SDU✦

MSc in IT - Product Design

Front page for Master's Thesis project

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Title of assignment: Learn through play. An Augmented Reality Tangible User Interface (TUI) music system	
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Abstract

Nowadays, the traditional way of learning used by the teachers does not seem to be very appreciated by children. Teachers began to look for a modern way of teaching to keep children motivated in the classroom. New interactive technologies offer opportunities for new activities and modern teaching methods.

To address this, I began to look through a new active teaching method provided by a music teacher for 5th and 6th graders students. The teacher has adopted a new way of teaching, using digital learning content, such as websites and online games, to teach children about music. Moreover, recently, the teacher began to use a more practical way of teaching music by involving children in various tasks of composing music. The teacher started using a telephone application called Garage Band, to teach children about the rules of composition and how to create melodies, giving children small tasks in which, they must combine digital musical instruments loops. In this way, the teacher hopes to stimulate learning and open children's appetite for music.

Research showed that "digitalization may be a distraction in the classroom" in which children can get distracted by a fully digital activity and therefore, there was a need for an even more practical way of teaching by combining digital representations with physical representations (William F. Crittende 2019 "Embracing Digitalization-Student learning and new technologies")

In addition to many stakeholders involved in the prototyping process, I considered the music teacher to be the main stakeholder who was included in the participatory design research process. Therefore, together with a music teacher I developed a tangible user interface (TUI) music system, aiming to stimulate children's creativity through physical cooperation while learning to compose music.

In the paper I present an iterative process of prototype (TUI) which uses augmented reality as digital output and music cards as physical input in which I constantly refine and improve the design and interaction, in order to continue to create the best value for the end-user.

Sketching, paper prototyping and rapid prototyping are the main inspiration tools that helped me to build a functional TUI prototype system. As methods, qualitative data such as video recording, observation and semi-structured interviews played a crucial role in finding solutions; Finally, a field visit played a crucial role in understanding children's behaviour towards the TUI prototype system, helping me to identify how children cope with digital and physical representations.

Therefore, the study reported in this paper showed an attempt to bridge the gap between cyberspace and the physical environment by transforming digital content, such as musical instrument loops into tangible physical cards, that illustrate different rhythms of instrument loops.

Therefore, there has been "a strong emphasis on understanding physical objects as inputs, rather than by considering purely visual enhancements" (Hiroshi Ishii 1997) and trying to bridge the gap between digital content with physical tools.

In the current study I explore the implications of a tangible augmented reality tool that supports digital content, allowing a shifting from the computer desktop environment to the physical environment. Therefore, to address this, I created a graspable manipulative tool using music cards as physical inputs. The mission was to find the most effective method of combining learning with play and stimulating children's cooperation while composing music.

In the paper I included the analysis of the Tangible Interaction Framework (Eva Hornecker and Jacob Buur, 2006, "Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction") which played a crucial role in developing the prototype and its interaction. The analyses analysed Tangible manipulation, Spatial interaction, Embodied facilitation, and Expressive themes, which contributed to the exploration of different tangible interactions and the generation of design ideas.

The analysed results showed that the cards (illustrating the musical instruments) represented the best physical representatives, representing the main inputs of the prototype. As a digital representation, 3D Augmented Reality animations were chosen to be further tested and to see what can improve learning and whether it can stimulate children's motivation to learn.

At first, I believed in creating a tangible tool using a "ready-at-hand" approach, that allows experiencing a natural and intuitive interaction, in which physical tools (in our case AR cards) are perceived by users as "invisible" objects and therefore, paying more attention to digital content and stimulating learning.

Finally, the research showed that a "ready-at-hand" approach leads to a minimal cognitive effort of the user who begins to fail to realize the ability or usability of the physical representation (cards) in a physical setting and focusing only on outputs, respectively, sound and 3D AR elements.

The study shows that there is a need for a "handy" approach (present-at-hand) that "leads to increased planning and reflection, which in turn leads to improved learning, compared to easy handling of concrete objects (ready-at-hand) that leads to a reduction in reflection, planning and learning " (Paul Marshal, "Do tangible interfaces enhance learning?" 2007)

Hence, concrete materials were needed for creating expressive learning. Therefore, the TUI system got improved and I decided to include more rules on the use of cards and began to constrain the free handling of cards by bringing a boundary plate on which the cards were to be used.

Moreover, the current research also showed that one of the most important elements that stimulate children to cooperate and learn is not in the digital or physical representations themselves, but in the strategy of the teacher's scaffolding strategy, which has the role of motivating children in the classroom and makes the task easier to manage "the teacher is seen as a facilitator or coach who supports the development of a student's attention, helps manage frustration and so on." (Michael Mascolo 2009).

The paper showed the importance of a moderator that is between the user and the tangible user interface and therefore acts as a "bridge" between play and learning.

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INTRODUCTION

The inspiration

The direction of my thesis was inspired by my previous experience in developing a promotional tool that was intended for BTB clients. ARPI (Augmented Reality Portable Installation) represented an ambitious new way of advertising different stakeholders' businesses. My team and I developed a portable wood suitcase (see figure 1) that could be transported having the aim of promoting different activities of our stakeholder.

Once you open the suitcase, the user will experience an augmented reality effect. To make it work, the user had to use a tablet that comes together with the suitcase. Our first client was a cultural house called Building 5 from Kolding Municipality. They wished to promote their activities and expend their brand awareness in Kolding to attract more students from schools and universities.

We have decided to build a wood model (wood suitcase) containing four floors that would represent and promote the Building 5' rooms and the activities that are happening inside those rooms (see figure 2). Since we only focused on the promotional sector business, while testing the prototype, our business supervisors challenged us to think more about the implication of augmented reality in other sectors as well, such as education.

My team and I knew that the entire entertainment' effect stood in the target images of the objects' floors. The target image represents a trackable image that you can scan with your phone in order to produce the desire effect. (see figure 2). In ARPI' case once you scan the floors, 3D animation would pop-up, illustrating people that are dancing, playing on computer or working in a woodshop.

While testing, the business supervisor understood the interaction and he pull out the "floors" from the wood object. He pushed away the wood suitcase and he showed us only the floors (see figure 3). We did not realize that the object could actually be used only by having the floors in the hand. We were so absorbed to build a portable suitcase; we forgot the aim of the Augmented Reality and we stop explore. The supervisor started to play with the floors and create a "sequence" of tracking images (see figure 4).

The supervisor feedback made me think that the story the AR object conveys is much more important than the entire wood artefact. The artefact looks good, but we forgot about the story and the experience we want to share.

I decided to go back, and I become interested into the implication of AR and target images into the educational sector. Therefore, become interested in combining digitalization with physicalization in order to create different activities such as treasure hunt, storytelling. Etc. I also realized how important is to co-design together with your stakeholder in order to bring value to your prototype.

Figure 1 ARPI Suitcase closed

Figure 2 ARPI Suitcase open

Figure 3 AR 3D models

I have learned that creating experience become a very important feature for future products nowadays and we can no longer should look only from a technology perspective when comes to build new interactions but listen more to the customers, hence, shift the attention from technology-driven innovations and look more into the
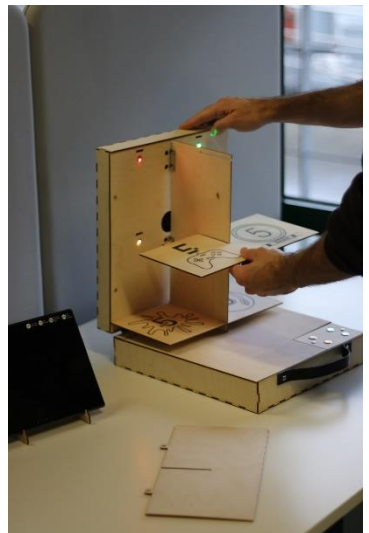
human-driven innovations. Experience as stories told through products has the potential to change the way we think and design" (Marc Hassenzahl, 2011).

Considering my experience with ARPI project, I believe more qualitative research should be done before designing a Hi-fi prototype and an analyze of the tangible interaction elements should be done before defining the design of the prototype and its final interaction with the final user. This mindset could help us to realize the target images "the floors" could be used differently and create different tangible experiences.

I decided to bring a new analyze model that would help defining the relationship between augmented reality technology and tangibility.

Therefore, further investigation should occur, and a framework of tangible interaction elements could be helpful to be used in the further research such as Tangible manipulation, Spatial interaction, Embodied Facilitation, Expressive representation themes before starting to create a finished and Hi-Fi prototype. (Eva Hornecker and Jacob Buur 2006. "Getting a Grip on Tangible Interaction: A Framework on Physical Space and Social Interaction")

Looking back to the ARPI project it seems to be incomplete. My team and I tried to create a digital-physical interaction, but feedback and testing showed us that the result was not that tangible.

Figure 4 Target images- business supervisor meeting

Therefore, I have asked myself what is the value of grasping and manipulation? and how-to bring captivation of tactile interaction with the AR artifacts? How can we use tangible objects (physical environment) together with digital (cyberspace) that supports learning and moreover cooperation between users?

RESEARCH PROCESS

"Long before the invention of personal computers, our ancestors developed a variety of specialized physical artifacts to measure the passage of time, to predict the movement of planets, to draw geometric shapes, and to compute" (Hiroshi Ishii and Brygg Ullmer 1997. "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms ")

Given the musical elements, I chose to organize workshops in which I chose LEGO bricks as a support tool that helped to test the musical elements. I chose a more visual way of doing it, instead of discussions and interviews. Such a procedure will allow the user to better visualize their emotions or images created in the "world of imagination" by "building" those images in a real setting.

The final LEGO models will help me to find what influenced people to build, combine and create, such as the color or shape of bricks.

We know that music can boost people creativity "Music activates both hemispheres of the brain and helps with transferring information from one side to another […] in which music embeds and activates sequences of knowledge and action" (Lucille M. Foran 2009. "Listening to Music: Helping Children Regulate Their Emotions and Improve Learning inthe Classroom").

It was important for the workshop to bring an element that boost people creativity, emotions, and knowledge. Daniel Joseph Levitin a neuroscientist, cognitive psychologist, and the author of "This Is Your Brain on Music", finds that "music engages all the sensory areas and facilitates their differentiation and development […] and listening to music appears to help students access parts of their brains that function poorly or not at all […] in which listening to music is wired to improve or lower our mood".

Therefore, I decided to create workshops including three different music scenarios such as Tone color scenario, Instrumental scenario, Genre scenario and observe the people reactions. I chose LEGO bricks as a tangible graspable and manipulative object that would support people behavior and help the participants to expose (in a physical way) their emotions and feelings that let me to understand the users' psychology in order to create a valuable future prototype.

LEGO bricks properties

- They are tangible and graspable
- Allows you to create different patterns
- Contain different shapes, size and colors allowing people to build whatever they feel.
- Are easy recognizable and to manipulate
- Are used on a tabletop environment allowing to see and talk about the final results (models)
- The bricks are fun for everyone
- The bricks are simple to use
- The bricks encourage people to play together

A description of workshop process- What intrigue people to start build, create, and combine. An exploration of sounds elements

For exploring and describing how different music elements such as tone color, instruments, and music genre influence people imagination and therefore the final visual representations students from IBA (International Business Academy, Kolding) and SDU (South Denmark University, Kolding) were invited to be part of the experiment.

