Visual and Haptic learning amongst beginner musical enthusiasts: The Saxophone Teaching Glove

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Abstract

Saxophone learning is a time-consuming activity requiring the user to multi-task from the very beginning and has multiple barriers of entry making it rather inaccessible without the proper guidance and support. Using a haptic interface in the form of a glove, we want to open up this instrument to beginners, by making it more accessible to have a “guiding hand” throughout the beginning of the learning process. Our attempt here is to gather an understanding of the problems affecting the saxophone community and try to use that feedback to design a haptic interface which would enhance the connection between a teacher and student, allowing for an easier time to understand while also focusing on allowing students to repeat patterns to practice their finger positions and actually play the instrument without having to multitask, shifting their attention between playing the notes, reading them and properly following the articulations required for each of them in turn.

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Introduction

Haptic learning is the process of studying which involves the sense of touch. Such an activity can occur actively, where the user is focused on completing the task, but also passively while doing a completely unrelated action, through the use of tactile stimuli. There has been studies which prove that haptics help significantly in the learning process [1-7], and as such is present in a variety of fields.

Haptic technology is becoming an integral part of today's musical field and is playing a large role in its development [8]. There have been numerous attempts to utilise it on a piano, guitar and even a flute among others [2, 9-11]. The PianoTouch glove project [11] suggests that if a glove with vibrating motors were used on an instrument with 1 to 1 finger to key mapping, then the studying process could be fully passive. However, no such research has been done for the saxophone, which would fit in with the aforementioned paper.

What we propose in a glove prototype that would be able to record and replay and relay directly live movement from teacher to student, thus allowing them to strengthen their connection and ease the learning process. Such a device should have a dramatic effect on complete beginners, who struggle with a myriad of problems, a major one of which is uncomprehension of the teacher. With it, we would help the advancement of the haptic field in music by providing an example of a saxophone playing that could be learned entirely passively. In addition, we would be able to determine the efficiency of active versus passive learning on this instrument.

We will achieve that by following the qualitative methodologies and conducting various activities that would help alleviate the mystery behind the research question at hand. The interactions would be heavily focused on how various groups of people, such as teachers and students, utilise the saxophone and what is their connection to it. This will be answered by doing interviews with several musical professors and their students, followed by general surveys where we try to quantify and justify our previous finding and reach the harder to interact with groups - autodidacts.

Lastly we would try to observe how exactly each participant behaves and how the learning session is executed from various perspectives and points of view. Based on those results, a glove prototype would be constructed, in addition to a thematic analysis, which would be used to find the underlying themes, thus allowing us to tackle the research questions at hand knowing what exactly our participants expect and feel and how that influences their decisions and interactions.

Report structure

This report is structured into several distinctive parts, which outline and define all of the processes that we have gone through in a chronological way.

The problem formulation would focus on how we came up with the specific problem and the whole task of trying to reach it, as well as the proper formulation. We would briefly emphasise some of the issues our target groups are facing and what exactly this project aims to do.

The background chapter would allow the readers to have a more concise view of what has already been done in this field and follow through with the history of advancements and innovations.

The methods section would explore all of the methodologies we have used to gather the data required to have some answers and a clearer view of the problems and the possible solutions. We will go over the activities we have conducted, the way we chose to approach them, but also specify and justify why exactly we went with those. We will additionally explain how we went on to work with our participants and the way we prepared to interact with them. In this section, we would also briefly examine a prototype, which would be based on assumptions and preconceived notions before the results were analysed, which we believe would serve as a base for the final product.

The results part is going to explain what data we managed to extract from all of the activities we have conducted, all the way from individual codings to the currently finalised thematic analysis.

The discussion is where we try to tie all of this information together and try to relay it to the physical prototype that we have. We will go over the process of going from a simple product and the changes our research has influenced on it.

The future works would include all of the ideas and research questions that we did not manage to answer, but deem necessary for the progression of haptics and music.

The conclusion is the final part of the report, which would try and summarise the whole information in this document in a short and structured manner, allowing the reader to decide if we have succeeded in answering the proposed research question.

Problem Formulation

What really is passive learning? What does it actually mean? Simply put, passive learning is “learning that may occur without the intention to learn, through exposure to information or behavior” [12]. There can be many different activities that would fall into that category of learning like reading books, listening to lectures or watching some videos to name a few. It is essentially the process of transferring data to the student and is regarded as teacher centered as the whole operation is entirely dependent on the way the teacher themselves has chosen to establish the data.

On the opposite side of things is the student centered learning, also known as active learning, which focuses more on the actual student and their attempts on acquiring knowledge. Examples of such behaviour include actions like doing group projects, discussions and role-playing amongst many others.

Whilst both methods offer their own benefits and drawbacks and each student reacts to them differently, there are still those who vehemently try and justify the superiority of one. [13]. However, this is a long debated subject that has no clear answer as every person is unique enough in a sense that they are going to have different preferences when it comes to learning. In fact, it is quite widely considered the best when combining the two methodologies, as essentially the student would have all of the theory related to them and then be able to exercise it with their own hands.

It is at this point the reader is wondering how all of this relates to the title at hand and more specifically to haptic and visual learning. By looking at the diagram below, we can identify that typically the learning styles are divided into three main categories - visual, auditory and haptic. The first two are pretty self explanatory, however, we believe that the third might potentially cause some issues to the reader. As illustrated below, haptic is defined as “of or relating to tactile sensations and the sense of touch as a method of interacting with computers and electronic devices:” [14].

When it comes to haptic technology, then it means that we are trying to recreate some sort of experience through various kinds of feedback. It is important to mention that some time the sensory systems involved are split into several additional categories such as kinaesthetic, which is about awareness of the positioning and movement of body parts, and cutaneous, which is about pain, temperature and general skin feel. However, for the sake of simplicity, we are going to be grouping all of those as haptic and not make a distinction. What we are going to differentiate between is the types of system there are instead, which are separated in graspable, wearable and touchable.

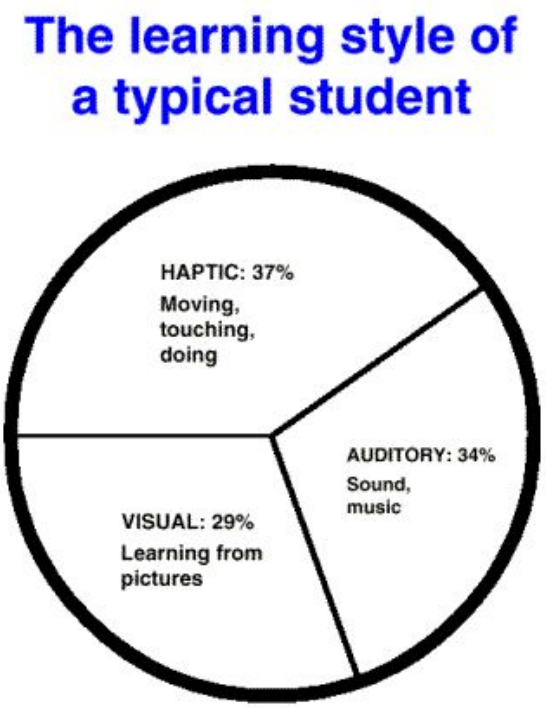


Fig 1 : Learning styles of a student [15]

Figuring out the Problem

Now that the basic terminology has been established, it is time to form the process which we followed, allowing us to build on, research, prove the existence of and eventually attempt to solve a problem that is common among our interests. Because we have had prior interactions, we had an easier time coming up with similar areas of interests. Whilst there were several that we shared, we decided to try and exclude some, that we thought would not make for a very exciting project - such as roleplaying and video games. Instead we focused on the more “humanistic” ones, which do not rely that much on technology and we thought would benefit greatly from it. What we ended up with was the following three themes - haptic, music and learning. All of those are different enough from one another, that the potential amalgamation of which makes us quite excited.

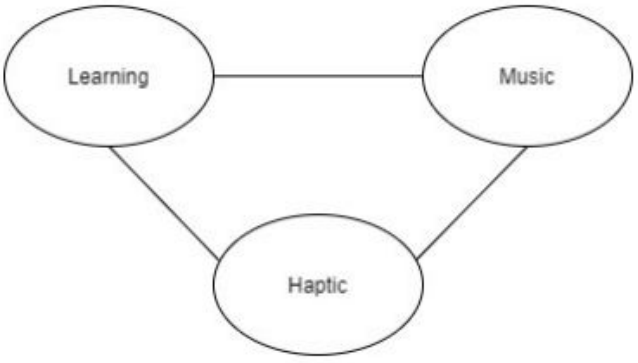


Fig 2 : Triangle of interests

After establishing the main focus of the project, we decided to not be too close minded and have a narrow vision and instead chose to further analyse potential areas of interests that could combine well with one or multiple of the already found ones.

Touch Amplification System for Augmented Surfaces

Key: Haptic Augmented

Ref: https://show.mat.ucsb.edu/2018/page.html?id=17

Fig 3: Mood board item

We came up with a few dozen ideas and projects that we would like to use as inspiration. Each item, as shown above, was made so that it would fit in and be put in a mood board - so in essence it should have some form of an image or visual representation, together with a small text briefly summarizing the whole idea. In order to speed up and ease the process of distinguishing between the various different themes and commonalities, we decided to additionally put down some of the keywords that would fit in, as well as a reference to the source in case we wanted to further explore the suggestion that we had. Of course, this did not apply to all of the items we had, however, it greatly aided us when it came down to trying to figure out what exactly each of them have in common.

Fig 4: Mood Board

Once all inspirations were properly connected with one another, we were able to clearly see some defined themes such as:

- Materializing Complexity
- Physical Training
- Medical
- Products
- Nature Activism
- Helping the blind
- Haptic interactions

Overall, there were a lot of differences, but there was one sub-theme that triumphs the rest in sheer magnitude of quantity - that of the glove. After some deliberation, we gave each piece a score of our interest, which eventually led to us choosing a very particular kind of a project. A glove that would have a way to track the movements of the teacher and then have them replayed to the student. This would be done live or “replay” mode, where the motors would grow in intensity when the time would be to play.

With that premise, we explored various potential target groups from traditional students and teachers, to more obscure but still related, such as VR cafes and visually impared people. After all of those discussions and research in the field, we decided to go with the most popular binary based musical instrument, that has not already been heavily researched like the piano, which is the saxophone. All of that eventually led us to the following formal problem statement.

Problem Statement

Playing an instrument is a rewarding hobby that many people strive to be able to do, whether as a pass time or as a way to connect with other people. However, the effort needed to reach a level of skill which can allow you to play the instrument casually for fun acts as a powerful barrier of entry for many would-be musicians. Formal education can be intimidating, both from a financial investment point of view as well as time investment and taking online classes can lead people to bad practices without the ability to properly learn techniques as well as rhythm. This can also lead to demoralization of the learner by having to constantly rewatch videos and try to replay while slowly following along with someone who does not and cannot take your personal learning speed into account. There are also problems when repeating the same practice patterns with having people nearby who would begin to resent the sound after a while.

Education Institutions, which formally teach players have problems balancing their budget with a proper education for their students. They also have issues with students lacking the motivation to continue working towards bettering themselves. Another effect on these institutions is the increasing need in our lives to separate, due to social distancing requirements, which also brings forward a need to increase the tactile awareness of a student, for the actions of their teacher.

We offer a technologically enhanced instrument solution, which would act as a personal instructor for a student, taking the time to train each movement required to play a song as well as the rhythm by leading the saxophone player to move between the required buttons at the correct intervals. Our prototype would be able to be used also without an instrument, allowing a user to practice patterns while in situations where playing an instrument would not be feasible.

As such, our end goal is to develop a way to learn to play the saxophone which gives also visual and tactile feedback and forgoes the need to focus on the movements of others and instead only focus on yourself, with the teacher, if involved, to act as a reviewer of your progress and not a constant focus point, distracting from the learning.

We decided to focus on the saxophone for a number of reasons. To begin with, the fingering system is relatively simple compared to others in an orchestra, which was important for us due to our solution needing a direct mapping solution between the fingers and the note buttons. Through this, they offer an experience that will always evolve, never fully mastering it, especially due to it’s versatility, as it is available in different shapes, while always following the same fingering system. The last reason being one of personal appeal, we were both interested in the instrument coming in, never getting the opportunity to learn it before.

All of this eventually lead us to this specific research question:

“*How does visual and haptic feedback affect the learning process among beginner saxophone players through the use of a glove prototype*”.

Background

There have been numerous articles and papers dealing with haptic and semi haptic learning [1-10, 16, 17]. One of the more famous and well regarded ones is that of Thad Starner and colleagues, where they explored how through the use of haptic feedback they can help beginners learn to use and interact with the Braille alphabet. That study showed that through the use of passive haptic learning (PHL), users can significantly increase the recognition ~72% and reduce the error rate in typing by ~32% compared to their control group.

While there are many similar papers that focus on learning alphabets or keyboard typings [3-5], there has also been significant research in the use of haptics and its use outside the aforementioned. A big interest has been shown towards the more medical, mental and physiological side of things. A prime example of that would be the wearable vibrotactile stimulation paper by Caitlyn Seim. The utility of tactile stimulation is shown as opposed to the abundant use of audio and visual stimuli in other articles as suggested by the paper. Through the use of that technology, a product is made which could potentially help reduce disability after stroke.

Haptics has also played a large part in the musical industry as well. One such research comes from Ellen Do, Kevin Huang and Thad Sterner and their PianoTouch glove[11], which teaches users to play the piano with it. A simple design that utilises vibrations on all 5 fingers of the hand based on the notes required to play. After half an hour, the subjects have shown significant progress. However, said improvement was not entirely done passively and instead required active attention in order to initially learn the song. The team speculates that this is due to having too many buttons and suggests that this would have much better results, and possibly done entirely passively, on a one to one finger to key instruments such as a saxophone or a flute.

That research has concluded more than a decade ago and many improvements have been done in the fields of haptic, music and those related to them since. Some of them include optimisations on the accuracy of the sensors [16], where with just 8 vibrotactile motors, one can encode 36 symbols or that through the use of vibrations and machine learning you can predict with up to 89% accuracy the finger tapping on a piano [2]

Such advancements can be seen in Ferhat Pala and Pınar Turkers paper [9], which heavily imitates and pays homage to the earlierly mentioned PianoTouch glove. Another more recent example would be the paper called “ShIFT: A Semi-haptic Interface for Flute Tutoring” [10], where the authors focus on beginners learning to play the flute and try to achieve a more realistic learning by focusing on duration, pitch, and motion ranges.

While a lot of research has been shown in the field, there has not been one on saxophone based on our findings. There are a lot of papers and articles when it comes to learning piano, both passively and actively with the use of a feedback system. There are numerous other instruments, but there is not a big focus and more in depth analysis on the saxophone. Additionally, there are many who have attempted to use haptics in the learning process,

however, we could not find any that have attempted to try and have a live or “replay” like functionality between two people of different skills.

One of the aims of this project is to try and strengthen the connection between student and teacher, and allow them to practice in a seamless way either when doing a learning session one on one or when practicing alone. We want to allow beginner saxophone enthusiasts to be able to learn efficiently by enabling them to feel and experience what the teacher is doing through the use of haptic feedback and technology.

This project is going to try and fill in this gap in the saxophone and technological industries. Our target is the advancement in the haptic field, which would grant us the ability to be able to relate technology to humans and aid the learning process in a teacher-centered, passive way. All of that would be achieved through the use of a prototypical glove.

It is also crucial to define what exactly we are going to be the limiting factors, the scope of this project. As already stated, the research question is as follows - “*How does visual and haptic feedback affect the learning process among beginner saxophone players through the use of a glove prototype*”. With that in mind, we can define that our primary target group would be people that are complete beginners and those who have not tried using a saxophone at all. The other group we will work with is the teacher. While there are other groups, such as autodidact, we would not have our focus on them as we expect the glove to be used between a professional and beginner.

Additionally, we would have to limit our interaction in favour of online ones due to restrictions in the country caused by a lockdown. That being said, we would be working with people around the globe and not lock down to a specific region. In terms of time duration, the only limitation would be that of the deadline of the project. This paper would not go over music theory or specifics on how the saxophone operates and would instead focus on the interactions players have with it and the glove prototype.

Methods

In this section of the report, we describe all the various methods we've used to gather data that would be used to justify the validity of this research. They have been grouped together based on type and have been generally ordered chronologically, so that the reader would have easier time navigating.

It is very important to note that all participants and institutions in the study have given us their prior consent and have allowed us to use their data. For the sake of anonymity, none of their vital information would be revealed, but only significant facts that have direct correlation to the topic at hand.

