21th century music lessons: Design and prototyping of a piano visualizer that augments digital music lessons with visual feedback

Thomas de Rooij

Faculty of Electrical Engineering, Mathematics & Computer Science

Supervisor: Prof. Dr. Mariëlle Stoelinga
Critical observer: Benno Spieker

13/07/2022

UNIVERSITY OF TWENTE.

Abstract

Due to the COVID-19 pandemic, all education was moved to online alternatives for multiple months. During this time, teachers and students involved in music education found that the available online platforms were not satisfactory for musicians' needs. These platforms gave rise to a long list of problems related to lacking social interaction, lacking user-friendliness for low digital literacy users or lacking features tailored to musicians. For this reason, the company Briegel has been developing an online music school platform commissioned by Kaliber Kunstenschool, a music school located in Enschede.

This bachelor thesis describes a Creative Technology approach of designing a concept to aid the quality of online music education for individual instrumental lessons. In this thesis a concept is formed, prototypes are built and thereafter these are tested. This concept aims to solve some of the problems found in existing platforms. The final prototype is a tool that consists of two parts. The first part is a visualisation meant to visualise the instrument played by the teacher. The second part is a sheet music function, where users can write a piece of music score onscreen. This prototype is built within the environment of Briegel's online music school and was qualitatively tested with piano teachers and students.

To conclude, the developed tool aids in the quality of online music education, regardless of digital literacy. The tool needs to be developed further and needs to be tested with larger sample sizes to further confirm its validity. Next to this, there needs to be further research into visualising how an instrument is played. Future work directions could include looking into a similar concept for instruments outside the piano or developing a platform suited for music education without the presence of a teacher.

Acknowledgement

First and foremost, I would like to thank Prof. Dr Mariëlle Stoelinga and Benno Spieker for the supervision of the project and the continuous help and feedback. I would also like to thank Briegel and Kaliber Kunstenschool for their help in the project. Lastly, I would like to thank The Line-Up a group of graduating students who motivated me to come to the university every day and work on this project as hard as I can.

Table of contents

List of figures

1. Introduction

Due to prolonged lockdowns, instated to limit the effects of the COVID-19 virus, much of (music) education was forced to move to online alternatives. Online education can be challenging, especially for musicians [1], since much of music education relies on physical aspects and online education gives rise to problems such as delay, video and audio quality and lack of physical proximity, which in turn cause several problems in the didactic methods of the teachers. Currently, online music classes (for individual instrumental teaching) mostly take place via platforms such as Zoom, Skype or other video conference platforms. These platforms allow for online education to take place, but next to the problems mentioned above, this often leaves students feeling disconnected from teaching materials, fellow students or their teachers, which demotivates students to study and attend classes [2]. Currently, no platform exists that is purely aimed at individual (instrumental) music lessons that solves both the technical difficulties as well as allows for teachers and students to apply the didactic methods that are applied in the physical classroom.

Thus, a new concept must be developed that will provide the key aspects that the physical classroom provides for students and teachers. Briegel, a company specialising in growing new businesses, is developing such a product for Kaliber Kunstenschool, a school of the arts located in Enschede. Briegel has already made a web-based platform with several functionalities including a metronome, recording function and the ability to upload and view images, among other functionalities. The platform allows a teacher to be in a ‘studio’ and after a student has logged in, they can join their teacher’s studio and make use of the functionalities mentioned.

In collaboration with Briegel, this research is focused on finding a solution to the lack of a full-fledged online music school. The solution should aim to increase the quality of online music education and be fit to use by all age groups attending Kaliber Kunstenschool. It must also cater to the didactic methods of the teacher at Kaliber, so they will not have to change their approach when switching between online or physical classes. This research will also be building on the existing platform that Briegel has made and is aimed at individual instrument music lessons of students aged 18+ to limit the scope of the study.

In this research a concept will be formed, thereafter a first prototype is built and tested which leads to a second prototype. This prototype is tested qualitatively again in a class-like environment. Finally, the prototype is evaluated on and conclusions are drawn.

The challenges facing teachers in online education allow for the following research question:

- How to design a concept to improve the quality of online individual instrumental music lessons?

This question allows several sub-questions to be composed that will also be answered during this research.

- What are the didactic methods of teachers and how are they satisfied?
- What practical functionalities (that are used in physical classrooms) should the product include?
- How should the social aspect, found naturally in physical music schools, be incorporated into an online platform?

A concise literature review is presented in chapter 2. There, research is done on what was missing during the COVID pandemic, what methods and platforms music teachers were using and what other online music school tools were providing. Chapter 3 provides brief explanations of the methods used in chapters 4 till 7, which are steps from the Creative Technology Design Method, as described by Mader & Eggink [3]. These include an ideation phase, a specification phase, a realisation phase and an evaluation phase. The research will conclude with answering the proposed research question(s) and making suggestions for potential future research.

2. State of the Art

2.1 Exigencies in music education

Instrumental music education has several elements that are regularly used in the physical classroom, beginning with the approach a teacher takes in music education. Traditionally, the approach taken in instrumental tuition is focused on immediately applying and putting a particular piece of music in context, the same goes for specific instrumental techniques [4]. This calls for use of multiple methods such as evolutionary mentoring and the Critical Response Process method, according to Hasikou. These methods need to be taken into account when creating a new concept for online music education, as the successful execution of the teaching methods leads to higher quality classes [5]. These methods are mostly based on verbal feedback and pedagogical knowledge, something easily practised in the physical classroom.

Next to the pedagogical approach, the physical attributes in a classroom are of importance too. Specifically, the instruments provided by music schools like a piano, guitar or drum set [1]. As not everyone can afford to have a classical piano at home, being able to practice at the music school is key to mastering the instrument for some. Research by Rucsanda et al. showed that both teachers and students agreed this was an important part of physical music schools [6]. As found by Calderón-Garrido et al., other important attributes of the physical classroom can write down notes in sheet music, having a metronome, being able to play together and being able to correct fingering or positions on the instrument [7]. These are aspects that are not included in the design of current online platforms but are imperative in the physical classroom, as will be shown in the next section. So these should be taken into consideration when designing a new concept for musicians.

2.2 Music education during the COVID-19 pandemic

A long list of challenges caused by online education can be made since teachers and students educate and learn in different ways, but here the three most important factors, that are generally found to be the biggest challenges, will be identified. Moreover, some advantages that online platforms provide will be identified too. The first problem is the missing physical aspect, which comes with a lot of the social part of the interaction such as face-to-face teaching and social relationships that are harder to maintain online [8]. Adding to this challenge of the digital environment are the missing attributes of the physical classroom, writing down notes and rhythms in sheet music, having a metronome, being able to play together and being able to correct fingering or positions on the instrument [8].

Among others, these are essential tools that are vital to mastering an instrument. Closely related to this challenge is the involvement and motivation of the students that need to be

taken into account [9] [10], which again is harder to maintain online. The missing physical aspects raise more challenges that will not be discussed here, as other aspects are deemed more important by teachers and students [8].

The next challenge is that both teachers and students have limited digital skills as well as being limited to technical requirements, according to correspondents of a nationwide survey in Spain [8]. Thus, the older the teacher, the less the advantages weigh up against the disadvantages, as was also found in the survey by Rucsanda et al [6]. This lack of skills prevents exclusive focus on the expressive interpretation and didactic methods usually applied by the teachers. The technical requirements of equipment are especially a problem for students in high poverty, where the money to buy a proper camera, microphone or even device to run a video conference program, might not be available to everyone [11] [12].

The third challenge lies more toward the didactic part of online education. Teachers found the social part, as mentioned before, to be an important part of the development of a musician, as they highlighted the ‘human warmth and relationships that are formed at school, both between teachers and students as students and fellow students.’ Which they find inspires students to try new things or play together with other people. Since online teaching is so different, teachers have had to renew their teaching methods and adjust their goals [8] [9]. New approaches in online learning lead to the loss of features of dynamicity, expressivity, and interactivity, all of which are crucial factors for enhancing students’ performance skills [8].

Although teachers and students found a lot of disadvantages in the sudden move to online systems, they also found some benefits too. Online platforms offer facilities such as “messages, emails, board discussion, file sharing, recording, chat, forums, better time management due to flexible hours, access from any location, and gain of time on transport” [13]. The advantages of flexible hours and access from any location were also found in a study by Theano [14], in this study it was found that most students found these to be the factors that proved to be beneficial for both students and teachers. More digitally skilled teachers have also been able to overcome the current challenges by using programs such as ‘MuseScore’ to be able to write down sheet music on the go, and find that the advantages weigh up the disadvantages [8]. So depending on the teacher, using online platforms could be beneficial.

2.3 Other online music school tools

Some software does exist that tackle some problems in online music education and provide more functionality for musicians than the average video conference platform. Examples of these include Elk.live & Doozzoo. Elk.live focuses on playing together, but admits there is still a 20ms delay [15]. Along with this comes jitter, the variance of delay, which means that

playing together is not fully real-time. To add to this, Elk.live does not seek to solve many of the problems found in the literature research done in this report. Doozzoo is aimed more at individual music classes, as it adds functionality and sound quality to the standard video conference software. These programs both aim at several problems that are found in online teaching but do not cover all problems. An example of this is the visualisation of musical instruments. This means there is still room for the development of new tools.

2.4 Discussion of background research

The goal of this literature review was to identify what students and teachers need in music education, what was missing in existing systems during the pandemic and what was done right. During the review, multiple problems were identified. The rise of the pandemic also led to a rise in research in this field, which is why so many sources provided extensive answers and came to the same conclusions. Ideally, a newly developed platform will include the aspects that students and teachers stated they missed during the pandemic, as mentioned above. Next to this it should provide the imperative aspects the physical classroom also has, like being able to practice pedagogical methods, having a metronome and being able to write down sheet music. More so, the different levels of competencies with technology mean the program has to be easy to use while including many different functionalities. If this is included in the design of an online music school software, it could lead to a more seamless integration to a point where the line between a physical and digital classroom is blurred. Unfortunately, not all of the advantages mentioned earlier apply to every software and every user, so the effectiveness of class in an online method might vary per individual.

A limitation of this literature research is the lack of research available on important (specific) attributes in music schools and how often or when teachers and students make use of these. An example of this is the exact number of students that do not have instruments at home but instead only play at the music school. To add to this, there should be research specific to the instrument and then the necessities are still very different per student, teacher and school. This makes it difficult to compare what students were missing in the pandemic to what was being used, in terms of physical attributes. Another factor limiting this research is culture. Methods and teaching differ a lot per country and culture [16], so the factors that students might be missing in Spain might not be as important to Dutch students. Another limitation that this project has is the ‘live playing together’ component of music education. Even though teachers have mentioned that this was of high importance, as found above, this is too hard to implement in a new platform. This is due to delay and jitter, a variation in delay. Delay can be compensated for but this can not be done for jitter. As made clear by the participants of a study by Riley et al. [17], even low latency solutions do not fully solve the problem. This means that online collaborative music will not be handled in this research.

3. Methods

3.1 The Creative Technology Design Process

The methodology of this research is based on the Creative Technology Design Process [3], the core of the Creative Technology bachelor's study. This method will serve as a guideline for designing, testing and implementing the concept of this project. This approach, as proposed by Mader et. al [3], can be seen in Figure 1. It shows the four phases of designing, ideation, specification, realisation and evaluation. These phases consist of diverging and converging phases, where in the diverging phase the design space is opened up and defined. The converging phase, on the other hand, reduces the design space until a solution is found.

The ideation phase entails the process of finding a general solution to answer the proposed research question. This means coming up with a creative idea by making use of methods such as divergence and convergence techniques, the stakeholder analysis, interviews and more, depending on the design aspect. This phase results in a product idea with several design requirements.

With the output from the ideation phase in mind, several prototypes are used to explore the design concept in the specification phase. Here, a short evaluation and feedback loop is applied, since the functionality affects the user experience and the user experience unveils possible required changes to the functionality. Based on this, new concepts are formed and evaluated. This phase ends with a new, more specific prototype.

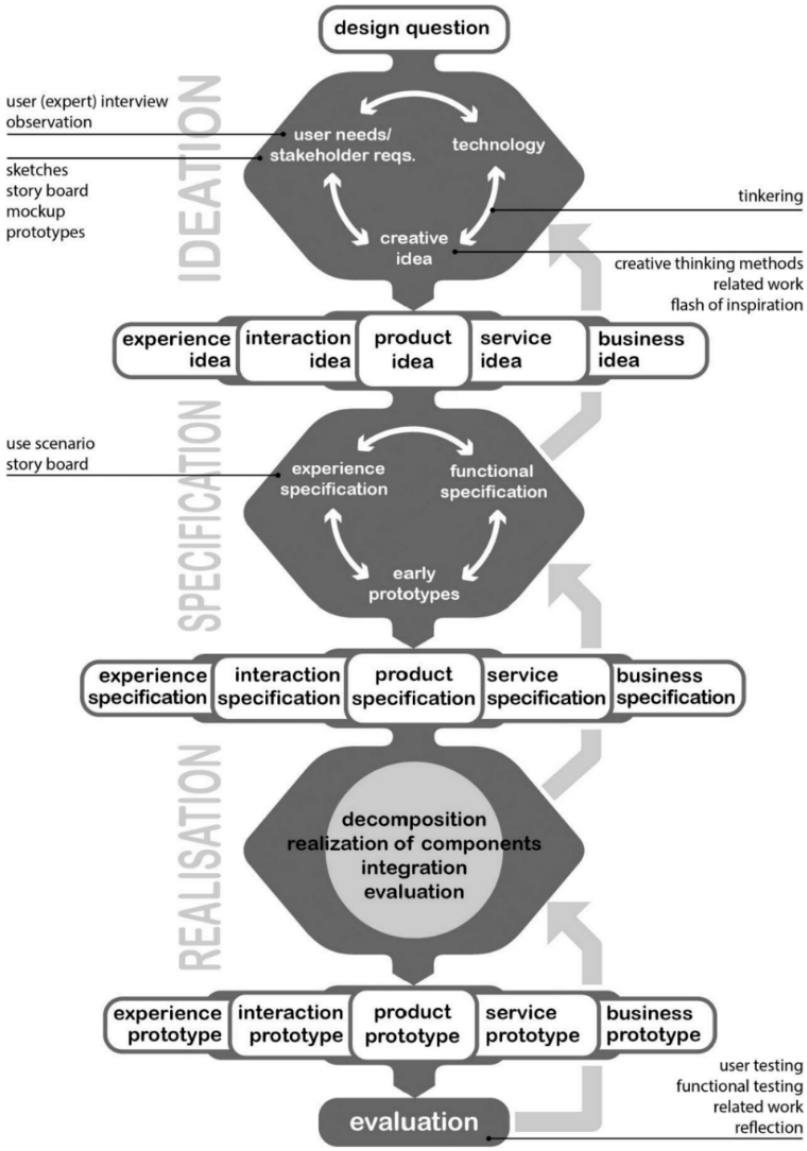


Figure 1: Creative Technology Design Process

Next is the realisation phase, where the finalized prototype is tested as a whole, so the concept can be fully verified. This also requires an integration of all the previous findings and data.
The final phase is the evaluation where no more changes will be made to the prototype, but instead, the final concept is evaluated on based on the previous user tests to see if all the design requirements are met. This is then reflected on and recommendations for future research will be given.

