound is audible.

The virtual environment was designed to be as real as possible. A classroom was modelled, which is one of the areas a pre-service teacher generally teaches music to primary school students. The characters were chosen to be cartoonish, but they were animated to indicate which student was playing. After modelling and animating, the assets were imported in Unity, where the virtual music class was assembled and the training was developed. The developed listening exercise for the VR training was based on one of the common deviations in music class. This common deviation was that the student played along with a different chord. The virtual student of note C was playing as if he was playing the note C', which meant playing too early.

This VR training was evaluated with participants to get a better understanding of the product that was being developed. The participants were enthusiastic about it and most of them would like to use it. Half of the participants were able to identify the correct virtual student deviating from the rest of the virtual music class. The most important feedback was they noticed a delay in animation and sound. Therefore, they were confused as they thought every virtual character was making a mistake.

At last, the delay of the animations and sounds were removed and feedback options were added. The feedback options are added to test the understandability of the simulated event in the training.

In conclusion, a proof of concept for a supportive VR training for pre-service teachers in music education has been established. A step has been set to support them in their teaching. It is feasible to develop such a VR application and it might be worth it to further develop the application.

Chapter 8 - Limitations and future work

8.1 Limitations

Out of the MoScoW prioritising, the elements that were defined under "Must have" were completed. During this process, there were limitations identified, which affected the process and progress of the development.

First of all, the music class was fixed at eight virtual students. In a real music class, there might be 30 students. For now, it can't be concluded if the number of students will have an impact on the virtual music class and on the comprehensiveness of the pre-service teacher. The hypothesis is that the pre-service teacher will find it more difficult to localize the position of one virtual student. This should be tested, when more students are implemented in the virtual music class.

Secondly, the animations were a limiting factor in my research. An approach was not found to automate the animations from Unity. It is a great chance that a PC and a CPU have a hard time running the application due to the long streams of animations of each virtual character. Not only was it time consuming to calculate the positions the virtual characters had to play, but it will also be inconvenient when in the future a new listening exercise will be added to the VR training.

In the third place, there was a high focus on the audio. In the end, there was less time to focus on other aspects, which will still be valuable to research for this VR training.

8.2 Future work

Of the MosCoW prioritising, the elements underneath "Should have" and "Could have" are recommended to be developed. In the first place, the number of exercises is limited. There is currently only one song ("The lion sleeps tonight") that serves as a base for the virtual music class playing chord notes with boomwhackers. There could be clapping exercises, singing exercises and exercises with different rhythmic instruments. The design of the listening exercises could be in close consideration with the pre-service teachers. In that case, the pre-service teachers could think of exercises that they would like to practice in the virtual music class. The aim of designing these exercises are to fit the VR training with the personal needs of the pre-service teacher.

In addition, the current listening exercise cannot yet be pinpointed to a certain grade in primary school. For this specific research, there have not been observations made of a real music class with a pre-service teacher. If observations were made in primary school, the designers of the VR training would have a better idea what kind of exercises could be developed for each grade in primary school. Furthermore, through user testing with newly invented listening exercises, the exercises could be classified into exercises with a difficulty level.

Furthermore, hints (i.e. visual feedback) could be implemented to steer the attention of the pre-service teachers to a certain position in the virtual environment. It could help them to notice what happens in the virtual environment. For instance, in the current music class the students are already divided into 3 sections. Each section could light up, when it is the turn of this section to play.

Also, the behaviour of the virtual students does not improve over time. When looking at the simulations of Mursion, people answer in real time to questions of the pre-service teacher (Dalinger et al., 2020). In the current virtual environment, animations and sounds are played, without other interaction between teacher and student. The implementation of this feature could make the simulation more real, as they would play the note correctly after making a mistake that was identified by the pre-service teacher.

Besides, if the teacher at the PABO suspects someone could benefit from a listening exercise, he could advise him to take a particular listening exercise. However, there are not yet accounts created for the various students at the PABO. This is part of future work. Adding to these accounts, insights can be provided, which only the teacher at the PABO can view. During his music lesson he can do a follow up on what exercises the students find hard in the VR training.