Another key note is that all of the gathered information here has been collected during a pandemic in which many parts of society have been restricted or completely shut down. A lot of institutions and people have been fearful of the situation, which proved to make things much more difficult. For that reason, as well as the safety of both researchers and participants, all the methods used were virtual, whenever possible, or taken with extreme precautions and following the regulations imposed when done face to face.

Method Overview

We're looking at different methods to get the data we need, one interesting idea we have floating around, depending on who we convince to meet with us more, is to attempt the participant observer method. This would work since part of the question we're looking at is what effect does our prototype have on absolute beginners trying their luck at learning a musical instrument, and we both fit that definition. Before we can look at any of these approaches, a more theoretical one is required in which we conduct some sit ins followed by in depth interviews, for which we are preparing with a question guide for ourselves. This is all really meant to help us gather the relevant data to see which of our assumptions can be validated. Afterwards we will be looking at studying the effects of the prototype, or prototypes themselves, depending how it goes, by having a number of users with the prototype, some without and observe whether there is a difference in both the time a level of skill is achieved and the recollection capability.

Researchers Views

While the researchers perspective is going to be addressed throughout the report, it is important to emphasise on some of the key preconceived notions we have when it comes to this project.

One vital detail is that neither member of the team has played or has in-depth knowledge into how the saxophone works. An example of that would be that in order to produce proper sound, the reed (the mouthpiece) is required. Because of that a huge focus when it comes to playing is that of blowing and mouth control - something that we did not account or expect for in the beginning.

When it comes to more generalistic opinions, we strongly believe that when it comes to music, the only “proper” way to learn is to have a teacher who is going to be guiding you and making sure to correct your mistakes. This notes stems from the believe that a complete beginner is “unconsciously incompetent” and as such has no way of knowing how to improve and how and why they are making a mistake. [18]

We also come into this project with a big preference and believe that a glove based prototype would be the most optimal solution that would allow for an efficient and user friendly way of learning.

Those are some of the bigger conceptions that we come with and some of them do not retain throughout the project, however, they still have had a huge impact on the way we have approached and conceptualised the glove and a large part of the methods written below.

Research Approach

When discussing our research, it is important to identify and align it to the already existing paradigms so that readers would be able to comprehend and reason why the method and methodologies selected try to help answer the question posed.

The research question in place is interested in the effects haptic and visual technology would have, as previously mentioned. As such we do not expect to come to a singular correct answer, in fact quite the opposite – by the very nature of the question we expect a myriad of various opinions and results, all of which could be valid. By the premise of it, we seek to gather more rich data, such that it is filled with complex details and interpretations, and try to understand its meaning, rather than have broader and shallow ones. As it is also very exploratory and open ended, its assignment would fit best with the qualitative one.

Additionally, as the focus is on our participants experiences and feelings, we decided to take an experiential approach to this project. While we would like to be able to understand how they interpret things, we also recognise that there are going to be certain and inalienable truths as we are the ones directly developing the product tested. Taking ontology into account, this would place the project within the realms of critical realism as defined by Braun and Clarke. On top of that, being able to determine what is actual good meaningful data and how it is generated is the subject of epistemology, which is about the nature of knowledge. Whilst our prototype is built with specific context in mind, namely saxophone beginners, it could potentially be used in others, however that is not a subject of this study and thus the information is highly dependent on the situation, which positions us on contextualism in the epistemological continuum.

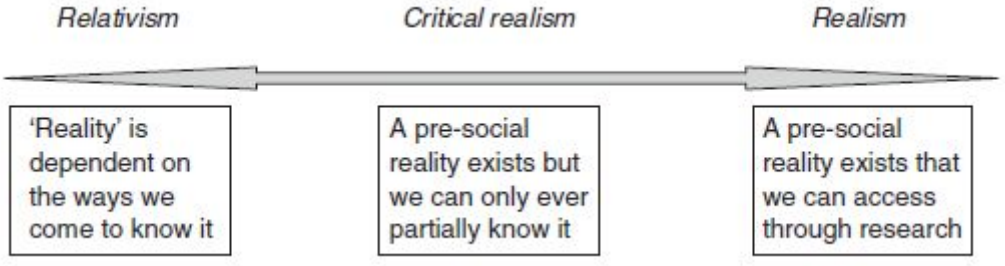


Fig 5: The ontology continuum [19]

Interviews

One of the most efficient ways of getting good useful data is by performing interviews, as they are well suited for experience related information. Additionally, they serve the purpose of trying to comprehend how the interviewing party feels about certain subjects and practices.

Initially, as neither of us had any or very limited experience with playing the saxophone, we needed to talk to experts in order to provide validity to the possibility of our research, as well as gather necessary connections, details and even proper nomenclature, which we could use to establish trust and understanding between us and our future collaborators.

We gathered information on various music schools and teaching institutes and proceeded to try to both extract contact details to several lecturers but also attain knowledge in their inner workings through unstructured interview-esque conversations. While receptive, they did not give almost any useful new input, which was evident by their general lack of knowledge in the manner as well as the increase of complexity and busyness due to country wide restrictions caused by a virus.

Another attempt for interactions originated in our immediate circle of friends, who were already playing or guided us towards someone whom they knew would be of help. This proved to be of huge help, as this allowed us to establish connections to several university professors and other professionals whilst ignoring all the bureaucratic issues.

Preparing for the interviews

We managed to get a hold of a semi-professional saxophone player, with whom we conducted an informal unstructured synchronous virtual interview. Said conversation was used as the underpinning for all future endeavours. While we had details on others, even some non saxophone enthusiasts, due to the pandemic situation in the country, they could not work with us in a timely manner. This ultimately also was used as a deciding factor for choosing to proceed with saxophone players.

Based on the accumulated materials we composed an interview guide, which would be used for semi structured interviews of both virtual and face to face kinds. In order to prepare for this endeavour, some sort of format is required to be followed, however, because we want to get the way our participants experience various things, we need a more open ended approach to this, rather than following concrete questions. So instead of having a specific questionnaire, we compiled a more abstract list of topics we would like to discuss with them. This way we can ask more open ended questions and allow us to follow through with them based on the feedback we receive. This gives a more in depth overview of the participants feelings and perceptions, thus allowing for much more rich, quality data, in contrast to the quantitative approach which focuses on mass of data, which is more superficial.

As already stated, the interview guide is a more abstract collection of general questions, themes, we would like to touch upon. The topic all ranged across various aspects of saxophone players' life, motivations and ideals. The list we used is as such:

- Personal connection to saxophone playing
- Job related interactions

- Student related interactions
- What is learning and how is it conducted
- How technology influences saxophone playing

These were the more general and abstract topics we wanted to talk about with the selected players that we could find. Each of them had a subtopic that would help us guide the interview interactions, which allowed us to encompass a variety of musicians, from beginners to experts, and from autodidacts to professionally trained.

The first one focuses more on how each person started dealing with the saxophone and explored what to them is saxophone playing and how they approached it. We asked them to try and describe their journey and give their impression of how much they have learned and how good they are. This way we would be able to identify their levels of expertise, but also deal with what their personal and professional goals are. By describing their motivations and drives, we can pursue a more thorough investigation and allow us to guide the future questions.

The second topic is about how they interact with it from a more professional standpoint. This was mainly intended for the more advanced users. In it we explore how said musicians deal with their day to day life as a paid instrumentalist and the various challenges they experience. Because a lot of time, the playing has to be made in a special room, a studio of some sorts, it is vital that we try to learn more about how they deal with playing on the run and going from location to location for example.

Onwards we dealt with the interactions between students and teachers. This was one of the more extensive and interesting to us topics, as we get to explore more of the cooperation between the two roles. It was of great significance to us to learn about the way they each approach one another and what are the general age ranges. This is vital as our target was beginners and if the primary group of students were children, then the design of the prototype would drastically change to try and accommodate for that factor.

Then we approached the main point, which was that of learning. As previously mentioned, there are a lot of different ways of learning music and in fact, there are various types of saxophone playing such as classical or rhythmic. So it was crucial that we delve deeper into this one. We had a huge interest in the way teaching and learning is conducted, as well as what are some of the challenges and tribulations during the session and outside of it. Not only did we explore all activity during the session, but we also needed to do so with exercises outside of it, when they practice as this is the part where they usually spend the most time based on preconceived notions of a typical studying process. In addition, we tinkered with their feelings and asked them about their favourite and less so activities, but also their motivation to continue doing as they have so far.

The last section, after the continued escalation of intensity of questioning, was that of technology and what part that plays in their process, a more relaxed part of the interview, where they can divulge some possible ideas for future endeavours. With it, we would uncover the various tools and online platforms that are already being used. Due to the sudden global pandemic, it was important that we identify how it has impacted the participants, and how they try to stay connected. Lastly, we wanted to touch upon how and in what they do they imagine and want technology to try to improve things. This way we can gather diverse opinions about features that we could try and deal with, but would also show exactly what are the potential downfalls of traditional learning, if they have not been mentioned already.

All of those topics were used and compiled into the interview guide that allowed us to follow a more structured form of questioning. And as they are quite abstract, it would be up to us to

decide how and in what way to follow through with that conversation. It was vital to try and make it feel more of a discussion, rather than interrogation, as it would help our participants stay relaxed and let them speak freely and openly. The whole process was also timed to last around 45 minutes, so that we can gather enough information, but also to not exhaust both parties. In addition, there was a focus on trying to keep the dialog in a positive way, so that the interviewees are more likely to conduct future ones.

Choosing Participants

Another key point when preparing oneself for the interview is to know to whom you are talking to. This way, we can try to ask more concise questions based on what we know and don't, but also allow us to relate to the participant, thus allowing them to feel safe, secure and open. All of this is done in order to be able to extract as rich of an information as possible. In order for this to even happen, we are required to first recruit said people, so that we can interview them.

Getting humans to cooperate is relatively easy as we are all generally willing to help others . To further increase the odds, we could always give some sort of incentive - be it some food items or even a gift card, that is all done deliberately so that we can have easier time persuading people to collaborate with us. Even though nowadays, this task becomes quite challenging due to distance and meet up restrictions and general panic of the population, we were able to gather several individuals that were more than willing to share some time with us and help us with attempting to answer our research question.

In order to be able to collect various kinds of saxophone players, we decided to try and dial directly several musical institutions and schools and asked them to collaborate with us. This proved to be quite fruitful and meaningful as more often than not, we were communicating with receptionists which proved to be quite knowledgeable about the instructors and could easily supply us with the contact information of them. In the very few cases that they did not want to divulge any sorts of data like that, we were able to scout out the teachers through other means like asking someone who is already close to them that we knew or through social media and lessons adverts.

We also wanted to have a discussion with students and general beginners, however, trying to directly find such people is quite difficult as they do not usually publicly announce that. We tried initially by asking around people we already knew and the social networks. Additionally, we wanted to try other methods like giving away some flyers or approaching directly some shops, restaurants and general places where potential participants may visit, but sadly most of them were already closed due to aforementioned restrictions. Instead we focused mainly on the teacher side of things, as naturally we would be able to interact with their students if both parties would agree to it. On top of that, because both the student and the teacher already knew each other and have worked together, this would allow us to explore their connection and deduce more in depth how the learning process goes for each individual from both perspectives and how potentially different they all are from one another and from student to student.

The last group we were trying to interact with was the rest of the saxophone players such as autodidacts and professional players. One thing we noticed is that those people are generally independent from associations and the common venue they usually gather at are mostly online forums and chat rooms. Whilst they were not regarded as our primary target we wanted to be able to interact with them as well, and learn how things stand from their perspective. As already stated, both researchers had the notion that one needs proper professional guidance, most commonly in the form of one to one learning sessions, if they are to succeed. This is due to the fact that complete beginners generally have no idea where to start from, what to do and what they have done incorrectly and would thus greatly benefit from a teacher. However, autodidacts learn by themselves, so this would greatly benefit us by allowing us to uncover some other scenarios, teaching techniques or similar, that are not usually found in the traditional learning process that we expected.

Transcribing the data

Once we finish with the interviews, it is essential that we deal with transcribing them, or in other words - writing down what was said. This way, we can have a much easier and faster time dealing and analysing the data, as it is quite slow and difficult dealing with audio recordings compared to written text.

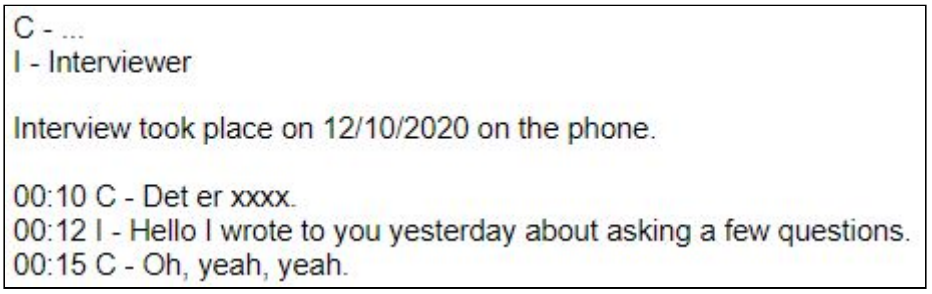
It is important to note that we chose to write down the interviews verbatim, or word for word, also commonly referred to as orthographic transcription. In it, we make sure to note down every single moment of pause, all words and non-semantic sounds (“umm”, “hmm”, “ehh”, etc.), without removing, editing or paraphrasing anything. That way, we can judge properly and take into account the whole train of thought. This is done so that we can easily identify how the participants are talking and the emotions that they are experiencing. Speech is much different than written text and often it is very challenging if not impossible to be able to transition from one to the other. One such reason would be the fact that whenever we speak, we do not “follow” proper sentence structure and this can cause issues if the transcriber would want to try and enforce that.

For such instances, there are various notations that could be used to try and point to such infractions in the sentence structure. Clarke and Braune suggest using several parentheses to identify long pauses and “(.)” for short ones for example. Amongst many others, some of the more relevant and crucial details that we would like to also know are some of the non spoken expressions of emotion - such as laughter or crying, which are denoted with parentheses. Their way of notation, however, is not the standard as there is no popular commonly established one, but instead, it is up to the transcriber to decide what notation to use.

We, for once, decided to ignore the difference in pauses, and instead treat each one the same, noted by “...”. The main reason we decided to ignore it, is because both the interviewer and the interviewees do not have English as their main language, and in some cases, there are several interludes, which were caused due to language troubles. Because of that, trying to differentiate between each one and the meaning behind them becomes too detrimental. Additionally, due to technical difficulties or trouble comprehending the language of expertise, there are several points in the conversations, where they were omitted, by just

denoting them as several x's. Thankfully, there were no cases, in which there were any other problems, such as overlapping the conversation as an example, that took place during the interview process.

Lastly, we always make sure to write down the details of the where, how and with how the interview took place in. Below is an example of the beginning of one such instance. We have omitted all the information in this case for the sake of anonymity. During the whole transcription process, we made sure to refer to the participant with their initials, in a way that it would protect their identity in a case of a breach or if we were required to share the finding, but so that we know to whom we are referring to. On top of that, as with most other transcriptions, we made sure to note down the time in the audio recording, in which the spoken words were said. This way, we can easily come back and check, in case of trouble comprehending or something else related to the file. As already mentioned, the whole transcript would be used for fast and easy abstraction, which would allow us to bypass the additional time required to check all the files, and would relay all the information we need in a format that would act as a substitute for the spoken language.


C - ...
I - Interviewer

Interview took place on 12/10/2020 on the phone.

00:10 C - Det er xxxx.
00:12 I - Hello I wrote to you yesterday about asking a few questions.
00:15 C - Oh, yeah, yeah.

Fig 6: Interview transcript example

Surveys

Surveys are another great way to gather data from willing participants. And while it is rarely seen in qualitative types of research, it can easily be adjusted and made to fit in by simply trying to ask more open ended questions, rather than having multiple select options. We had several target groups, all of whom had different needs and experiences with playing the saxophone and as such, we needed to tailor and adjust the surveys for them so that we can maximise the richness of the data.

While there are several different kinds of surveys, we decided to go with online ones. With it, we can easily gather large amounts of data and not have to spend too much manpower and huge costs. We had to account for responses which are fake, joke-like, however, we believe that this would not have much influence in the final results and such answers are generally easy to spot. Additionally, besides giving us more potential codings, we can use the data for quantifications, so that we can have easier time to decide what theme is more prevalent and common amongst our participants. When it comes to the platform, we decided to use google forms. We believe it to be the best blend of ease of use versus efficiency and functionality offered. While there are other, more popular options out there, such as surveyMonkey, which offer additional benefits like automatic coding amongst others, we wanted to use something we already had experience with and are comfortable utilising to its fullest capacity. Another,

albeit personal experience, is that surveyMonkey is quite disliked throughout our friends circles and online communities we frequent, as more often than not, they are targeted by poorly written surveys and researchers that do not really want to disclose or even share some of their findings. That being said, as already mentioned, this is entirely based on personal feelings and experiences from us and those whom we are close with, and it is not based on supplementary evidence. However, as it is one of the reasons we went with google forms, we wanted to provide some justification.