As shown in Table 1, a total of 3 sessions were settled, including 7 workshops. During the workshops, participants were invited to listen to music in headphones, individually and not to interfere and influence each other. Each session contained different rules. As can be seen after each session, modification of the workshops occurred. Slowly the participants were constrained (right side) by the new session rules such as elimination of Lego boards or asking to build the models using one color Lego bricks.

FIRST BRICKS SESSION (ONE WORKSHOP) (2 participants)	SECOND LEGO BRICKS SESSION (3 WORKSHOPS) (8 participants)	THIRD LEGO BRICKS SESSION (2 WORKSHOPS) (3 participants)
The rules		People were told to think abstract and to do not associate sounds with activities, movies, games or stories.
People were told to build models while listening to tone color and instrument sound. They were asked to build whatever they feel	People were told to think more abstract and to do not associate sounds with activities, movies, games or stories. Different music genre was added.	The workshops allow users to look at each other finished LEGO model and make a guess of what instruments they were listening to. (game context)
Helping tools		Was brought two times of Lego bricks such as multicolored and one color in order to observe people reactions.
In order to run the workshop, three tools were used. wood bricks, large plastic bricks and original Lego bricks	In order to run the workshop it was decided to only use LEGO bricks as a more efficient tool allowing people to explore more. A "BOARD" was added as well in order to observe their reaction.	The boards were eliminated in order to constraints user to only build models and not stories.
Purpose of session		
Tone color exercise allowing users to build models using as many wood, larger and original Lego pieces they want	**Tone color exercise**. Constrain users to choose only one LEGO piece that reflect upon tone color. Include 3-4 minutes time limit/ piece	Tone color was excluded. Listening to only instrumental sound and music genre, allowing users to build models using as many LEGO bricks they want. Include time limit of 5 minutes/ model.
Instrument exercise allowing users to build models using as many wood, larger and original Lego pieces they want	**Instrument exercise** allowing users to build models on a board using as many LEGO bricks they want. Include time limit of 3-4 minutes/ model	
Music genre exercise allowing users to build models using as many wood, larger and original Lego pieces they want	**Music genre exercise** allowing users to build models on a board Include time limit of 3-4 minutes/ model	
Bring more constrains (narrowing)		

Table 1 The overall "bricks" sessions process. Searching and defining music aspects

Explaining the chosen music elements

The tone color or timbre symbolize the quality of the sound. As Kyle Coughlin a clarinetist, saxophonist, teacher, author, and composer say that "Is important to know that this should not be characterized as a rhythm (duration), volume (amplitude) or pitch (frequency). The timbre allows to a listener to identify a sound that is produced by a specific instrument". Example- A trumpet sounds different than a violin even if both play the same frequency, duration, or volume. The difference is made by the timbre of the instrument and allows you to recognize the difference between sounds. According to Kyle's website called "Fundamental of Music" (http://www.fundamentalsofmusic.com/tone-color.html) there are 8 different tone colors such as bright, clangy, crisp, deep, buzzy, warm, dark and clear that I chose to be tested.

The instrument sounds such as drums, handpan, classic, guitar bass and violin were chosen from a software that I have experience of working with called MusicMaker (https://www.magix.com/int/music/music-maker/). The instruments have the same rhythm and harmony so that it does not create bias between the participants and to do not influence the results (building models).

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First brick session (Experimental workshop)

Figure 5 Three testing tools (wood, large and Lego bricks)

First session contained 2 experimental workshops that had the purpose of testing tone color and instrumental sounds using different physical elements, observing people reaction, and defining the next workshops. The reason of using three different elements such as large size, wood and original Lego bricks was to find which tool was much more comfortable to use for the participant and which one could better enhance the people creativity. All the elements were distributed on a table and the participants decided what to choose. They were not told what to choose and were allowed to build whatever they wanted using as many bricks as possible.

Results

Observation of the experimental workshop in which two people were participating (one from IBA and one from SDU) shows that using wood bricks can be easy but it can easily become chaotic. Moreover, according to feedback the participants think it does not support their imagination and become creative and therefore, they could not finish the model as one user claims "It keeps falling down, you need to take super care of the model! If you want to build more and more, you need connections that LEGO bricks offers" (see Figure 6 participant a, sample a - shows a castle model that was built by a user while listening to violin and piano instruments).
The castle needed to be built 3 times because of the pieces that kept falling. Due to the poor wood bricks' properties prevented the user to build abstract models, compared to LEGO bricks which allowed the other participant to "build" and visualize their imagination or feelings in more a rich and spectacular model.

It was also observed that wood bricks (which do not have any contacts/studs to link the blocks together) pushed the participants to think of different motion and active scenarios while listening to sounds. Compared to wood bricks, LEGO bricks gave to the participant a more abstract image and pushed the participant to build models and not actions.

Figure 6 First brick session, Instruments and Tone color

The large size bricks were used only one time by the participants. According to the uses the bricks are too large and does not allow them to put their imagination into practice. "I would prefer smalls sizes that let me to decide how big the model should be" quote from one of the participants. Therefore, these bricks become quickly excluded from the workshop.
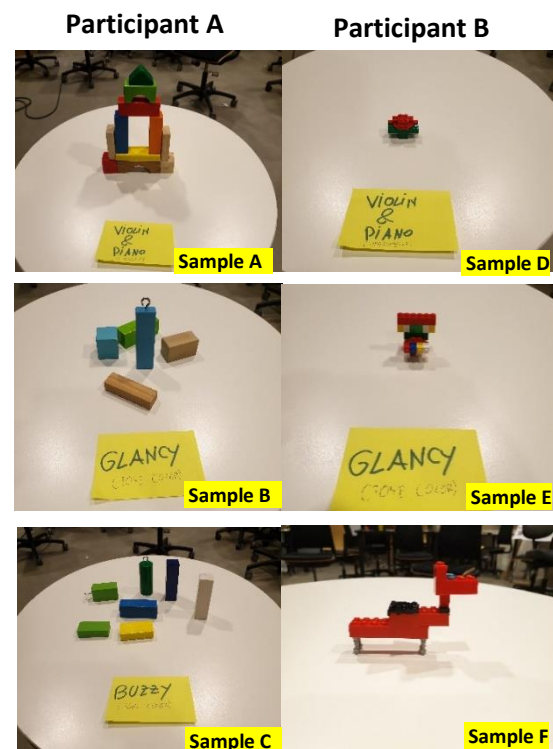
A few examples of using wood bricks compared to LEGO bricks

- Violin and piano (participant A, sample a). "For me, such instruments represent something peaceful and it reminds on Disney movies. A peaceful picture. As I build a fairy tail image comes to mind. The violin and piano were not agitating me and give me the feeling that I have more time. So, I could better focus and come up with a castle (perhaps associating with classic sound which make you concentrate)"

- Violin and piano (participant B, sample d). "It was also peaceful for me and I imagined it more as a garden, so I created a flower. My model is a bit abstract, but I tried to express the harmonious feelings that the violin and the piano gave me "

- Clangy tone color (participant A, sample b). "For me it sounds like Tom and Jerry cartoons sounds effects. I was trying to make a visualization of an impact in which things are hitting between them in a funny way"

- Clangy tone color (participant B, sample e). "It was a fun sound for me as well. I was thinking about chiding colors that compress together. So, I have tried to make an abstract cloven illustrating the month and eyes that are looking at you. It reminds me on old funny cartoons as well"

- Buzzy tone color (participant A, sample c). For me is like Signal and gives me annoying feelings. So, I tried to illustrate a falling down action using wood bricks.

- Buzzy tone color (participant B, sample f). I consider this sound being something annoying, strange that is followed by hilarious feelings. So, I tried to make a red and ugly animal that makes you to wonder what that is? So, it reminds me on someone when making mistakes the red button is pressed to announce that whatever the person is doing is wrong, like an alarm. Red is also an extreme color that accentuate.

What have I found? (Conclusion of first brick session)

I was not sure what music element intrigue people to create and build more. Considering the participants' reactions, I noticed that they had almost the same thoughts and feelings. But it was still unclear for me how sound influence people and what are the sounds elements that makes people wish to create and build. Therefore, I could not draw a conclusion and I decided to continue to host more workshops including more instrument sounds and a new music element, music genre including rock, hip-hop, latin, classic, jazz and blues.

I was interested to see the participants reaction to this element and find if genre helps them to become even more creative and motivate them to build "Music genre and its meanings inform people, quite profoundly, about who they are. From aging punk rock fans and passionate opera connoisseurs to youthful dance club devotees and bluegrass music enthusiasts, music both signals and helps constitute the identity of individuals and collectivises" (William Roy and Timothy Dowd, 2010 " What Is Sociological About Music?")

I was also pleased by the efficiency of LEGO bricks and I decided for the second sessions to do not change with another tool and exclude the wood and large bricks.

Second brick session (3 workshops- collecting data)

Second session contained 3 workshops and 8 participants (2 IBA students, 2 SDU students and 4 Musicians)

The workshops had the purpose of testing different sound elements such as, tone color, instrumental sounds and music genre, using LEGO bricks as a supportive tool. I wanted to see which sound element better support their imagination and gives them inspiration to build.

From previous experimental workshop it was clear that LEGO bricks represented a much more comfortable tool to be used by the participant, better enhancing their creativity.

For all 3 workshops the LEGO bricks were distributed on the table in order for the participants to be able to faster grab the pieces and manage to build their models in a time limit of 3-4 minutes per sound. There was no restriction considering the color, size and number of pieces that they can use but instead, they were told to try to build abstract models and try to do not associate different sounds with places, movies, games, stories or activities.

LEGO boards were also included, and participants were asked to build their models on it, in order to keep the it more organized.

Regarding tone color element, feedback and observations from the first session, exposed that even having LEGO bricks available, it was hard to visualize the tone colors and considerable time was spending, making it difficult for the user, struggling to build the models. Therefore, for the next workshops the users were told to only choose one piece for each tone color and a more attention was shifting to instruments and music genre.

More percussions and strings instruments were added and in total 6 instrument sounds were tested such as drums, handpan, classic, guitar bass and violin.

The most popular genres were used such as Melodic Metal rock, Punk rock, Latin, Jazz, Blues, Classic and Hip Hop.

Tone color reaction

According to Kyle's website called "Fundamental of Music" (http://www.fundamentalsofmusic.com/tone-color.html) there are 8 different tone colors such as bright, clangy, crisp, deep, buzzy, warm, dark and clear that I chose to be tested.

The examples below are just some of the most significant that show the similarities between the participants' thoughts

Bright (sample a & d) tone color element was characterized being a sharp sound. I was surprised to see participants similarities even when comes to choose one LEGO piece. As figure 7 shows just a few examples of different participants' choices. They all tend to choose light-yellowish brick color for such element.