3.2 Chapter 4: Ideation phase

The ideation phase is the phase used to form a concept or design. In the case of this research, this is done by performing a stakeholder analysis, conducting interviews with music teachers and setting up a list of requirements that are then ranked.

3.2.1 Stakeholder analysis

A stakeholder analysis is performed to identify the relevant parties in this research. The key parties will be identified through brainstorming as well as findings from the literature research. The stakeholders will be ranked in an Importance / Influence matrix [18]. This matrix maps the influence of a certain stakeholder as well as the importance of a stakeholder. Here, the importance is the priority given to satisfying the needs and interests of said stakeholder and the influence is how much their needs weigh in to the final design.

3.2.2 Interviews

To get a better insight into what teachers in the Netherlands have experienced during the pandemic, interviews are conducted. These interviews will be done with two teachers from Kaliber Kunstenschool and one teacher from ArtEZ, the University of Arts in Enschede. These interviews are semi-structured, addressing several important topics related to this research but with the freedom for the interviewee to add any comments and assist in generating ideas as to what the new concept should include. This information will be used in the concept creation during the ideation phase.

3.2.3 Requirement analysis

To be able to identify the requirements that the concept should include, a requirement analysis is performed. Here, the key stakeholders will be interviewed to gain insight into what they require. How these interviews are done is elaborated on in the next section. The requirements will be analysed using the MoSCow method [19]. MoSCoW is an acronym for:

- **M**ust have
- **S**hould have
- **C**ould have
- **W**ould have

This is a prioritization technique to rank all aspects of a project so the most important things are worked on first while less important things can be left for future sprints. Or in this case, future research. This way of ranking priorities gives a clear expectation for each items' completion.

3.2.4 Concept formation

Based on the methods in the ideation phase, as mentioned in 3.2.1-3.2.4, it can be decided what functionalities should be included and how these should take shape. This includes the requirements found in the requirement analysis, relevant insights from the interviews and the stakeholder analysis. The results from these will give a broad sense of the concept that can be made more detailed in the specification phase.

3.3 Chapter 5: Specification phase

3.3.1 First prototype

As mentioned before, this research builds on the platform that is currently being developed by Briegel. Currently, the product is a web interface consisting of a studio environment. Using the requirement analysis done is section 4.3 and the other results from the ideation phase, a first prototype is created. The prototypes will be developed by adding features to this interface, by using a User Interface design program. For this research, Figma & Adobe Dreamweaver are used to visualise the tools and make them partly functional. In order to specify the concept in-depth, the prototype will have multiple stages. The first prototype will consist of two separate Lo-Fi (Low Fidelity) prototypes, to test separate concepts. These have little functionality as they test if the concept solves a certain design requirement. After these are tested, a Hi-Fi (High Fidelity) prototype is made that is tested again. This will be closer to a completed product. Next to the user experience, this prototype tests if the functionality of the concept meets the design requirements.

3.3.2 Evaluation of the prototype

When the first prototype is created it will first be shown to the experts at Briegel. The functionality of the designed tools influences the user experience, and demands on this experience may require changes in the functionality [3]. New demands, based on the input from Briegel, will be set and the prototype will be evaluated. These demands will be incorporated in a new prototype, that will be tested, as according to the feedback loop mentioned by Mader et al. This Hi-Fi prototype is then taken into the Realisation phase.

3.3.1 Usability testing

Data will be collected on the usability and functionality of the designed tools. This will be done with piano teachers who have taught during the COVID-19 pandemic. The subjects will be asked about their digital literacy beforehand, so the prototype can be tested on people

with varying digital literacies. The subjects will be asked to perform several tasks relating to different goals for the usability test. During the performance of these tasks the participants are observed and afterwards they are interviewed about their experience with the prototype.

3.4 Chapter 6: Realisation phase

3.4.1 Second prototype

In the realisation phase, the concepts that were tested separately are brough together and made into the second prototype. As the prototypes have been tested on functionality and user experience separately, there will now be a final user test in which data will be collected to verify if the design has met all requirements. This prototype has also incorporated solutions to any issues found in the first usability test.

3.4.2 Second Usability test

The prototype will again be tested in a setting closely resembling online education. Here it is important to verify if the product meets its goal, aiding in increasing the quality of online music education. Here two things will be verified:

- Verification of the functionality
  Do the concepts provide the features that were missing during the pandemic? Are they user-friendly?
- Verification of aid in quality of education
  Do the concepts improve the online education environment?

3.5 Chapter 7: Evaluation phase

In the evaluation phase the final prototype is evaluated on technical aspects, functional aspects and if it has met the requirements. This evaluation is done based on the data from the first and second usability test and by looking back at how the prototype was made. This evaluation is then used to draw conclusions.

4. Ideation

The goal of the ideation phase is to find the design requirements. Through multiple methods explained in sections 3.2.1-3.2.4, multiple requirements are found. In this phase, a visualisation will be made for what these concepts should look like in the first prototype. These concepts are then incorporated in a first prototype in the specification phase.

4.1 Stakeholder analysis

The stakeholders of this project will be analysed using an Importance / Influence matrix [18]. The requirements for these stakeholders will then be included in the requirement analysis in section 4.3. First, a table is made where all stakeholders are listed and their importance and influence are ranked. A stakeholder's Influence is the power a stakeholder has to facilitate or impede the achievement of the concept's objectives. Importance is the priority given to satisfying the needs and interests of said stakeholder.

The relevant stakeholders in this project include:

Teachers at Kaliber: The teachers are the users that will be using the interface the most, as they have to interact with numerous students per day. As they are the ones who decide if the program is suitable to use when teaching online, their importance and influence are both high.

Students at Kaliber: Students at Kaliber will be using the interface about once a week for 20-30 minutes. The students also have a high importance, since their satisfaction weighs in with the teachers' opinions. Their influence is slightly lower than that of the teachers, however, as teachers spend the most time using the program.

Briegel: Briegel is the company on which the concept, formed in this research, builds on. Briegel has a vision for their platform and this research will be accommodating that vision as well as do independent research of what is necessary.

University of Twente: The University of Twente is the stakeholder that both provided the project and supervises it. The university also gives feedback and an assessment of this research. The guidance from the University is of high influence of the direction of the research, but in the design there will be no requirements that take the University into account, hence its low importance.

Other music schools: While teachers at Kaliber Kunstenschool are the end-users of the developed concept, the aim of this research is to increase the quality of online education, so the concept should be applicable in all of music education. This leaves this stakeholder to not have a high direct influence, but their needs should be considered.

Kaliber Kunstenschool: Next to the teachers and students at Kaliber Kunstenschool, the rest of the school is also seen as a stakeholder, due to the management of Kaliber making the

decision whether or not the product should be bought and should be applied in their educative environment.

Future students: During this research, multiple problems are found in online education and during the ideation phase some solutions for these are found. However, due to the time span of this project not all solutions can be worked out. This is left for future research.

Table 1: Importance & Influence ratings for all stakeholders

Stakeholder	Importance	Influence
Students at Kaliber	5	4
Teachers at Kaliber	5	5
Briegel	4	5
University of Twente	1	4
Other music schools	3	1
Kaliber Kunstenschool	3	3
Future students	1	2

The results from Table 1 lead to the following Importance / Influence matrix in Figure 2. This matrix is used to look at what requirements should weigh in more while creating the prototypes.

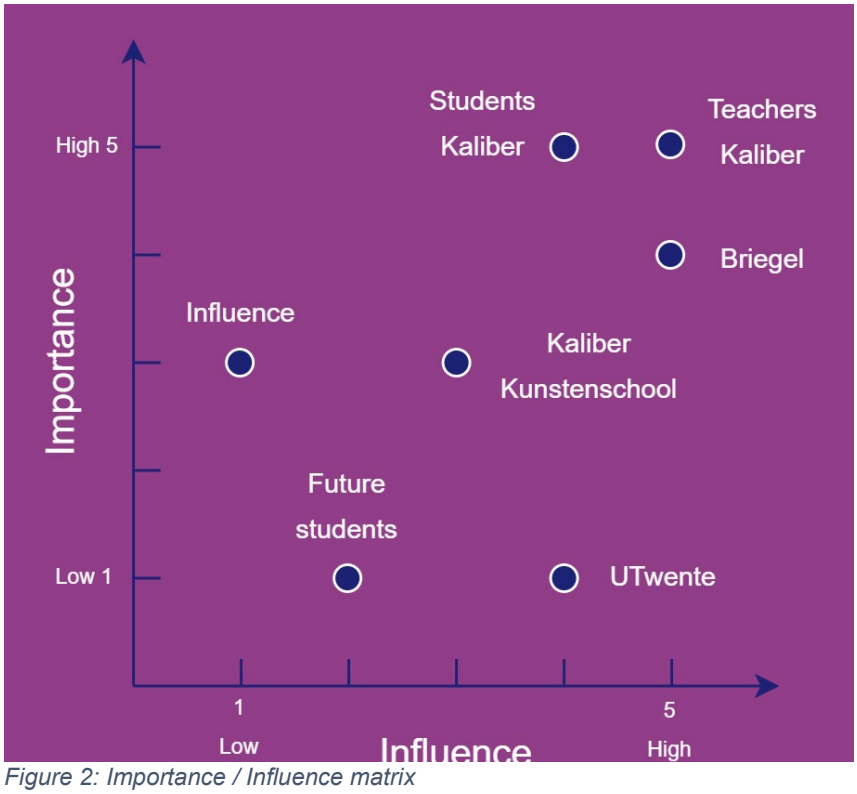


Figure 2: Importance / Influence matrix

4.2 Interviews

As part of the ideation process, experts in the field of music teaching were interviewed in order to generate ideas for what the tool should provide as well as ask about their experience during the pandemic and incorporate this in the requirement analysis. Three teachers were interviewed, all in the context of music lessons for one to three students lasting twenty to thirty minutes. The questions were asked in the context of students that are 18 years or older, since that is the target group for this research. A drum, piano and recorder teacher were interviewed based on the questions found in appendix A. The drum teacher teaches at ArtEZ, meaning they mostly teach professional musicians. The other two teachers teach at Kaliber Kunstenschool, the music school for which this tool is being developed. First, some general findings about online music education during the pandemic will be summarized, according to the answers in the interviews. Second, it will be discussed what specifically was missing in existing online platforms. Last, the questions aiming at the new concept formation will be discussed.

To get a sense of the general experience the teachers had with online education, some questions were asked regarding their lessons during the pandemic in terms of quality of education, teaching style and what online tools they used. During these exploratory questions a lot of issues were raised that will not be handled in this research nor will they be solved by the tool developed during this research, but they will be mentioned for future research. The first major issue here was technical issues. Teachers mentioned that most students do not have a home studio with proper recording devices and the ones that did, still had issues with internet connection or camera quality. Not having proper microphones or cameras led to teachers not being able to properly hear the instruments, especially the more nuanced sounds that are more apparent in real life. As for the camera setups, most students used the cameras built into their laptops, leaving teachers struggling to see the whole instrument or the exact hand placement on an instrument. This is not always necessary, but combined with stuttering audio due to a bad internet connection, this meant understanding what the person on the other side was playing was a lot harder than in real life. Even though the pandemic lasted for multiple months, teachers mentioned they could not expect students to buy equipment, since the situation was considered to be temporary and equipment can be expensive. Another issue caused by online platforms is not being able to play together due to latency. All teachers also mentioned that there were some small advantages. However, these did not weigh up to the disadvantages of the current state of online music education. They did mention that they see the potential in the platform if it becomes more tailored to musicians. The advantages these teachers found included having everything at hand (being able to easily show a .pdf containing sheet music, or browsing the internet for examples), not

having to travel to or from the music school and making music lessons possible even when someone is sick or has the corona virus.

As briefly mentioned before, teachers felt that online platforms had potential to be incorporated into their standard practice, but they would not do so in the current state of the platforms. There are multiple key problems that need to be solved in order for the workflow of the short, individual lessons to be efficient. The first problem specific to the online platforms these teachers used was the social interaction. As stated in section 2.2, social interaction relies heavily on physical presence. Two out of the three teachers in this interview also found mentioned this and experienced the lessons to be more “one-directional” than before. So teachers expressed their needs for a platform that is less one directional and instead gives way for a more interactive way of teaching online. A second problem the drum teacher added was automatic gain control for drum lessons. As the gain would compensate for the loudness of the drum set, their voice would not be audible anymore for multiple seconds after they stopped playing the drums. The other teachers too mentioned they had problems with audio being of poor quality. A problem that all teachers found was showing what was being played. For guitar, the camera can often see either the teachers face or the guitar, but rarely both without the guitar being in a weird position. For more experienced students, this was less of a problem as they heard what was being played or the teacher would say what note it is and the student could find it themselves on, for example, the guitar. For students less experienced with these skills, however, showing where the note is on the instrument is imperative. Two of the teachers also mentioned this is the case with piano and drums, as they heard from other teachers too.

When asked about the didactic methods that these teachers used, they replied that they did not use any specific methods for students above the age of 18. All teachers did state that they looked at what they had done the previous lesson, how they had improved and where there was still room for improvement. After this the teachers would look at what they would play next class. Even though the teachers stated that they did not use any specific methods, this closely relates to Gagné’s Taxonomy of Learning [20]. This model describes nine levels of learning:

Gaining attention → Identifying objective → Recalling prior learning → Present stimuli → Guiding learning → Eliciting performance → Providing feedback → Assessing performance → Enhancing transfer.

From the context provided by the teachers, this learning model was used most of the time. This model can be incorporated in online platforms too, if the teachers are able to view and listen to the students performance to provide feedback.

The questions in the last part of the interview were more focussed on problem solving, rather than identifying. Before the interviews, some topics that are commonly found in the physical

classroom were listed based on the background research done in sections 2.1-2.4. For this list of topics, possible solutions were thought of to translate how this topic might take shape in a online classroom. This was done by means of brainstorming. The teachers were asked to rank the solutions based on importance, meaning the feature they feel is the most important to have in a program is ranked the highest. Teachers were also free to comment on the specifics of a solution or add their own solutions. The solutions that was ranked the highest was the ability to write notes in some form of sheet music, both for rhythmic notation as well as for playing notes on any instrument. Next was a social media feature. As stated multiple times before, the social interaction that physical classes bring was missing and is a vital part of music education and education in general, also according to these teachers. Ranking third, was a visualisation of the instrument, being able to see what notes are played where. The three interviewees were in agreeance that these things had the top priority, so the others will not be discussed here. Two of the three teachers mentioned the sheet music functionality to be a must, while the third-ranked the visualisation feature higher.

4.3 Requirement analysis

4.3.1 List of requirements

To preform the requirement analysis, the MoSCoW method is used [19]. A list of requirements has been made, through brainstorming and based on the research done in earlier chapters. Some requirements are listed here:

- Concept is usable regardless of digital literacy.

As the concept will be used by people of all age groups, it should be usable with low-effort. This means controls have to be intuitive and user-friendly.