Preparing the survey

Once the survey type was chosen, it was time to structure it in such a way that we would be able to get responses that would allow us to answer the overwhelming research questions that we are facing. As already mentioned before, we are focusing on trying to follow the methodologies of the qualitative type of research and as such we need to ask open ended questions rather than the typical multiple choice selection that is presented in most quantitative studies. This way we can allow participants to express themselves freely, without restricting them, thus granting us with much more rich filled data.

When it comes to formulating the questions and their order, there are some subtle guidelines that are suggested. The first point of emphasis is that of the title and description, which would allow the users to have some sort of understanding of what this survey is about, who it is targeted at and so on. While we make sure to properly prepare our participants and write adequate information on places we have shared it on, it is entirely possible that there could be someone who has not read this information for whatever reason. As such, we would like to include everyone and establish a trusting connection, thus making sure that the participants are comfortable and open to divulge more information.

One such point that tries to bring trust is the fact that we do not require any personal information to be shared and it is entirely up to the user to give it to us if they so choose to do so. However, this is done at the very end, so that we can make sure that they have gone through the survey questions and are confident in our intentions.

Another key thing is to let users know that they grant us consent to use their data and that they can withdraw information at any point if they choose to do so. Similarly, we must establish some deadline, a time period, in which we are to gather data. By having that we can set a time frame for collecting responses thus “pressuring” participants to answer on time, in addition to making it much easier to schedule our workflow and account for the vast amount of potential data. Lastly, participants are given details on how exactly this information is going to be used, which in our case was summarised as trying to improve the learning process of the saxophone instrument.

When it comes to the questions themselves, we wanted to have mainly open ended ones, with several multiple choice ones only to help identify the audience and check if there are some correlations in terms of age, sex or similar with the answers provided. That being said, all of the questions were written in as simple a way as possible, so that we can avoid any confusion and ambiguity. On top of that, we wrote the questions to be non judgemental and

as inclusive as we can, trying not to have our preconceived notions too much of an effect on them and come across as close minded or discriminatory.

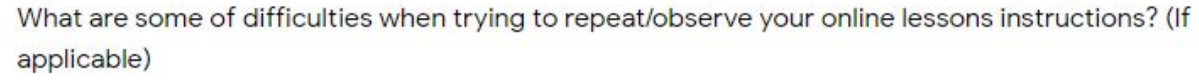


Fig 7: Survey question example

The questions themselves were largely based on the ones we have compiled for the interview. However, unlike with that type of data gathering, this does not allow for flexibility to such extent, thus limiting us and forcing us to have a more structured approach. Based on the previous section, the questions were largely group as follow:

- Personal connection to saxophone playing
- Job related interactions
- Student related interactions
- What is learning and how is it conducted
- How technology influences saxophone playing

Because we lack the ability to adjust to the participants and instead have to focus on a more generalistic and abstract order, we needed to separate the survey into several different ones so that we can avoid questions that are not really applicable for all such as “job related interactions” for students as an example. That being said, the survey questions were almost entirely the same as the interview one as the open questions allowed for it.

The various versions of surveys

As already stated, we needed to separate the surveys to several types based on the target group that we were questioning. Whilst there were a lot of similarities, we split our questions into two categories - ones for students and ones for teachers. Autodidacts were considered close enough to students and so were grouped together as one could argue that everyone has some sort of a teacher - some have a face to face ones, some online and others text based one, such as from a book. We tried to adjust to as much as possible for the solo learners, however, they weren’t our primary target group and we did not expect to get many responses from them.

The very first iteration served as a pilot, in which we just allowed a small amount of people to fill in the data and give us their feedback and based on their responses, we would be able to adjust to a properly written one. The pilot for students and teachers was posted on an online forum website, where 18 people gave feedback. Whilst we did manage to collect some data, we received a lot of criticism for the way our survey was written. There were several complaints, however, the majority of them were pointed as the survey ignoring the solo learners completely. While we do not fully agree with that narrative, we tried to adjust to those comments to an extent - by adding “where applicable” to the questions or switching from “lecture” to “learning session”, which was seen as a good alternative to the community. There were a few problems with some people failing to understand the questions, which forced us to be more explicit and simplistic in our approach, however, it is important to note that those online forums are not entirely dominated by native english speakers, so some discrepancies were expected.

Once all of the criticism and comments were taken into account, we released a brand new version to all of the online platforms we knew saxophone players gathered. For the sake of clarity and easy distinction, we had 3 identical versions, all dedicated to the large communities we found - “saxcast”, “reddit” and one for general smaller forum and similar spaces. We did that so that we know from where those answers come so that we can adjust it to fit better to the responders while still remaining the same in terms of trying to aid answer the question.

The way we approached those communities was to become a member of each of them, then talking directly to the admins in charge of them. We asked if we could be given consent for posting our surveys and in case we were rejected, we would simply not collaborate with them. Thankfully, they were all welcoming and we even caused a discussion to happen on the benefits and drawbacks on various studying methods.

Additionally, Saxcast were very interested in our research and the admins decided to boost the popularity of it, by promoting it to all members. They asked us to provide the raw data of our findings, which we obliged, after cleaning it up to remove any personal information that participants might have written down by a mistake. Thankfully, no further adjustments were needed and we managed to gather enough data in the timeframe provided, which was 3 weeks - an arbitrary number, that would allow enough time for responders and would correlate well with the deadlines of the project.

Observations

As mentioned in the previous sections, our prior knowledge coming into this project was very limited in the field of playing the saxophone, most of our knowledge of it being in passing from our own interests in music and other instruments. We acknowledged this and so we tried to have as diverse sources of data as possible in an attempt to not miss on perspectives and data that could become more visible in some methods than others. This was part of our approach to the project, coming at it with a participatory mindset, not an expert one.

Our initial idea was to provide a solution, which we hoped would enhance the experience of learning the saxophone, however this came from our own brainstorming and wasn’t based on any proof that what we were focusing on was indeed a problem, and we had no real understanding of what students go through when learning the saxophone, due to this, it would not be possible for us to be aware of the actual needs, which could result on us focusing on certain elements that would not be necessarily seen just as important by actual students and ignore key others.

Between the types of observation, we went with the naturalistic approach, lending itself well for the process of ideation [20], which we needed in order to form as many possible ideas as possible from the actions and behaviours we wanted to record. It was also additionally helpful that one of us participated in an online class as a student. We chose to also do this

participant observation method, in addition to the naturalistic one, as a way to gain further insight into what problems and needs a regular student might face.

Originally we planned to attend classes provided locally by music schools, however due to the newly placed social distancing rules, none of the official channels were able to provide us with concrete answers on when we could do so, or even if it was still possible, as weekly changes in regulations would force them to switch between online and offline education, or doing lessons at students' home, and so forth. We also faced issues in contacting them originally, however through effort and convincing from our supervisor, we kept trying to contact teachers, attend music events and build and find old connections until we were able to find what we needed. We ended with two sources, one was Professor Christian Vuust, which we were able to observe in the last lecture of the semester, after interviewing his students and having them agree. The other was an online class [21] that was recommended to us by one of the representatives from the schools we contacted, one of us took this class up as a student, taking notes and trying to follow along with the rest of the students, asking questions when possible.

Naturalistic Observation

For the observation of the lecture which we were to attend in real life, we prepared by having three devices to record, in an attempt to ensure as much material as possible and to not miss anything, and a laptop on which to take notes. At the time of the hour long lecture, only one of us was able to attend. The laptop was set up in the back of the room, as to not distract the teacher and his student, while the other two were placed to film from different angles.

Fig 8: Title: Observation of Christian Vuust and Nikola Bankov, Time : 34:44, Description: working together to identify the best pattern for a section of the song.

Since this was not a controlled observation we did not have a list of what we expected them to do, instead, during the hour we had it was important to take notes on what both the student and teacher were doing. Originally, the one of us that was there took field notes, which we later worked on together by watching the videos, annotating specific times and actions as well as writing things that were missed during the taking of the field notes.

We followed the guideline from the interaction design [22] on how our notes should look like. The notes focused on describing the space in which the observation would take place, the actors present during it, the activities they do during the whole time and in what sequence, what they are trying to work towards, in other words, what their goal is as well as what the mood is through the experience.

As here, the observer was not directly participating, it allowed for detailed note taking, the following is an excerpt from the original field notes:

“Nikola often practices patterns/phrases without actually blowing into the saxophone, just doing the fingering, he only starts blowing when he wants to prove/show a specific thing to Christian. Then Christian gives feedback, either playing slower or faster. Interesting to note

they do not use timing notation or theory, not while practicing, they just say if it should be faster or slower.”.

The notes are not verbatim transcripts, instead they are paraphrasing everything that was seen at the time, and they are supplemented by later edits done by the both of us watching the videos together.

Participant Observation

Before we got the chance to actually observe, interview and meet in general with other people, we were left very limited on our data gathering activities. It was good that one of the representatives at the schools we talked to recommended a course on udemy which people who wanted to become students at their school and were stuck in the waiting list for over a year at the time of the interview were also recommended taking.

To change the way this would be experienced, we attempted a variant of the natural observation, which would involve one of us actually joining in and becoming part of the group of students, which would give us a deeper insight and understanding as one of them [23].

It was not needed to do this secretly, as anyone could become a student by simply buying in, and there were students from all around the world and from different age groups. However we did not act in an overt manner, by announcing in the forums of this course that the one of us who was going to participate was a researcher, instead acting as any other student, with questions and confusions same as theirs.

“Afterwards he plays it with the camera on his fingers, asking us if it was the same, in this situation the fingers are not very visible and the comments section represents this, by having people not sure if they were correct or not.”

We used the data from both of the observations as signposts for later work, adding anything extra that was not noticed the first time and started working on actually preparing the data for the thematic analysis.

Initial Glove

In order to better understand the design and gain an insight on whether it would work without negatively affecting the user with the sensor, we built a series of proof of concepts from different parts we had available until we made one that was stable enough to test with.

Fig 9: Proof of concept glove

It was built from a surgical glove, with the coins acting as placeholders for where the motors would be and the pill containers acting as the LED placeholders. We then had a few different variations, putting the coins at the tip of the fingers and using thick wires as placeholders for the flex sensors.

In order to properly get the insight mentioned at the beginning of this section, our plan was to first use the glove proof of concept ourselves while doing a number of tasks, trying to check if the dexterity we are usually used to was lessened by wearing the glove ourselves. Later on, we wanted to get a hold of other people and see what they think.

Workshop

We invited three of our friends, and we imagined three tasks that they could do, which we thought would fit properly. The idea was that they would first do a task normally, without wearing the proof of concept, afterwards they would wear the glove and attempt the same task. Each person would then rate the glove with a fail or pass, depending if they felt that, while wearing it, they felt that it was noticeably hindering them in doing their task.

Title	Task Description	Pers 1	Pers 2	Pers 3
Can you feel the “motors”?	Stretch fingers for 10 seconds.	pass	pass	pass
Can you see the “LEDs”?	Pick up and hold a PVC pipe, can you see the “LED” spots?	pass	pass	pass
Can you move your hand normally?	Play two rounds of chess.	pass	pass	pass

Fig 10: The three tasks with their ratings from the workshop

As seen in the image above, our proof of concept seemed to be successful at not hindering any movement from the wearer. This of course was not equivalent to playing the saxophone, but with our limited available resources, it was the best we could do.

After the workshop, we had a quick talk with each person, trying to involve them in the design process, by attempting to reflect together on the current design and see what ideas they would have at improving it. They were all very excited at the possibility of a glove guiding their movements, in what seemed like a quick way to learn to play an instrument and most of the conversations offered us ideas that we had not considered at the point, for example, how would the glove know when to start recording movement, discerning between playing the saxophone, or pressing a button to start the glove.

When we showed them the flex sensors which we were going to use in building our actual prototype, they also pointed out that the position of the motors would be uncomfortable if the flex sensors would also add to the bulk over them. Feedback which we took to heart when designing the first prototype.

We did this as part of our iterative approach to our design. Had we not done this, we would have missed out on this feedback, and any other information that we would miss by developing a sort of tunnel vision instead of trying to understand how others would see this project, what their perspective would be on it.

Results

Thematic Analysis

Introduction

We approached this project with the plan to generate our thematic analysis through inductive means, as we did not have our own strong enough theoretical framework on the topic and all of our themes were as such generated directly based on our findings. As such we needed the help from people with different backgrounds relating to the field to validate our hypothesis and allow us to iterate upon it. To achieve our wanted level of insight, we worked towards gathering data through multiple methods and followed through with people as much as we could to ensure a high understanding of the context in which the data was given to us. The purpose of our research was to find what factors influence learning to play the saxophone and analyze both the negative and positive ones. In an attempt to gain a clear understanding of these factors, we followed the guideline developed by Virginia Braun & Victoria Clarke [24], which allowed us to still benefit from the flexibility given to us by qualitative research while having a clear pathway to gathering our data from the diverse sources.

We began by settling on ground rules of how our analysis would be conducted and on what basis our results would be seen as usable. These conversations were held based on the suggested process recommended to be done both before data is even gathered as well as an ongoing activity, both enabled by the flexibility of the thematic analysis as well as enabling it, allowing us to make changes as needed. We began this by first agreeing on what constitutes a theme, what makes something prevalent enough for us to see as a pattern and how would we measure it. As we have a qualitative focus, our first priority is not the proportion of data across a theme that is encountered, but how it relates to our research question and what meaning we draw from the data through it. This of course implied the need for us to use our own judgement and interpretation, which resulted in moving codes multiple times, grouping them together and finding different themes during the entire process.
As we attempted working using the inductive approach, the themes were formed from the data gathered, which we first coded. This is in direct opposition to “theoretical” thematic analysis, which would have required us to have a coding framework pre-generated and attempt to fit the data in whatever themes we would already have described based on our knowledge. Through our focus, our original question evolved based on the information we gathered. The original question focused on learning any instrument and how the activity would be affected by our assumed solution at the time, based on a glove. Later on, from the need to focus on a specific instrument and the available sources we moved towards focusing on the saxophone. Also based on our research, we saw it important to explore multiple solutions in order to understand what would be more useful, which gave us the idea of

replacing the glove with a faux saxophone tool that could be used to practice on (**see future work/discussion**).

As mentioned before, the template on which we based our work to develop our Thematic Analysis from an amalgamation of data to an interpretation supported by analytical theory and which allows us to gain a more educated view on our research question was taken from the paper by Virginia Braun & Victoria Clarke. Instead of only writing the report part of the analysis, we saw it more fit to organize our thoughts in notes as we went through each phase in the form of a log of activities during a day such as data gathering, meetings etcetera. The structure seemed ideal to share our thoughts and to keep track of them in a manner that would allow us to navigate through our work with relative ease, as such we followed a similar structure in our writing. That is why, instead of only documenting the final product and discussing it, an approach which lends itself to being prone to the pitfall of presenting an unconvincing analysis by not succeeding in presenting the data corpus in a manner that showcases it as adhering to the central concept of the project due to failing to provide a rich enough interpretation; We chose to describe our work as we followed each phase during the timeline of our project.

Familiarization with data

Our data came from multiple sources as mentioned in the previous sections. These were interviews, either face to face, by phone or messenger, observations of online and live classes and multiple surveys, which we developed to focus on different themes and changed based on feedback we got from participants. Due to having multiple sources, we inadvertently became more versed in the data that each of us took, the other one needing to be introduced to the results as they came in. We did this by helping each other handle the data, taking personal notes and writing comments on them, and beginning early to form possible codes and selecting data extracts for later. We were not looking and creating legitimate codes at this time as such, if any were formed, they were descriptive and to be used for later.

All of the interviews which we recorded were transcribed, usually one would conduct the interview and the other one would transcribe from the audio file, which we thought would aid in both of us becoming familiarized with the data in question.With our observations, we worked similarly, however one of them we were provided with the transcription, as it was an online class, so we read through it while following the video, checking for accuracies while also taking our own notes on the whole class. Our other observation was done face to face and recorded with multiple devices. After we both rewatched the videos and took notes of comments one of us made extensive field notes which we analyzed together to ensure we both knew what it was about. The results that came from each survey we analyzed after each of their lifespans was over. We recognized this as when the responses would not change for a few days, however we kept checking even later into the phases of the analysis if there were more coming, although we were usually correct in our assumption, which was usually connected to how high up in the current topics of the communities we posted our surveys were, where if we had no comments for a few days, no one would see our surveys anymore, this not being the case only with one survey which was pinned and promoted by the administrators of a community.