At last, this research has made use of the VR headset “the Oculus Rift S”. Oculus has become part of the company Facebook. For this research, it was possible to create an independent Developers Account. Via this account, the terms and regulations are part of Oculus rather than Facebook. As from January 2023 the Developers Accounts will be declined and everyone has to sign up via a Facebook account (“Registreren als Oculus-ontwikkelaar”, n.d.). This might invade the privacy of the students at the PABO. Other options for VR headset in education should be considered to preserve the privacy of the stakeholders.

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Appendix A: Manual for transferring graduation project to others

Materials

For this project, I have built my own PC. The VR headset “Oculus Rift S” requires a strong PC. The advantage of a PC ready VR headset is that you can test your Unity builds immediately. However, it was not a requirement for this project to have a PC VR headset. It can also be developed with a stand-alone VR headset. Another advantage of the Oculus VR headset is that there is an integrated stereo sound. This means that the virtual music class could be played via this stereo sound system instead of a pair of headphones. There still is a possibility to plug in headphones, but it is not mandatory to experience the virtual music class.

The PC that was built has the following specifications:

- **Graphics card**: RTX 2070 Super Windforce
- **Board**: Z390 Aorus Pro Wifi
- **CPU**: Intel Core i7 9700k
- **RAM**: Corsair 32GB DDR4-3200 Kit

For recording purposes, the monophonic microphone “Big Blue Ball” was used.

Setup Developers Account

To develop a Unity build for the Oculus, a Developers Account was created (link: https://developer.oculus.com/sign-up/). Hence, a Facebook account did not have to be connected to Oculus. Up until January 2023, it will be possible to set up a developers account. After this date, it will become a requirement to log into your Oculus VR headset with a Facebook account.

With this developer account you can create Test accounts. With these test accounts others can test your application.

Setup Oculus Rift S

To directly set communication between the Oculus and your PC, the program “Oculus” needs to be installed (link: https://www.oculus.com/setup/). Choose from the list the VR headset that you will be using for your project. In my case, I used the Oculus Rift S and scrolled down to find the software install button for this VR headset.

After completing the download, you have to follow the instructions. First, it is necessary to sign in with your Developers Account. Next, you can connect your Oculus Rift S or any other VR headset of Oculus to the Oculus software by pressing “Devices”, which can be found in the left panel. Follow the instructions provided by Oculus. Moreover, it is important to click “Allow unknown sources” underneath the tab “General”.