- Concept visualises the instrument that is played (what notes/drums are hit etc).

The concept should provide an accurate and (close to) real-time visualisation of what part of the instrument is being played by the teacher/student.

- Concept visualises the notes being played on said instrument in a sheet music form.

Next to the instrument being visualised, the notes played can be visualised for students who are educated to read sheet music.

- Concept is suited for all skill levels of students.

These means the product should also include all combinations of notes or complex harmonies in sheet music etc. Ranging from beginner to advanced, the concept should be an asset to the education of the student.

- Concept allows for teachers to explain music theory in full.

The concept should not be a drawback when explaining theory. It should accommodate for all major elements in music theory.

- Concept includes a rhythmic / sheet music notation option.

Writing rhythms or melodies on the fly / onscreen with simple interaction to quickly visualise what the teacher is explaining.

- Concept is fit for multiple instruments.

As the end-users are teachers at Kaliber Kunstenschool, all the instruments taught there should profit from the concept.

- Concept allows for students to practice music theory without the presence of a teacher.

The concept can be of additional help outside the range of individual instrumental lessons, with interactive ways of learning theory or practicing scores.

- Concept is easy to setup.

The concept should be 'plug & play' meaning only one or two actions are necessary by the teacher to start working with the concept.

- Concept visualises hand/body position when playing the instrument.

Next to the note being played, how it is played is of importance in music too.

- Concept fits into Briegel's product.

As the concept builds on Briegel's product, it should be made to fit into that environment.

- Concept allows for playback of MIDI files, recorded or uploaded by the user.

The concept provides options that current platforms do not, in terms of uploading MIDI files.

- User can choose what parts of the concept are visible on screen.

To change the layout to fit the needs of a teacher or student, the concept should be customizable.

- Concept improves social interaction, as compared to the current state of learning platforms.

Using the concept leads to an improvement of social interaction as compared to platforms used during the pandemic.

4.3.2 MoSCoW Analysis

Now that the list of requirements has been composed, they will be ranked according to the MoSCoW method. First, the definition of each category is given.

Must Have requirements are the requirements that the concept needs in order to successfully fulfil the given design problem. These may be defined using the following guidelines:

- No point in delivering on target date without this; if it were not delivered, there would be no point deploying the solution on the intended date.
- Not legal without it.
- Unsafe without it.

- Cannot deliver a viable solution without it

Should Have requirements are defined as:

- Important but not vital.
- May be painful to leave out, but the solution is still viable.
- May need some kind of workaround, e.g. management of expectations, some inefficiency, an existing solution, paperwork etc. The workaround may be just a temporary one.

Could Have requirements are defined as:

- Wanted or desirable but less important.
- Less impact if left out (compared with a Should Have).

Won't Have are requirements that are left for future implementation, due to the time frame of the project. Suggestions to meet these requirements will be mentioned in the future research section.

Having defined the definitions of the four categories, all requirements can be divided. Using the definitions, first the Must Have requirements are set up.

Must Have requirements:

- Concept is usable regardless of digital literacy.
- Concept visualises the instrument that is played (what notes/drums are hit etc).
- Concept visualises the notes being played on said instrument in a sheet music form.
- Concept includes a rhythmic / sheet music notation option.
- Concept is fit for multiple instruments.
- Concept is easy to set up.
- Concept improves social interaction, as compared to the current state of learning platforms.

Should Have requirements:

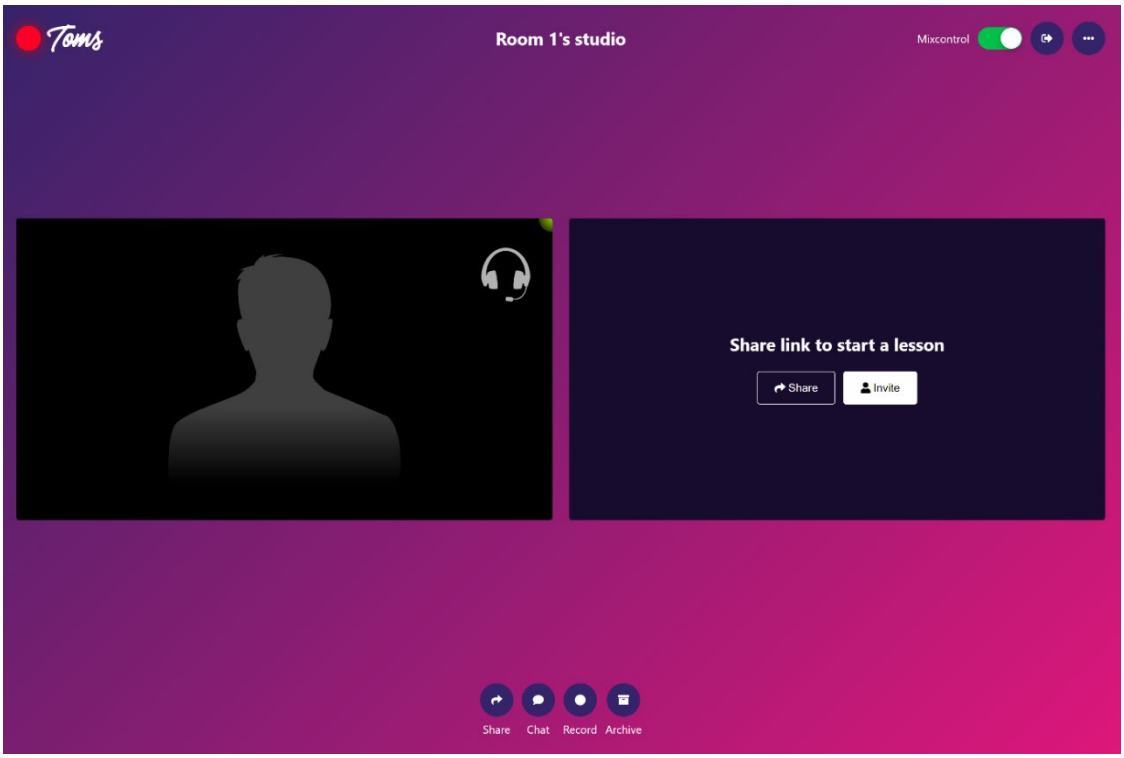
- Concept is suited for all skill levels of students.
- Concept fits into Briegel's product.

Could have requirements:

- Concept allows for teachers to explain music theory in full.
- User can choose what parts of the concept are visible on screen.

Won't have requirements:

- Concept allows for students to practice music theory without the presence of a teacher.
- Concept allows for playback of MIDI files, recorded or uploaded by the user.



Having categorized every requirement, the concept can now be formed. Some requirements will be used in the concept, but will not appear in full in the prototype, as the time span of the project allows for a proof-of-concept prototype and not a fully developed one.

4.4 Concept formation

4.4.1 Concept

In sections 4.1-4.4 multiple requirements were found. Due to the limited time span of this project, two solutions will be developed and other solutions will be discussed but not developed nor tested in his research. For this research, the lack of visual elements of the instruments will be looked at as well as the problem of writing sheet music. These solutions will be developed within the existing product of Briegel, as shown in Figure 3.

To start off, the concept should be applicable for multiple instruments as Kaliber Kunstenschool teaches in wind, string and key and percussion instruments. Next to this it should clearly be visible to the student what the teacher is playing on their instrument. To accommodate for students with different learning styles, for example visual or theoretical, both of these ways will be incorporated. As is the case in many keyboards, electric pianos or online piano visualisers, this means the instrument is visualised (visual learning) as well as the notes being played in sheet music form (theoretical learning). This leads to the following first concept, worked out in Adobe Photoshop:

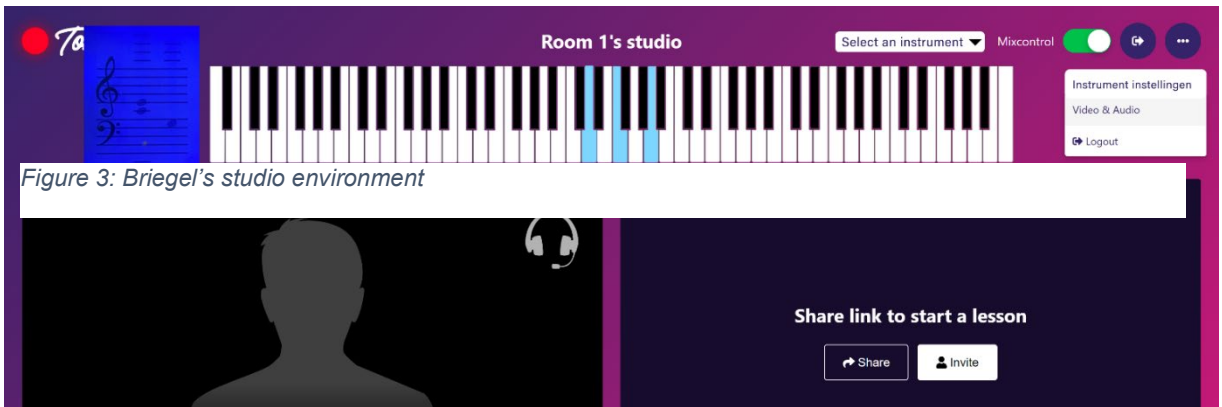


Figure 3: Briegel's studio environment

As can be seen in Figure 4, there is a piano above the student and teacher (student on the left, teacher on the right) of which the keys light up when the teachers plays those on his piano, in a blue shaded colour. These keys will light up automatically, if played and an electric piano is connected via a MIDI cable. In the top right a “Select instrument” option can be seen where the teacher can choose what instrument is displayed on the screen. To add to this, by clicking on the three dots in the far top right the settings of the selected instrument can be adapted. These settings could include the time a note is displayed, the colour of the keys is or perhaps the size of the piano.

In the top-left corner a picture of sheet music notation can be seen, where the notes displayed on the piano are also shown as score, to accommodate for students that are more used to sheet music. This picture was taken from a keyboard in a music store, that served as inspiration for the sheet music part of the concept.

In the current state, the tool aims to solve two problems. First is the visual aspect that is present in the physical classroom. The tool visualises what the teacher is playing, without the teacher having to aim a camera at their hands or have two cameras set up. In this way, both the teacher and the piano can be on screen. This brings us to the second problem, the social interaction. This is again something that is hard to do online, but keeping the camera free to aim at the teacher and not the instrument should accommodate to this problem.

As mentioned before, the concept is not only developed for piano but also for other instruments. The concept for a percussion instrument looked very similar, as can be seen in Figure 5. One worry, that will be addressed in section 5.2, is that on smaller screens the drum-kit will be too small to see, especially since the user is far away from their laptop since they are sitting behind their drum-kit. Another disadvantage, for both the piano and the drum-kit, is that the teacher needs to own an electric piano or drum kit in order for it to be visualised.

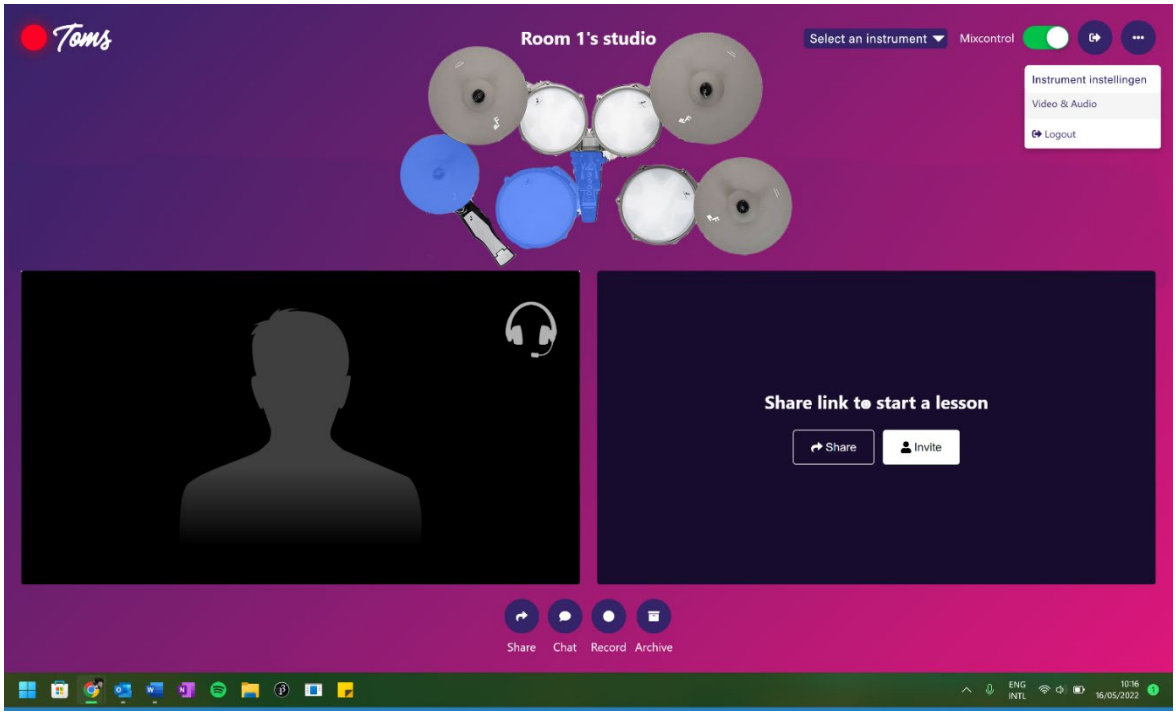


Figure 5: Percussion visualisation concept

For string instruments, it is harder to recognise what note is played, especially since two of the same note can be played at different locations on some instruments. For this reason, the concept for guitar lessons will work differently than the concepts for percussion and piano. Instead of the instrument lighting up on screen when music is played, the teacher will be able to select by hand what note is played where by clicking with the mouse on a position on the guitar. Above the instrument, the note will be displayed. This makes that the interaction with the tool takes longer than the other instruments, as every note has to be manually selected. A solution to this could be to make a set of pre-made chords that the user can choose from. This window could be on the right of the guitar and the user can choose “C chord” after which they choose a position, for example the first position as shown in the picture in Figure 6. What is important here is to also display what notes are selected. As can be seen in Figure X, the notes C – E – C are displayed when the C chord is played. Their heights vary, depending on what string they are being played, to give a general shape of the chord when reading the notes. This is the same shape as highlighted in blue on the neck of the guitar.