Coding

Generating initial codes

We began the actual coding by first looking at the interesting extracts, item by item and assigning descriptive codes to them, as well as trying to keep track of the times they occurred. Even though our end goal was not to use prevalence by number to generate the themes, we decided it was needed in order for us to gather a better understanding of what are the common needs in different communities and groups of people. As our sources ranged from experts with decades of work to complete beginners who had just taken it as a hobby to spend the time in social isolation with and they were also separated by their approach to learning, some seeing it as something to do in complete solitude without needing anyone while others coming from professional schools, unable to even imagine learning the saxophone in a context separated from a social aspect. We wanted to see what would be common between sources this different and from that, what we could tackle and what would be irrelevant. After assigning codes by ourselves separately, we met together and developed an initial affinity diagram, grouping codes together and trying to see what themes could take form.

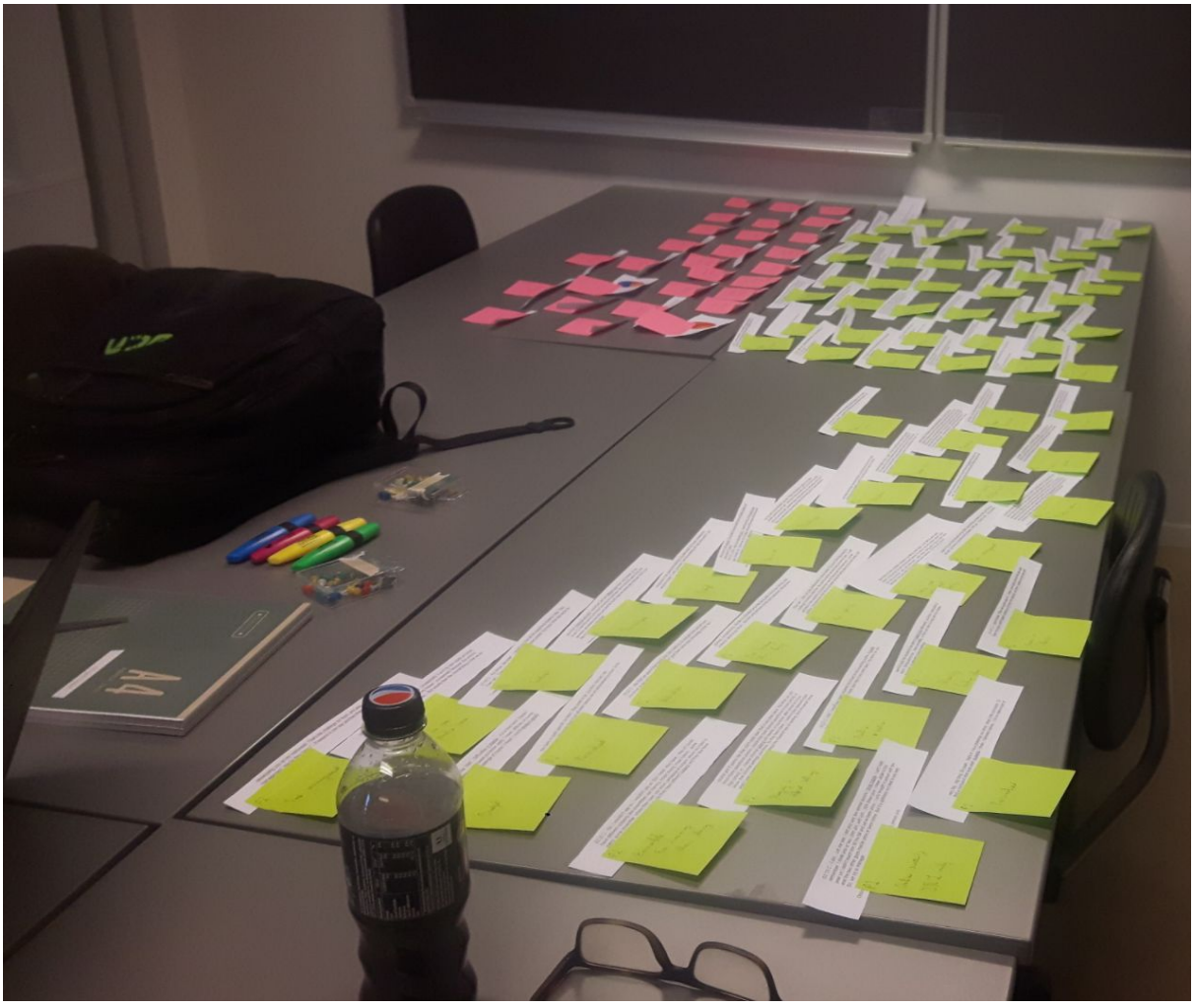


Fig 11: All of the codes attached to the data extracts we took them from.

Searching for themes

To do this,we first organized them based on the sources they came from (be it interview, survey or observation) and then worked towards generating our initial themes, which were predominantly descriptive. The sticky notes containing the same codes were stuck together as a chain, to allow us to get an idea of the predominance of said code. The codes were extracted using a comparatively small dataset as opposed to what we managed to gather later, this was due to the slow progress we made in gathering our data. The iterative nature of the thematic analysis allowed us to continue working and not having to wait until we would feel that a "quota" would be fulfilled. The themes at this time were as follows:

- Personalized
  We followed the information we got about the effort teachers put in creating an altered curriculum based on the interests of the student. An example of this is from the data item we gained from interviewing prof. Chirstian Vuust, of the Royal Academy of Music, in Aarhus :

Data	Coded for
"...So you know, if I had the same curriculum for everyone you know. And in the third week of the third semester we always play this tune and the fourth week we always play that tune. But it is not like that. It is very individual."	Personalized curriculum

It was also important to students, since it was directly connected to their motivation to practice as well as their ability to learn the basics. We got this information both from the surveys:

Data	Coded for
Q: What are the hardest things for you during a learning session? A: "*It very hard to read music for me so I just skip that.*"	difficult to read music sheet

As well as the interviews we lead with Christians' students, one of them explained his dislike for the usual music with which the saxophone is associated when playing and

how he appreciates when Christian moves away from it in the exercises for his personal curriculum.

Data	Coded for
"*03:17 A - And I guess there's... there is that thing with the saxophone that is very, very often associated with jazz music.* *03:26 I - Mhm.* *03:27 A - And I don't really play jazz music.*"	Personalized curriculum needed

- Basics

We originally grouped many codes under this theme, we later on extracted other main themes from it however at the time, lacking the hindsight we gained later in the process it seemed that everyone had many diverse problems without much cohesion when trying to get started. We also soon realized that this theme was not valid from the point of developing our analysis through inductive means, since it wasn't that we realized people had problems with the basics, instead it was a direct result of us focusing our data gathering towards people that would, such as students. As a result, numerous data extracts pointed us in this direction, later on, these same data extracts we interpreted and they became part of other themes. As a few examples:

Data	Coded for
Q: What are the hardest things for you during a learning session? A: "*Playing the wrong notes*"	hard to play correct notes
Q: What are the hardest things for you during a learning session? A: "*embouchure and articulations*"	hard to do mouth control
Q: What are the hardest things for you during a learning session? A: "*terminology*"	difficult to understand the nomenclature

Similarly, from our observations we had seen the issues that students encounter and have a hard time getting used to when trying to understand the basics of saxophone playing:

Data	Coded for
"*Afterwards, he brings up the problem of timing with the fingers, when switching between B and C*"	problems timing switching between notes

- Motivation

From multiple data items, we noted down the frustrations people encounter when learning the saxophone as well as how they try to solve them.

Keeping motivated is a challenge in doing anything that has its rewards on the long term, and with the saxophone problems are compounded due to the many things that people need to work on, which we gathered from our original survey:

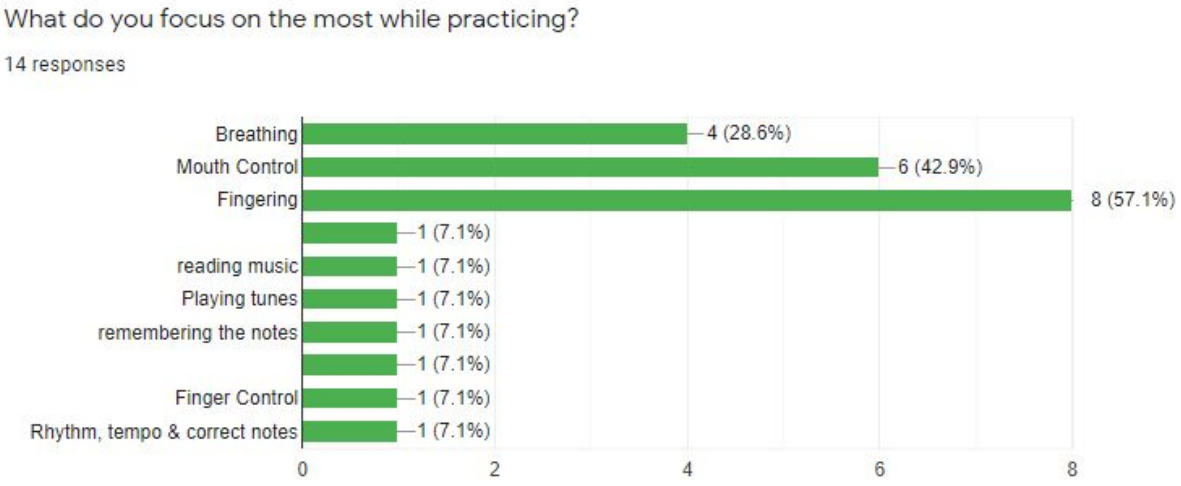


Fig 12: Survey question - Focus while practicing

Certain interviewees spoke of a lack of hope as a musician, which affected their will to continue practicing and their fear that they would not be able to do anything with all of the effort put into it.

Data	Coded for
"*I remember a lot of outdated facilities, a stressed teacher and an eventual hopeless feeling that no matter how hard I tried, I would turn into a poor musician anyways. The industry lacks hope I feel.*"	Hopeless to become a good musician.

This also seemed to be compounded by problems with funding which were also brought to our attention by prof. Christian Vuust, who acknowledged this as one of the main reasons why students he had were unhappy.

Data	Coded for
"*But I mean, considering the restricted budget - I can't, you know, I can't do everything.*"	restricted budget

Building on the same theme, we had multiple supporting statements from people who filled our surveys as well as in public conversations we found on communities we joined which highlighted the need for perseverance:

Data	Coded for
Q: What are the hardest things for you during a learning session? A: *"Keeping motivated on what I am learning as there is always more to learn"*	keeping motivated
Q: What are the hardest things for you while practicing? A: *"Motivation to practice and also my desire to 'not overload' the people I live with with my practices."*	motivation to practice

- Area

This theme was formed from the different data extracts related to different places, online or in real life, people use to practice. From the information we got, this became more relevant for people as Corona hit initially, as many schools had to slow down or even stop classes until they could figure out other solutions, eventually starting to use Zoom and other online applications.

We had several data extracts which we grouped under this umbrella theme, which, similarly to the rest of the mentioned initial themes we later either separated into different themes or refined using our interpretations. Here are a few examples:

Data	Coded for
Q: Do you use any online platforms other than the school itself for learning? A: "*Ehm, I think youtube is very nice*"	Online platform like Youtube

"*We have all of our lectures in the class itself, but if someone cannot come, either because of sick or whatever any other reason, they can call and we setup a zoom session for them.*"	One on one, Zoom sessions

- Guidance

  We had multiple survey responses from teachers as well as an interview with a professor. This gave us an idea of the role that teachers have in learning the saxophone, which even if not an all encompassing need, as some students feel that they learn perfectly well by themselves, was still something that was visible enough that we even created surveys targeting teachers specifically. Students of teachers also relayed to us the importance they saw in their relationship with their teachers and this was also made clear by the multiple saxophone community administrators we spoke with, most of, if not all, had become teachers over the years purely due to their many decades of experience. The answers we received focused broadly on the need that students have to receive feedback and help along their development period. The following are a few data extracts we saw as fitting here:

Data	Coded for
"*also their interests are very I would say, are very different you know. Very diverse. So you know, if I had the same curriculum for everyone you know. And in the third week of the third semester we always play this tune and the fourth week we always play that tune. But it is not like that. It is very individual.*"	Diverse interests
Q: While practicing, is it broad topics or do you focus on one thing? A: "*I think every time it is a different thing, but yes - I try to focus on something specific.*"	Focus on something specific
"*One of the qualities of a practice routine is that you don't question what you are practicing. You practice what you set, what you decided to practice in, you know, in collaboration with your teacher*"	Practice agreement

- Issues

  Learning to play the saxophone presents a plethora of difficulties which range from being on a waiting list to join a school, which can take more than a year, which affects the odds of finding a good teacher; to neck pain caused by the weight of the saxophone and the strain it causes on the students muscles. At this stage in our research we grouped all of the negatives people reportedly face and labeled that group as “Issues”. Some examples of codes found in this theme are as follows:

Data	Coded for
“*Ehh… it’s been quite difficult, because I am… I live where I can’t really play at home.*”	Can’t play at home
“*The teacher talks about how holding a saxophone around your neck with the strap can be quite taxing, so he shows a series of exercises to do before starting playing, to warm up.*”	Neck pain

Fig 13: The affinity diagram holding our initial themes

Our initial themes were developed through the grouping of all of our codes and not considering much about what was relevant at that point to our research question. We did this following the advice in the paper regarding the specific steps of thematic analysis, where we would generate themes which might interest us later or create more meaning later. We continued iterating over them a number of times, while also getting more data from multiple sources. However due to social distancing needs we moved the rest of the work online, as such the rest of the diagrams were made predominantly using awwapp [25].

Reviewing themes

At this phase of our analysis, we had found more reliable data sources through partnerships and discussions with community administrators and musicians we met, as such we were able to reliably identify codes as it seemed that our ability to interpret the data extracts would be aided by further context from different people, instead of making assumptions from very little data. From all of the surveys alone, we now had over 100 answers, giving us different perspectives from people with varying backgrounds and amounts of experience.

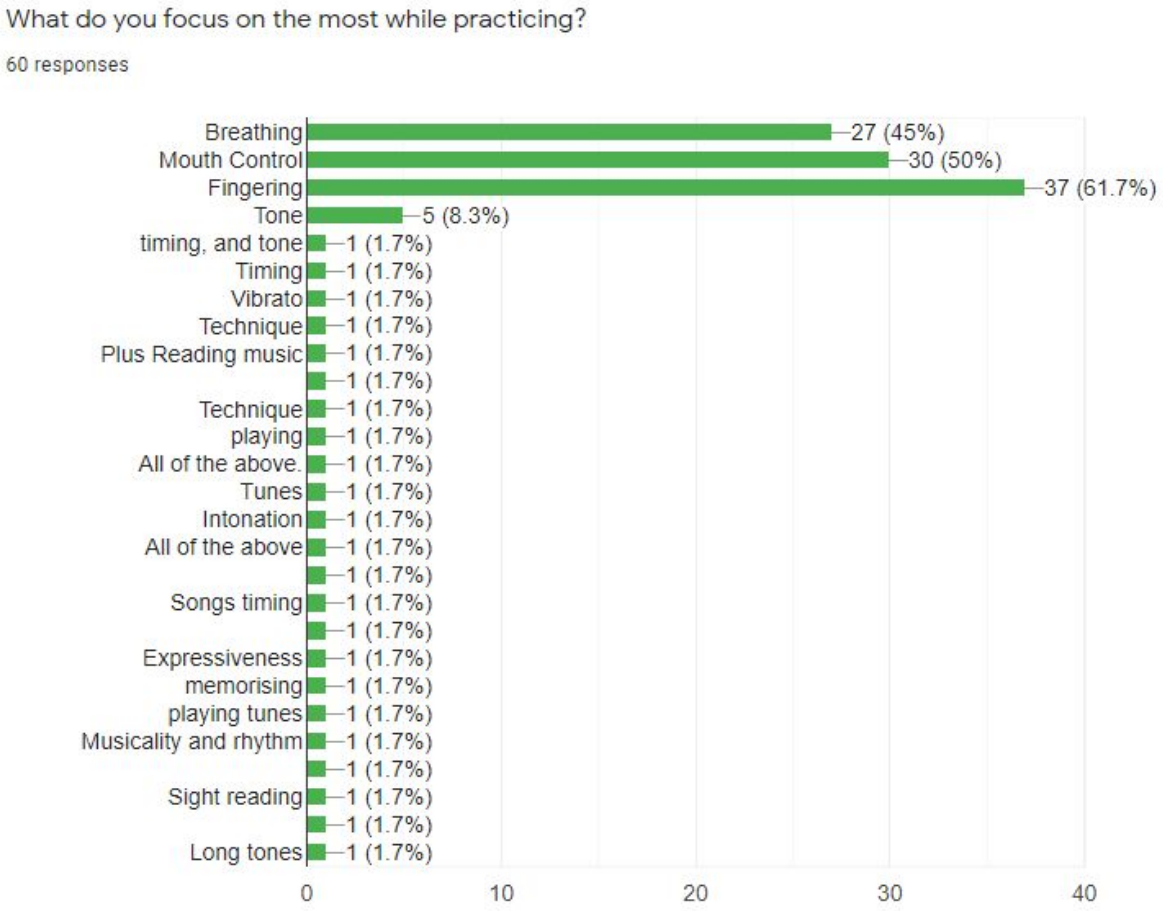


Fig 14: Survey question - Focus on while practicing 2

Almost all of our questions were open ended, so seeing that so many people had problems with the three points gave us a good start, even if we did not set a requirement that prevalence from the point of numbers would be absolutely important.