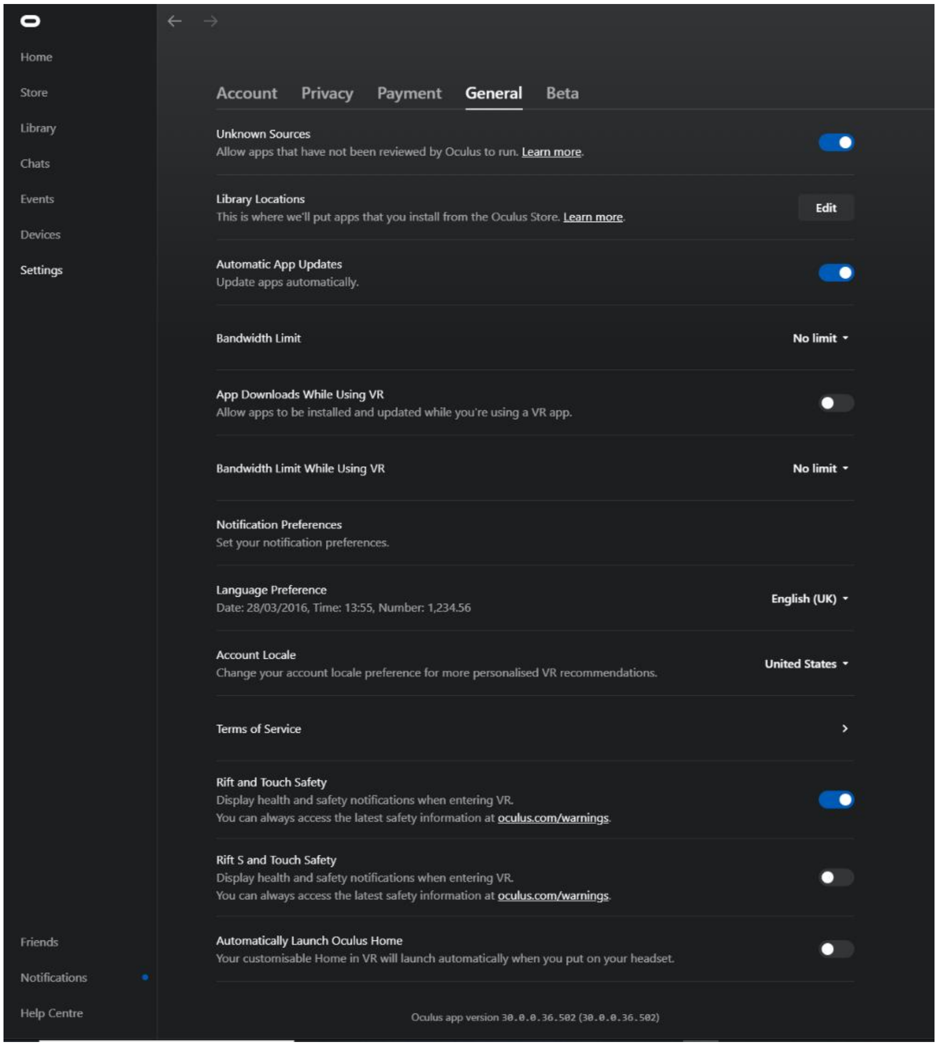

Figure 31: Screenshot of the Oculus software; in specific, it is important to enable the first option "Unknown sources".

Setup Unity project

On the website of Oculus, there is information available on how to integrate Oculus with Unity or any other platform (link: https://developer.oculus.com/rift/). Especially for Unity it is important to download the Oculus Integration Package via the Asset Store (link: https://developer.oculus.com/documentation/unity/unity-import/). With this package, you can use their assets and you can drag and drop the OVRcamera into the scene (to look through the VR headset in the virtual environment).

On YouTube, there are various tutorials available to set up the Unity Project. One of the tutorials I have used is the following: https://www.youtube.com/watch?v=J5pWiDf16mM&t=30s. Another tutorial I have followed is the following: https://www.youtube.com/watch?v=sKQOlqNe_WY. They also explain step by step how you can have hand presence with the Oculus Touch Controllers in your Unity Project.

Setup FMOD project

For this graduation project, I have used the middleware “FMOD”. FMOD is designed for music instruments and is easy to use with Unity. First, you have to download the software via their website (link: https://www.fmod.com/).