Warm (sample b & e) element was characterized being a danger sound and this time the participants used the same red color to indicate the anxiety of this color.
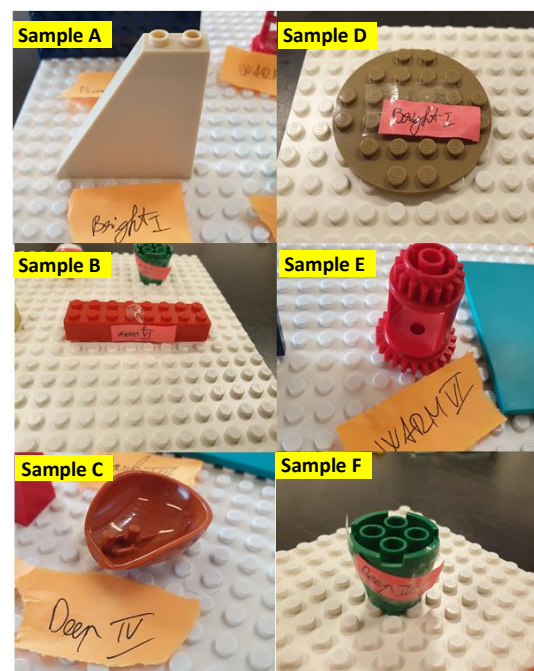

Figure 7 Second brick session, Tone color

But for Deep (sample c & f) sound things were different. Participants agree this being a "curved" sound that should be represented by un upside down shape. Again, similarities were found here as well.

After finalizing the workshop, I have conducted open discussions together with the participants. They were asked if such workshop helped them to fully describe their feelings and if was hard or not to find the Lego pieces. Feedback from participants, showed that tone color is a "dry" element. Even the Lego bricks could not help to perfectly visualize their feelings. Sometimes it was too confusing for the participants and sometimes the only way to visualize such sound were sketching methods. Some participants were drawing the elements reaction on the paper helping to better visualize their image from their mind.

Instrument sound reaction
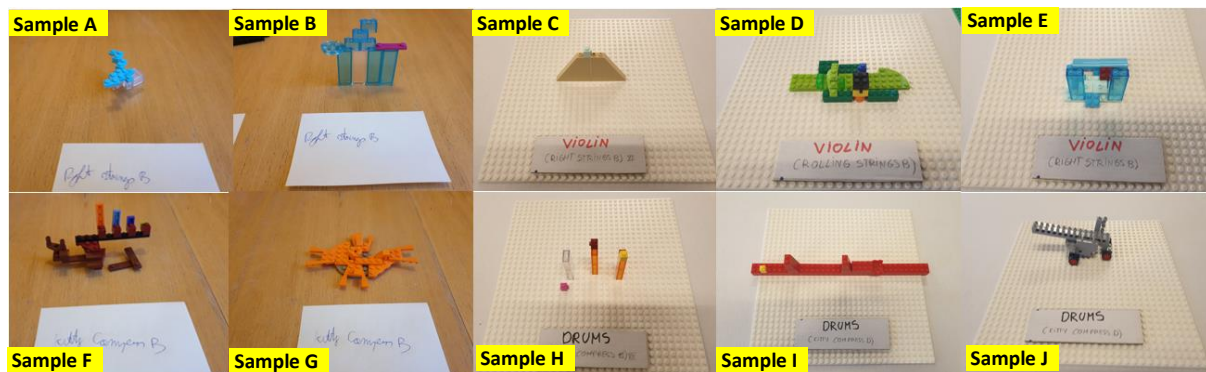
Figure 8 Second brick session, Instruments

While the participants, were allowed to use more LEGO pieces than the previous workshop (tone color), people started to get creative and start express their feelings and imagination by building models. The participants really enjoyed this session whereas the instrumental sound gives them inspiration. Again, huge similarities between participates LEGO models were found as Figure 8 shows

- According to participants, guitar bass sound like something static, deep and dark colors representing a deep and dark sound.
- Regarding drums for the participants, such sound was more like demolition action, reminding them about war. The participants had a more aggressive tendency choosing more sharp Lego pieces and red, grey, orange colours, illustrating the intensity of the sound.
- For violin everything is much more different as can be observable. They consider such sound being chill and relaxant making them to choose smoother shapes and lighter colors illustrating the simplicity of the sounds.

Almost all the users were able to build abstract models and just a few of them started to build regular models such as war machines or illustration of "people that are jumping".

Music Genre reaction

Figure 9 Second brick session, Music genre

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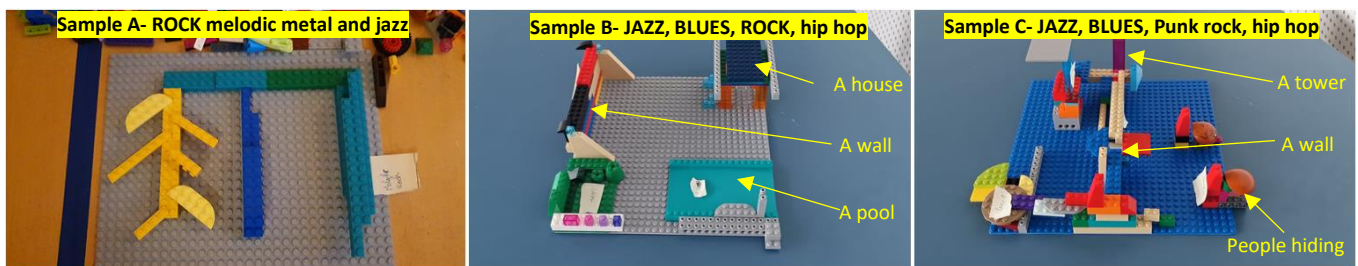Here, the things are different. Despite telling people to think abstract the participants started to build stories related to movies, activities, or games that they have experiences before. For this workshop, the similarities were not that close because each genre influences the user in a unique way.

People were asked to build different genres on the same LEGO board in order to keep the models more organized. A surprising effect occurred by asking people to build their models on the LEGO board. They started to build stories around the models, associating the models between each other.

Figure 9 shows few examples of the students and musician participants. They claim that Jazz and Latino genre gives them impression of a garden. It is a sound that express life. Green colors or yellowish colors illustrating a garden or a beach, expressing good vibes.

"The musical structure of heavy metal (e.g., rhythms, timbres) ties to broader notions of masculinity." (William Roy and Timothy Dowd August 2010). Rock and Hip-hop in general was associated with danger, action, reach and luxury, making them to build walls and surveillance towers houses, swimming pools. Interesting was that the musicians were able, only for a few genres, to build abstract models associating different genres with the chords of a guitar or the piano notes (see Figure 9, sample a.) But the majority presented models based on stories activities (see Figure 9 sample b and c,) illustrating a house with a pool or a wall and people hiding.

What did I find? (Conclusion of second brick session)

After second sessions Tone Color and Music genre music element was decided to be eliminated from future research and only Instruments were the most relevant element to keep.

Even with the advantage of using LEGO pieces, for the participants it was still hard to make associations using Lego bricks. People found such aspect of music (genre), sometime confusing and hard to understand. Even by telling people to use only one piece per Tone color this exercise for most of the participant did not makes sense. It was hard to express people thoughts and feelings even if you allow them to use more Lego bricks (firsts bricks session). Therefore, it was decided to complete eliminated it from future research.

The music genre represents a very interesting element that deserve to be explored. While participants designing activity, it was observed a narrative and an attachment behavior of the participants with the objects. From a narrative point of view, the users share a unique personal history image with the object while listening to musical genre. Users felt a strong emotional connection to the object, due to the service it provides, the information it contains and the meaning it conveys. "I love Latino genre; it reminds me on vacation and the colors of the seaside" quote of SDU student participant.

Despite the interesting stories and interactions that arose during genre workshop, this was not the point of interest of my project. The current research tries to find the perfect music element that could be used in developing future prototypes. Results showed the genre element was too rational. LEGO bricks just helped the participant to build and finish the image from their minds and it did not burst abstract models or push people to think more in a creative way. The participants build figurative models such as a wall, a house a river a windmill (figure 10 probe a) and rock n roll lady singer (figure 10 probe b).

Sample A
A Windmill model while listening to JAZZ

Sample B
A rock n roll singer lady model while listening to Melodic Rock metal

Probe C
A "floating object" while listening to violin

Figure 10 Second brick session, Music genre and Instruments

According to my observation the LEGO boards played a significant role in building actions and stories. The drums example (Figure 8, sample h) shows a model in which "people were jumping on different blocks", illustrating a danger action. For future research it was decided to eliminate the board as well in order to push people building models making it harder.
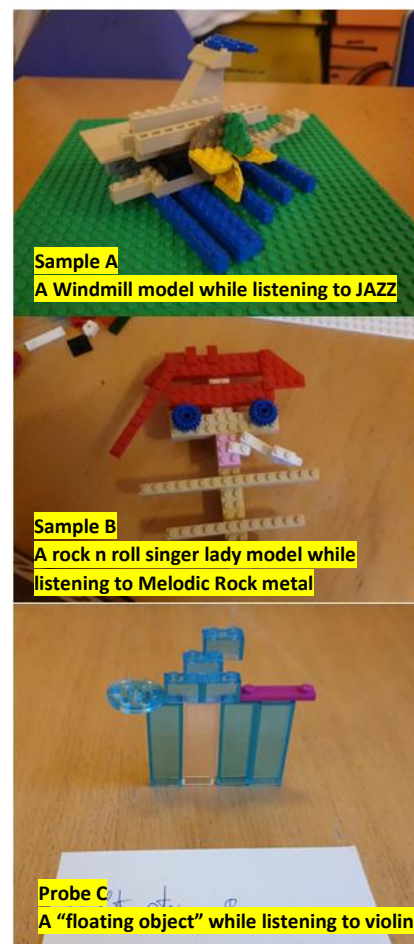
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The Instruments sound element seems to be the perfect aspect to continue with. According to some participants, the instrument sound loops is "a non-finished art piece that intrigue people to imagine and start building abstract models that will reflect upon their imagination". It was interesting to see the LEGO models results that mostly become abstract and not that rational. "Instruments sound makes me to build and never stop, I feel I will never finish my model and this intrigue me to use more LEGO pieces" participant quote.

According to feedback the instruments challenged people to create "non-understandable" and abstract models and in general non association with life activities or places were implied. The figure 10, probe C shows an abstract LEGO model that according to the participant "this is a floating object".

Therefore, I chose instruments as an important component that will allow people to create, combine and explore more.

One interesting observation came from one SDU' participant asking if I could create a game out of it. He suggests using cards containing some guidelines of the game such as quiz questions, and different stories listed on the cards. His suggestion was taking into consideration for further research.

Participants also told that would be much easier if the LEGO pieces would be more organized on the table and be classified by size in order to allow a better visibility of the entire Lego set. This feedback was taking into consideration and it was used for future research.

Therefore, for the third and last session I have decided to make an experimental game that could be played by two participants at the time in order to explore more the social aspect and boost the dialog between participants. I have also used two types of LEGO bricks such as multicolored and one-colored bricks in order to challenge and observe the participants' reactions and imagination and how they shape their behavior when comes change.