During this phase we further developed our themes and tried to ensure that each code inside of a theme would fit coherently, as well as ensured that our themes did not have overwhelming connections between each other, by merging any of them which did and generating new ones as we moved the codes to more fitting groups.
As an example of this would be the original theme “Basics”, which albeit initially it was of a coherent scope, it later seemed far too bloated with codes that lacked meaningful connections between all of them. Due to this, we separated it into “Barrier of Entry” and “Emphasis on learning the Basics”. The rest of the themes were also renamed and their codes moved in between to try and figure out more meaningful connections. The following are all of the themes developed at this stage together with descriptions of what meaning we identified in them related to our research question and a few examples of data extracts and codes they contain. These themes were developed from data extracts used in multiple themes from before which were by now mostly recorded using the interpretive coding technique, as well as new data extracts that we gained from all of the new data items gathered between the time we created the earlier version of the thematic analysis and the one currently discussed:

- Connection between teacher and student
  Students of different levels who have the opportunity to have a teacher showing them the “ins and outs” of playing the saxophone encounter certain difficulties and provide us with certain requirements that they have in order to enjoy the full amount of perks that this relationship can gain them. A small number of examples of the codes part of this theme together with their data extracts are as follows:

Data	Coded for
“*One of the qualities of a practice routine is that you don’t question what you are practicing. You practice what you set, what you decided to practice in, you know, in collaboration with your teacher*”	Cooperative play
Q: What are the hardest things for you during a learning session? A: “*The fact that I can't play together with my student & that I can't see the mistakes my student is making. I also can't hear the real tone they have. All of these things make it more difficult to determine if they are doing things correctly, or where they are having difficulty*.”	The feeling of being connected between teacher and student
“*I think you are more... At least I am more uhh... critical when I am alone.*”	Practicing alone breeds self-consciousness

The data extracts in this theme come from a mixture of almost all of the previous themes that seemed to fit better in this context as well as multiple new extracts. Later on, in our final themes this was further changed by developing sub-themes and more in depth connections between the main themes themselves.

- Pressure
  Certain data extracts which before were grouped under “Personalization”, “Motivation” and “Basics”, we realized were focused around the urgency people feel to succeed and the stress it puts on their minds and bodies to practice the amount of time needed to succeed, as such, we created this theme to keep them under and we presumed that we could see how to solve these problems for them.

Data	Coded for
"*I even go wrong and panic as soon as I see someone walking past the house.. in case they can hear... I saw some workman mucking about dancing last year so got really put off…*"	Stage fright

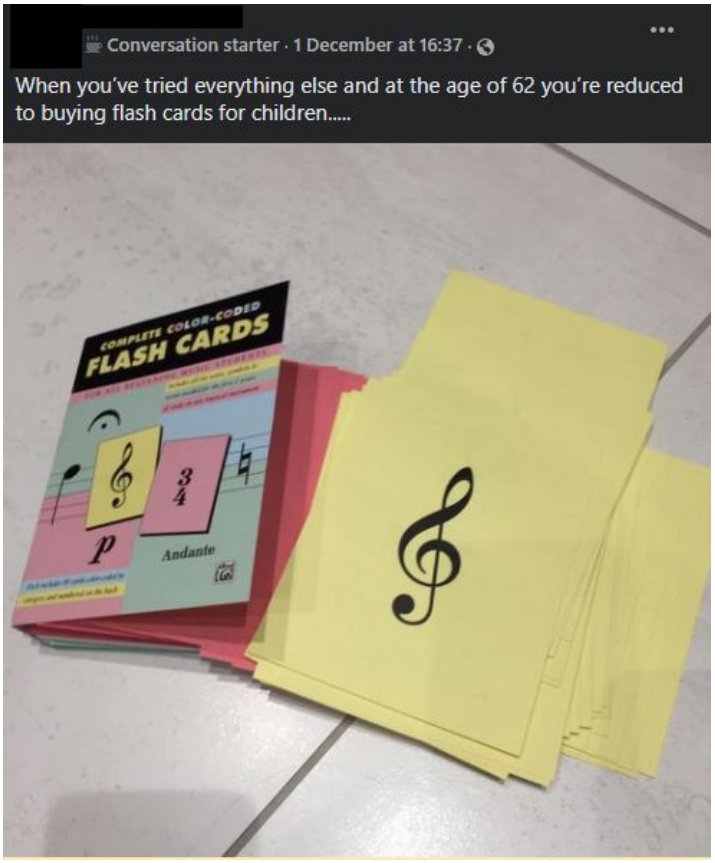


Fig 15: Coded for "Embarrassed due to skill level"

- Barrier of Entry

  There are varying difficulties commonly encountered by people who want to learn the saxophone, which become less prevalent as their expertise increases. During our research we found multiple instances of these problems, both from active students and from teachers having to combat these problems. The following are a few examples of the data extracts and the codes we interpreted from them and saw fitting together, forming this theme:

Data	Coded for
Q: What are the hardest things for you during a learning session?	Reading music is difficult

A: "*Some terms are not easy to understand.*"	

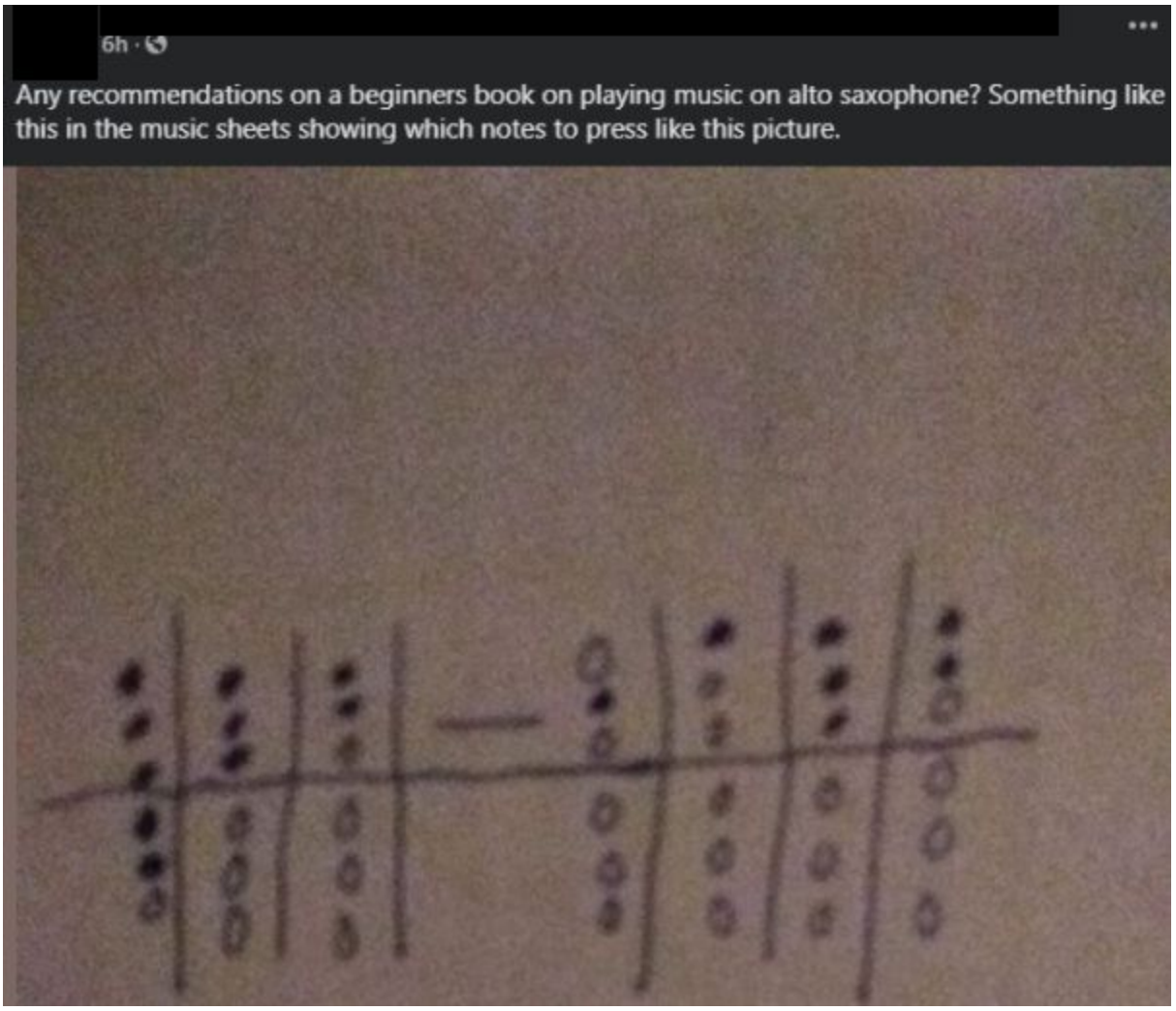


Fig 16: Coded for "Struggle with finger position"

Data	Coded for
"I remember a lot of outdated facilities, a stressed teacher and an eventual hopeless feeling"	Lack of funding for proper education

We later built upon this theme since it became visible that helping students face these difficulties would be something that would very much be related to what we initially set out to do.

- Learning needs to be personalised

This was a theme that we had originally as we were first generating the codes, however as opposed to it's initial version, where we based all of our themes on descriptive codes and connected things that in hindsight were of better use under groups with different monikers, this theme was formed from the way we assessed the information we gained from students and the visible confrontation they have with standard ways of learning. Many of them spoke from experience how frustrating they found reading and then were saved by alternative solutions such as videos and flash cards and others offered ideas of how else learning could be propped up using diverse techniques and approaches. The following are only some of the data extracts of people actively engaging in ideating and showcasing their dissatisfaction with the current procedures:

Data	Coded for
"*I've tried all the apps, the issue is when the notes get together on a stave they interfere with each other in my head*"	Difficulty reading music
Q: Do you have any ideas on how technology could help you learn? A: "*A way to play music without having to constantly read and try to understand, I have to focus on too many things*."	Learn by abstracting away other tasks
Q: Do you have any comments, suggestions or thoughts that you would like to share? A: "*If you are not aware of the Suzuki style of teaching I'd suggest that you examine this as it's a workable and alternate style of teaching. It advocates learning to play by ear FIRST, then eventually learning to read music and many aspects of music education. The principle is 100% sound as the student makes a connection between the instrument and their hearing what they want to play*."	Alternate learning styles, avoiding reading music

- Emphasis on learning the basics

  As in the previous phase, we moved our codes around trying to find a better grouping with more meaningful contexts. At this stage we still had different data extracts pointing at the common theme of basic problems that students have to contend with, later on this theme would become a parent theme of multiple other ones, however at this point, we did not realize the smaller themes the codes were forming inside of it.

The following are a few examples of the codes and data extracts that later formed their sub-themes of the basics:

Data	Coded for
"*The student has to play 4 quarter notes of D, rest, 4 quarter notes of E, rest, and keep alternating and repeating the pattern.*"	Emphasis on timing and note playing
"*he does an exercise with the students, using the notes above. Using a metronome, the students are to count the beats and clap every time a new note starts, this is used to better understand the timing and when you'd have to switch the note. He does this two times to try to emphasize the lesson.*"	Emphasis on rhythm
"*For me it was real tough to keep track of what notes I was about to play, not get confused between them with my fingerings, follow the correct articulation and do the right embouchure.*"	Focusing too much on one task, distracts from another

- Difficulties

  There were multiple challenges that we became aware of when learning the saxophone. Originally this theme was "issues", the name change came from us trying to separate between problems students and teachers can have, which may fit better under other themes and become more distinguished elements and the challenges which affect students and prevent them from getting the most out of their practice and learning sessions. This theme was later broken down further however, at this point, the codes were still combined under only an abstract moniker of these negative aspects of learning:

Data	Coded for
"*Staying focused on learning and not just playing what is fun and easy.*"	It's hard to not get distracted
"*you are going to have a fixed point a view on a teacher, who moves around*	Difficulty imitating the teacher

between students, so you won't have the same experience or see what the teacher is doing on their instrument exactly."	

- Motivation
  Between this version and the previous one of this theme, the contained codes have changed while the meaning of the theme itself hasn't. The intention of it is to follow along with the needs of the students and how to generate and sustain excitement for learning and practice through a feeling of achievement while lessening the grind. The following are a couple of examples of data extracts and their associated codes that we have fit in this theme:

Data	Coded for
"*I guess same as the kids nowadays, it's real nice to pull it off, I'd show off to my dad every time I got it right and he'd tell me to keep going.*"	Excitement from success

As mentioned before, we worked on this phase of the thematic analysis, as well as the rest of the work afterwards online, therefore all of our artifacts produced afterwards had to be made using online development tools. The following diagram contains all of the themes with the new codes generated using the interpretive method.

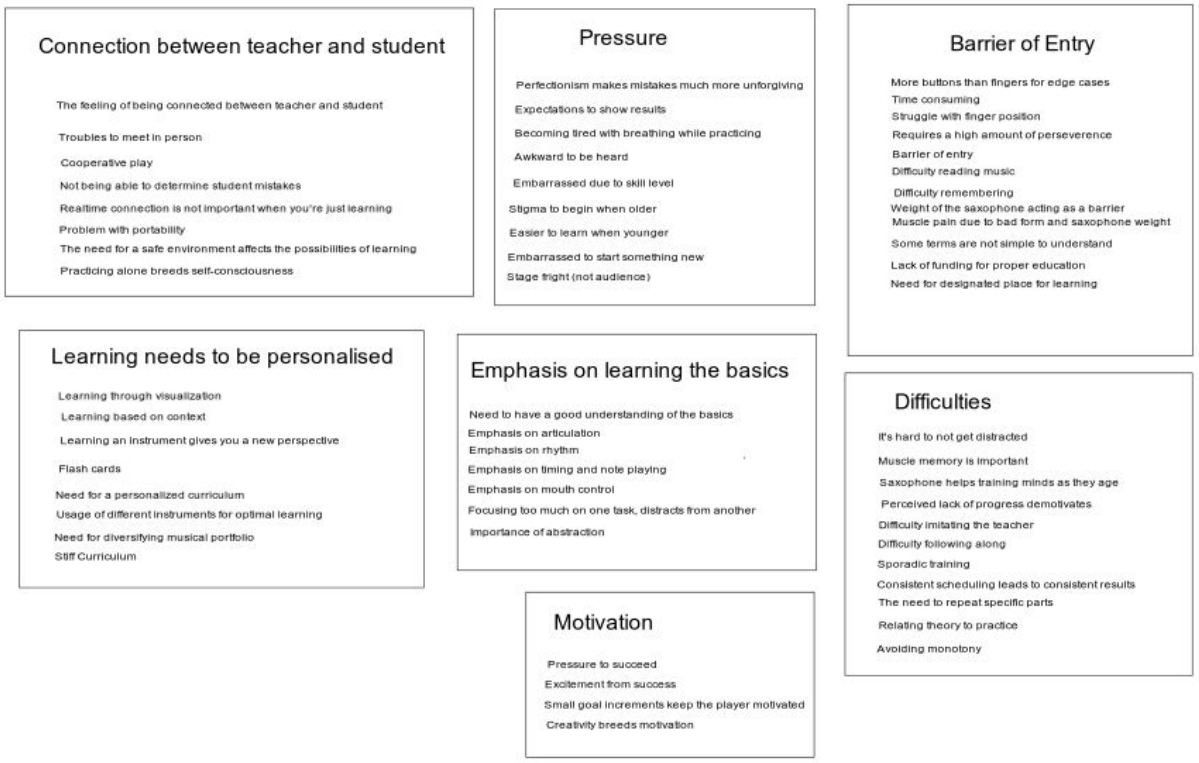


Fig 17: Affinity diagram

Defining and naming themes

In this phase of our thematic analysis we worked towards further refining our themes as well as preparing the narrative of what our data that created them means, in our interpretation. An important part of our work here was to develop the themes we identified as covering topics that were too abstract and continue subdividing them into sub-themes. We also tried to get a better image of how themes were connected and attempt to explain this interconnectivity as well as towards what general theme they all guide us.