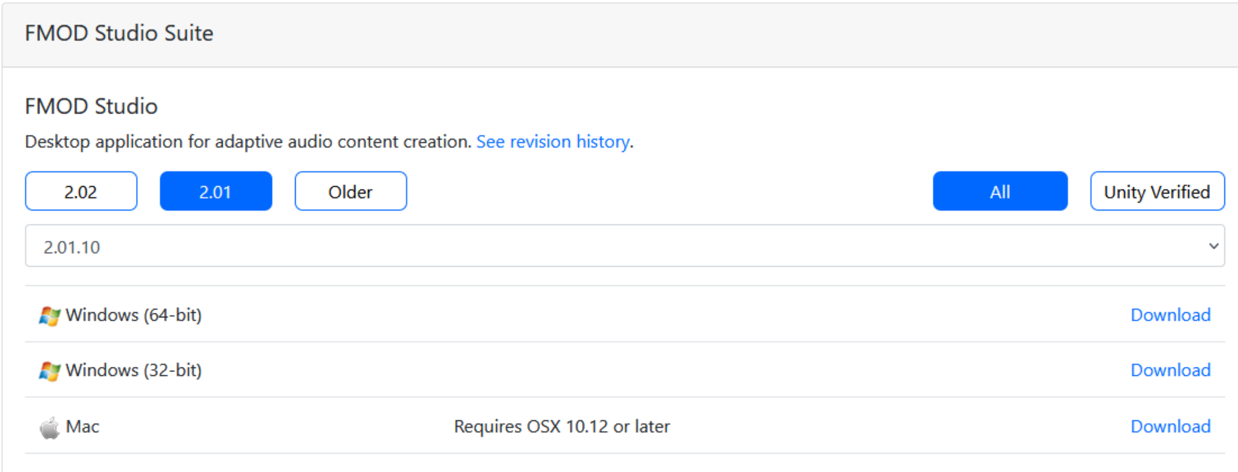

Figure 32: A screenshot of the download page of FMOD.

Then, it needs to be able to communicate with Unity. Therefore, a FMOD plug-in needs to be downloaded via the Asset Store in Unity. Typing “FMOD” in the search bar, the FMOD integration package can be found.

After the integration of FMOD with Unity, you have to set the Studio Project Path. Click on FMOD in the top bar, then click on “Edit settings”. Afterwards, you can set the project path by clicking on “Browse”.

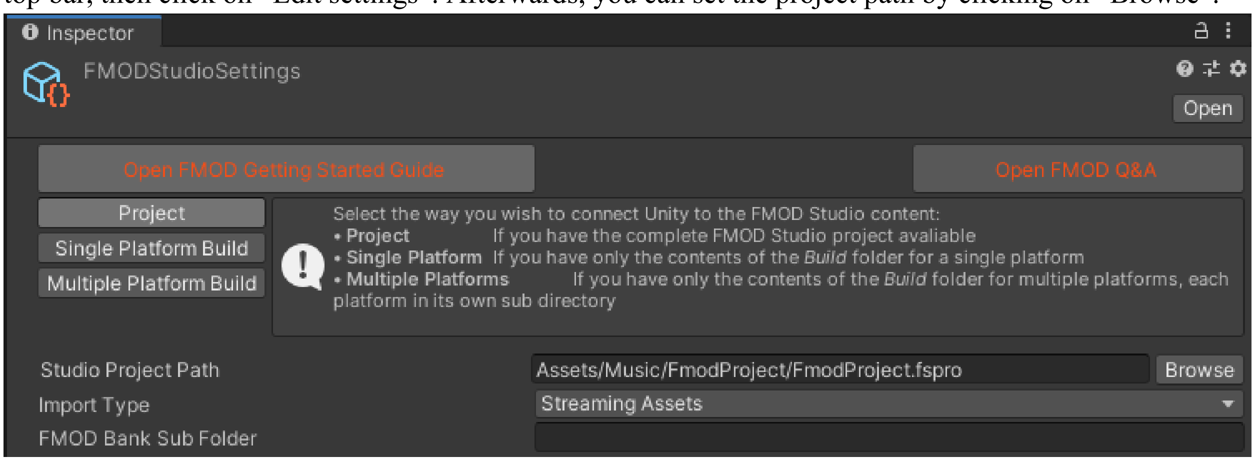

Figure 33: A screenshot of setting the FMOD Project Path.

A more detailed tutorial can be found here: https://www.youtube.com/watch?v=TlqHnrFnJXs.

There are multiple ways to use FMOD. For a detailed description and help manual, you can find documentation here: https://www.fmod.com/resources/documentation-studio?version=2.02&page=welcome-to-fmod-studio.html

I will quickly go through some of the steps I have taken. First, I have added another plugin to FMOD and Unity: the Oculus Spatializer (link: https://developer.oculus.com/documentation/unity/audio-osp-fmod/).

Secondly, I followed this tutorial, which tells you step by step how to integrate the Oculus Spatializer with FMOD and Unity: https://www.youtube.com/watch?v=5M5zwxo91Ds&t=562s.