Third/final brick session

This session had the purpose of testing a game context using instrument sounds together with multicolored and one-color Lego bricks. People were told to think abstract and to do not associate sounds with activities, movies, games or stories.

The workshops allow users to look at each other finished LEGO model and make a guess of what instruments they were listening to. (game context)

Setup

The Lego bricks were nicely organized in boxes for a better visualization. I brought two times of Lego bricks such as multicolored and one-color in order to observe people reactions.

I have eliminated the LEGO boards in order to constraints user to only build models and not stories, therefore, constrain the participants to build models and not settings of models.

Purpose

Besides instrument sounds, the music genre aspect was also included for this session in order to test people reaction in relation to new one-colored Lego bricks. Tone color was excluded

Using multicolored Lego bricks

Using one-colored Lego bricks

Figure 11 IBA students – game context

As a first step, individually, the participants were listening to two different genres. While listening they had to build a LEGO model. Then, the participants had to guess by looking to the opponent Lego model, what kind of musical genre or instrument loops he/she was listening to while building the shape.
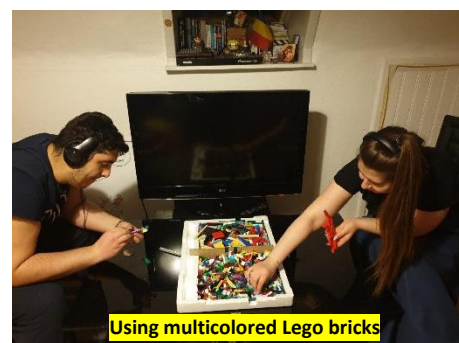
Results

After finalizing the workshops, I have conducted open discussion with the participants and asking how they felt using one color and multicolored Lego bricks. Feedback shows that is harder to use one color bricks and more time was needed to finalize the models

 "I like to use the colored bricks; it makes much more sense and I can better visualize the bricks" IBA student quote

 "It is much more interesting to use colored elements. It gives a unique touch of the finalized model" SDU student quote

"The colored ones are more dynamic for me! I could get more creative with those" IBA student quote

Even with one-colored brick and no Lego board as disposal, it was observed that stories and settings of models were still used while listening to the music genres. For the entire sessions, the genre shows that it will always influence the participants to make association with places, their experience or with activities they have had influencing the participants to build a, a faces, a bench a concert scene, even a park (see figure 12 green squares). But on the other hand, the instrument sound aspect shows a great potential to challenge people to create, combine, build and explore more, making the exercise process more interesting for them and influencing the participants to think more abstract (see figure 12 red squares)

It was interesting to see the people reaction. The game turned out to be funny and the participants enjoyed it. It was interesting to see that people can guess each other models. "I could know him better and who is him and what kind of mindset he has" quote of IBA participant

Figure 12 Participants' LEGO models

Conclusion

"Music and its meanings inform people, quite profoundly, about who they are" (William Roy and Timothy Dowd 2010). It was interesting for me to explore peoples mind and visualize their thoughts and how they perceive different sounds by physicalizing it using Lego models. "People like to see things that somehow reflect themselves" (Dunne & Raby project "Multimedia Services & Enabling technology). In some cases, the objects in their hands (finished LEGO models) will foster a more emotional attachment to the object and increasing the narratively of the object.

William Roy and Timothy Dowd in their paper "What Is Sociological About Music?" (2010) said that "music both signal and helps constitute the identity of individuals and collectivities" I also noticed this aspect in my previous workshops, and I learned that life experience of each person, matters.

People gives different meaning for a musical genre for example. It was also observable in my Lego models in which people, while listening to different songs, different meaning occurred. So, there is never one or general meaning and instead what kind of social activities he/she experienced before, will always influence them and therefore influence the finished Lego models. "People change based on their interactions with objects, events, ideas and they assigned meaning to things in order to decide how to acts" (William Roy and Timothy Dowd 2010)
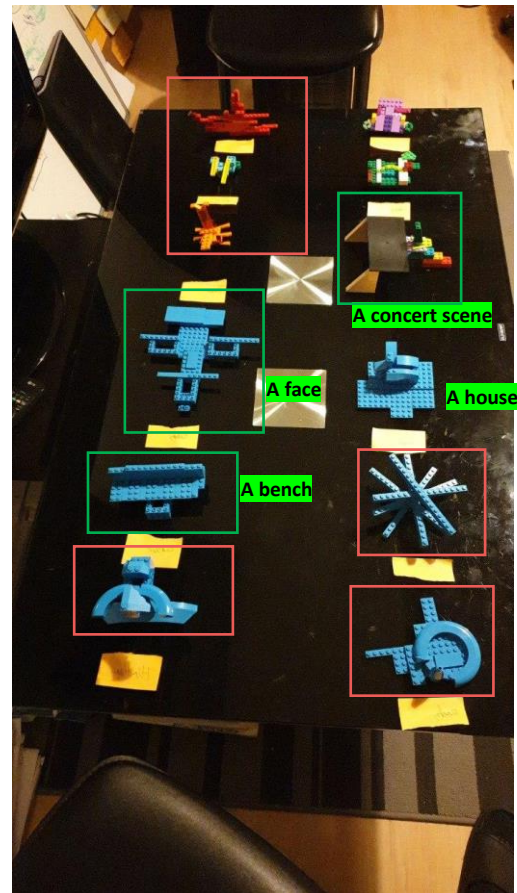
What is next?

Considering the previous sessions, it turned out that colors and instrumental sounds represented two important elements that helped the participants to get creative, be able to combine and intrigued them to build more. The game which arose from the third session, inspired me as well, deciding to go for a social interaction prototype that would support cooperation between people.

Prototyping and co-designing- With what I could replace the Lego bricks to allow sound testing? Build a TUI?

Stakeholders first meetings

Online meetings		
Occupation	Analytics and Game designer	Music teacher 2-5-6th grade
Institution	LEGO Group, Billund	Public School Petersmindeskolen, Vejle
Participant name	Frederic	Judith
Research type	Open discussions (Skype meeting)	Online Semi-structured interviews (Skype meeting)

Table 2 First online meetings- Share workshops results

I have started share the workshops results with different stakeholders such as LEGO group (UX research department) and a Music teacher.

Since I was interested in the people's creativity, how they get creative and learn through play concept, Lego group was chosen as a first stakeholder because, during my internship period in this company. I met experts in the Learn through Play domain.

Music teacher the second stakeholder was chosen to explain be the values of instruments and her methods of teaching.

The first online interview was with Frederic (Analytics and Game designer position at LEGO) in which I have showed him my LEGO bricks sessions findings, explaining how colors and instruments managed to boost the creativity of my participants. Frederic made me aware about LEGO values as well and it turned out to be very helpful.

According to Frederic the education element is an important value in LEGO group, "LEGO believes in Learn through Play concept. The children use LEGO bricks to achieve unexpected results […] in your sessions, you have used music to create Lego models and not using Lego bricks to create music. When children learn through play, they are given the best opportunity to fulfil their potential to become creative, engaged, lifelong learners" quote by Frederic

Learn through play could be characterized as an "active collaborative, experimental and problem-solving learning method. It becomes important to provide students with an opportunity to engage in the types of action that will allow them to construct for themselves the knowledge at hand" (Michael Mascolo, January 2009 "Beyond student-centered and teacher-centered pedagogy: Teaching and learning as guided participation"). Therefore, children need to construct knowledge through action bringing an educational tool that will support learn thorough play and in turn it will support cooperation between children and push them to cooperative strategies and develop cognitive skills.

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Cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" (Lucille M. Foran, September 2009 "Listening to Music: Helping Children Regulate Their Emotions and Improve Learning in the Classroom")

Regarding the "bricks sessions" it seems that music is a very important element in our lives. To go deeper, it was demonstrated that "Music activates both hemispheres of our brain and helps with transferring information from one side to another […] and research has shown that children with high levels of music training have increased ability to manipulate information in working and long-term memory" (Lucille M. Foran 2009), improving their skills in computation and reading.

Therefore, I become interested in music and its properties and how music could bring people together? "Music is a mode of interaction that expresses and constitutes social relations […] is not a thing at all but an activity, something that people do" (William Roy and Timothy Dowd 2010)

Therefore, I raised the question of "How children are taught in music classes. Is there any active learning method that music teachers are using for teaching? And how music is helping kids to develop their cognitive skills? Why music is important for children?

Music teacher semi structure interview and findings

As a second important stakeholder I decided to contact a music teacher. Online semi-structured interviews were held and demonstration of "bricks sessions" were shown as well. Initially was considered giving a questionnaire but it was not even clear initially what would be the most important questions to ask. So semi-structured interviews were chosen in order to "allow the interviewees a degree of freedom to explain their thoughts and to highlight areas of particular interest and expertise that they felt they had"(Joanne Horton, Richard Macve and Geert Struyven, "Qualitative Research: Experiences in Using Semi-Structured Interviews")

Therefore, I brought two general but meaningful questions that helped stimulate the conversation such as

- What is the biggest struggle you faced by teaching the kids?
"The biggest trouble is the self-discipline; they do not take any responsibility for music/composition lessons" music teacher quote

- What teaching methods you use and what do you teach?
"I am teaching for 2, 4 and 6th graders. For the small ones I am introducing the basic of the music trying to play with some small instruments such as xylophone, tambourine, shakers. I also use spelling exercise with them and try to, sing together. For the 6 graders I start to introduce more instruments that they can use to build a melody together. They are learning too much about the notes, but the classes teach them mostly about the rhythm. So, to teach musical notes is a bit harder for them. So, is a bit more complicated to teach them how to play on a real instrument" music teacher quote

Judith is a 2, 5, and 6 grader teacher in Petersmindeskolen, Vejle. As a music teacher her role is to teach children how to compose music and what are the important principles kids needs to take into consideration while composing such as (rhythm notes, beats, etc). She claims that she is using two kind of teaching methods such as practical traditional and practical modern methods. The teacher said that she is also uses several "static" or reading and writing methods for teaching music's theory (notes) but since she is teaching for 6 graders this does not represent the most important part. Instead, she is focusing on helping children to train their musical ear, hence a greater implication of practical composing methods is required.

Practical "traditional" methods - the kids play to the actual instruments such as xylophone, tambourine, shakers, drums, guitars, violins and piano and try to sync the instruments between them. "This is the biggest challenge for them. Not everybody can follow the right rhythm, they fall out of the song. Is hard for them to keep focusing and keep playing on the same rhythm and hit the write notes while using physical instruments.

Practical "modern" methods- the teacher is using digital content such as
- Clio website (https://www.clio.me/dk/) represent an interactive portal filled with educational material from which the tutor find inspiration and learning materials such as text, videos and activities.