The following diagram shows the finalized structure of our thematic analysis, following this we have a step by step description of each theme as well as the aforementioned attempt to understand the narrative and the global theme formed from them.

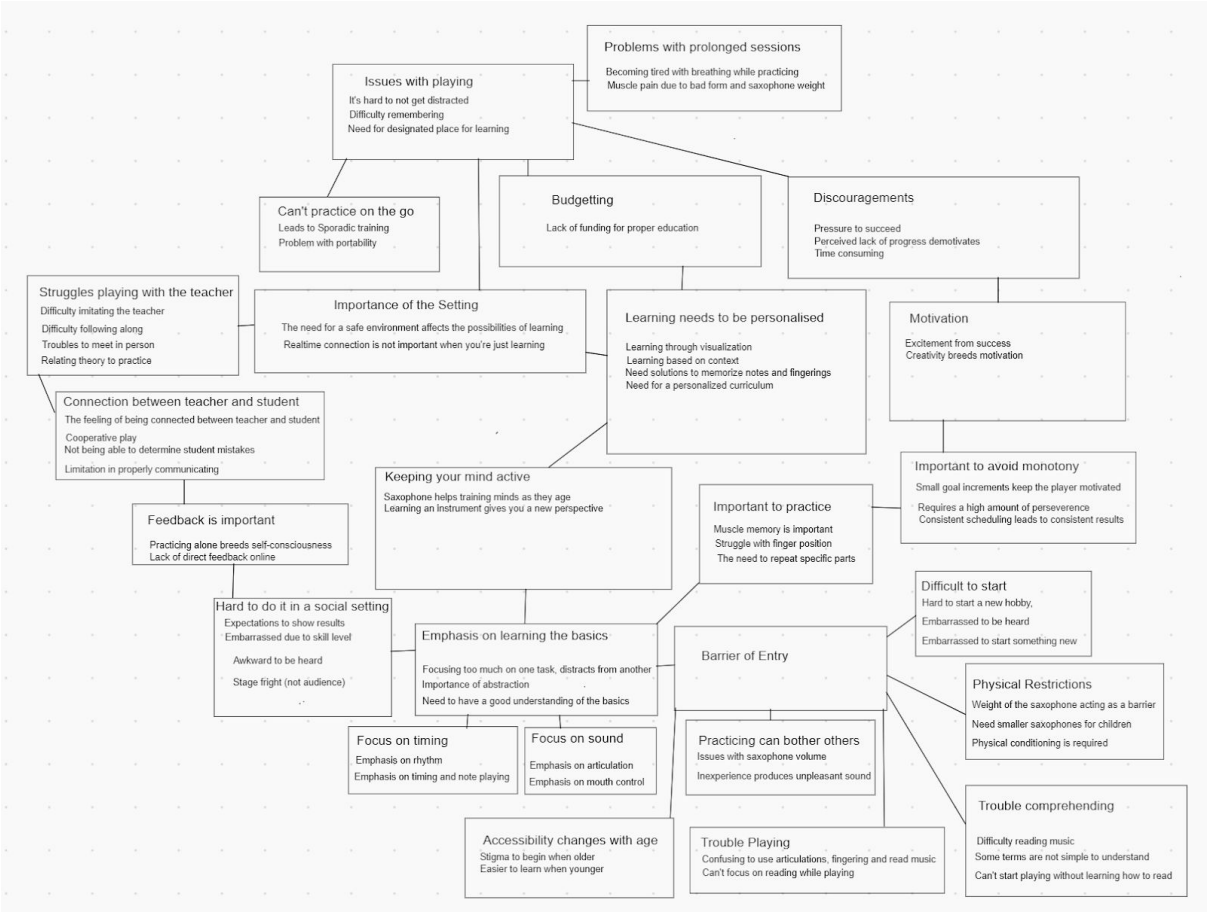


Fig 18: Affinity diagram 2

The final affinity diagram showcasing all of our final themes together with their sub-themes and connections.

During this phase of our thematic analysis we discarded a number of codes that we interpreted as being irrelevant to our research question, they were primarily focused on the worries of the more advanced students on how to make themselves more attractive in a job pursuit element and their professor working towards that same goal, for example:

Data	Coded for
"*Quite narrow, quite specific sub genre, you know. And we want them to... And then I try to learn them, teach them to... to get... you know, broader, you know. To be able to do more.*"	Need for diversifying your musical portfolio
Q: Do you have any comments, suggestions, or thoughts that you would like to share? A: "*I felt that I needed to do as many performances as I could and saw them only*	Focus on job seeking can take away the joy of playing.

as things to grudge through, which was needed to get a better CV and become more attractive for job offers."	

In order to have a structured direction in describing each of the main themes, we've arranged the final themes by how they fit in relation to our research question. They are placed as follows:

1. Barrier of Entry
2. Learning the basics
3. Motivation
4. Connection between teacher and student
5. Learning needs to be personalized
6. Issues with playing

1. Barrier of Entry

We identified this theme from our data after the initial coding phase, where we had first identified the theme "Basics" which over encompassed most of the challenges and needs one would face as a beginner saxophone player. Later we developed the idea of separating the problems and prerequisites that restrict people from actively learning and engaging in playing the saxophone by getting a better understanding of the data through conversations with students, teachers who were aware of these problems and our surveys. These restrictions can be summarized as being purely psychological, physical and in regards to the ability and need to comprehend information. They all play a large part in the research question as they portray how our solution should be designed, in particular as our goal is to try and supplement the learning process and if we do not take into account the challenges under the umbrella theme of "Barrier of Entry", then we would not be able to accurately target the issues that we could be having and measuring an effect over, as such we would miss the possibility to satisfactory offer a comprehensive solution.

During our research, we gathered and built our data corpus from a myriad of sources in an attempt to have a diverse and healthy range of backgrounds and opinions to lean on which would allow us to identify patterns of issues and opportunities present beyond the limits of what would otherwise be anecdotal evidence. As mentioned before, we had identified this theme earlier, however by working on the thematic analysis iteratively we saw as more data came in, which we coded and saw it would fit under this theme, that the cohesion of the code was becoming less apparent, that is why we started working on developing sub-themes from the codes we saw addressed a specific topic.

Inside of this main theme, we have a number of these sub-themes, the first one being "Difficult to start". Under this sub-theme we placed the codes related to the personal issues students reported having in regards to trying something new.

Data	Coded for

"*Does anyone else immediately clam up if they know anyone is listening? Even if I set my phone on record I suddenly can't play in tune*"	Embarrassed to start something new
Q: What are the hardest things for you while practicing? A: *"At first, the hardest part was just to get going, I am too nervous even now, but when starting out, being heard was horrifying, and when I first tried the saxophone, it was so loud! I have to play at home so it's still a bit nerve wrecking."*	Hard to start a new hobby, Embarrassed to be heard.

This is a common stress source people have when it comes to doing any activity out of the norm for them , especially one as intimidating as learning to play an instrument. We saw our contribution against this problem could be making learning the saxophone more accessible as well as discussed allowing students who do not feel comfortable practicing and being heard if they may find it useful to practice using our glove or another solution we may create later without having to actually blow on the saxophone and make noise, focusing primarily on their finger control until they would feel more competent. This idea came from a couple of our observations:

Data
"*Nikola often practices patterns/phrases without actually blowing into the saxophone, just doing the fingering, he only starts blowing when he wants to prove/show a specific thing to Christian.* "
"*The focus on this exercise is finger control, the teacher suggesting to try practicing crossing the break without focusing on embouchure and mouth contro*l"

The following sub-theme , titled "Trouble comprehending" fits all of the codes that were under the umbrella theme of "Barrier of Entry" while also tackling the common thread that people presented to us in regards to being faced with multiple layers of complexity until reaching the actual instrument practice phase.

Data	Coded for
Q: What don't you enjoy about your learning sessions?	Difficulty reading music

A: “*I hate having to read music I can't focus my mind on it and it feels like the teacher is wasting his time and I am wasting mine*”	
Q: Do you have any ideas on how technology could help you learn? A: “someway to get me out of needing to read music please”	Dislikes the need to learn theory to practice
Q: What don’t you enjoy about your learning sessions? A: “I don't like that if you don't know how to read music, you're stuck in the waters with this instrument, also a problem is that if you don't get good at it and read fast you can't play any song, I hate it!”	Can’t start playing without learning how to read

The level of depth needed to properly understand enough about music theory and the amount needed to practice are a barrier for many, layers which we would attempt to abstract away by subverting the requirement students have to first gain an in depth understanding of music reading before they can try playing any pattern, giving them a chance to just dive straight in to playing and see if the hobby is really for them.

Following along in the chain of sub-themes, we have “Physical Restrictions”. This governs codes which are related to barriers formed by the size and weight of the saxophone. It became visible to us through different data sources that various people saw the physical attributes of the saxophone as a barrier for them to study it. Some can see it as a complete blocker and force them to try another instrument or give up entirely, while others resort to different solutions, such as smaller beginner friendly saxophones.

Data	Coded for
“(I) - the saxophone is pretty heavy, what do you do about this? (T) - *We've talked about this, and it's not necessarily a problem, though it is the reason why for example at younger ages, boys usually choose the instrument more than girls.*”	Weight of saxophone acting as a barrier
“*Anyway, what we did relatively recently is start recommending and also investing in*	Need smaller saxophones for children

these plastic made saxophones called JSax, they produce a lot of different types of woodwind instruments. It's smaller so kids can use it"	
"*The teacher talks about how holding a saxophone around your neck with the strap can be quite taxing, so he shows a series of exercises to do before starting playing to warm up the muscles.*"	Physical conditioning is required

Through the previous data extracts, the saxophone is presented as a physically taxing instrument which can act as a barrier for many, either as a complete denial of access or a limit of the time they can spend practicing before their bodies are too exhausted. An idea to solve this would be to provide a way to practice that is less taxing on the muscles, with a smaller solution. An example of this was mentioned by one of the interviewees, JSax, a small plastic saxophone built after a soprano model, built especially for children. The existence of such a product, of enough popularity that it is available worldwide on the market shows this barrier as being shared by enough people for the need to exist and attempts to be filled being present.

The fourth sub-theme is "Trouble Playing" and it was formed to contain the problems beginners often face when actually trying to practice, specifically the issues generated by the need to multitask when playing the saxophone.

Data	Coded for
"*For me it was real tough to keep track of what notes I was about to play, not get confused between them with my fingerings, follow the correct articulation and do the right embouchure. And of course, just like any other learning, you learn by doing, but when it came to these basics, and especially switching the fingers for each note, especially since they have different types, usable depending in which scale you're in, it can get really confusing.*"	Difficult to multitask
"*I have problems keeping track of notes while also focusing on my fingers, I often stumble over myself and eventually lose interest.*"	Frustrating to make mistakes while focusing reading and playing

Some teachers encourage doing each of the tasks separate for a song and then trying to combine however, even with such a solution, this is still a hurdle that students need to overcome and it is something that stems from the aforementioned layers of complexity

present in learning to play an instrument, something that we would be interested in attempting to affect with our solution.

The sub-theme “Practicing can bother others” contains the codes covering problems people encounter from the volume of the saxophone. This creates the need for a space in which they can practice in peace and not annoy other people around them. It can create a harrowing experience for people who are told they annoy others or an issue that can be tackled by an academy or a sound isolated room.

Data	Coded for
“*When I was first in school, we had music class, I was the only one who picked the saxophone and I was very happy with it, after a few days of practicing my dad said, and I think I’m quoting ‘please stop, better fail the class or I write you a note, I just can`t hear that anymore*’”	Inexperience produces unpleasant sound

The previous are some of the data extracts which fit under these two codes and they showcase the problems that people need to tackle to properly learn to play the saxophone. Some issues force students to terminate the studies while others are able to get past this barrier and continue their musical career or hobby. This sub-theme gives us an idea of just how diverse the problems encountered in even beginning to play the saxophone really are and we thought we could possible have an effect on the sound produced by beginners, as they would be guided by our solution and not trip on themselves to play the correct sound and read while also reducing the time needed to practice if reading notes no longer acts as a distraction from simply making a good sound.

The last sub-theme which details a barrier we identified for learning is “Accessibility changes with age”. We found multiple data extracts expressing issues people have with trying to learn to play the saxophone at a later stage in life. There is an argument to be made for students who begin younger having different progress rates than those that begin later in life, however that is not to say that those who begin later in life are not to be encouraged to take up the activity, indeed there are those who started in they young adult years or later and enjoy professional success [26]. However, this problem has less to do with actual possibility of success and more to the ageist stigma of beginning anything later in life, in your senior years as it is. This can be exemplified in any activity taken later in life, such as learning to swim, ride a bike or anything else that would be expected of a person to do in their development period.

Data	Coded for

“(S) - It affects the price, if you look on our website, you will see prices based on type of class as well as instrument, they are all for students under 25. Afterwards, all prices are double.”	Easier to learn when younger
“Majority of lessons are designed for able bodied people. Also most of the pedagogy is similar and based on teaching young people rather than older hobbyists”	Most education is geared towards young people.
“..having problems with easily that is easy to navigate especially for older people who are not quite as tech savvy as the younger generation”	Easier to get information for tech savvy generation
“I feel awkward to interact in the live lessons, the people my age are usually the ones helping everyone and the young ones are asking what I ask, makes me feel a bit embarrassed.”	Stigma to begin when older

Unlike the previous barrier which related to the physical limitations of oneself in regards to the ability to handle the weight and size of the saxophone, this sub-theme is more about a psychological blocker that people have, formed by a culture that can be considered as encouraging ageism, which encouraged them in their youth to avoid older people, as a way to cope with their own aging and mortality [27] thus gaining over the years a lifetime of internalized stereotypes related to aging [28].
A solution for this can be having the option to get similar teaching experience that a young student gets with an actual teacher, while not having to pay exorbitant amounts of money for the currently available options, our attempt would be to try to provide an additional option for learning which would allow people who are only interested in gaining the ability to play the saxophone to do so without facing scrutiny from others practicing the same ageist negative stereotyping they did in their own youth. For others, who are in the situation where this is not a large barrier or one that they can face head on, this does not act as a problem large enough to stop them from studying, with or without additional options.

Another problem presented in the previously mentioned data extracts is the fact that information is more accessible towards those who are younger, which makes them more used to technology or more “tech savvy”. A barrier that can be quite frustrating to overcome is the added level of complexity for someone who is not used to remote learning and having even more limited options of sources for learning.

2. Learning the Basics

Early in the coding phase we had the “Basics” theme. At the time it covered a large amount of challenges which students face and teachers try to help with. Later on, other themes were formed which held a more cohesive narrative between groups of codes and their own sub-themes however, there were still codes that we interpreted as being widely focused on the need to learn the basics before doing anything else.

“Repetitio est mater studiorum” - derived from latin, it translates to “repetition is the mother of learning”, also widely known as “practice makes perfect”. This is a widely popular phase which has been engraved into many languages and has become an idiom synonymous with learning and hard work. We have found evidence that this also plays a vital role in the lifespan of a saxophone player and as such, many have decided to emphasise their training on the bare basics. Having a good grasp of them is something every beginner focuses on and as our target group, this collaborates well with the research question that we focus on.

Unlike the previous main theme “Barrier of Entry”, here we have not only sub-themes, but also codes that seemed to fit well under the umbrella definition itself, these iterate the importance of learning the basics before moving anywhere as a saxophone beginner as a general rule, not focusing on specific element of learning.

Data	Coded for
“*the issue is, you introduce that to a kid...or anyone I’d guess and then you also want them to keep rhythm and you also want them to do the correct fingerings with each note they learn and then even learn how to read them and the rests in between, you know, the pauses, and then it gets confusing*”	Focusing too much on one task, distracts from another
“*not making the sax squak...I also have a problem that I never practiced the scales well enough, and this made me not be an ace at the note fingerings, which is a problem now, because I feel like I have no fundamentals so I have to go back to older sessions and it is really annoying.*”	Need to have a good understanding of the basics

Without a strong grasp on the fundamentals, there is no foundation to build upon for later learning and development. We see this in any field where an evolution is expected as more experience is gained, including our own and what we find useful is having ways to easily access the basics and be able to quickly return to them in order to practice and refresh at any time, the more convenient the better. Our attempt would be to provide a similar solution, going past flash cards and fingering charts which would allow the students to quickly practice

and remember patterns or songs through haptic learning. Similarly, we wish to study the effect it would have on the problem of all of the complexity levels that playing the saxophone has. By guiding the fingers of the student and removing the need to focus on reading in order to play, we would hopefully allow them to focus on improving one thing at a time, especially if the thing they wish to learn is the actual playing of the instrument.