After adding the Oculus Spatializer to FMOD and Unity, it was possible to create sounds with the Oculus spatializer. In FMOD, I created a 3D event. Then, I added the soundtrack to the timeline. Then, I removed the default spatializer.

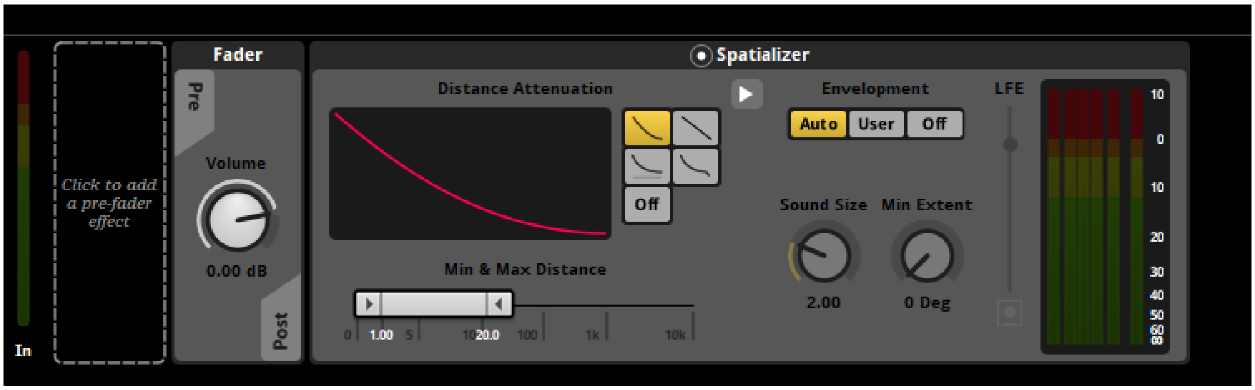

Figure 34: A screenshot of the default spatializer in FMOD.

After removing this spatializer, I clicked on the master track. Then hovered over the input signal “In”. I clicked with my right mouse button on to this input signal and clicked “Mono”. This is a mandatory step, because the Oculus Spatializer only works with mono input signals. The next step was to add the Oculus Spatializer to the FMOD project. You can right click on the following item to add the Oculus Spatializer:

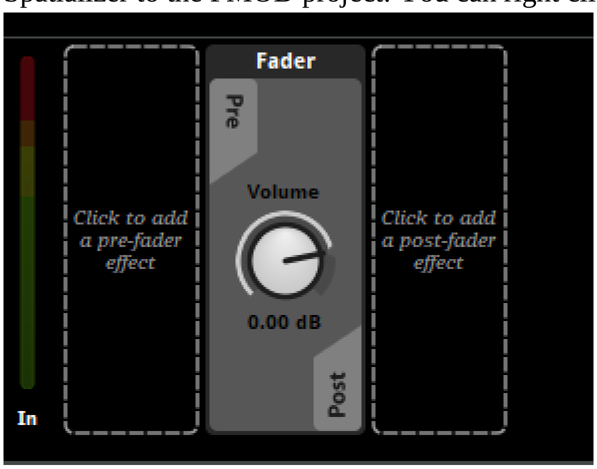

Figure 35: A screenshot when the default spatializer is removed from the FMOD 3D event.