- Kahoot game (https://kahoot.com/) is a free learning platform based on a game and an educational technology. The teacher is using it to monitor the kids by hosting a live Kahoot play in class game via on a big screen challenging the students to answer questions and create competition between the students who got the highest score "This is not an evaluation this is more like a feedback for me to see if the students understood the lessons or not. I change the Kahoot game every time after finishing a lesson. A lesson can contain a history of blues or the formula of blues or what instruments include blues and so on" music teacher quote

- GarageBand mobile or tablet app (https://www.apple.com/mac/garageband/) is used by the teacher to teach children how to compose, record ad mix different types of instruments loops "While using garage band they do not think about formula of music genre or history of it. Is more like to sense the melody and create rhythms with percussions or combine some instruments on different rhythms" music teacher quote

What attract my attention was the practical "modern" method in which she is using GarageBand app as a cognitive digital tool for learning in which children needs to work on phones and tablets in order to compose their melody. When I asked why she is using such tool and what are the benefits of using it she said that "They love it! The children are crazy for that. At least in my class. This helps them to find a rhythm to compose […] with exiting instrumental loops that will teaches them the sense of music and training their musical ears". In her opinion it represents an active collaborative learning method that involves more children to complete a task and ease children understanding of composition's principles. She also said that "children tend to overcomplicate the whole thing" and "they need someone to tell them to keep it simple" and teach them that "music not about to be complicate but is about the simplicity of the notes and tones".

According to Judith it seems this app has more benefits than I thought, such as
- It helps them to get and unleash their creativity
- It helps them to think by their own
- Help them to work in groups
- increase and accommodate their musical language
- It also trains them to follow the rhythm

Therefore, I asked her to explain how such an activity works (music exercise for Garage Band applications in the classroom), and she responds

"In groups of 4, kids had to create their own rhythm (made by a maximum of 5 instruments to keep it simple and do not get lost in the task.) by the help of Garageband. Here they could make a completely new rhythm OR they could choose to use existing loops (Most of them chose loops). After creating and saving the rhythm, they had to start to write lyrics. Here, they had 3 choices, they could choose to write: RAP; POP or Spoken word (I have students, who are not comfortable with singing, therefore they could write an advertisement). When they were done with their lyrics, they had to start to record it together with the rhythm. When they were done with the whole song (rhythm + lyrics), they started to brainstorm about the video. The last step is to create a video for their song and put the two together and present it in front of the class" music teacher quote

The above example is used by the music teacher in the class. She claims that after doing a few exercising with them she will increase the difficulty by telling the kids to build songs that should fits a genre and create lyrics that will fit the specific rhythm. "Even the if it seems to be simple is not. This is a big project for them, and it take a few days until complete it […] moreover sometimes kids get be distracted" quote by music teacher.

Conclusion

According to discussions with the music teacher, the GarageBand activity require a lot of attention from the teacher to her students. Therefore, "digital disruption is creating new relationships" (William F. Crittenden 2019 "Embracing Digitalization: Student Learning and New Technologies") in which the teacher had to adopt new approaches to teach students or to maintain control and to ensure that students learn the new information provided by the new phone/tablet application.

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Even if GarageBand it seems to be a good tool, sometimes it represents a distraction for children even if they love it. It seems that the teacher operates as a facilitator or coach who designs learning activities for the kids and in order to maintain the control, scaffolding occurs to make the task more manageable in which "the teacher is viewed as a facilitator or coach who supports the deployment of a learner's attention, helps to manage frustration and so forth." (Michael Mascolo 2009).

Michael Mascolo in his paper "Beyond student-centered and teacher-centered pedagogy: Teaching and learning as guided participation" says that are seven types of support/scaffolding. Considering the interview with the music teacher her strategy would be attributed to the fifth one called Direction scaffolding in which the teacher "provide explicit and specific direction about how to perform an action or procedure […] in which novice follow the explanations". Here, the teacher is giving many explanations to make sure they are using the app properly and this can represent a challenge.

"The important challenge is creating interactive, digitalized platforms, and digital activities that meaningfully engage students, where learning can be adequately assessed according to a specific framework where, students need to develop personal self-control in their use of digital tools" (William F. Crittenden 2019). Regarding the semi-structure interview, when the teacher was asking "What is the biggest struggle you faced by teaching kids?", She answer that, quote "The biggest trouble is the self-discipline, they do not take any responsibility for music/composition lessons". We notice that new methods come with new risks and therefore, the teacher needs to adopt new strategies of supporting, directing, and encouraging kids to perform the required tasks.

The GarageBand app is used individually by each student or group of students on phones and tablets, making harder for teacher to be aware on what is happening. This is why she is asking for a video that should be presented on front of the class by each student, in order to make sure that the kids followed the composition principles.

According to discussions the teacher main object was to boost the cooperation and the creativity of her students by offering them an easier way (Garage Band app) of composing music, allowing students to combine instruments in a smoother and easier manner. "To teach musical notes is a bit harder for them, so, is a bit more complicated to teach them how to play on a real instrument" music teacher quote

The Garage Band app represent the perfect definition of Graphical User Interface in which the user interacts with the "desktop" using gestures on the screen. "Interactions between people and cyberspace are now largely confined to traditional GUI (Graphical User Interface)-based boxes sitting on screens, desktops or laptops" (Hiroshi Ishii and Brygg Ullmer 1997 Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms)

The teacher saw creative children that had a wish to compose but they did not have the right skills to do so. Therefore, the teacher decided to bring a tool/an app (GUI tool) that will allow those children to start to create. But new technology brings new problems. The teacher claims that the children do not cooperate as they should because of "phones and tablets which are sometimes a great distraction for them" and cannot complete the task.

Regarding discussions with the music teacher we realized it was a need for a haptic interaction in which physical contact between the computer (phones/tablets) and the user should occur using an input /output device and make the activity from the class more physical participatory and challenge the children to explore more while composing and therefore, bridge the gap between cyberspace and physical environment

Therefore, the aim of the current research is to create an immersive experience looking for tangible inputs that will work as a bridge between physical and digital and therefore supporting interaction and cooperation between children.

From GUI to Tangible UI

In my last project (ARPI) I observed that gap between cyberspace and the physical environment is not easy to bridge. There are many inputs which can make the link, but which one is the most efficient and easy to use?

We live days in which "we are constantly wired so that we can be here (physical space) and there (cyberspace) simultaneously "(Hiroshi Ishii and Brygg Ullmer March 1997. "Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms"). Due to the evolution of different graphical user interfaces, there is now a greater interaction between people and cyberspace.

> "Ready at hand. This concept refers the way to that when working with a tool or representation we treat it almost as if it were invisible"

(Paul Marshall. "Conceptualizing tangibles to support learning")

"It seems the Augmented Reality technology represents new research, trying to integrate the real world and computational media" (Hiroshi Ishii and Brygg Ullmer, 1997). I decided to test this hypothesis and find if AR could be used as an active learning tool for children. In my research paper was not looking to challenge novel and disruptive technologies, instead I was looking for existing tangible user interfaces technologies that could be easily implemented to children' socio cultural activities from classrooms and homes in which augmented reality interaction will be tested with students from universities (helping in developing the prototype) and children (end user, get qualitative feedback that will help for future improvements).

Therefore, I become interested to challenge the idea to develop a Tangible User interface that support augmented reality and make the interaction of the user with the cyberspace more natural and intuitive using "ready at hand" tangible tools that leads to a minimal cognitive effort of the user. The hypothesis was that in this way users will be able to cooperate more between them and push the users to become more creative together.

As mentioned in previous sections (LEGO bricks workshops), since my research interest is in creativity, cooperation and exploration, music has been chosen as an important and powerful element of current research. Because, trying to find a natural and intuitive TUI, I first found music an incredible source that stimulates people's creativity and imagination. "Listening, exploring and analysing represent fundamental activities at the basis of the development of meta-cognitive skills such as attention, concentration, and control" (Luca A. Ludovico and Dario Malchiodi December 2017. "Fostering Computational Thinking in Primary School through a LEGO - based Music Notation")

Sketching modeling and Paper prototype
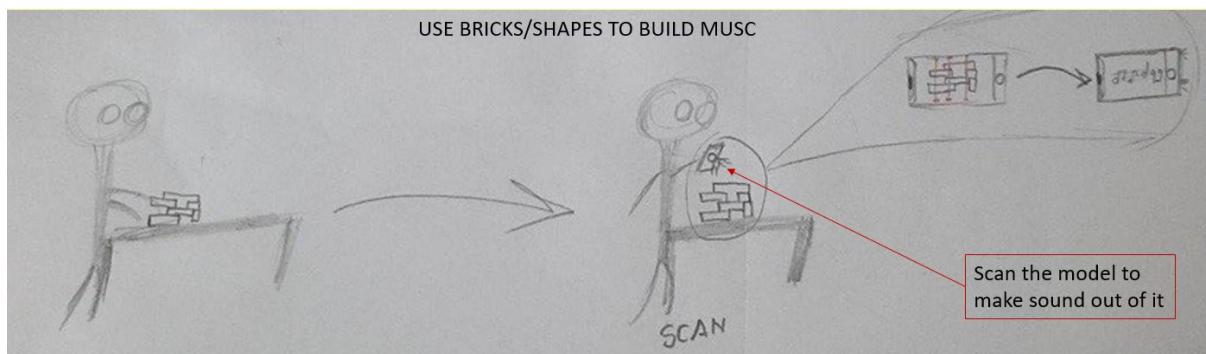
Sketching modelling was the first method that was applied in order to capture the idea emerging from workshops and semi-structured interviews. According to Milton and Rodgers "Sketching models are helping the designers to test the public reaction to the new design and evaluate it. (Milton and Rogers, Making chapter)

The first sketching simulates a Tangible user interface interaction in which Lego bricks represent the tangible inputs and the phone represent the digital output. The sketch illustrating a tabletop environment in which the user uses his phone to scan the finished Lego model to produce music. My previous findings in "bricks sessions" shows that people become more interested and more involved into interaction when there is a tabletop

environment. Therefore, I have decided to look more into such environments. If we speculate more about everything reality will become more malleable. "The ideas freed by speculative design increase the odds of achieving desirable futures." (Anthony Dunne and Fiona Raby 2013, "Speculative Everything"). The illustrated interaction in the sketching was something fictive and speculative that provoked me to create not things but ideas.

Several researchers have already used tangible user interfaces for musical application. Audiopad, Bach blocks, Audio d-touch, reactTable are a few examples of TUIs music controllers using tabletop environments that allows user to build their own sequence of sound using tangible and graspable objects and interactive areas (some physical and some digital boards) for allowing the interaction between physical and digital. This examples of TUIs were developed to create patterns and beats, rather than adjusting preset ones.
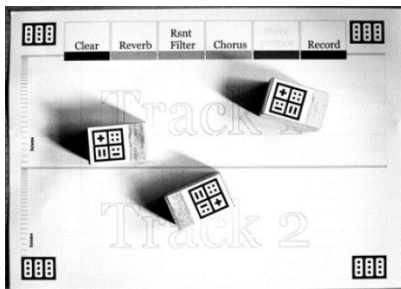
Example of TUIs

Figure 13 Audio D-Touch system

Let us take the example of Audio D-touch music controller. They have developed a musical controller in which children can compose melodies or teach the kids the music notation. Here, "the user can build complex drum rhythms and naturally adjust them by moving the blocks. Each block is labelled with a fiducial symbol hidden in the shape of a musical note" (E.Costanza, S.B Shelley, J. Robison 2003 "Introducing audio d-touch: a tangible user interface for music composition and performance").