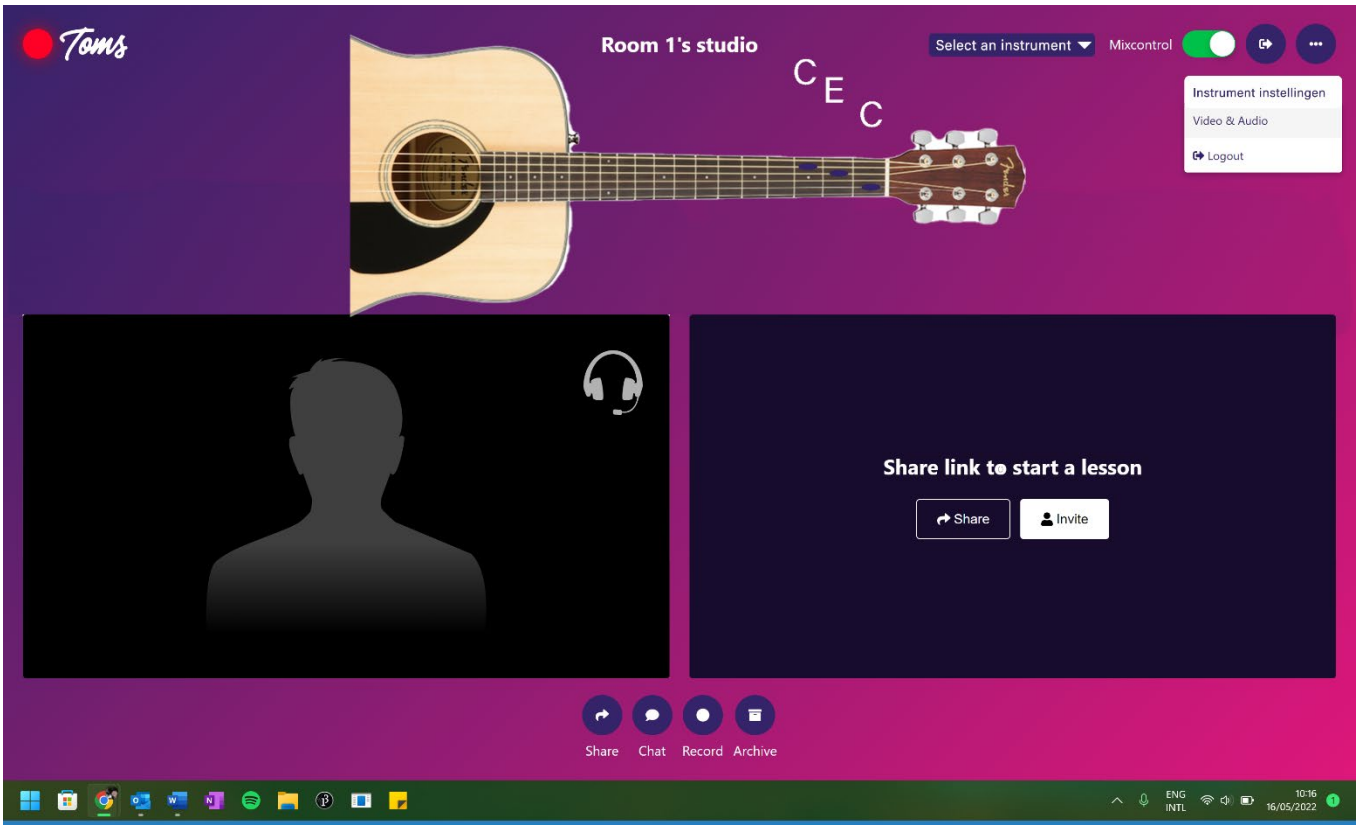


Figure 6: Guitar visualisation concept

Next to the visualisation of an instrument, the teachers that were interviewed ranked a sheet music function to be of high importance. The sheet music feature does not have to be too complex, as several sheet music programs exist that have numerous complex features and allow for a big variety of functionalities. Teachers and students can share their screen or upload images in the studio environment, so if a teacher wants to explain theory to advanced

students, there are other options. These options include screensharing Logic, MuseScore or Notion 6. This means that the sheet music feature is aimed at beginners who are no masters of music theory, so its features will reflect this.

The user needs to be able to write down notes at varying places with varying lengths, preferably by means of using just a mouse to keep interaction as simple as possible. On screen, two bars will be displayed, where the user can hover over certain spots to place a note. For rest notes, the user can click an option in the top-left, to change the functionality of hovering from placing a note, to placing a rest. To add to this, sharp and flat notes will have a similar button, where the next note placed will be a sharp or flat, depending on the state of the button. The concept can be found in Figure 7.

This concept will be placed below the teacher and student in Figure 4.

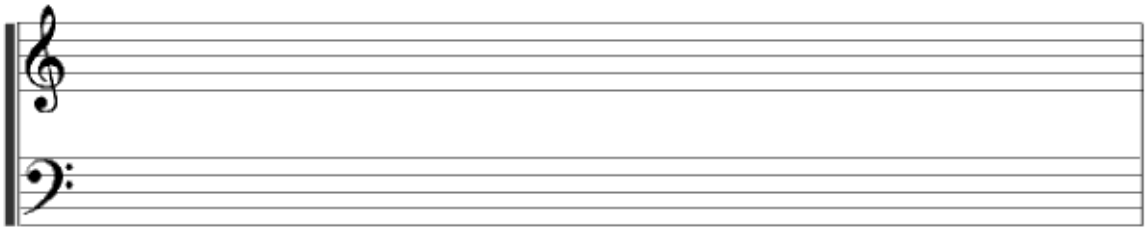


Figure 7: Sheet music function concept

So to conclude, the final concept looks like Figure 8. At the top there is a piano visualisation of the keys, in the top left corner the piano visualisation notes can be found and below the users the sheet music function is found. From here on out these will be referred to as such, the piano visualisation keys, piano visualisation notes and the sheet music function. The concept has been worked out for the 3 main types of instruments at Kaliber Kunstenschool. The tool visualises what is being played / supposed to be played, where the student can see on their screen what the teacher is doing. This concept can be applied to multiple instruments at Kaliber Kunstenschool and fits into the design of the program by Briegel.

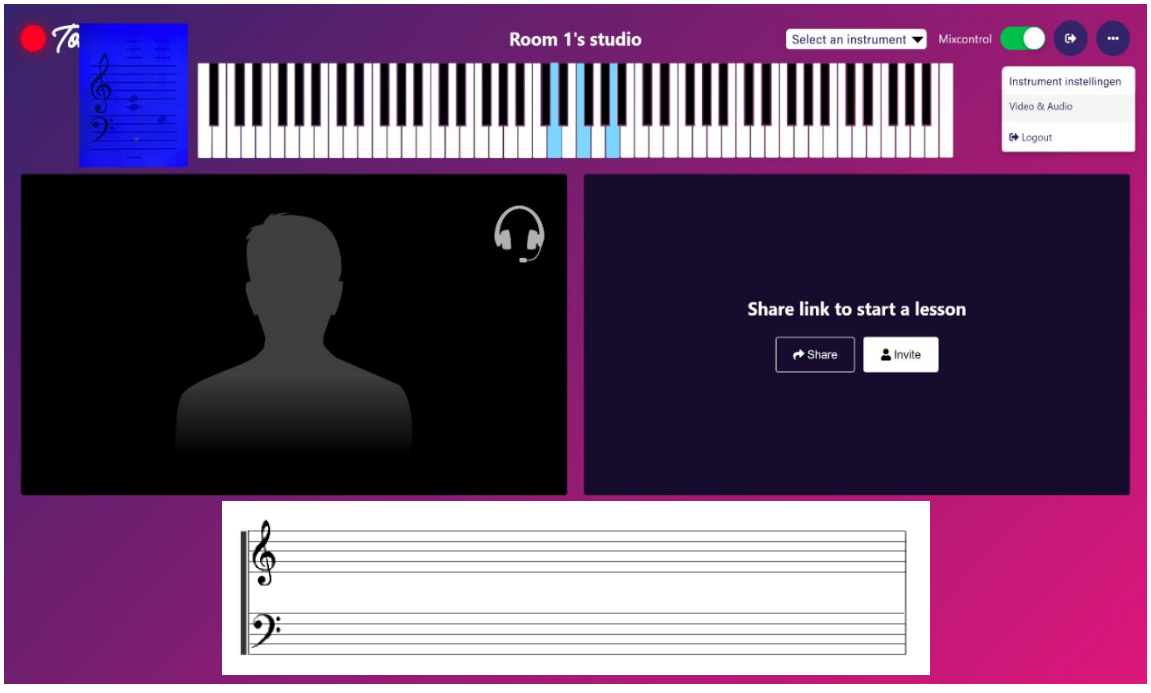


Figure 8: Full concept

4.4.2 Concept evaluation

Before the prototype is made, an short evaluation is done as per the Creative Technology Design Process [3]. First, the interaction will be analysed. The interaction of the prototype should be kept as simple as possible, to accommodate for users with low digital literacy. Currently, the interaction is straightforward. The teacher plugs in their electric device, the program connects and can be used. The only controls necessary to operate the sheet music function is the mouse, by clicking to place notes.

Currently, the concept is different for string instruments like the guitar. Since guitars can no be connected with a MIDI cable, future work should look into different solutions to recognise what is played on the guitar, for example with image recognition and sound recognition. This problem will not be tested in this research, however.

Next to this there is an option for instrument settings, but it has yet been decided what these settings should contain precisely. This is something that will have to be investigated during the usability tests.

As of right now, the piano visualisation notes are relatively small compared to the camera of the students and teachers. This might make it hard to see, but this is again something that will have to be tested. Another thing to evaluate on is the aesthetics of the design. Even though aesthetics is not the main goal of this concept, it is important to mention. In the concept formation the sheet music function appears a big white block on screen, which does not match the style of the rest of Briegel's program. This will not be handled in this research since it does not regard usability or functionality, only appearance.

Finally, the user needs to have an electric piano to be able to use the tool. This might not be available to all users, which mean some users would be excluded.

5. Specification

Based on the concept formed in the previous sections, a prototype is developed. In this chapter it will be explained how the prototype works and the changes it goes through as it develops. First, the basic structure and the functionalities of the prototype are explained. After that, the prototype is evaluated with the experts at Briegel and through means of an usability test. Thereafter conclusions are drawn on what should be changed for the second prototype.

5.1 First prototype

5.1.1 Environment

Part of the first prototype, the piano visualisation, is developed in Adobe Dreamweaver, an editor for web-based programming languages. Since the product by Briegel is a web interface based on HTML & JavaScript, the tool should also be built in these languages so Briegel can incorporate the tool into their product as easily as possible. To avoid creating problems within Briegel's product, the tool will not be built inside their environment but is instead built in a mock-up environment. This means it is not actually accessible for Briegel and it can not make use of the functionalities Briegel has already built. Instead, an image is used as the base image on top of which the tool will be built. This is the base image that can be seen in Figure 3. This choice was made since this research has limited time available and to avoid having to deal with complex problems that might arise in the software environment from Briegel. This way, the environment is simplified and thus the chances of problems in coding structure etc. are lowered. This does not effect the functionality of the tool but does avoid potential problems. The second part of the prototype, the sheet music function, is developed in Figma. Figma allows for easy visual design aimed at prototyping interfaces. These two will not be combined for the first prototype, since the concepts need to be tested and this can be done separately.

5.1.2 Program structure

The program that displays and updates the tool consist of a few different aspects. First of all, part of the prototype is developed in HTML using CSS and JavaScript. Here the main functionality of how the piano visualiser tool interacts with the user is mostly done in JavaScript. The script written makes use of the WebMIDI API by J. Cole [20]. This API allows for easy manipulation of information coming from a Musical Instrument Digital Interface (MIDI) cable, something that most electric instruments allow for. This includes pianos, drum kits and even recorders among others. The MIDI protocol saves information from the instrument like what note is played, its attack, release, duration or volume. Not all information will be necessary for this tool. For the first prototype it only needs to be known what note is

being played and for how long it is being played. Second is the other part of the prototype, the sheet music function, which is developed in Figma. For the first prototype, the design of the sheet music function is not yet put into the same environment as the piano visualiser, to be able to test it separately before implementing it.

5.1.3 Piano visualiser

The piano visualiser is the part of the tool that uses information from a MIDI cable. The program recognises if a MIDI device is connected making use of the WebMIDI API as mentioned before. If a device is recognised and a note is sent from the MIDI device, a corresponding image is toggled. The program has a base image of a piano with multiple, hidden, blue piano key images layered on top. Every key on the piano has a corresponding blue key, that is shown when that note is being played on the MIDI device. The blue keys were created in Adobe Photoshop where every separate key was exported as a PNG image, so it can be layered on top of the base image. Every image has a number attached to it, again corresponding with the information from the MIDI device. It is common that the left most key of the piano is communicated as the number 21 and the right most key is communicated as the number 108. The blue key PNG images are numbered the same so the program checks what note is played, e.g. 69, the A4 note on a piano and the corresponding PNG image is then toggled to be visible on screen. This method allows for multiple keys to be played at the same time, an important requirement for piano.

5.1.4 Sheet music function

For the sheet music function prototype, Figma is used. As mentioned, Figma allows for quick prototyping of interfaces with simple interactions. For this project, a template developed by Julia Diebold will be used as the basis [21]. In this sheet music function, a user can hover over 16 spots to place a note. These spots are arranged from left right, so in total 16 notes can be placed next to each other with the option to place multiple notes in 1 spot to form, for example, a chord. Depending on where the mouse is, the length of the note that will be placed changes. Hovering to the left of the note gives the smallest possible note length, 16th of a note. In Figure 9, the mouse is hovering to the left of the note. By clicking, it confirms the

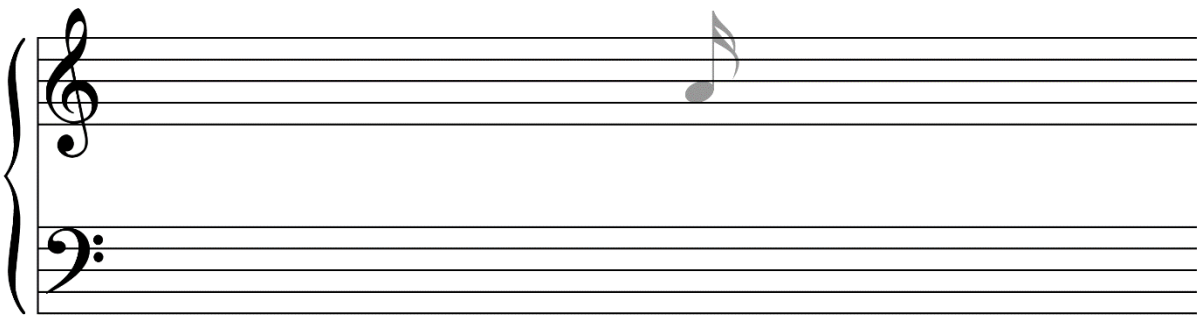


Figure 9: Sheet music function

note length, making the note a dark shade of black, like found in normal music notation. On the left of Figure 9, the G-key and F-key can be seen. The user can hover over these as well, so they can be changed to the opposite key. This gives flexibility to the user so the notation can be used for piano, in which a G key and F key are both commonly found, one describing the higher notes and the other the lower notes, respectively. On the left of these keys is the accolade, also commonly found in piano sheet music. The bottom key can be changed back to a G key, making the sheet function more suitable for guitar music. The sheet music feature allows for making simple melodies or explaining music theory concepts.
A user can, for example, write down a melody in the 4/4 time measure, like illustrated in Figure 10.