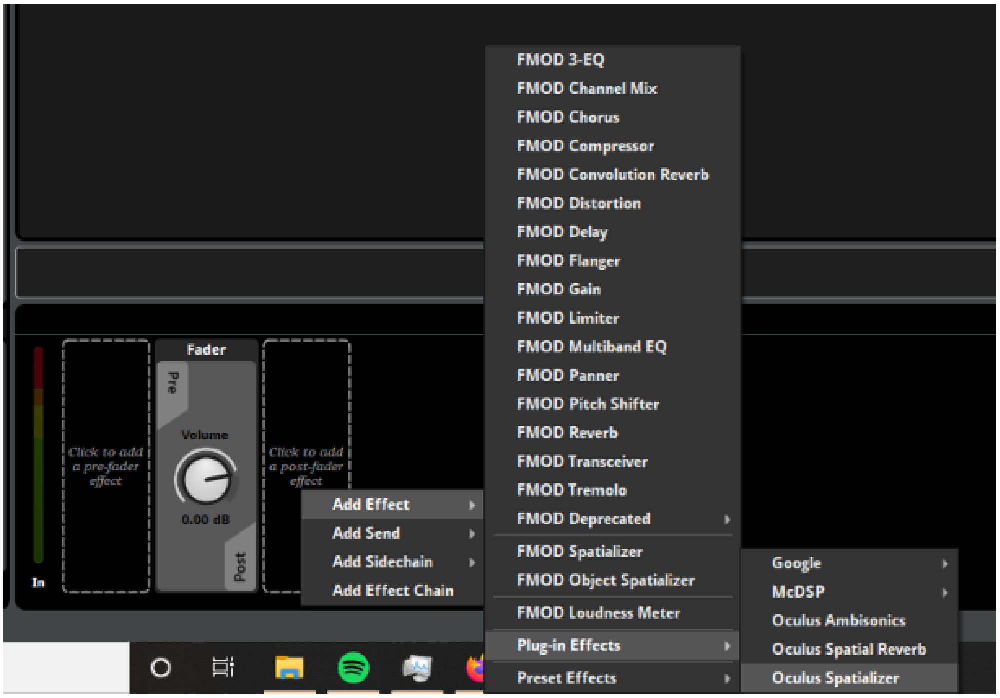

Figure 36: A screenshot of adding the Oculus Spatializer to the 3D event.

Adding my project to your Unity Hub

To try out my application, you can open it via Unity Hub by clicking on the “Add” button. Afterwards, you can find the application in either your downloads folder or your folder with the other Unity Projects.

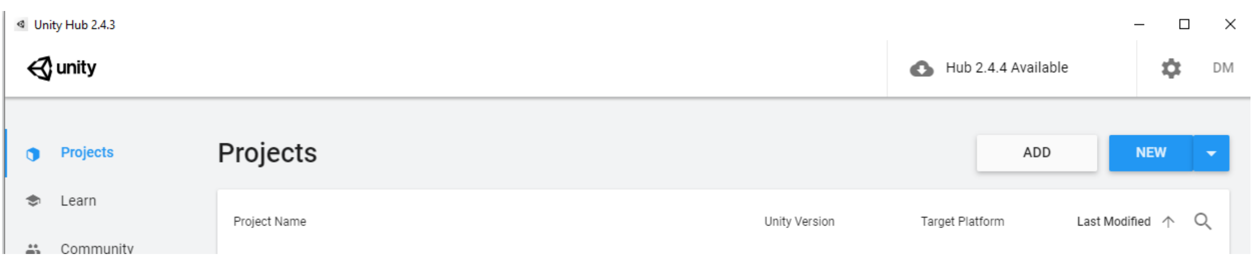

Figure 37: A screenshot of Unity Hub; with the Add button, projects can be added to the Unity Hub repository.

Appendix B: Information brochure

Informatiefolder onderzoek in de klas
'digitale technologie bij muziekonderwijs'
Universiteit Twente

Onderzoeksgroep:
Human Media Interaction
Benno Spieker MA, doctoraal student
b.p.a.spieker@utwente.nl

Deze brochure gaat over deelname aan onderzoek van Universiteit Twente en Gent Universiteit. De informatie in deze brochure helpt je te beslissen of je mee wilt doen.

Het onderzoek wordt geleid door Benno Spieker. Als iets niet duidelijk is, kun je hem altijd om extra uitleg vragen. De contactgegevens staan hierboven vermeld.

Technologie voor het muziekonderwijs van de toekomst

Onderwijs is altijd in ontwikkeling. Er komt steeds meer aandacht voor muziekonderwijs en digitale leermiddelen die het leren van kinderen kan ondersteunen. Bij de Universiteit Twente doen we hier onderzoek naar, met onderzoekers in interactieve technologie en muziekonderwijs.