As figure 13 shows, they use an interactive area in which pitch depends on the vertical position of the object and the horizontal position of the note determines the sequence in which the sounds are played.

The TUIs examples form above (including Audio D-touch) rely on the position of the objects on an interactive area which is meant to produce effects such as volume floating, frequency, change pitches, accelerate the rhythm, time, etc. Audio d-touch team says that there are different objects available (that user can grasp and manipulate) and each object correspond to different sound effects. Therefore, this "yields the interface where the user can build complex drum rhythms and naturally adjust them by moving the physical blocks" (E.Costanza 2003). Such interaction and the complexity of the objects "shows, that it is sometimes hard to tell what point of the loop was being played at any particular time". (E.Costanza 2003).

Nevertheless, it seems Audio D-touch and other TUIs controllers makes efforts to allow users to produce sounds without requiring background computer knowledge by creating simple interfaces that can be understandable by anyone and encourage interaction using as inputs physical objects.

Considering the complexity of other TUIs I have decided to avoid it and challenge the idea of bringing a simple TUI that will support the children cooperation and successfully connect physical with digital. Moreover, going back to the semi-structured interview, when teacher respond to the question What is the biggest struggle you faced by teaching the kids? She said that "the self-discipline represent the biggest difficulty, they do not take any responsibility for music lessons" and the second bigger problem is that "children tend to overcomplicate the whole thing" and "they need someone to tell them to keep it simple" and teach them that "music not about to be complicate but is about the simplicity of the notes and tones".

The discussions with the teacher were taken into account while designing the TUI prototype. Therefore, more sketches were made including a jigsaw game as a first try (see figure 14- Jigsaw sketching). Soon, this idea turns out to be excluded because my research was focusing on bringing a freely manipulation of TUI which does not include any rules that tend to complicate the interaction.

The concepts soon transformed in colored squares (see figure 14-Instruments sketching). The idea was that each square will be attributed an instrument. As a choice, primary colors were included in order to improve the visibility and make it easier for children to differentiate the instruments. Also, the findings from "bricks sessions" shows that colors will always represent an important element that helps people to better visualize and helps them to make combinations intriguing them to build more. (coming from multicolored vs one colored brick workshop).

Data collection (discussions with stakeholder)

Soon I chose paper prototype that allowed me to "visualize, organize and articulate basic design concepts" (Milton and Rogers, Making chapter), so it helped me to faster explore the combinations of the paper squares. The idea was presented to the music teacher in order to confirm the identity of the cards.

She agrees that the 2D squares "is something children will find interesting" and "it should not be changed in 3D models such as cubes because children are not responsible enough and they will start perceive the TUI as a toy" quote by Judith – music teacher.

Once I had the confirmation, I started to develop physical 2D squared cards (see figure 15). For each card, an instrument will be attributed in order to allow instruments to be combined one each other, simulating in this way the GarageBand app exercise but using physical instrumental cards instead.

While designing the physical cards, the teacher suggestions were taken into consideration. She said, "music is about simplicity, and not complexity". It was important the prototype to be simple to use allowing students to acquire composition skills and learn the difference between music elements. For more complex exercises, she would use the other traditional methods and therefore, this would not be my research field interest, instead, my research purpose is to find an easy and efficient way in which children will be able to compose music, using different percussion and strings instruments in which we will challenge the idea of using augmented reality in order to enhance learning and stimulate children's creativity, cooperation and communication.

Jigsaw sketching

Instruments sketching

Figure 14 Sketching the prototype

Sequence of instruments- paper prototyping

Classification of instruments- paper prototyping

Figure 15 Paper prototyping

As the main "engine" I chose to work with Unity 3D software to implement augmented reality technology, which will allow the operation of the future functional prototype and, therefore, allowing an immersive experience, which leads to increased user motivation "Impacts of AR include socialization, challenge, accomplishment, fantasy, stress-relief, alleviation of boredom, escapism, and exploration" (Gary Bitter, October 2014. "The Pedagogical Potential of Augmented Reality Apps").

My purpose was not to find and implement novel and disruptive technologies but instead trying to integrate existing technology in a more efficient way that could be used as an active learning tool, mostly for children. Considering the augmented reality (AR) technology complexity, I was not trying to bring too complicated tangible objects, instead my research paper explored the AR possibilities using simple tangible tools and therefore, narrowing to 2D physical objects such as Cards.

First functional prototype

The functional prototype is helping to experience and "demonstrate what is like to actually use a product in a given situation and provide findings that can help develop a product through an interactive prototyping process" (Milton and Rodgers, Making). In the next sections this research will provide an iterative prototyping process that is helping in gaining valuable insights about the user's experience.
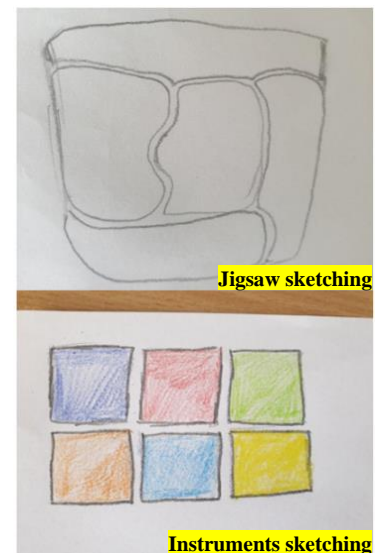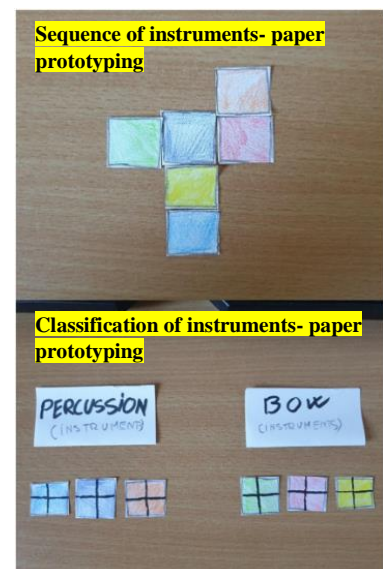
As a main software I have used Unity 3D to animate the AR 3D animations. In order for the software to work it needs input and in my prototype's case, the input is called target/tracking image.

The tracking image represent a 2D visualization of instruments that works as an input for the Unity software. I have designed the 2D pictograms (tracking images) in Adobe Illustrator program (see figure 17). After designing process, the images have been uploaded to the Unity software.

As in figure 16 can be seen that the tracking images were kept in a digital form being uploaded on the phone as well. As figure 16 shows, the phone was used as a helping tool in which the computer webcam was used to scan the digital 2D pictograms (target images) from the phone. As a result, the 3D animated digital cubes pop up, illustrating instruments and their creators. The 3D digital cubes were created in Unity as well.

The application needs a cellular phone or a tablet with Android operating system or you can simply use your computer. (The phone and tablet are recommended for a better camera focus)

While designing the 3D Animation (cubes) I got inspired by a very interesting active learning method used in schools called Artifacts kits that "consists of any human-created object that provides clues about the culture of the people who created and used it […] and encourage the active learning by creating curiosity […] allowing students to ask teacher to bring lessons and topics aligning with student interest" (James E. Hauf Jun, 2010, "Teaching World Cultures Through Artifacts").

Therefore, I have decided to use the 3D models to provide clues (AR pictures) about the culture of people who invented the respective instruments. In my case, the virtual 3D representations could be seen as virtual artefacts that provides images and animations "in order to create an immersive and a joyful way to learn new things from the past" (Adri Gabriel Sooai Virtual Artifact: Enhancing Museum Exhibit using 3D Virtual Reality 2017)

The virtual artifacts are used in museums as a "reconstruction of the era of civilization; fossils; statues; etc" to create more immersive exhibition experience in which "young generation can use this application to gain more information from an object which is virtual artifact, exploring it without damaging the real object. Adri Gabriel Sooai 2017)

Figure 16 AR 3D models

As my first experiment, the first augmented reality object was a 3D cube that pops up while scanning the tracking image from the phone. The digital 3D cubes had the purpose of illustrating both images with instruments and the inventors of those instruments in order for the user to gain more information about the instruments' past by visualizing it and listening to it.

The reason of using such digital 3D models was to improve the interest and learning of kids about specific instruments including an immersive experience. Moreover, each card will present sound for the specific instrument which "adds an auditory dimension and can provide additional clues about the culture/instruments (James E. Hauf Jun, 2010)
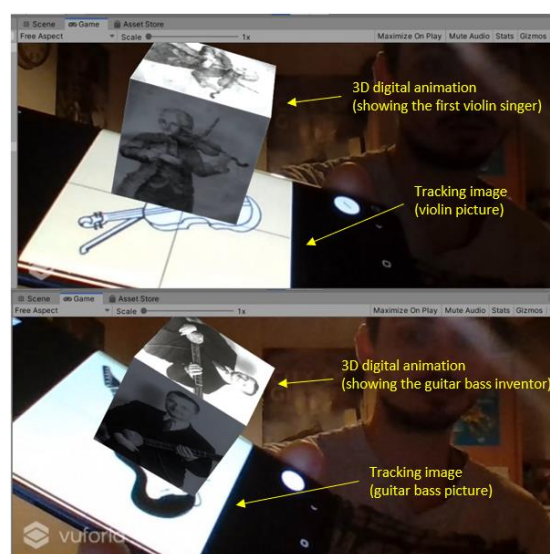

Figure 17 Tracking images made in Adobe Illustrator

Regarding the first 3D animation cube test (video can be found here, make sure you have sound https://www.youtube.com/watch?v=8om9BQhKoiM) was meant to only explore the AR technology possibilities, using the phone as an input (target image); the computer's webcam as a scanning device and computer's desk as an output in order to see the 3D cubes. Therefore, this was just a mockup helping to "demonstrate the basic mechanism of the product" (Making- Milton and Rogers), testing the AR technology mechanism and its usability. Fortunately, everything worked well, motivating me to continue by creating physical 2D cards as an input and use a tablet and its screen both as a scanning device and as an output.

Prototype evolution

After finalizing the basic of the AR technology, I have decided to replace the digital tracking images with physical ones.