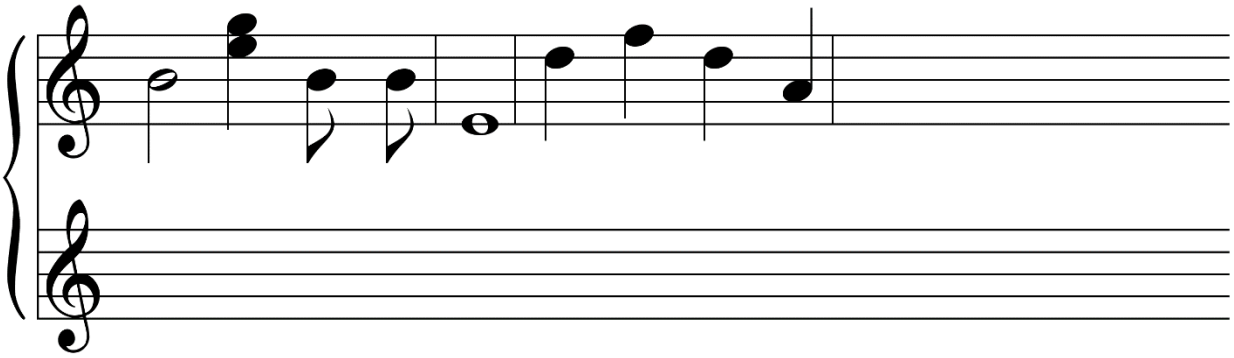


Figure 10: Notes in 4/4 time measure on the sheet music function

Or the feature can be used to explain theory with the help of a visual aid, like explaining all notes in the key of C, as shown in Figure 11. The location of this feature is underneath the user's webcam, that can be found in Figure 8.

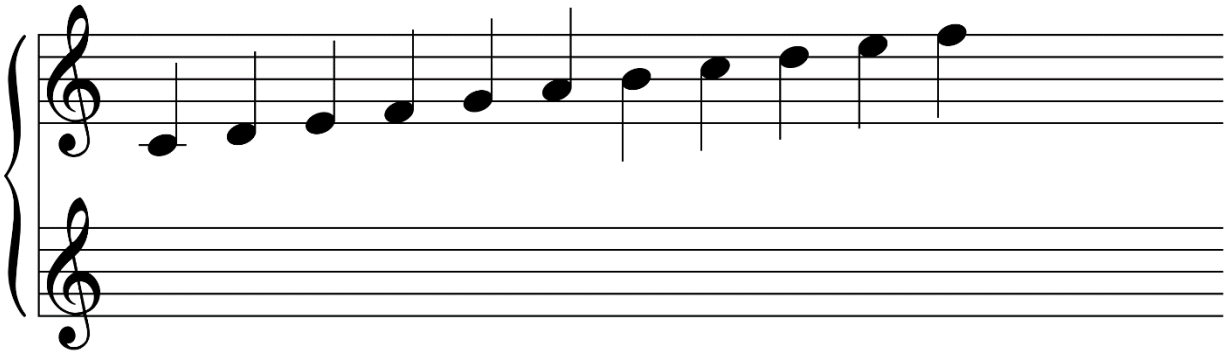


Figure 11: All notes in the key of C on the sheet music function

5.2 Evaluation of prototype

The first prototype was shown to the experts at Briegel. From this evaluation, it was concluded that the instrument should have a different place within the existing web interface,

namely in a similar way as the share screen option is displayed in the current program. This was decided because if the instrument is on screen, this is where the focus should be. This also eliminates the problem of the instrument being too small to view properly. When clicking on the ‘Share’ option on the bottom the screen changes to the following screen (Figure 12):

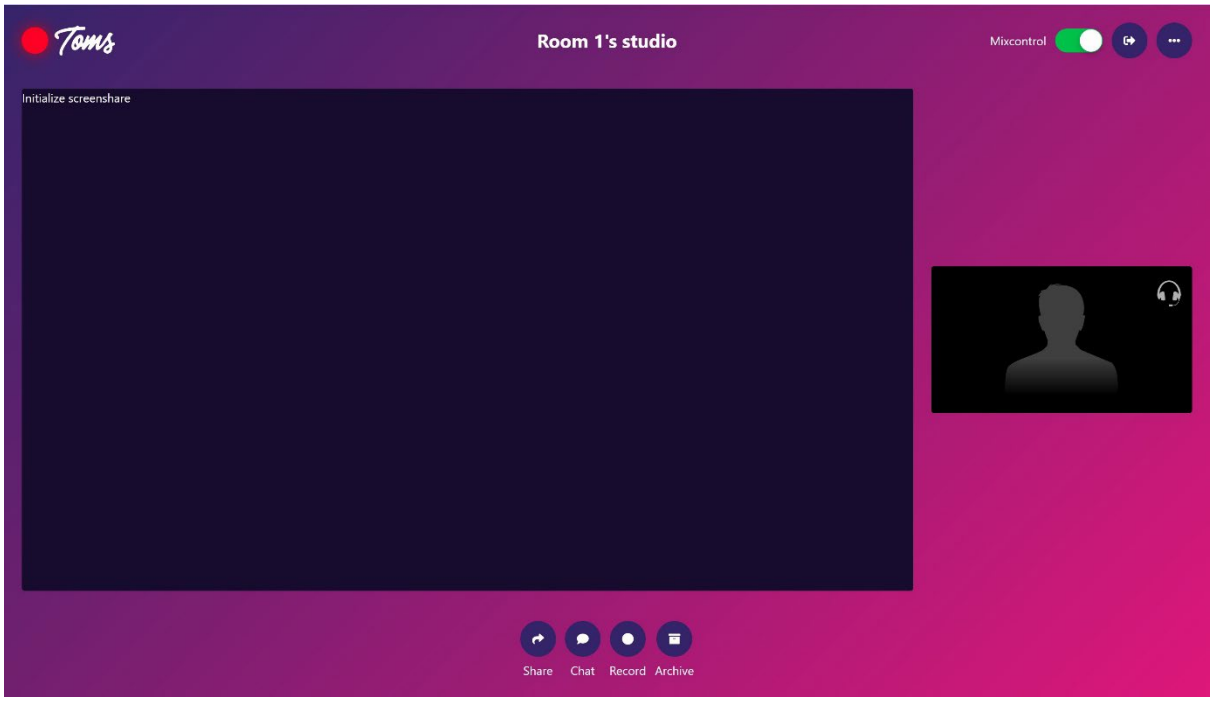


Figure 12: Share screen option

During a class, the teacher and the student will be displayed on the right, so the social component currently missing in online music classes, is still present through the video feed.

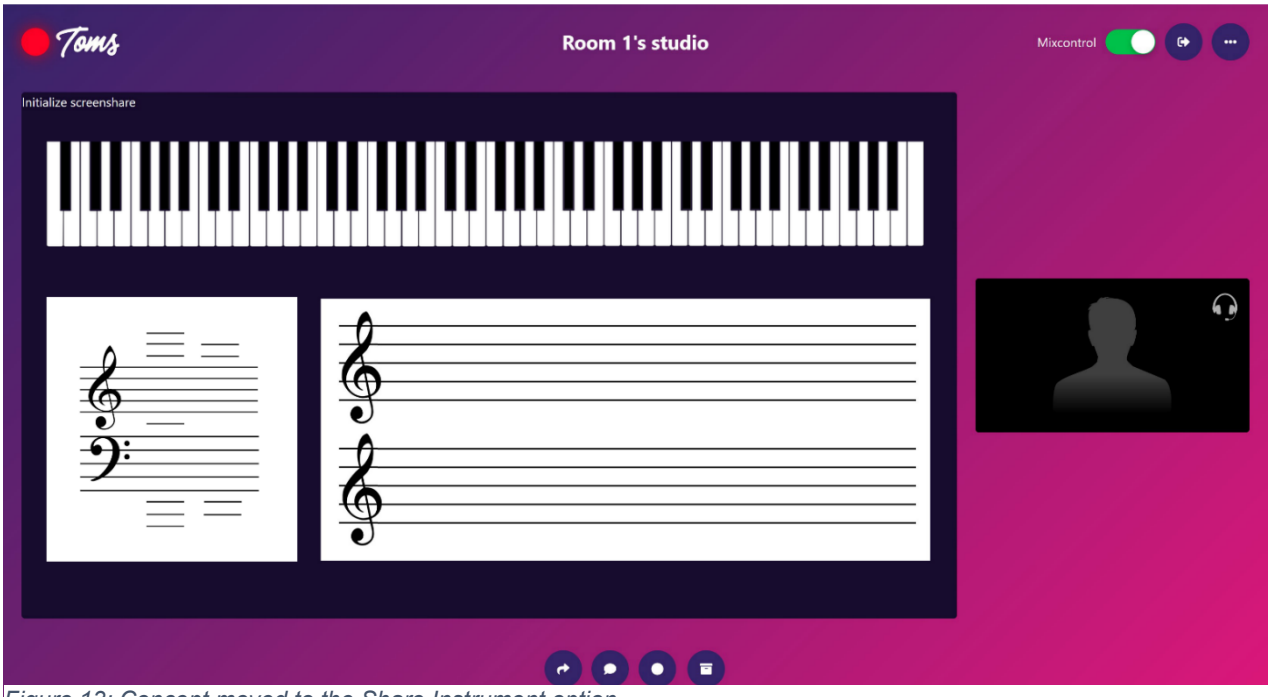


Figure 13: Concept moved to the Share Instrument option

In the big square on the left of Figure 12, the screen that is shared is displayed. This is where the instrument tool will also be displayed. Combining the previously shown piano tool with earlier mentioned sheet music tool in the new location, the leads to the following concept, as shown in Figure 13.

Below and to the right of the piano, the sheet music functionality can be seen. Here, the user can click on the signature (in this case the G key signature) to cycle through the available signatures. For piano scores, the bottom signature can be changed to a C key, so the top part of the sheet music function represents the right hand and the bottom part displays what should be played with the left hand. There will be designated locations to the right of the signatures where notes can be placed by clicking on the spot and then selecting the note that you want to place. Since this part of the tool is only for quickly writing down some simple rhythms and melodies, a time signature is not included as the teacher will always be with the student to explain what they are noting down and can provide context to the written music. It is important that this tool allows users to write down notes above each other too, to be able to write down chords or harmonies, which are more complex than just having writing down one note.

Now that the place of the prototype within the studio environment has moved, the interaction flowchart should be updated too. As seen in Figure 14, There is now a ‘share instrument’ option in the flowchart. Previously, the piano/instrument would always be onscreen. With the new design this is not the case, it is only used when the teacher or student need it.

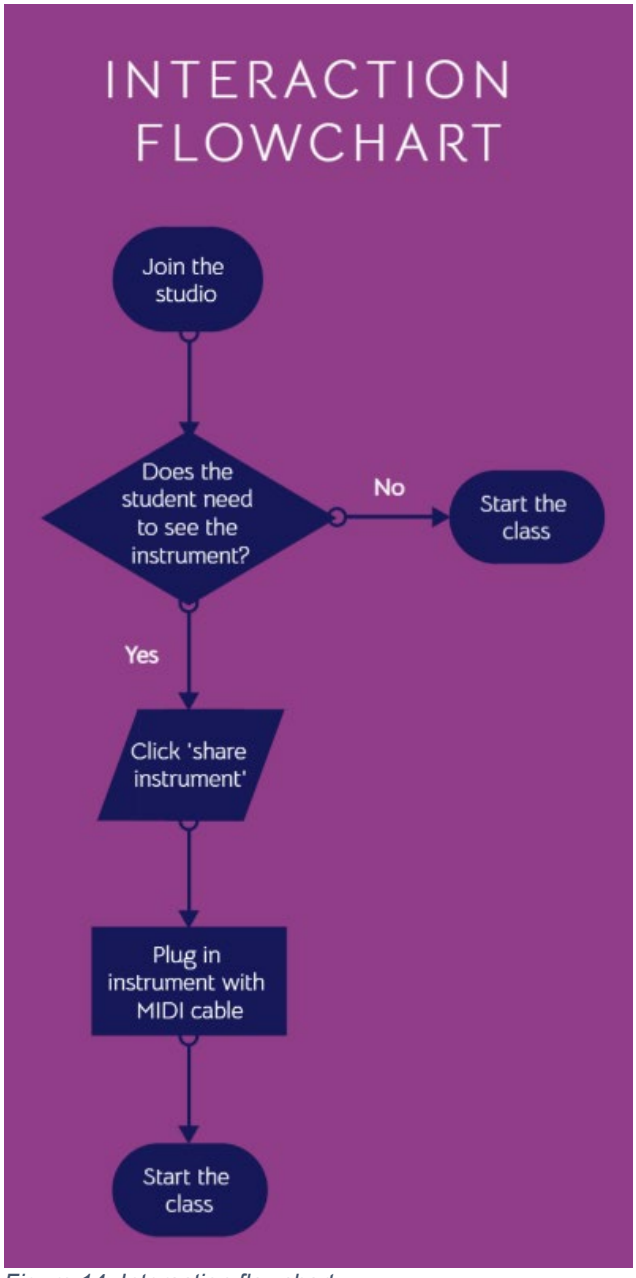


Figure 14: Interaction flowchart

5.3 Usability testing

5.3.1 Goal & course of the experiment

To further evaluate the prototype, the first round of usability tests were performed. Due to the availability of piano teachers at Kaliber Kunstenschool, this test was performed on piano teachers from other music or piano schools. The goal of the experiment is to investigate the usability of the concept, its features and if the concept solves the proposed problem. During the experiment, the

piano visualisation and the sheet music function are tested separately. First, the piano visualisation is tested after which the participant is asked multiple questions in a semi-structured way about their experience. After this, the sheet music function is tested and again the participant is asked about their experience in the same way. During the testing of the two components, the participant is asked to perform tasks while the researcher observes how these tasks were performed. Here the researcher was specifically looking at the interaction between the participant and the program, to observe if the participant had any particular feelings towards any features. This includes being confused about the functionality of something or a button being in a non-intuitive place. In the case of the piano visualisation, the tasks were as follows:

1.1 Connect an electric piano via a MIDI cable.
1.2 Open the visualisation feature.
1.3 Play a piece of music while observing the piano visualisation tool.
1.4 Play separate notes to see if their notation in the program matches standard music score.

After the tasks, the participant answered multiple questions about their experience with the interface in terms of usability and their opinion of how the concept solves the given problem. During these tasks, observations were noted down in a document, the results of which will be discussed in section 5.3.3.

The sheet music function was tested in a similar manner. The tasks for this function were as follows:

2.1 Write a simple melody (with varying note lengths) in a 4/4 measure.
2.2 Write a simple melody in a 3/4 measure.
2.3 Write all notes in a scale of the participants' liking.
2.4 Write a chord to the participants' liking.
2.5 Change the key from a G key to an F key.

Again, the participant's interaction with the program was observed and noted down. After the tasks, the participant was again interviewed about their experience with the program and their opinion of the concept, which will also be discussed in section 5.3.3.