One of the sub-themes is “Focus on timing”, it describes the importance attributed for students to understand and play notes at their correct time, understanding when breaks are needed and the length of each note. This currently requires students to read the music sheet which has specific symbols for breaks of different beat lengths, as well as notes of different lengths. Remembering this while also having to deal with proper articulation as well as the notes to be played and having to deal with possible changing beats per second is reportedly a challenge which students solve by practicing as much as possible until it becomes second nature to them.

Data	Coded for
“*Following this, he does an exercise with the students, using the notes above. Using a metronome, the students are to count the beats and clap every time a new note starts, this is used to better understand the timing and when you’d have to switch the note. He does this two times to try to emphasize the lesson.*”	Emphasis on rhythm
Q: How does a typical learning session go? A: “*then we play duets, whole new dimension - my timing is atrocious. need to get more rhythm, instructor is very encouraging.*”	Emphasis on timing and note playing

Students work hard to build up the experience needed to play the saxophone properly and the effort they put is what we focus on with this sub-theme, as well as the other ones related to the main theme. Our aim would be to see if any of these struggles could be affected by a different way of learning, supporting the audio and visual ways of learning new things with a haptic solution.

The next sub-theme is “Focus on sound”. If focusing on timing is needed to keep a good rhythm, focusing on sound is what is needed to replicate the note at that time correctly. With a saxophone the sound is produced from the reed piece which vibrates when held correctly with the mouth and blown on. It can be easy to make mistakes and create “squeaking” sounds or failing to properly control the mouth muscles, including the cheeks, can make the

students play bad sounds, not having the ability to keep it steady as the air flow changes strength based on mouth movement.

Data	Coded for
"*He focuses on the need to know ahead of time, whether a note needs a slur or a tongue*"	Emphasis on articulation | Source : Udemy Saxophone class observation

Another important part of properly producing the correct sound is the use of the right articulation, as shown in the music sheet. This is something students need to be able to identify at a first glance and be practiced enough to be able to change between them, for example tonguing or slurring, which are two of the more common articulations we have identified from our observations and other data gathering activities.

In regards to how this would be connected to our research question, we would like to explore by creating an artifact which would notify the user of which articulation to play, either by creating a haptic animation, in the way we vibrate the expected fingers or using a visual element with LEDs, this can be discussed further outside of the scope for this thematic analysis.

The next two sub-themes act as connections between this main theme and others. As such we will go through them in both main themes focusing on their elements as they relate to the current main theme while also explaining, where needed, how their elements act as connections in between the themes themselves.

The first of such sub-themes is "Keeping your mind active". Speaking to older students who took to learning the saxophone as a way to better themselves and not fall into the trap of slowly losing the training one's mind needs to keep being healthy and active, using this to also have an activity or a purpose to keep learning and better themselves, which is also associated with a reduced risk of Alzheimer's disease [29].

Data	Coded for
Q: How do you see learning music? Is it more of a hobby or do you want to do music professionally? A: "*hobby, brain development as I age*"	Saxophone learning helps training minds as they age

About learning for seniors, as mentioned before, playing the saxophone is resource intensive, requiring attention, time and effort to get to anywhere and multi-tasking is a big part of it, something which becomes increasingly challenging with age [30]. This was part of the barrier we addressed previously and our work would focus on attempting to see if haptic

learning would make saxophone learning more accessible for those who would like to use it as an activity to keep their minds active and keep improving themselves.

This sub-theme connects “Learning the Basics” with both the main theme “Learning needs to be personalized”, as there are specific requirements that need to be addressed when it comes to a curriculum which should be designed for older students or those with more need to deviate from the standard general solutions used by all. As well as “Connection between teacher and student”, seeing as mentioned before, older students face difficulties in finding and engaging with a teacher comfortably. As we move onwards from this theme to the others that we have mentioned, we will go into more detail how they fit inside them and how they are related to our question.
The second and last sub-theme is “Important to practice” and it is the connection we identified to the main theme “Motivation”. As the interest which students have to properly invest the needed time and effort to be able to practice and get good results come from just how motivated they are and the practice options can be more appealing the less monotone they are.

The codes forming this sub-theme relate to the emphasis that is put on trying to reinforce actions over and over until they are second nature to the student and learnt to do on queue. We saw it important as our solution would attempt to affect the memorization process of the finger positions for each note as well as the order in which they are played for a pattern or a song the student is attempting to learn.

Data	Coded for
Q: What don’t you enjoy about your learning sessions? A: “*sometimes don't know if its the reed or me but sounds bad. don't have the muscle memory in fingers or embrachure. I lose focus and then make mistakes.*”	muscle memory is important
Q: How does a typical learning lesson go? A: “*I turn on PC, listen to what I am told and then I fail and fail until I succeed at repeating*”	the need to repeat specific parts

The previous data extracts, seemed to us to both point towards the importance of imprinting the ability to play deep in ones memory, as well as the problems encountered by beginners especially, where it can feel defeating to them to keep needing to shift focus between multiple things, making progress feel like it would be stagnating, we would look to aid people in studying by acknowledging the importance of practicing and offering a solution to aid that while also attempting to affect the motivation to keep at it for students, which is why we saw

this sub-theme as being a connection between the “Learning the Basics” theme and “Motivation”.

3. Motivation

This theme contains codes which relate to the driving force behind people’s want to better themselves. This can come from the inside, where the inspiration and will to better oneself at a certain activity is strong enough to face the obstacles or from the outside, where another person or events in our lives are inspiring us to take charge towards something. Abraham Maslow created the hierarchy of needs which puts forward that if the basic needs listen in these categories are taken care of, people will be motivated to better themselves, and that they will prioritize them based on the order of this hierarchy. [31]. This is related to our topic and the information we’ve gathered as people who want to learn the saxophone do so to fulfill a need. This can be one related to a physiological or safety need, as playing the saxophone can be a job which can fulfill those needs or can give the person in question a boost of self esteem, a self of connection to a community or even to simply better themselves. Whatever need that is to be fulfilled, motivation is a key resource which if ignored and lost, can put a stop to any improvement.

Oftentimes, the perceived lack of progress demotivates the students, which in term causes them to lose interest in the instrument. This could have various origins - from time constraints to mood swings and pure boredom amongst others. It is a common trouble that teachers eventually face with their students as well as the main reason many autodidacts give up. By having an effect on the motivation, we can try to aid and ensure that those people would continue to progress and learn more. [32]

Data	Coded for
“*it’s real nice to pull it off, I’d show off to my dad every time I got it right and he’d tell me to keep going.*”	Excitement from success

From the extract above we can gather the results that the dopamine we get from success can really have upon our motivation to keep going. As a side note, it is also visible that the encouragement from others can be helpful in keeping motivated, as mentioned before, it can be intrinsic or extrinsic,from others inspiring us. Similarly, mentioned during the “Barrier of Entry” theme, we saw how negative and damaging it was in one of the data extracts we placed under that theme for someone to tell a beginner to stop and show no support, making them stop entirely from even trying.

This theme is connected to “Learning the Basics” through the sub-theme “Important to avoid monotony”, which relates to the other theme due to the constant need to repeat the same exercises and practice, which can become boring and affect a students’ motivation negatively. This can be countered by trying to work at ensuring that one's' motivation is

stronger than the barriers it must overcome. Working with small goals of improvement or developing a consistent schedule can lead to being able to go through the phases of practice and learning without losing too much motivation [33].

Data	Coded for
"*18:23 C - Well, I would say many students find it hard to find a working routine.*"	Consistent practice is hard but important

In our interview with prof. Christian Vuust, he acknowledged the difficulty that students have in creating and respecting a routine, however he continues on. Saying that this also stems from a need to be skilled at time management and it is something that he believes teachers should attempt to help with.

Data	Coded for
"*I really try to help them out with that - how do I work in a systematic manner, developing you on my instrument. That's the challenge for them, and also, you know - time management. Maybe they have 7 - 8 lessons in one day and then they are completely exhausted and then they should practice, prepare for class and practice and so on. Maybe they ought to do that for 4 hours more or something, but many of them just simply can't find the energy to practice enough. They have a hard time organising those things.*"	Time management can help motivation

Learning in general does take a large amount of perseverance and it can be quite mentally taxing to do tasks which can be considered boring and not mentally stimulating, repeating them over large periods of time.

Data	Coded for
"*It takes a fair bit of perseverance as it gets annoying when you can't get the info to store in your head*"	Requires a high perseverance

Our attempt would be to encourage the students to employ the strategy of focusing on small goals, achievement fueling their process of going through more difficult parts and giving them a steady feeling of progression through their learning career.

The other sub-theme is “Discouragements”. We saw it as belonging both under “Motivation” and “Issues with playing”, as getting discouraged and losing hope can be extremely demotivating and often, it happens when trying to play the saxophone and working at improving your skills. The data extracts we assigned under this sub-theme refer to the demotivating aspect of taking up the saxophone and the issues that directly affect the ability to follow one's goals and not surrender.

For example, practicing is time consuming, and if the feeling of progress is missing, the time investment can feel like a waste.

Data	Coded for
“*(P) - I had 30 minutes lessons every week, and then homework to practice over and over again.*”	Time consuming

This can be further exacerbated by the problem many students have of lacking time management skills, as brought before by prof. Christian Vuust.

Data	Coded for
“feeling like I'm not getting anywhere, I know that my teacher says I need time and some sessions I wont improve, but it gets to me, slow progress is a real motivation killer”	Perceived lack of progress demotivates

There are many ways to increase the abilities of time management, our attempt would be to affect the need that students have to keep changing focus when learning and practicing, which would allow them to focus on one specific goal and perceive progress more clearly, removing the power that distractions have over them and their need to choose them over actual work, affecting the time they actually put in working on their skills [34].

4. Connection between teacher and student

Whenever people try to start something completely new in a topic they don’t have any knowledge in - they would seek guidance and help in terms of books, study materials, online courses and lessons with teachers. Beginners, require to have a strong connection with their teachers, they need to comprehend and trust their instructor as they are the ones to guide

them in the learning process. Following the hierarchy of competence, all newcomers start at the very bottom, where they are unconsciously uncompetent and as such, they cannot spot all mistakes they are making needing the help of someone with more experience [35]. Said interaction, be it online or in person, are vital to the efficiency of the learning and as such are something that we would like to explore.

This theme contains codes related to the general need of connection between a teacher and a student and the problems that are encountered in a more limiting environment, such as online education. Looking at the data extracts themselves, we see how important playing together is for an education.

Data	Coded for
"*(P) - He would play alongside me, taking sections of the music sheet and play along with me until we got through the entire thing*"	Cooperative play

This type of structure for a session is common among most of the students we've talked to or gotten information from via surveys. This can be quite limited online, as for one, the teacher has to assume that the students will follow along correctly and two, the students can't get as much information as they could in a face to face setting.

"Feedback is important" is a sub-theme which is very much affected by the limitations set upon learning by online means. The ability to get feedback is seen as so important that many major courses, especially now, advertise themselves as sources of feedback [36]. This does not mean that it is a barrier and it can very well be enough for many students who are more independent however, this was repeated to us many times from various sources, the fact that they need feedback to know if they are going in the right direction and that they feel limited of the currently available options. The following two data extracts are from our surveys, which we believe enforce that point.

Data	Coded for
Q:What are some of difficulties when trying to repeat/observe your online lessons instructions? (If applicable) A: "*Lack of direct feedback from an observer (physical/video/audio). Feedback is often indirect via recordings posted on a forum.*"	Lack of direct feedback online

Q: What are some of difficulties when trying to repeat/observe your online lessons instructions? (If applicable) A: "*...I've started being paranoid since I took the intermediate online lessons and I definately have no idea if I am just obsessing too hard*"	Practicing alone breeds self-consciousness

Our work would attempt to identify any effect on how students receive feedback from their teachers as well as hopefully, give teachers a better control on the movements they want the students to make. This could be done possible by taking advantage of the pressure we could simulate using haptics to showcase exactly which fingers a teacher is talking about and what they are doing.

In the way we designed our thematic analysis, we saw that feedback very much relied on the possibility to practice in a social setting, we also had multiple codes which were related to the difficulty of doing so. This is why we created the sub-theme “Hard to do it in a social setting”, which connected to “Learning the basics”, due to the importance of feedback from early on when fundamentals are all that is studied, and “Connection between teacher and student” through the previously mentioned sub-theme “Feedback is important”.

Students reportedly faced problems when attempting to play in a social setting as beginners or if they already had social anxiety. This limits their possible encounters with teachers as well as their peers therefore less chances to receive feedback.

Data	Coded for
“*I even go wrong and panic as soon as I see someone walking past the house.. in case they can hear... I saw some workman mucking about dancing last year so got really put off…*”	Stage fright

If this is a psychological problem, it is not something in our scope of things we can tackle to solve, however we would attempt to present an option of getting some of the perks of feedback and leading correct finger movements through our solution in an attempt to create some effect that may be noticeable and maybe even positive for the students who face these problems.

Being able to have a proper connection between teachers and students also relies on the setting available for them as well as the needs they have. For example, a group of students wanting to play live together and get feedback from their teacher for it would face an uphill battle against the common delay problems of streams and regularly used communication

applications, however if the teacher simply needs to review the progress of a beginner student, they do not need 0 latency connections in order to fulfill their job. Problems still occur due to the limitation of online solutions versus real life meetings, however those are there to stay for now.

Data	Coded for
"*(I) - So you can teach multiple students at once?* *(T) - Yes, I mean, not right now, if we do one on one, it's either at a students home or in a classroom where we keep it very clean, but with kids, parents either prefer at home now, to not get them at risk or just online.*"	The need for a safe environment affects the possibilities of learning
"*(I) - Has that given you any troubles?* *(T) - No not really, I mean, you can't use Zoom when you want to jam together, like when we prepare for a big band practice and with the orchestra, but when you have a 7 year old and you want them to practice a scale, a bit of delay and the sound not being perfect is not really the problem. The issue more is the fact that I keep having to move my saxophone up to my camera to show the fingers since it's hard to explain.*"	Realtime connection is not important when you're just learning. Limitation in properly communicating.

The data extracted above, discussing the delay not being as important for students does still mention the limitation of online solutions, the teacher having to constantly change cameras or move awkwardly, we've also seen this behaviour in our observations of online lessons. This is something we would attempt to affect by allowing the teachers to explain, while pressing the correct keys while the students would feel the appropriate haptic feedback on their end.

In regards to the safe environment, this has become far more of a concern since social distancing has become more of a hot topic. This has gotten some students to quit entirely while others have become limited to studying online only while previously doing it in real life, which may not be felt as limiting to someone who was only used to online study, however it is perceived as a problem and an inconvenience for someone who is not, in the very least, since their homes may not be equipped to allow for the loud noises that saxophone practice are bound to produce. In this, our focus would be to see if we could affect the way beginners practice, by removing the need to interpret music symbols and instead, being told in a haptic manner which buttons to press before making the sound. We would also want to see if we would have an effect on the time it would take until the student would be able to consistently play the notes they would learn via our method versus learning from the sheets themselves,

if it would be possible to accelerate it, we would shorten the amount of “annoyance” those around them would experience from bad sounds and squeaks.

The last sub-theme is “Struggles playing with the teacher” , which we formed from codes we gathered which were about the problems we gathered from students about connecting with their teachers when trying to play or practice together, due to this, we saw these problems as being related to the other main theme “Issues with playing”.

Data	Coded for
“*work with Zoom and see what we can do, so we don’t know yet what the results are. Obviously you are going to have a fixed point of view on a teacher, who moves around between students, so you won’t have the same experience or see what the teacher is doing on their instrument exactly.*”	Difficulty imitating the teacher
“*Due to our current limitations, there have been people on the waiting list since before January of last year, so yes it can become even 1 year.*”	Trouble to meet in person

The previous codes represent the range of problems in this sub-theme, the already hard to access service of a real life meeting with a teacher has become even harder to reach, and this has resulted in the limited use of online services for students who are not used to them and teachers and educational institutions who are not prepared to handle them. Adding a haptic element to the learning, as mentioned before, would hopefully cause a possible effect by giving more feedback and more immersion to the student and facilitate a better connection between the student and the teacher [37].