Therefore, I decided to start design (by hand) 6 colored instrumental paper cards (see figure 18). The package consists of two categories such as percussions and string instruments (3 instruments per each categorize see figure 18, middle picture). I chose the most popular percussion and strings instruments and one rarely percussion instrument in order to explore and observe people reactions and if they find it interesting. Therefore, the 2D cards consist of percussions instruments such as drums, hi-hat, and hand-pan and string instruments such as bass guitar, classic guitar, and violin
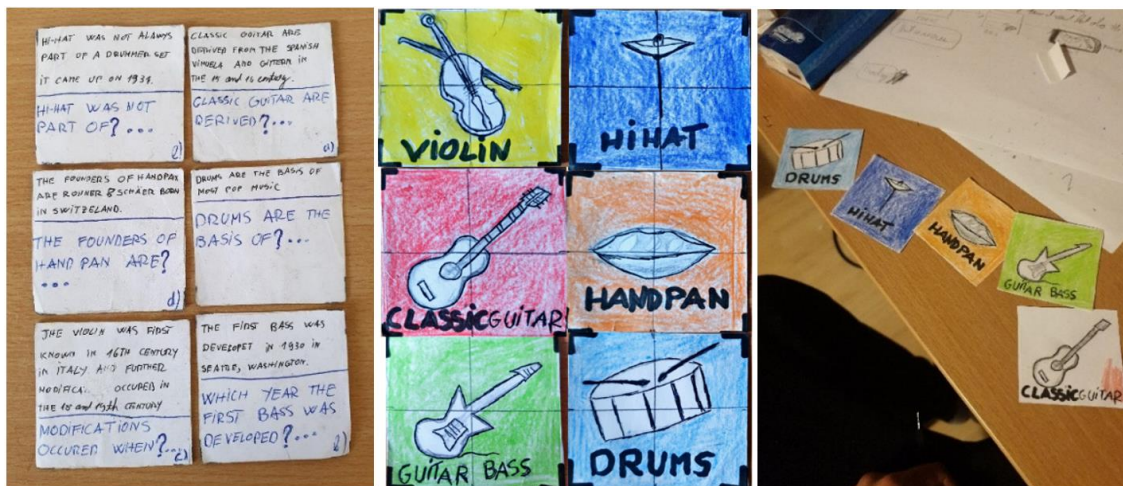
Figure 18 Paper prototyping

In addition, to try enhancing learning, questions on each back side of the card were included (see figure 18 left picture). The quiz questions were related to each instrument in which the answer could only be found in the AR 3D text from the front side (3D text explain on the next section).

The cards were labelled with instruments symbols which were placed on the top of the cards in order to ease the interaction and better observe the instruments. Another advantage of the instruments symbols consists of the technical part. The symbols are working as a tracking image in order for the tablet to be able to track, scan and show 3D images on the screen.

Once I changed to physical cards I was able to explore even more the power of augmented reality technology that will allow in adding and testing different interactive elements such as GUI volume sliders, AR pictures, video and text with the purpose of exploring implication of AR as a learning through play tool.

AR elements explained

For the 6 cards paper prototype I chose to include different AR components and Graphical digital components such as (video that presents a progressive representation in which AR and GUI elements are added one by one can be found here https://www.youtube.com/watch?v=hS_gOZQL4_w&t=3s)

23
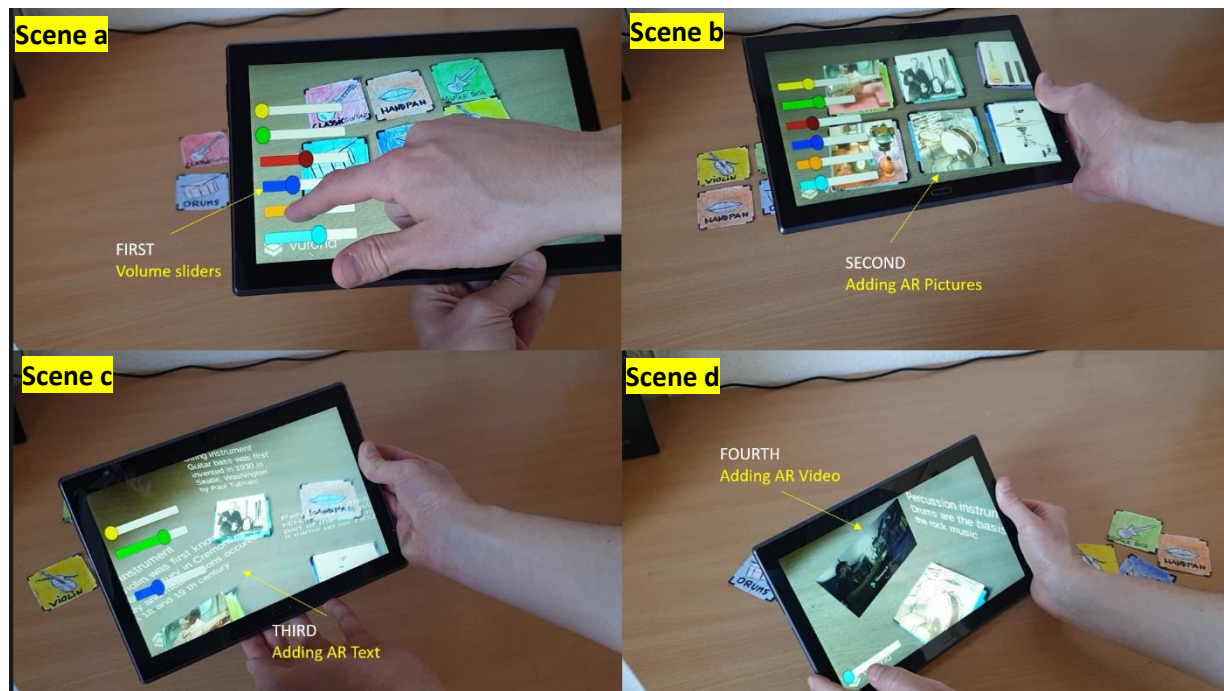
Figure 19 GUI and AR elements- functional prototype

- **GUI Volume Sliders**

The sliders are used for volume to allow the user to decide how loud the instruments should sound. To activate the slides, you must scan the cards to allow slide volumes to appear on the screen. As soon as you slide (by hand) in the right side, the music will start sing. You can also decide the volume of the sound using the same slider, but as soon as you take the tablet apart and no longer scan the cards, the sliders will no longer be visible but the sound will continue to sing, even if the cards are no longer in front of the tablet's camera.

- **AR Pictures**

The AR pictures had the purpose of illustrating pictures with instruments in their old times (a historical perspective of the instruments). Some pictures show the creator of the instrument as well. To activate the AR images, you must scan the cards using the tablet, to allow pictures to appear on the screen. The AR pictures will be found on a horizontal position on the physical card that you chose to scan. You can see more AR pictures at the time by scanning more cards at the same time. (see figure 19 scene b)

- **AR text**

The AR text has the purpose of explaining the classification of each instrument and a few historical facts. The text is matched to the pictures for challenging the learning activity. To activate the AR text, the same as AR pictures, you must scan the cards using the tablet, to allow text to appear on the screen. The AR text will be found on a vertical position close to the physical card that you chose to scan. You can see more texts at the time by scanning more cards at the same time. (see figure 19 scene c)

- **AR videos**

The AR video had the purpose of showing to the user how people can sing to each instrument by showing professional musicians/instrumentalists performing to the instruments. To activate the AR video, the same as AR pictures and text, you must scan the cards using the tablet, to allow video to appear on the screen. The AR video will be found on a vertical position close to the physical card that you chose to scan. You can see more videos at the time by scanning more cards at the same time. (see figure 19 scene d)

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All these elements were added with the purpose of stressing the AR implication and trying to extract the value out of it. I tried to exploit people reactions to different AR and GUI elements and see if I could combine all these aspects together to work simultaneously and smoothly and "successfully to communicate with and motivate users". (Gary Bitter, October 2014)

Therefore, the 2D cards were perceived as an experimental component to "further investigate people reactions" to the physical paper prototype and interaction between digital with physical content by creating online and physical testing (Milton and Rodgers, Making).

After developing the interaction between digital and physical and before starting to further develop the prototype, I have decided first to have online discussions (See table 2) with LEGO UX department in order to investigate their reactions and get suggestions of improvements.

First Online feedback LEGO UX

Online testing		
Occupation	UX manager	Project manager
Institution	LEGO Group, Billund	Lego Group, Billund
Participant name	Thomas	Stefan
Research type	Open discussions and prototype video demonstration (Skype meeting)	Open discussions and prototype video demonstration (Skype meeting)

Table 3 First online tests & feedback

Considering the first stakeholders meeting (page 15) with Frederic (Analytic and Game designer, Lego Group), he mentioned that learn through play is an important element which is characterized as an "active collaborative, experimental and problem-solving learning method" (Michael Mascolo January 2009). We concluded that Learn through play becomes important to provide students with an opportunity to engage in the types of action that will allow them to construct for themselves the knowledge.

Therefore, The UX manager and the Project manager were asked to evaluate my prototype by watching online demonstrations. Since I am trying to develop a prototype to enhance learning and boost creativity, I have asked my colleagues to evaluate my prototype from an educational perspective.

As method I chose open discussions and I decided to share the prototype video demonstrations to them on Skype. Such method of evaluation my prototype (online) represented an advantage due to the quick response but a disadvantage because they could not feel the cards and the interaction in reality world.

After visualizing the 6 cards prototype videos, my colleagues from LEGO UX department brought their feedback. Stefan (Project Manager position) and my LEGO supervisor brought into question the validation of learning "How should my prototype validate learning"? and social interaction "How is this game cooperative?"

According to them the prototype "reminds and look like a Music Maker" associating it with a DJ card game in which you play with different melodies called Dropmix. "This game example is not coming from an education angle at all is just for fun". According to Stefan the interaction between user and cards is too freely "You need more restrictions in order to create challenge to turn it in an educational tool"; "Challenge the users to do not just be able to use the all the cards so you need some limitations". Stefan and my supervisor were talking about "the intrinsic motivation that keeps the player motivated by solving different tasks in which players are

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motivated to provide a solution in order to continue with the game"(Maja Pivec, Olga Dziabenko, and Irmgard Schinnerl, July 2003, "Aspects of Game- Based Learning")

Therefore, they have suggested four different games scenarios (see table 4) in which the users are challenged to learn the instruments & genre and exploring melodies by keeping them curious in which there is a "continual of the new information without determining the outcomes" (Maja Pivec July 2003).
To better visualize the findings from the LEGO online meeting I have designed a table based on the meeting findings with Lego designers, that will help to differentiate the game suggestions.

Genre game	Evolution of music
You can find different pieces of music from different genre. For example, you have to create a metal rock concert. For building the metal rock genre you cannot use a certain amount of instruments and you must choose only the specific instruments used in metal rock music such as bass guitar. This could be played in two persons by holding and trying cards	Build an old fashion rock band or a 21-century rock band and find the differences between old and new days. Also the cards could illustrate the evolution of different genre and how it changes over time.
Anonymous cards	Find the instruments
Here the user is not aware of the instrument. When they slide the card in front of the camera, the tablet will start produce the respective instrument sound, so you need to guess what instrument is playing. With what kind of instrument am I dealing here? Could be more instruments per one card.	We play violin card. Pick up 3 pieces of music cards that you think it has violins in there. Once you find all melodies that include the violins you could see information about the usability of the violin in that piece of music. Regarding this example you could include more elements in the same game. For example to find different beats in the melody cards or find the 4/4 rhythm in a melody cards.