5.3.2 Participants

For this experiment, two piano teachers were asked to partake. The participants will from here on out be referred to as teacher #1 and teacher #2. Both teachers work at piano schools at different locations and have both taught piano classes during the corona pandemic to individual students ranging from beginner to advanced students. Before the experiment, the participants were fully briefed on the concept, the goal of the experiment and this research but not all features and functionalities of the prototype were explained. This

was done to leave room to test if the product is intuitive to use for people with low digital literacy and high digital literacy. The teachers were also asked about their knowledge and skill with technology, to determine their level of digital literacy. One teacher (teacher #1) can be classified as having a high digital literacy, as they are very familiar with different music programs and often use their laptop, tablet or phone for communication. To add to this, they were familiar with a big variety of music-producing programs. The second teacher (teacher #2) has a lower digital literacy, ranging from low to medium. They use their laptop for work, but not much for personal use. They are more classically educated in piano and have little to no experience with music editing/recording software. This teacher also mentioned that giving education during the COVID pandemic was challenging at first due to their lack of experience in the technical domain.

5.3.3 Findings

First, the piano visualiser was tested. As mentioned, the participants were observed during their performance of the tasks listed in section 5.3.1. During the performance of task 1.1, the participants were both visibly confused about whether or not the piano had been connected properly or not. When asked about this afterwards, they mentioned that the program did not reflect if the device was connected.

Teacher #1 performed task 1.2 quickly, as they felt the position of the option to share the instrument was in an intuitive location. This was less the case for teacher #2, who pressed the settings icon in the top right of the screen (can be seen in Figure 13) before pressing the share instrument button.

During the execution of task 1.3, participants expressed being positively surprised about the response time of the tool. When asked about this later, teacher #1 mentioned they were expecting the visualisation would be delayed. Next to this, both teachers found the visualisation to be accurate and clear. Teacher #2 added to this by saying the piano should be slightly bigger on the screen, as there was room on both sides of the piano, so it could be bigger.

As for the next task, 1.4, multiple problems were found. While evaluating the sheet music notation of the played notes, teachers #1 and #2 both found that the notes being played did not correspond with standard music scores. As teacher #1 explained, in music

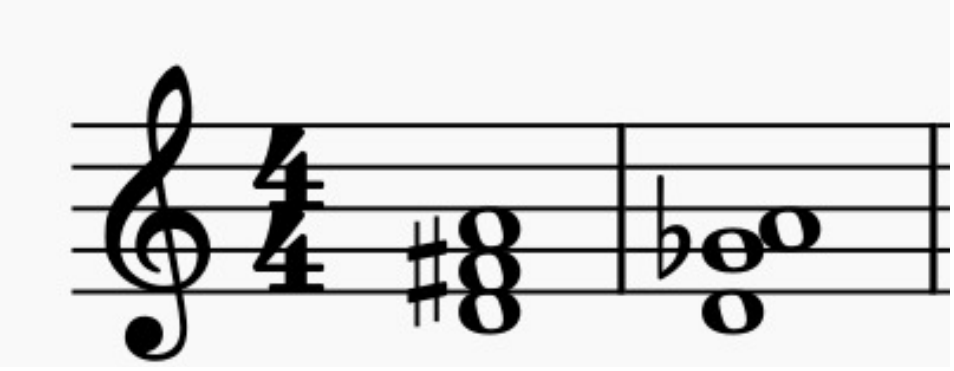


Figure 15: D major chord, right and wrong notation

score a note depicted as a sharp or as a flat depends on the other notes that are being played. This will be illustrated with an example. In Figure 15 on the left, a D major chord is displayed. A major chord starts with the root note, D in this case. After this, you move up 4 semitones to get the third of the chord, which is an F#. Move up another 3 semitones to get the last note of the triad, the A. In standard music score, this is depicted as the notes on the left of Figure 15, whereas this could also be shown as the chord on the right in Figure 15. Playing the left or the right notation results in the same chord, but as both teachers pointed out, only the left notation is standard. In this example, the third of the chord is displayed wrong, which is the F#. In some cases though, the fifth of the chord is displayed wrong, which can be seen in Figure 16. Here the same principle applies, but fifth of the B major chord (F#) is displayed as a G flat.

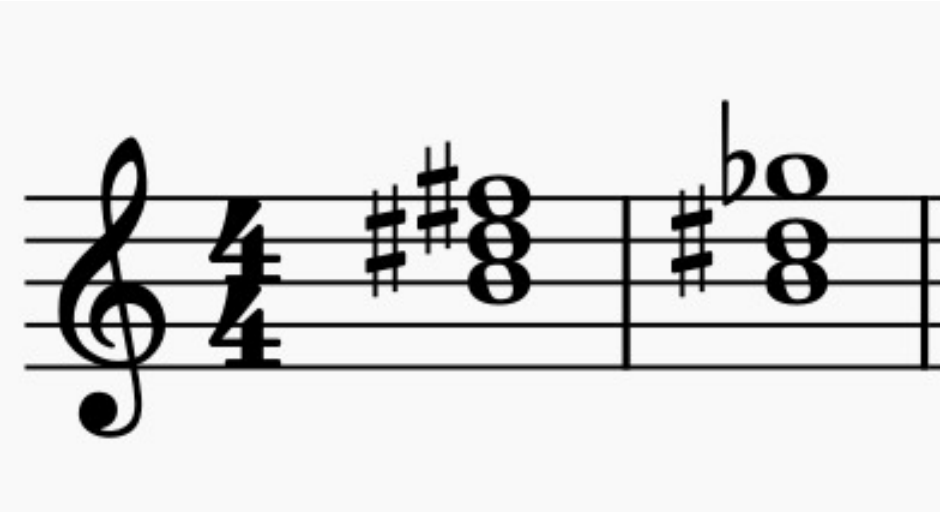


Figure 16: B major chord, right and wrong notation

In case of the program used in usability testing the black keys were displayed as sharp, flat, sharp, flat, flat, from left to right. In Figure 17, the program displays the black keys shown as C#, Eb, F#, Ab, Bb. This design choice was made based on inspiration from other keyboards or electric pianos, who displayed this in the same manner.

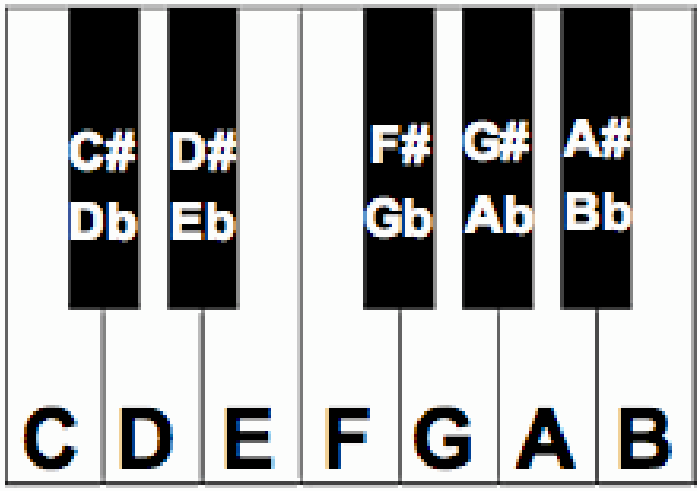


Figure 17: Keys of a piano octave

Another thing teacher #1 found to be counter intuitive is the placement of the notes. In standard music score, notes that are placed on top of the lines and notes placed between the lines are closer together than the program displays them. Usually notes are displayed as shown in the left side of Figure 18, while the program displays them like shown on the right side of the same figure. Not only is this standard, the teacher found it to be slightly easier to

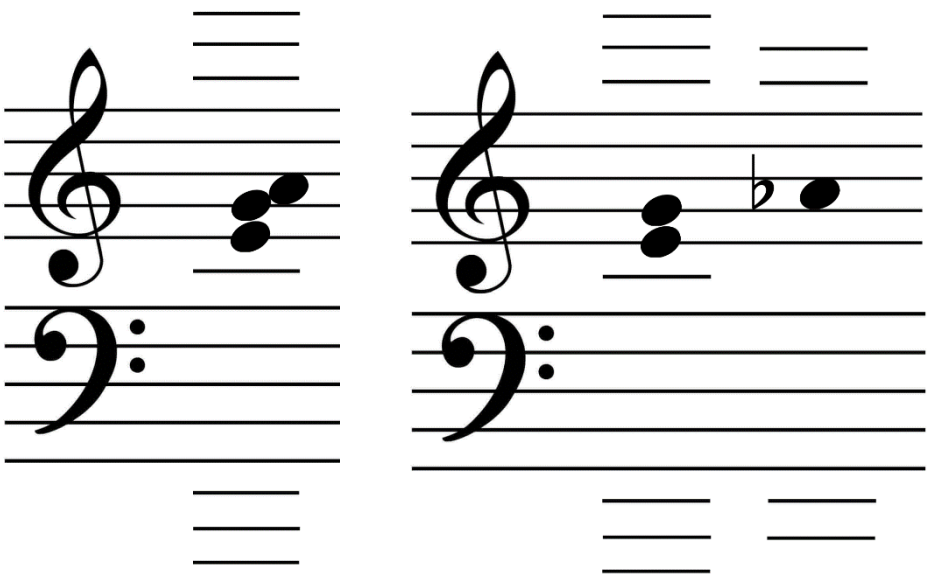


Figure 18: Right and wrong display of the piano visualisation notes

recognise certain chords or voicings. They did mention this is especially the case with genres like jazz music, where certain voicings are of importance. They suspected that, for beginners, the tool is adequate to explain theory and shown the notes being played. This stops being the case for more complex theory and voicings, like those found in jazz. Teacher #1 concluded that this visualisation “does work, but is different from what students are used to”. Therefore it should be changed to match standard music score as close as possible.
Having finished all tasks regarding the piano visualiser, the participants were asked about their experience and their thoughts on the overall concept. Both teachers #1 and #2 were very satisfied with the piano visualiser and expressed this would be of “tremendous help” (according to teacher #2) during lessons. Previously, teacher #2 had made a setup where they made a stack of objects to put their laptop on so the camera could have a top-down view of the piano. This meant having a chair on a table, with boxes on top of that chair and their laptop being angled down toward the camera. This meant they could not see the student well and their laptop was not in a safe location. Overall, they would want to incorporate this feature into their daily practice when teaching online. For the sheet music visualisation, they think the notes should be closer together to be able to recognise certain voicings and chords more easily. That the program does not show all the flat and sharp notes accurately is not too big of a problem. According to the teachers, they would explain more

advanced theory either by writing notes themselves (in the sheet music function that will be tested next) or by sharing examples in the chat or via the screen share option.
Next, the sheet music function was tested. Here both teachers were asked to start with task 2.1, without any explanation as to how to use the tool except that you can use the mouse to operate it and what the tool is used for. Both teachers started noting down a melody without trouble and were observed to easily fill the entire bar with notes. As the task was specific on a 4/4 time measure, teacher #1 did ask if it was possible to change the time measure, so it recognises that the measure has ended after 4 notes are put down. In it's current state the program does not do this, but since the teacher expressed having the time measure on the left of the first measure is essential, this will be taken into account when working on the second prototype. Teacher #2 mentioned the program does not allow for the placement of rest notes nor dotted notes, that increases a note's length by half. This was done purposefully since the time scope of the project does not allow for the prototype to include all features that would be necessary for the end product.
The next task, 2.2, was to write a melody in a 3/4 time measure. Both teachers found that writing the melody in a different time measure was doable, but the time measure was not mentioned at the beginning of the bar, which is what students are used to.
In task 2.3 no difficulties were found with the interaction with the program. Here it was observed the participants had gotten used to the program and were writing down the notes quicker than before, with little hesitation.
During task 2.4 teacher #1 said that the stems of the notes should be pointing a certain way depending on what note is placed above it, which the program currently does not. Teacher #2 noted here that when placing two eighth notes together, the stems should connect to each other. That this is standard in music scores was known during the design process, but required a more complex program so was left out of the prototype for testing purposes.
The final task, 2.5, was performed without any trouble too, although it was observed with teacher #2 that they were not aware the key could be changed to a different key. From the observations and comments by the teachers, it can be concluded that the program is not suited for chords or voicings in its current state, but is suited for more simple melodies. Here, there is still some room for improvement by making the stems of the notes connect to each other when applicable. After all tasks were performed, the participants were interviewed again on their opinion of this part of the tool. Both teacher #1 and teacher #2 stated they would use this tool to explain simple things to beginner students. In the opinion of teacher #1, it was very useful to be able to write simple sheet music in the program by Briegel, as it means the teacher does not have to switch programs and has the function at hand. They added to this by saying that if they were going to explain complex music theory to a student, they would share their screen instead and open a program that is more suited for this, like

MuseScore. Teacher #2 had a quality of life improvement for the program, namely a ‘clear’ button. The prototype did not allow for the notes to be erased all at once, only one at a time. Furthermore, they stated that their first impression of the sheet music function is very positive, as it was easy to use and placing and selecting notes felt intuitive, regardless of their digital literacy. Teacher #1 explained some ideas for future functionalities, namely to be able to upload MIDI files to the program, so the piano plays back the notes and the sheet music functionality displays these notes correctly. This does not fall within the scope of this project, though, but can be implemented in the future as was decided during the requirement analysis. With this, the concepts were tested on usability. The key take-aways will be analysed in the next section.

5.4 Second prototype feature proposal

During the usability test multiple problems were found. Due to the time span of the project, not every issue can be addressed in the next prototype but all issues will be discussed here. The first issue that will not be solved by the second prototype is the problem in the sheet music part of the piano visualiser, where the sharp or flat notes are not correct. Fixing this issue is possible, however it requires a lot of time to workout all combinations of notes that will lead to a certain result. This is something that should be done with someone who is very experienced in sheet music and has the time to fix this problem. For showing a proof of concept in the form of a prototype, this is not necessary as was found by the teachers too. In its current state, the program visualises the notes being played and it would be suited for basic online lessons. To add to this, high-end music software does this too, but this would require teachers to share their screen, losing the option to visualise the piano keys. Another issue with the piano visualiser is visualising the hand position of the pianist. The product does not satisfy this need and this would be too complex to incorporate into the current design. Some possible solutions would be to have a separate “hand camera” to display the hands or for the teachers to work around this problem. Ideally, the tool is used with beginner to intermediate students, where there is a special focus on the hand position via the camera or the student is experienced enough to not need assistance in this. One smaller improvement to be made is the size of the piano on the screen, which can be made bigger. The last quality of life improvement for the piano visualiser is the lack of visual feedback when a MIDI device is plugged in. This is something that will be solved in the next prototype, by providing an on-screen notification whenever the MIDI device is plugged or unplugged from the program. This notification will consist of wide block with text inside on the status of the device, being either “A MIDI device was found!” or “No MIDI device was found.” The user has to exit this notification to start the program, so it cannot be missed.
For the sheet music function, some issues were already addressed that can not be solved

within this project. These includes playing/uploading MIDI files, stems of notes connecting and having dotted and rest notes. The first issue requires a lot of programming, for which the time span of the project does not allow. The second and third issue should be incorporated as soon as possible but since the final prototype in this research is still close to a proof of concept, focussing more on easy usability and visualisation, this is for future work too. The issues that can be addressed here are the missing time measure and clear button. The first will be included in the next prototype in a similar way the keys are currently displayed, by hovering and then clicking over the time measure it changes from 4/4 to 3/4. Ideally, there are more time measures available in the end-product, but for the first prototypes these are left out. The final adaptation is the clear button, something that can easily be introduced into the design in Figma. Having an idea on what needs to change from the first prototype, the second prototype is developed in Chapter 6, Specification.