5. Learning needs to be personalized

People are unique creatures that learn and comprehend information in different ways - some learn easier more visually for example and some even excel based on the context and setting of which they are conducting their studies. As with the barrier of entry, there are different factors that play into account but ultimately boil down to the fact that the standard teaching doesn't work on everyone and there is a need to personalise the learning material. This helps alleviate some of the difficulties and is also beneficial for the motivation. People need to easily relay from theory to practice and together with the aforementioned items makes personalisation a critical part of the learning process and it directly correlates to our research topic.

A generous amount of data presents the idea of pressure and frustration that students feel to succeed and enrich their own abilities. This stress can be compounded and result in psychological problems, in younger students this being problems like bed-wetting, which is perceived to be related to the stress felt by the children facing this problem, this issue is so prevalent in fact that a new paradigm of musical education seeks to move away from a focus on skill increase only and look at the socializing aspect of music learning, giving the chance of teachers to personalize music practice and learning for students and give an opportunity for students to improve more from their interactions with the community, practicing together and helping each other, in other words an attempt to abstract away some of the barriers of learning any music instrument or theory and focusing more on the feeling of actually creating music and entertaining oneself and their peers. [38].

The codes we saw fitting in this theme and forming it we interpreted as addressing the needs students have for different ways to learn. Some of them telling us their problems while others offering their homemade solutions which related to their preferred way of study. We also asked them for ideas of what could better improve their education.

Data	Coded for
"*..I assigned little cues like… G lines up with the target on the Treble clef, B is the centre line, D is the next line up, and so on…*"	Learning through visualization

The previous code is only one example of the work students have to put into creating their own solutions in order to use visualization in their learning, as standard curriculums are not designed to support irregular learning styles. There are teachers who take the extra step to design individual curriculums and practice styles for their students, such as:

Data	Coded for
"*if I had the same curriculum for everyone you know. And in the third week of the third semester we always play this tune and the fourth week we always play that tune. But it is not like that. It is very individual.*"	Need for personalised curriculum.

However, this is also limited, simply by the time and budget availability given to them by their position and educational institution supporting them as teachers. This was made clear to us through on of the data extracts which we gained from one of our interviews, which seemed to us to be covering a sub-topic of the need to personalize education, namely the budgetary limitation, while also affecting the other main theme "Issues with playing", as due to budget limitations, requirements such as a place to practice in peace become problematic to handle.

Data	Coded for
"*The resources are only for 10 times per semester, where I can meet one lesson, which is 50 minutes teaching and 10 minutes break, so one lesson basically is 50 minutes and I can do that 10 times in one semester and if I meet, you know, with them for a group session. Then I have to take those hours from the solo. Those, you know, from those 10 lessons. That means maybe we only have 9 lessons in a semester and so on. So, since the budget is quite small, there has to be a really good reason to meet in a group session.*"	Lack of funding for a proper education

This limitation would affect students on many levels, as such, we would like to provide solutions to attempt to affect the learning process, with hopefully a small billing footprint. We were interested in what wishes and ideas current students had and incorporated that in one of the questions of our survey, there were multiple answers, however the following was seen by us as very related to our research question.

Data	Coded for
Q: Do you have any ideas on how technology could help you learn? A: "*maybe let me know somehow what notes I have to play next and how, I've seen similar tools for guitars and there is games for piano and guitar too.*"	Need solutions to memorize notes and fingerings

Our attempt would be to provide a tool which does just that, working towards aiding in memorization of notes and fingerings, using haptics as an enhancement to regular training and attempting to generate a positive effect through it [39].

6. Issues with playing

People naturally face difficulties when studying and saxophone playing is no exception with some of the major issues being the lack of comprehension and finger control. Among the previously mentioned ones, there are also purely physical, monetary and even outside challenges. The collection of those problems can halt and harm the progress of beginners and thus gravely affect the efficiency learning process. As aforementioned, we want to

observe the various effects haptic and visual technology would have, so it is required to take into account the already existing complications.

To begin with, we mentioned before when addressing the budgeting limitations which affect the requirements present in the previous main theme “Learning needs to be personalized”, that it is very important to have a designated location to actually learn and practice. A student can be prepared by having such a place at their home or nearby accessible, provided by the school for example, however in these times, many students found themselves without such a thing, and this quickly became an alarmingly growing reason to quit practicing.

Data	Coded for
“*05:55 C - It is at the school, it is at the school. Occasionally, it is in my own studio at home, in my own practice room, my own studio in my house - occasionally because. But only for practical purposes it is. But you know if we... But usually then the normal thing is that we do it at the academy one on one.*”	Need for designated place for learning

The place for studying can have different reasons of importance, some are for giving the ability to make as much noise without feeling like the students bother anyone, however another reason is allowing teachers and students to meet in order to provide and receive feedback respectively. We would attempt to enhance the experience of doing so online, which would lessen the impact of a sudden lack of one of such places from this perspective.

Focusing is also a problem we identified during practicing to play the saxophone, both in the ways of actually paying attention but also to remember what the student was trying to focus on.

Data	Coded for
Q: What are the hardest things for you during a learning session? A: “not getting distracted away by something else on my computer, I had to block facebook and youtube when I have my time for learning”	It’s hard to not get distracted

We would work towards engaging the students through the tactile system, which would offer students a different option that might be more engaging to some [40].

Outside of the codes that fit this theme, we had groups of them that fit this narrative better as sub-themes, the first one of two being “Can’t practice on the go”. This is caused due to the scale and noise level a saxophone reaches while practicing on. A problem which can lead to breaks in training, which will slow down the progress and grow as more of a problem eventually, soon affecting the other issues we addressed before, such as motivation, by what would eventually become regression of skill.

The other sub-theme is “Problems with prolonged sessions”, and it is about the issues we gathered from our data extracts that would be caused from spending a long period of time practicing and affect the students negatively due to the sheer weight and size of the saxophone as well as the constant need for powerful breathing to create a correct and constant sound.

Data	Coded for
“*adjusting the neck strap until the saxophone goes directly into his mouth, avoiding:* - *putting additional strain on his muscles* - *Negatively affecting breathing* - *causing a slouch.*”	Muscle pain due to bad form and saxophone weight

We would try to address both of these sub-themes by offering a solution that would allow practicing on the go, by allowing the student to focus training their finger skills instead of all of the skills repertoire currently needed to play the saxophone while also being usable to shorten the amount of time needed to lug around a heavy saxophone, which would tire the student out.

Summary

We’ve worked on our thematic analysis for a large part of this semester and it has given us the opportunity to better understand the problems plaguing the saxophone player community as well as learning at large in certain ways.

While working on it, we have become aware that this is our interpretation of the data corpus present, and as such it is twisted by the subjective nature of the thematic analysis and of us, the ones who gathered the data, coded it and analyzed it. Due to this, the best we could do was to avoid the common pitfalls of a thematic analysis, such as using the questions we had from our surveys as the “themes” we reported on, while relying on the provided definition of what makes a thematic analysis good and attempting to follow the guideline. As such, we are aware that someone with a different mindset, approach or research question, could look at our data corpus and come out of this process with different themes.

From all of the data gathered and through the process of refinement we ended up with 6 main themes, each covering an aspect that students, primarily beginners, have to tackle:

1. Barrier of Entry
2. Learning the Basics
3. Motivation
4. Connection between teacher and student
5. Learning needs to be personalized
6. Issues with playing

We organized them by how they were connected to each other, further separated the codes in sub-themes where needed and looked at how we could have a positive effect on them by relating their problems to our research question "*How does visual and haptic feedback affect the learning process among beginner saxophone players through the use of a glove prototype*".

We believe that working with a haptic solution at a minimum, hopefully adding visual feedback too, would allow students to work through their issues presented and have an easier time to learn the saxophone as well as reinforce patterns as muscle memory. We would do this to better create a connection between the teacher and the student, allowing them to have a way to seamlessly send and receive feedback haptically or have the ability to revisit it during practice sessions.

Design Through Research

Our development nature was, as previously mentioned iterative in nature and indeed, though our work followed the ideals of Research Through Development, where we wished to create new knowledge through activities common in design [41], we titled this section in this way in order to emphasize how important we saw every data extract we analyzed and every bit of feedback while testing our prototypes in regards to the design choices we made to continue developing our prototype while generating artifacts as we would move between versions.

Fig 19: The initial prototype, based on the Proof of Concept

After the original workshop, which we tried to use in order to gain a better understanding on how the glove would be used. We started working on a prototype using flex sensors and cylinder coreless vibrating motors to begin with. The parts were relatively cheap, especially since we decided to build our own flex sensors, however soon after the first prototype was ready, we identified a few weaknesses in the design. For one, due to us sewing the sensor into the glove, it was almost impossible to take it out once wired if we needed to make modifications or fix any of the soldering. And secondly, due to the motor we were using, the rotating part of the cylinder had to not touch anything, including parts of the glove, or it would not have enough force to rotate. We updated our prototype accordingly, the second prototype gaining the ability to easily be altered by having the sensors in sewn bags, from where they could be removed and switching to coin vibration motors, which no longer had a problem with being touched or bumped into.

Fig 20: A coin motor and a cylinder motor

The following image is of the second prototype as worn by one of the original testers we had at the workshop. This prototype only supported two fingers, being able to record their movement, and at the press of a button, replicate the movement through the vibration of motors until all of the movements were replicated.

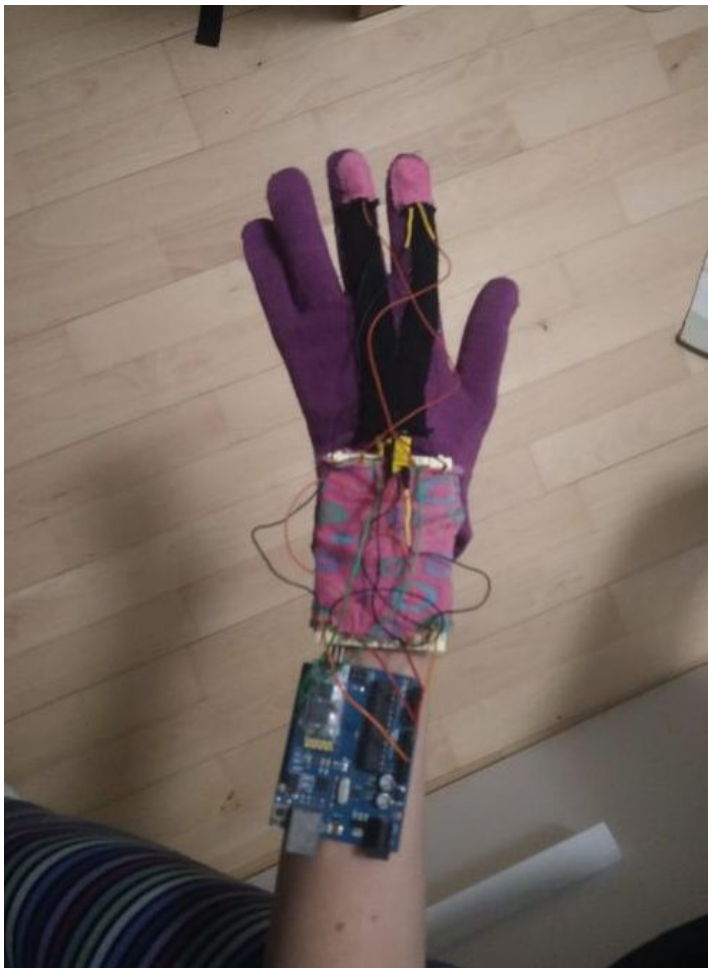


Fig 21: The second prototype

While the tester was trying out the glove she gave us feedback on the fact that for quick testing, as we were using the glove, there was no issue, however, when needing to use the glove in conjunction with a saxophone, assuming the user would have to first put on the saxophone, then turn on the glove, due to the way the flex sensors would function, there would be no way to exactly know when to record and when they would still be fidgeting with the saxophone.

This would be something we would have to handle in the Future Work, for which we have already started preparing.

Glove Design After Thematic Analysis

From the Thematic Analysis, we gathered that there are problems students encounter, affecting them at different rates based on their skill. For example, the problems that occur for beginners that act as barriers of entry would have affected experienced students initially, but that no longer happens once they've managed to face them, meanwhile issues like motivation or the need to have a more customized curriculum needs to be tackled universally by students of all skill groups.

Using the information we gathered, we started questioning our priorities with the glove design to try and see what parts of the problems we found we would mainly tackle and which we would affect as a result of our primary targets. If we were to look at “Issues with playing”, the idea of a glove becomes a bit redundant, as yes you can practice without holding a saxophone, but it would not give the same feeling, if they were to put on the gloves and then have them run passively while reading a book. As such, we would maybe drop the idea of serving both active and passive learning in order to better handle actively learning the saxophone and simulating that experience.

Discussion

During this semester, we've worked towards developing a haptic solution which would be included in the teaching process of playing the saxophone as an expansion of existing options. In order to achieve this we followed the methodology practices for qualitative research, by doing interviews, open ended surveys, observations and workshops. We not only were using our original idea, inspired especially by an iterative process, we relied heavily on input from current students as well as teachers to get an understanding of what their actual needs are.

What we found is that even high level professionals, capable of conducting live performances still require rigorous training in the basics. A surprising result was the fact that the majority of our participants identified with the idea of fear to start something new even if they have already existing experience in the field. The notion that musical experts enjoy what they practice is still present, however, an unexpected amount of people have reported that they lack motivation to continue going or to start all together. Finally, the belief that finger control is the main part of playing the saxophone was disproven, with a large portion being mouth and breathing control.

What all of this means, is that our initial idea of a glove product for learning how to play the saxophone might not be the best or most efficient way of learning how to play. There are a number of problems which prevent people from even starting to practice such as sound volume, weight, mobility issues and others. None of those items are currently being taken into account when designing the glove.

Another huge issue that has not been properly addressed in the field is the fact that players often lose motivation or find the learning to not be to their liking. The PianoTouch, but also the more recent ShIFT all focus on going for accuracy and efficiency [10]. However, they neglect to take into account the human factor and fail to try and personalise the process for the participants, which would bring forth a big boost of motivation in return.

The project did not succeed in its quest to try and answer the research question as there were no proper tests to determine the efficiency of the glove prototype. That being said, a lot of new information has come forth which would allow for advancements in the field. We believe that if we continue working we would be able to answer even more interesting additional questions - such as the importance of personalisation and motivation of the user and its effects on the performance, among many other.

Future Work

To begin with, we would want to finish the third prototype, which uses the pressure sensors and attempt to run a small scale experiment, to observe the actual act of learning a pattern using only our solution.

Afterwards, we may build upon our findings from the Thematic Analysis and develop a solution that would do a better job at simulating a saxophone, removing the need for the player to always hold the heavy instrument around their neck while practicing with our glove solution. Said solution should be tested and compared with the third glove prototype to identify which of the products is more efficient. Additionally, a new possible vector has been exposed and new potential questions can be asked, such as the importance of personalisation and motivation in the learning performance.

A possible idea would be to try and tackle the solo type of education presented by the findings from autodidact. In it, we can establish a system or a mobile application, where users would be able to upload and download various patterns, which would essentially connect saxophone players and give them the option to practice content from other professionals.

Finally, we would like to explore more about the dynamics of playing an instrument, we mentioned before the idea of actually expressing the type of articulation expected for each note, we would like to look into attempting it by using perhaps the visual aspect of our proposed original solution.

Conclusion

There have been multiple studies made with promising results in the field of haptic interfaces. The idea of having computers act as guides for humans has also been explored increasingly more over the years. Our attempt was to create a solution which would better allow students and teachers to be connected, especially during these trying times. Through our Thematic Analysis, we have proven that the limitations people find themselves forced upon them now, which they did not expect and are not prepared for affect their learning experience negatively. Our attempts at understanding this and iteratively designing a solution which would attempt to have an effect on their learning was the reason for the work we did this semester.

Due to our scope of mainly focusing on the relationship between students and teachers and their reduced abilities to communicate and understand each other, our proposed solution would have a limited appeal to autodidact students in its current state. We think, based on the results of the Thematic Analysis, that a solution focused on replicating the shape of the saxophone itself, by moving away from the glove-centric design would allow longer practice times and would act as a teaching tool for both students who learn together with teachers as well as those who learn by themselves. This solution could be further enhanced by not only having a record/playback feature but actually have a database of patterns saved on and accessible either by an onboard control or a mobile application.

As mentioned before, another element of practice that was brought to the foreground of our priority list from the Thematic Analysis results was the effort it takes to practice and memorize the articulations and their correct order. A better solution would also focus on that, displaying it could be done with either the motors, by having them pulsate in a specific pattern based on the wanted articulations, or through visual cues. Recording of these specific actions is another thing however, which we would need to figure out if it should be done within the recording act using our future prototype, or assigned manually through a mobile application.

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