Voor dit onderzoek organiseren we leeractiviteiten op (hoge)scholen, waarbij onder andere gebruik wordt gemaakt van digitale technologie. Tijdens deze activiteiten evalueren we hoe kinderen, studenten en/of (vak)leerkrachten werken met de nieuwe technologie. Dit doen we met behulp van vragenlijsten, interviews en observaties van de deelnemers tijdens de activiteit. De (hoge)school en de deelnemers maken zo kennis met nieuwe vormen van onderwijs. Voor ons, de onderzoekers van de Universiteit Twente, levert dit waardevolle inzichten op, waarmee toepassingen van technologie verder ontwikkeld kunnen worden. Het onderzoek richt zich dus niet specifiek op jou als deelnemer, maar vooral op het verkennen van de mogelijkheden van de technologie in het muziekonderwijs.

Je hebt aangegeven te willen deelnemen aan een activiteit die deel uitmaakt van dit onderzoek. In deze folder leggen we uit wat dit voor jou als deelnemer betekent, hoe je mee kunt doen aan deze activiteit, en welke basis-spelregels we samen hanteren. Je beslist zelf of je meedoet aan de onderzoeksactiviteit.

Lees de folder rustig door voordat je beslist of je wilt meedoen. Als je vragen hebt kun je contact opnemen met Benno Spieker (contactgegevens: zie op de voorkant van de brochure).

UNIVERSITY OF TWENTE.

Contactgegevens onderzoeksgroep:
Human Media Interaction
Dennis Reidsma
d.reidsma@utwente.nl

V1.0 – Mei 2020

Onderzoeksactiviteiten van Universiteit Twente op school: Hoe werkt het?

Per onderzoek wordt gevraagd of je wilt meedoen aan de betreffende activiteiten. Je geeft jouw toestemming door het toestemmingsformulier in te vullen en te ondertekenen.

De toestemming geldt voor de periode dat het onderzoek loopt. Het kan zijn dat je aan meerdere activiteiten meedoet. Als je in de loop van deze periode van mening verandert kun je jouw toestemming ook weer intrekken. Gedurende de periode word je op de hoogte gehouden van de activiteiten die worden georganiseerd.

Is het verplicht om mee te doen?
Je doet niet mee zonder jouw toestemming. Je beslist zelf over jouw deelname aan het onderzoek. Als je besluit niet mee te doen, hoef je verder niets te doen. Je hoeft niets te tekenen. Je hoeft ook niet te zeggen waarom je niet wilt meedoen.

Wat gebeurt er tijdens de activiteiten?
Je neemt deel in een gesprek met de onderzoeker(s) en/of andere deelnemers, doet een interview of vult een vragenlijst in; je werkt (alleen of samen) aan een (leer)taak; je leidt een leertaak. De leertaak kan van alles zijn. Bijvoorbeeld iets met een tablet, op papier, met een (digitaal) muziekinstrument of andere leermaterialen. In sommige gevallen wordt de technologie van de activiteit op afstand bestuurd door een onderzoeker, soms zonder dat je dit door hebt. Tijdens de taak worden gegevens verzameld over hoe je met de leermaterialen en werkvormen omgaat. Op deze manier krijgen we beter zicht in het samenspel van technologie en leren. Nadat een activiteit is afgelopen leggen wij uit hoe de technologie werkt en krijg je de kans om extra vragen te stellen. Indien bij de leeractiviteit kinderen worden betrokken, zal eerst om toestemming worden gevraagd bij de ouders of verzorgers van de betreffende kinderen volgens een soortgelijke procedure als deze.

Wie verzint en begeleidt de activiteiten?
De activiteiten worden ontworpen door de onderzoekers van de universiteit. De directe begeleiding van de activiteiten is in handen van de onderzoeker(s).