6. Realisation

This chapter will describe the final stages of the prototype. First, the changes that are made are explained. After this, the prototype is tested more thoroughly, with a student and teacher in a class-like environment. Here the student and the teacher are to perform an online class, with the use of the prototype. The results of this experiment are then discussed.

6.1 Second prototype

The first change that was made was increasing the size of the piano slightly, utilising the available room better. The was a fairly straight forward processes, as the image in the HTML code was made bigger. The improvement that was made to the overall program was the flow of working with the program. This was done by adding a notification when a MIDI instrument is found or not found, which means the flowchart of the interaction is now updated, as can be seen in Figure 19. The notification, as per Figure 20, is large and has to be dismissed before the user can continue so they are aware of the status of the device.

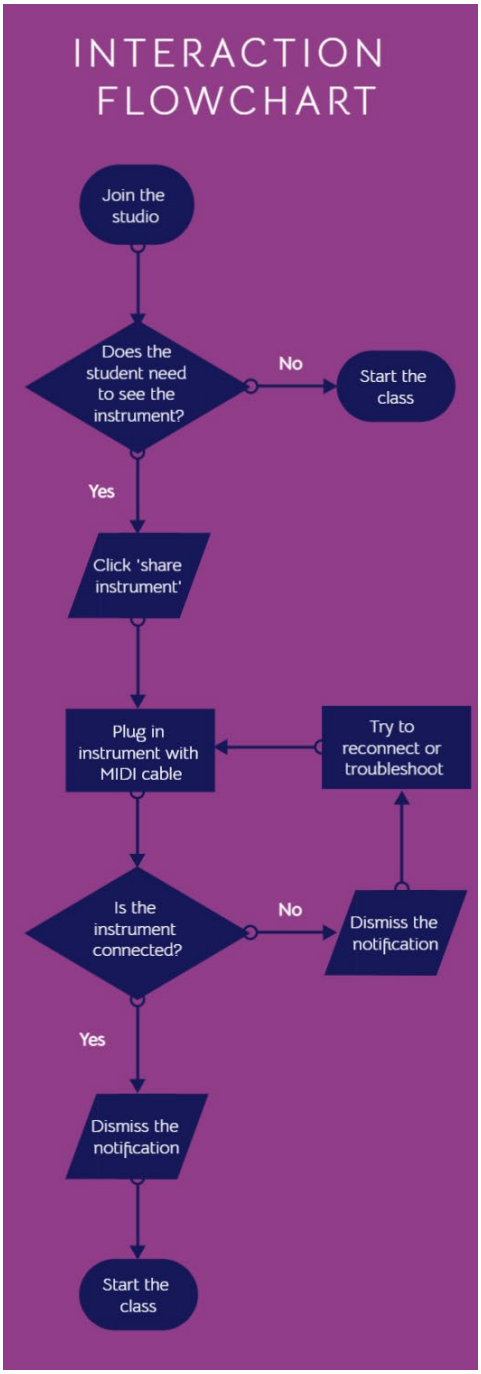


Figure 19: Updated interaction flowchart

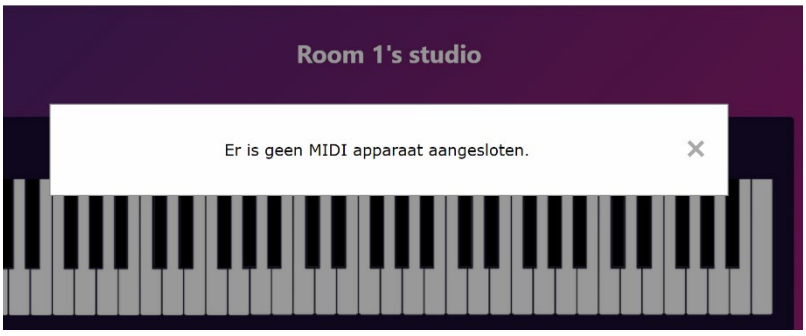


Figure 20: MIDI device notification

The sheet music function also received some updates. First, a time measure can now be selected. This works similarly as selecting a different key, by hovering over the time measure the next time measure can be seen. By clicking with the left-mouse button, this time measure is confirmed and the image switches. An example of this can be found in Figure 21. Here, the bottom time measure has been changed while the mouse is hovering over the top time measure. On the bottom right, the ‘Clear’ button can be seen. Clicking on this erases all notes that are currently being displayed.

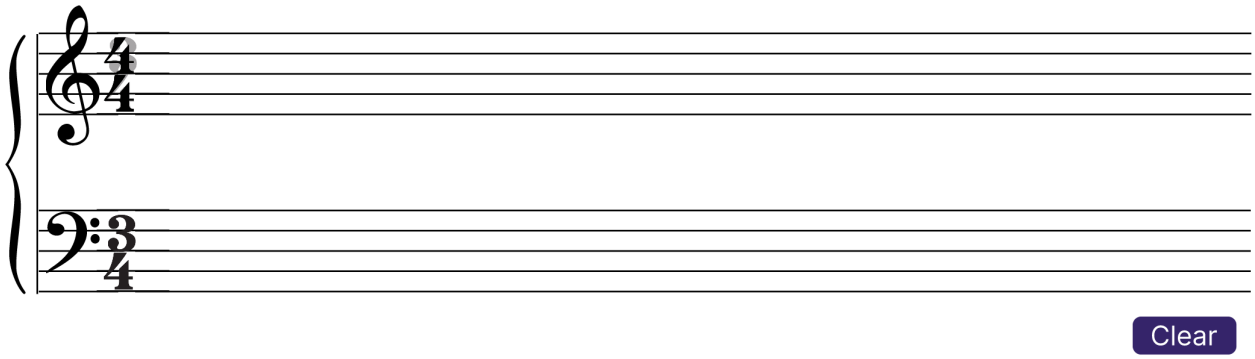


Figure 21: Updated sheet music function

6.2 Second usability test

For the second user test, an extensive qualitative test is done. This test will be based on the usability test plan by the U.S. Department of Health & Human Services [22]. This test plan includes numerous usability metrics and guidelines for setting goals in usability testing.

6.2.1 Participants

The participants of this test are one piano teacher and a beginner piano student. The teacher is the same teacher from the last usability test, namely teacher #2, the teacher with a lower digital literacy. One of the design requirements was to make the concept easy to use for all age groups, which can not be tested unfortunately due to the availability of the piano teachers in the area. The student is a beginner piano player who has some prior experience in playing the piano and taking lessons, but this was a few years ago.

6.2.2 Test setup

Since the teacher has already used most features of the tool, the new features are explained before the test so they have a full understanding of the program. The student, however, gets no explanation of the tool. During the experiment the subjects will be in two separate rooms. The teacher and student will be conducting the lesson on a video-conference application that has the ability to share the teachers screen. This is done to mimic the online environment that the product by Briegel brings. The experiment is not done in the studio environment by Briegel as the prototype is not functional within that environment, only as a separate system.

6.2.3 Goal & course of the experiment

The general goal of this usability test is to verify the functionality of the features of the concept as well to verify if the concept aids in the quality of online music education, in the opinion of the participants. The specific goals here are to test if the concept works in a class-like environment and to test if the problems present in the previous prototype have been solved. To verify this, a questionnaire is filled in by the participants after the completion of the experiment. As mentioned, the experiment will be as close to an online piano class as

possible. Before the start of the experiment, the researcher will explain to the teacher what the goal and course of the experiment are. Here, the teacher receives some guidelines to how the class should be structured, to try to test all features of the program. These tasks are few, since the focus of the class is to educate with the prototype being a tool. The prototype should not be the main focus of the class. These tasks include the following:

1. Start up the program independently and connect a piano.
2. Teach the student to play a piece of music (of the teacher's liking) while using the piano visualiser.
3. Teach the student any bit of music theory the teacher sees fit while using the sheet music tool.

During these tasks, the researcher will be present in the room of the piano teacher, to observe the progression of the class. During this time, observations regarding interaction with the software or functionality of the program will be noted down in a document.

6.2.4 Findings

After the execution of the above mentioned tasks, the participants were asked to fill in a questionnaire. In this section, the observations made during the experiment and the results of this questionnaire are discussed. To start off, the observations will be discussed. At the start of the twenty minute experiment, the teacher started the program and connected the piano without any trouble. This is different from the first user test, where there was visible confusion on if the piano was connected. During the class only two observations stood out, namely that the piano teacher had to ask the students what notes they were pressing and the student asking how the teacher was playing. This was also referred to in the survey by both participants. The first observation is caused by there being only one piano, namely on the teachers side. During the design process it was assumed only one piano would be necessary, but this was proven wrong during this user test. The second observation has to do with the visualisation of the tool. Currently it only visualises the instrument, but not the way the instrument is played. This might not be an issue for all students, as the teacher mentioned in their answers of the survey, but it is a problem for beginner students who heavily rely on copying the teacher based on what they see.

After the experiment, the teacher and student filled in a questionnaire with questions related to five topics, effectiveness of the concept, user-friendliness of its features, probability of use in the future, ease of use and product readiness. The questions asked in the questionnaire can be found in Appendix B: Questionnaire after second user test. The results of the questionnaire have been processed and can be found in Figure 22. In the questionnaire, the participants rated certain topics from zero to five based on how much they agree with a statements. In the spider diagram the middle point of the graph is zero, and the outer points

have the value of five. As can be see, the teacher and student both give the prototype a low score on product readiness, meaning it should be developed more before it is usable. The concept scores higher in the other categories. From this it can be concluded that, according to these participants, the concept is effective and is user friendly. Since this was tested on a teacher with low digital literacy, it can be concluded that the concept is suited for its user group. Preferably the concept would be tested with a higher sample size, but due to time constraints and the availability of piano teachers this was not possible.

Figure 22: Spider diagram with the results of the second usability test

The survey also included some open questions, to allow for suggestions for improvements or further expressing opinions. One suggestion by the student was to have the option to choose what is on the screen. They noticed that during the class they were only using one part of the concept at the time, which means the other parts were unnecessary or distracting. The teacher mentioned something similar about wanting to have an option to open a circle of fifths on screen. These two suggestions ask for more customizability in the program by being able to select which features are present on screen and which are not. This way, the concept can be customized to fit the needs of that class, student or a teaching style. Both the teacher and student also mentioned that it is a good solution to be able to still see each other during the class, which was not something that was an option before during online classes. However, the teacher did think the student should also have a piano connected. Even though few of their students have an electric piano at home, they stated that for students that do have one available they want to be able to see their piano using the tool.

To conclude the findings, the concept scores high in effectiveness, user friendliness, ease of use and willingness to use in the future, but there is room for improvement in the tool. The improvements done should mainly be in customizability, making the program suitable for any student, teacher or teaching style. It can also be concluded that the concept works in a class-like environment, to some degree. This was one of the goals for this user test, but it is not fully achieved due to the lack of visualising how the instrument is played. The second goal was to verify if the previous problems have been solved. These were solved, as the issues from the previous user test were not observed or mentioned by the participants during this test.

7. Evaluation

This chapter will evaluate the concept and the research. First the technical aspects of the created tool are evaluated on. Thereafter, there will be an evaluation on the requirements of the concept defined in section 4.3.

7.1 Technical evaluation

In this research, a concept has been created to aid the quality of online music education. This concept was developed into a tool that can be used to visualise an electric piano as well as explain music theory while making use of the sheet music function. To evaluate the technical side of the tool, the environment in which it is built will be evaluated first. Currently, the piano visualisation tool is not incorporated into Briegel's studio environment software. To add to this, the music sheet functionality is also built in a different environment, separate from the piano visualisation tool. Ideally the tool will be implemented in the environment in future user tests, to validate if the technical aspect also works within Briegel's code. The current use of the MIDI API allows for easy access to a piano, but this has not been tested for other MIDI devices like a drum set. Having a different instrument connected could also lead to problems within the code.

7.2 Prototype evaluation

Through user testing flaws and strong points in the prototype have been found. Some of these were fixed in the second prototype, but during the second user test new problems came to light. These will be repeated in this section and their implications will be discussed. The first and most important flaw found in the second user test was that the concept visualises the instrument as it is being played but not how the instrument is played. As learning concepts such as hand positioning and the shape of the hand are important in piano music, this flaw must be solved in future research. Depending on the skill of the student or the teaching style of the teacher, this might be less of a problem. However, since the design should fit any teaching style or student, it is a problem that needs to be solved. Next to this problem, there are some underdeveloped features in the prototype. Not having these features fully developed means there are lacking aspects of the prototype. The final issue is the lack of customizability. This was ranked to be a Could Have requirement as per section 4.3, but usability tests proved this was of higher importance than initially found.

7.3 Requirement evaluation

In this section, the functional requirements will be discussed individually to see to what extent the requirements has been met.

Must Have requirements:

Concept is usable regardless of digital literacy.

This requirement has been met. The concept has been tested on people with varying digital literacies and the results from the usability tests proved the concept was user-friendly for those involved.

Concept visualises the instrument that is played (what notes/drums are hit etc).
This requirement has been met. Although, through user testing it has been found that visualising how the instrument is played is of importance too, which the concept does not do.

Concept visualises the notes being played on said instrument in a sheet music form.
This requirement has partially been met. For individual notes the program works fine, but for different combinations of notes the result should be different, which the program currently does not do.

Concept includes a rhythmic / sheet music notation option.
This requirement has been met and has proven to function well.

Concept is fit for multiple instruments.
This requirement has been met. It is designed for multiple instruments, although the concept has not been tested on instruments other than the piano.

Concept is easy to set up.
Through iterations in the prototypes, this requirement has been met too, according to participants of the user study.

Concept improves social interaction, as compared to the current state of learning platforms.
By eliminating the need to aim the camera on the instrument, the camera can be aimed at the student or teacher. This means that there is much more social interaction, as the student and teacher can look at each other during the lesson. So this requirement has been met.

Should have requirements.
Concept is suited for all skill levels of students.
It cannot be confirmed if this requirement has been met from this research, since only one student participated in the second user test.

Concept fits into Briegel's product.
The concept has been evaluated early in the process to fit within the context of Briegel's platform. So this requirement has been met.

Could have requirements:

Concept allows for teachers to explain music theory in full.

This requirement has not been met in full, due to time constraints of the project. This caused that not all functionalities were developed fully, meaning this requirement could not be tested. Teachers did mention they saw the potential for this, but could not confirm it in the current state of the prototype.

User can choose what parts of the concept are visible on screen.

The was a requirement that was not focussed on during the development of the prototype, so this was not met.

Won't have requirements:

Concept allows for students to practice music theory without the presence of a teacher.

This requirement was not met. This is left for future research, as to be expected according to MoSCoW method.

Concept allows for playback of MIDI files, recorded or uploaded by the user.

This requirement was something that teachers also brought up to be a useful addition for future research, but was not met in this research.