Welke gegevens worden verzameld?
Gesprekken worden geregistreerd, bijvoorbeeld door het opnemen van audio of video. Leertaken worden geobserveerd, waarbij mogelijk video-opnames worden gemaakt. Audio-opnames, video's, observaties, interviews, vragenlijsten en op papier vastgelegde (leer)taken worden zo anoniem mogelijk verwerkt en bewaard. De onderzoeksgegevens worden conform de richtlijnen van de VNSU minimaal 10 jaar bewaard.

Wie kan de verzamelde gegevens bekijken of beluisteren?
De video- en audio-opnames, observaties, vragenlijsten, interviews en op papier vastgelegde (leer)taken zijn enkel toegankelijk voor mensen die betrokken zijn bij dit onderzoeksprogramma. Een lijst met namen van mensen die toegang hebben tot het materiaal is beschikbaar en kan worden opgevraagd bij de onderzoeker, Benno Spieker. De materialen zullen absoluut niet publiek beschikbaar gemaakt worden of gebruikt worden voor reclame- en communicatiedoeleinden tenzij je daar schriftelijk toestemming voor hebt gegeven, nadat dat aan je wordt gevraagd.

Kan je jouw toestemming ongedaan maken?
Natuurlijk! Als je aan het begin van de onderzoeks-periode toestemming hebt gegeven, maar je wil niet meer meedoen aan een activiteit, dan kan je dat doorgeven aan Benno Spieker. Je zal dan niet meer meedoen aan de rest van de activiteiten van die periode. Als je wilt dat de eerder opgenomen beelden en audio-opnames alsnog worden verwijderd, dan kan je dat ook doorgeven.

Wie krijgen informatie over de resultaten?
De universiteit zal de onderzoeksresultaten openbaar maken, onder andere als onderdeel van een publicatie. Daarnaast is het ook mogelijk contact op te nemen met de onderzoekers en te vragen om de resultaten. Deze zullen jou dan worden toegestuurd. Tijdens het interview kun je de aanwezige onderzoekers aanspreken met vragen over het onderzoek.

Meer informatie en onafhankelijk advies.
Wil je graag een onafhankelijk advies over meedoen aan dit onderzoek, of een klacht indienen, dan kun je terecht bij de secretaris van de Ethische Commissie (ethics-comm-ewi@utwente.nl). De commissie bestaat uit onafhankelijk deskundigen van de universiteit en is beschikbaar voor vragen en klachten rondom het onderzoek.

Voor overige vragen kun je terecht bij de onderzoekers van de universiteit.

Appendix C: Informed Consent

Toestemmingsformulier

Betreft: Toestemming voor deelname aan activiteiten op *ArtEZ Hogeschool voor de kunsten* in het kader van het onderzoek naar *'digitale technologie bij muziekonderwijs'* van de Universiteit Twente.

Studiejaar: 2020/2021

Als je akkoord gaat kun je hieronder aankruisen dat je toestemming geeft. Vervolgens kun je de verdere gegevens invullen en het formulier ondertekenen.

☐ **Ik ben over dit onderzoek volledig geïnformeerd en verklaar dat ik 18 jaar of ouder ben en vrijwillig aan dit onderzoek deelneem. Ik geef toestemming voor het verzamelen van geanonimiseerde onderzoeksmaterialen zoals beschreven in de bijbehorende informatiefolder. Ik geef ook toestemming voor het maken van audio- en video-opnames voor onderzoek en evaluatie. De video's worden enkel door betrokken onderzoekers bekeken. In het geval de betrokken onderzoekers de audio- en video-opnames publiek willen maken of vertonen aan derden voor demonstratie of rapportage, dan wordt mij daarvoor eerst om toestemming gevraagd.**

Uw naam ……………………………………………………………………………………

Datum………………………………………………………………………………………

Handtekening:

…………………………………………………………………………………………………….

Contact informatie

Mocht je vragen hebben over dit onderzoek dan kun je contact opnemen met de onderzoeker: Benno Spieker (b.p.a.spieker@utwente.nl). Voor meer informatie: zie de informatiefolder bij dit formulier