8. Discussion

8.1 Interpretation of results

The results provided an insight in how effective the concept is at solving some of the problems that arose during the COVID-19 pandemic. The concept was tested on users with different digital literacies, to test if the concept was user friendly. After the user tests, it was clear the concept was user-friendly, but was still missing some essential features. Despite this, participants expressed they would want to use this product in the future, as they found it did increase the quality of an online class. However, due to the small sample size on which the concept was tested, the results might not be representative for the entire user group.

8.2 Limitations

8.2.1 Limitations of the tool

To be able to understand the conditions in which results are found and conclusions are drawn, the limitations must be discussed.

An electric piano is required: For part of the tool, the piano visualisation, it is necessary to have an electric piano. Without this, half of the concept can not be used.

Only works in certain browsers: Due to the MIDI API that is used to connect a piano to the program, the program only works in certain browsers without having to install a plugin. As the concept is designed to be used for people with low digital literacy too, having an extra step for using the program is not favourable for the design.

Not fully developed: As mentioned before, the concept is currently missing some functionalities in the sheet music function. For example, the user can not place dotted or rest notes.

Visualising the instrument, not the way the instrument is played: The concept aims so solve not being able to see what the other person is playing. It does this partly, by showing what keys are pressed on the instrument, but this is not the full extent of how the instrument is played.

Concept is not developed for wind instruments: This concept was developed for Kaliber Kunstenschool, who teach a variety of instruments. The current concept only works for string instruments, key instruments and percussion instruments. Here, percussion and string instruments have not been tested on, so the validity of the concept for other instruments can not be confirmed.

8.2.2 Limitations of the research

Similarly to the limitations of the tool, the research has its limitations too that need to be mentioned.

Small sample size: The usability tests have been performed on a small sample size of N=2 for both usability tests. This is not ideal, as larger sample sizes lead to more different perspectives. The idea was to test on different digital literacies to see if there is a difference in results, a smaller sample size does not allow for this. Even though the test is qualitative, a higher sample size is also preferred to confirm the findings by other teachers / students.
Data gathered in experiment environment: As the user tests have been performed in an experiment environment, the data might be biased.
End-users' inability to communicate their unmet needs for innovative products: Through this design process, interviews have been held, the design has been evaluated and user test have been done with the end-users. During these steps, teachers expressed they wanted something as close to the physical classroom as possible. As participants might not have the vocabulary and knowledge about technology, communicating needs or possible solutions can be harder.
Time limit: Due to the time limit of the project, not all features have been fully developed.

9. Conclusion

This chapter will focus on answering the research questions of how to design concepts for individual instrumental music lessons as well as the sub-research questions. Next to that, possible future work directions are discussed.

9.1 Conclusion

The main research questions of this research was “How to design concepts for online individual instrumental music lessons?” The aim of this research was to develop such a concept for Kaliber Kunstenschool by building on the platform by Briegel. This was done by forming a concept and building prototypes which were then tested.

This research has answered the main research question by creating a tool that aims to aid the quality of online music education for individual instrumental music lessons. The tool aims to do so by providing a way of visualising the instrument, so the camera of the user is free to be aimed at their face. Next to this it allows users to write melodies or other music score on-screen. The realisation and evaluation phase of this research proved the concept was successful in achieving its aim, although there are still points for improvement.

The key take-aways from the design process, that answer the main research question, is to implement certain strategies and evaluate the design. In order to design concepts for online music education, the designer can make the design appropriate for all digital literacies, make interaction as simple as possible and make the concept customizable. These three strategies have been implemented in the design process or have been found during the second usability test.

Next to these strategies, evaluating with end users is of high importance too. This means testing with people with varying digital literacies, testing at multiple stages of the design to incorporate feedback and testing with both students and teachers.

The first sub-research question was “What are the didactic methods of teachers and how are they satisfied?” This questions was asked to aid the design process and make clear what requirements should be met in the prototype. While interviewing several teachers, they all gave the same answer when asked about their methods. They stated they did not use specific methods, but rather looked at the skill level of the student, what they had done last class and what they were going to do in the next class. This closely relates to Gagné’s Taxonomy of Learning [20], like discussed in section 4.2. This method calls the teacher to be able to give feedback to the student and being able to hear and see what they are playing, in the case of music education. The concept developed in this research aims to provide this in online platforms too.

The second sub-research question was “What practical functionalities (that are used in physical classrooms) should the product include?”. The outcome of this research question

was straightforward; mimicking physical proximity. In physical classrooms, looking at each others instruments is easily done and essential. The concept aims to provide this too. Another important aspect was to be able to write sheet music onscreen, without disrupting the flow of the lesson. This too was incorporated into the platform.
The final sub-research question was “How should the social aspect, found naturally in physical music schools, be incorporated into an online platform?” was investigated too. Several solutions were found for this, but the one chosen in this concept was to enable the user to aim the camera at their face instead of their instrument, making social interaction easier by taking ‘face-to-face’ instead of to a computer or instrument.
To conclude, the tool can be used during online music education to provide an experience that is more tailored to musicians. The results of this research are promising and show the concept developed in this research to have potential. However, future work must dive further into the actual development of the prototype to fix the standing issues.

9.2 Future work

During this research a promising tool has been made to aid in online music education. The tool has the potential to solve several problems that currently exist in online education for a variety of instruments. However, future work needs to be done to complete the tool and further aid in the development of a more accommodating platform for musicians. Next to this, the tool needs to be tested in the long term and on a bigger group of participants. This section will highlight some directions for future work to go in.
The first direction for future work is further evaluating the tool. Due to the availability of piano teachers at Kaliber Kunstenschool, this was not tested with the intended user group. Instead, the tool was tested with two other piano teachers, while a bigger group of test subjects is preferred. To add to this, more students should be involved in the testing too, since they are a stakeholder with a high importance and influence too (Table 1: Importance & Influence ratings for all stakeholders).
Another direction for future work is the development of features in the tool. As stated before, the tool currently lacks in some ways like the missing rest and dotted notes in the sheet music function, the wrong notation of notes when playing a chord in the piano visualiser and visualising the hand position of the tool. As this research produced a proof of concept and some first prototypes, the tool is far from fully developed.
Lastly, the tool currently only visualises the piano. The concept was developed for multiple instruments, as seen in section 4.4. During the realisation part of the process, it was decided to only work out the solution for one instrument, due to the time limit of the research. In the future, the concept should also be developed for percussion instruments, string instruments

and wind instruments, to accommodate for the entire range of education given at Kaliber Kunstenschool.

All in all, there are multiple interesting directions for future work regarding validation and functionality of the tool. This work needs to be done to provide a more complete aid in education across all types of instruments, skill levels of students and digital literacy of teachers.

References

[1] J. Savage, "Teaching Music in England Today," 24 January 2021. [Online]. Available: https://journals.sagepub.com/doi/10.1177/0255761420986213.

[2] K. P. &. A. Malex, "Othering in online learning: an examination of social presence, identity, and sense of community," 09 May 2017.

[3] W. E. Angelika Mader, "A Design Process For Creative Technology," *ResearchGate,* p. 7, September 2014.

[4] A. Hasikou, "New Approaches to Individual Instrumental," *Athens Journal of Education,* p. 10, May 2020.

[5] C. Johnson, "Teaching music online: Changing pedagogical approach when moving to the online environment," *London Review of Education,* November 2017.

[6] M. D. Rucsanda, A. Belibou and A.-M. Cazan, "Students' Attitudes Toward Online Music Education During the COVID 19 Lockdown," *Frontiers in Psychology,* November 2021.

[7] D. Calderón-Garrido and J. Gustems-Carnicer, 09 March 2021. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/14613808.2021.1902488. [Accessed 2022].

[8] D. C.-G. &. J. Gustems-Carnicer, 09 March 2021. [Online]. Available: https://www.tandfonline.com/doi/full/10.1080/14613808.2021.1902488. [Accessed 2022].

[9] A. G. &. L. M. Krull, "COVID-19 Remote Learning Transition in Spring 2020: Class Structures, Student Perceptions, and Inequality in College Courses," 22 September 2020. [Online]. Available: https://journals.sagepub.com/doi/10.1177/0092055X20954263.

[10] N. Wexler, "Forbes," 2020. [Online]. Available: https://www.forbes.com/sites/nataliewexler/2020/04/08/7-tips-to-help-make-remote-learning-more-effective/?sh=6d7612af62c3.

[11] M. W. &. M. K. &. L. Stone, "Technology and Equity in Schooling: Deconstructing the Digital Divide," 2004. [Online]. Available: https://journals.sagepub.com/doi/pdf/10.1177/0895904804266469.

[12] R. J. Dammers, "Utilizing Internet-Based Videoconferencing for Instrumental Lessons," September 2009. [Online]. Available: https://journals.sagepub.com/doi/pdf/10.1177/8755123309344159.

[13] D. J. Albert, "Online Versus Traditional Master of Music in Music Education Degree Programs: Students' Reasons for Choosing," 3 October 2014.

[14] K. Theano, "Online Distance Learning and Music Training: Benefits, drawbacks and challenges," 7 7 2013. [Online]. Available: https://www.researchgate.net/publication/304574795_Online_Distance_Learning_and_Music_Training_Benefits_drawbacks_and_challenges.

[15] B. Ehlers, Interviewee, *Elk.Live Brings Musicians Together to Play Online.* [Interview]. 30 August 2021.

[16] B. L. Johnson, "A Sound Education for All: Multicultural Issues in Music Education," *Educational Policy,* pp. 116-141, 2014.

[17] H. Riley, R. B. MacLeod and M. Libera, "Low Latency Audio Video: Potentials," *National Association for Music Education,* pp. 15-23, 2016.

[18] P. Dearden, S. Jones and R. Sartorius, Tools for Development, Department for International Development, 2002.

[19] A. B. Consortium, "Chapter 10: MOSCOW PRIORITISATION," [Online]. Available: https://www.agilebusiness.org/page/ProjectFramework_10_MoSCoWPrioritisation. [Accessed 23 06 2022].

[20] J. P. Cole, "WEBMIDI.js," 2021. [Online]. Available: https://github.com/djipco/webmidi. [Accessed 05 2022].

[21] J. Diebold, "Music Notation with Interactive Components," Figma, [Online]. Available: https://www.figma.com/community/file/966600174838115017.

[22] U.S. Department of Health & Human Services, "Usability Test Plan Template," 2021. [Online]. Available: https://www.usability.gov/how-to-and-tools/resources/templates/usability-test-plan-template.html. [Accessed 06 21 2022].

[23] R. M. Gagné, The conditions of learning and theory of instruction, New York: Rinehart and Winston, 1985.

Appendices

Appendix A: Questions asked during interviews with music teachers

Q1: Wat was jouw algemene indruk over online lesgeven (tijdens de pandemie)?

Q2: Welke platforms heb jij gebruikt tijden de pandemie?

Q3: Wat vond je de 3 grootste nadelen van dit platform? (Vraag om uitleg)
Q3.2: Heb je nog meer nadelen die je belangrijk vindt om te benoemen?

Q4: Wat vond je de 3 grootste voordelen van dit platform? (Vraag om uitleg)
Q4.2: Heb je nog meer voordelen die je belangrijk vindt om te benoemen?

Q5: Hoe effectief vond je online onderwijs tijdens de pandemie?

Q6: Denk je dat je online onderwijs nog steeds wil gebruiken na COVID? (Bijvoorbeeld als een student ziek is, of toevallig op vakantie is met het instrument)
Q6.2: Zou je het in de huidige staat gebruiken of zou het daarvoor moeten verbeteren?

Q7: Wat zou jij zelf veranderen aan de online platforms?

Q8: Had jij of een student vaak (technische) problemen met de online platforms? (Microfoon of webcam functioneren niet, internet verbinding slecht, uitleggen van techniek moeilijk)

Kwam nooit voor – kwam af en toe voor (1-2 keer per week) – kwam vaak voor

Q8.2 Wat voor problemen waren dit?

Q9: Leg de volgende oplossingen voor een aantal problemen op volgorde van meest belangrijk naar minst belangrijk. (Eerst alles uitleggen en toelichten hoe deze opties vormgegeven zouden worden)

Q10: Wat zijn jouw didactische methodes?
Q10.2: In welke maat kon je deze toepassen in online lesgeven?

Totaal niet – enigszins – goed

Q11: Denk je dat online onderwijs dezelfde kwaliteit kan hebben als fysiek onderwijs?

Q12: Is er nog iets dat je kwijt wil over online lesgeven ten opzichte van fysiek lesgeven?

Appendix B: Questionnaire after second user test

User test piano tool

In dit vragen formulier wordt soms verwezen naar 'de piano visualisatie' (de piano die op het scherm staat die laat zien welke toetsen je indrukt), de 'blad muziek piano visualisatie' (de noten die in bladmuziek verschijnen als je een toets indrukt) en de blad muziek functie (waar je kunt klikken om noten te plaatsen).

*Vereist

1. Ben jij student of leraar? *

Markeer slechts één ovaal.

- ◯ Leerling *Ga naar vraag 6*
- ◯ Leraar *Ga naar vraag 2*

Ease of use

In welke maat ben je het eens met de volgende stellingen?

2. Het is duidelijk dat de piano verbonden is. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

3. De notificatie is duidelijk en makkelijk te zien. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

4. De functionaliteit van de knoppen op het scherm is duidelijk *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

5. Alle functies in het programma waren makkelijk te vinden. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

Ga naar vraag 6

User-friendliness

In welke maat ben je het eens met de volgende stellingen?

6. Het gebruik van de tool verliep gemakkelijk. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

7. De tool is gebruiksvriendelijk. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

8. De visualisatie reageert correct en snel. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

9. De noten (bladmuziek) van de piano visualisatie zijn goed te lezen. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

10. Het is goed te zien welke toetsen de leraar indrukt. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

The concept

In welke maat ben je het eens met de volgende stellingen?

11. Dit programma is waardevol in mijn online onderwijs. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

12. Het concept maakt het gemakkelijker om online les te hebben. *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

13. Hoe helpt dit concept jou in je onderwijs? *

14. Wat zou het gebruik van deze app kunnen beteken in jouw onderwijs? *

Future use

In welke maat ben je het eens met de volgende stellingen?

15. Ik zou deze tool gebruiken in mijn online lessen (in de huidige staat). *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

16. Ik zou deze tool gebruiken in mijn online lessen (mits er aanpassingen aan gedaan zijn). *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeer mee oneens	◯	◯	◯	◯	◯	Zeer mee eens

17. Welke aanpassingen zou je willen zien? *

Product readiness

In welke maat ben je het eens met de volgende stellingen?

18. Vind je dat het product nog aangepast moet worden voor het klaar is om te gebruiken? *

Markeer slechts één ovaal.

	1	2	3	4	5	
Zeker niet	◯	◯	◯	◯	◯	Zeker wel

19. Wat vind je dat er nog aangepast moet worden? *

Vink alle toepasselijke opties aan.

- [ ] Piano visualisatie
- [ ] Bladmuziek functie van de piano
- [ ] Bladmuziek functie

20. Wat moet er aangepast worden aan de door jou gekozen onderwerpen?

21. Heb je nog opmerkingen over het product?