Table 4 LEGO UX game scenarios suggestions. A general overview of learn through play games

Explanation of findings

According to Stepan when designing a learning tool is important to think about "knowledge" and "How you take knowledge away from the users so that they have to find that knowledge". I found very interesting the idea of the Genre game (see table 4) because it seems to be a common choice with the music teacher who said that "You could create genre cards and then kids could scan each card to guess the instruments". The genre game could be characterized as an adventure game in which kids can create and discover and therefore acquire knowledge by using intrinsic motivation, so moving further only by solving the problem in which the players are" motivated to provide a solution in order to continue with the game" (Maja Pivec July 2003) so the access to the next card only by solving the previous card.

Therefore, according to Stefan and my Lego supervisor, "curiosity" and "control" are two important aspects that should be taken into consideration for future development in which curiosity "is sustained by the continual introduction of new information and non-deterministic outcomes" and control "in which the user/learner is the one making the decisions and choices" (Maja Pivec July 2003)

Also, according to Stefan, "time" aspect is a great game rule for challenging the user. "Different types of rules help players to reach a goal of the game" by motivating them to solve the task in a time limit.

Another important element to challenge the users is to allow them to make "mistakes". 'In game-based learning making a mistake is a primary way to learn and is considered the motivation for players to keep on trying" (Maja Pivec July 2003)

My research paper is focusing in finding an efficient tool that will boost cooperation and creativity of the children. The meeting with LEGO UX department inspired me and I have decided to create different game scenarios and try to integrate the Cards (prototype) in different "environments" in order to further explore the possibilities that will help the research paper to respond to the question "What do we want that learners learn?"

"Designing tangible interfaces requires not only designing the digital but also the physical," and by doing so, the Tangible interaction Framework analysis will be used in the research in which 4 themes will be included such as Tangible manipulation, Spatial interaction, Embodied Facilitation, Expressive representation that will be further explored "Frameworks in general serve to focus our view, providing us with concepts that systematize our thinking and allow for reflection." (Eva Hornecker & Jacob Buur 2006)

Therefore, for further research I will focus on designing the interaction itself instead of the interface using the Tangible interaction Framework analyze and come with a fully functional tangible and graspable TUI prototype that could be easily manipulated, using both the real-world environment and digital environment.

Generating design ideas (use tangible interaction framework)

The tangible interaction framework themes were placed in a table for a better visualization (see table 5). The tangible interaction framework includes 4 themes and 13 related concepts. Each concept comes with "provocative questions for a brainstorming exercise which were used in order to generate design ideas and analyze the current prototype design and interaction" (Eva Hornecker, The Tangible Interaction Framework Cards).

Since the current prototype present some limitations, it could not fit and respond to all tangible interaction framework's concepts such as **Full-Body Interaction** and **Access points**. The current prototype can be played on a tabletop environment, and its interaction does not depend on the user's bod/physical movements.

THEMES	Tangible Manipulation	Spatial interaction	Embodied Facilitation	Expressive representation
RELATED CONCEPTS & PROVOCATIVE QUESTIONS	**Haptic Direct Manipulation** • Can users grab, feel and move "the important stuff **Lightweight Interaction** • Is there rapid feedback during interaction? • Can users proceed with small, experimental steps? • Can users experience the interaction straight away, from the start?	**Inhabited Space** • Do people and objects meet and invite into interaction? • How can the human body relate with the space and create a meaningful place with atmosphere? **Configurable materials** • Does shifting stuff around have meaning? **Visual Access** • Can everybody see and follow what is happening? **Full-Body Interaction** • Can you use your whole body? • Can users take ownership of space by physically moving there? • Can users be proud of skilled body movement? **Performative Actions** • Can you communicate through your body movements while doing what you do? • Are actions publicly available?	**Embodied Constraints** • Is there a physical focus that draws the group together? • Does the physical set-up lead users to collaborate by subtly constraining their behavior? **Access Points** • Can all users get their hands on the central objects of interest? • Can you hand over control anytime, and fluidly share an activity? **Tailored Representations** • What is the entry threshold for interaction? - Can you provide a simple syntax of interaction regardless of the semantics?	**Representational Significance** • Are representations legible, meaningful, and expressive? Are they of lasting relevance? • Are physical and digital representations of similar strength? Can they augment and complement each other? **Externalization** • Does the representation give discussions a focus and provide a record (trace)?" and "Can users think or talk with/through objects, using them as props to act with? **Perceived Coupling and Power** • How easy is it to understand the relations between action and effects?

Table 5 Tangible interaction framework

The tangible interaction framework had the purpose of helping the current research paper to design future ideas and as a result of the "provocative questions" a few game concepts and settings were designed to explore different tangible interactions settings (see pages 34 and 35).

There are in total 22 provocative questions and only 14 of them generated design ideas/concepts that were tested in workshops. The discussions with Lego colleagues and music teacher stakeholder were also taking into considerations while designing the design ideas/concepts. Besides games, in addition, were brought different models (geometrical shapes and physical objects) to further explore the implication of the AR cards in a different settings and therefore, find if these cards could be used in another context than a tabletop environment. All the design results were tested in a few physical and online workshops in which IBA students and music students have participated.

- Tangible manipulation – refers to the physical manipulation of material representations
- Spatial Interaction- refers to the embedded in real space of tangible interactions
- Embodied Facilitation- refers how group behavior is affected by the configuration of material objects
- Expressive representation- refers to the expressiveness of material and digital representations

Tangible interaction framework analyzes

For each theme, I reflected on the current functionality and interaction of my 6-cards prototype. The provocative questions helped in evaluating the prototype interface and manipulation.

Theme- Tangible Manipulation

Haptic Direct Manipulation- "Can users grab, feel and move "the important stuff?""

The user can grab and feel the cards, move, and scan the cards using the helping tool (phone/tablet) and respond to the questions from the back side of the cards. If the main user does not know the answer, he needs to scan again the card and learn the instrument by reading the info provided in 3D on the screen. Such interaction provides playfulness, but this needs to be tested.

Lightweight Interaction-allow experimenting- "Is there rapid feedback during interaction?"

You will feel invited to grab and interact with the cards. The interaction is simple. The user is lifting the cards, placing it on any surface, scan it, play with it, and learn. The cards work natural and you do not need to make effort because the instruments will be played automatically, depending on the card. The user can make his/her own instrument combination allowing to experiment. Also, the physical icons form the top of the cards (the drawings instruments symbols), helps in understanding what is the game about.

Generate design idea. What could be add and test in workshop? The experimental phase could be improved by providing to the participants different size of cards; different shapes or even provide physical 3D models to play and place it on the table in order to express and test their ideas quickly.

Lightweight Interaction-conversational style- "Can users proceed with small, experimental steps?"

Coming from a technical perspective, considering the AR paper card prototype, the user can create their own assumption of how to organize the cards in a more logical way in order to play with the sound and learn the instruments. In this way they can play with sounds and add more sounds when needed. Perhaps they will want to make sketches for a better classification of the instruments or bring a better quiz game and give feedback to the moderator.

Generate design idea. What could be add and test in workshop? I could deliver different shapes (geometric shapes) and encourage sketches in order to see if they want these cards to be attached and used somewhere in a different "environment" in order to experiment more and create more discussions group and share the vision.

By bringing geometric medium size shapes, this could result to a constructivist model in which the user perceive the object and involves multiple acts of looking touching, turning and exploring the 3D physical objects (geometric shapes) and by attaching the cards on it the user will create its own perception about the object. (Michael Mascolo 2009).

Lightweight Interaction-usability- "Can users experience the interaction straight away, from the start?"

The interaction is made by phone. Once they open the scanning app the user will experience an immediate interaction with cards. They can also lift the card and find the quiz questions easily, realizing what the game about is.

Generate design idea. What could be add and test in workshop? At the moment, the phone represents the main input that generate outputs such as sound and AR 3D models and GUI volume sliders. Therefore, it could be add more physical inputs such as sensors or buttons that will trigger an action or improve the design of the app in order to make it more intuitive for the user, making it more **user centered**.

<div align="center">

Theme- Spatial Interaction

</div>

Inhabited Space-social interaction- "Do people and objects meet and invite into interaction?"

Currently (coming from a technical perspective), the AR Cards can be used by a person at the time with a possible implication of a second user. Therefore, the current game can encourage others to look and participating, only in a certain extend. For example, the second user can now test the main user' knowledge about each instrument by asking the quiz questions from the back side of the cards. If the main user does not know the answer, he needs to scan again the cards and read the info provided in AR 3D text on the screen.

Generate design idea. What could be add and test in workshop? Create a competitive game. Each participant could handle cards with different instruments. Each user must build their own instrument band, choosing from a bunch of instrument cards. Each player needs to ask key questions about each other's instruments. The game is focusing on competitive.

Perhaps such interaction requires a more "isolated" or directed direction by bringing a board where they could play, discuss, and get in touch. Perhaps rules will need to be applied explaining what steps they need to take to win. In this way the game will support social interaction between the users. Jigsaw puzzle concept is another example which focus on user's cooperation instead. I approached the idea of Jigsaw game since the sketching modeling (see page 21). This time I decided to consider it especially when Stefan, Project manager - LEGO Group approached the same concept using four different games scenarios such as Genre game; Anonymous cards; Evolution of Music; and Find the Instruments (see page 26).

Inhabited Space- body in a context & atmosphere- "How can the human body relate with the space and create a meaningful place with atmosphere?"

The current interaction does not depend on your body movement in a specific context. Also, currently the user does not need a meaningful space to make it work. Therefore, will not be any specific atmosphere around the game. At the moment, the Cards can be manipulated on a surface in one place (table, desk, floor) or it can be attachment to other external elements (such as geometric medium size elements).
From a technical point of view, in order the cards to work, it needs to be used in a static place in order for the tablet/phone to successfully scan and create interaction. Currently, if you move the cards your risk to lose the interaction between the phone/tablet with your cards.

Generate design idea. What could be add and test in workshop? Treasure hunt concept became a very popular game among children and adults where the meaningful place, contain psychological meaning and affects the user's perception of a setting. The cards could be places in a museum or archive setting or even in the user own house setting. The user could choose its play role (police investigator for example) and start search for the items (cards).

Could be two types of cards spread all over the house. The quiz and hint cards. Once he found the first card the user can scan it and info and sound will pop up. This interaction could lead the user to next card until he/she will reach the final destination and solve the mystery. This is a treasure hunt setting in which the movement and perception of the user are tightly coupled and a specific atmosphere will be created around the game.

Configurable materials- meaningful objects - "Does shifting stuff around have meaning?"

The current game' exploration works by adding and removing cards in order to create your own sounds sequence or learn about each instrument by reading the AR text and respond to each card's quiz question. The

meaningful interaction is made by the 6 cards itself. Example. Having 6 cards on the table and then remove 2 cards from this set it will change the results and new sound will pop up. (having 4 cards representing 4 instruments). Besides the 6 AR instrumental cards, there are not any other significant objects that the user could play with and explore the environment

Generate design idea. What could be add and test in workshop? I could add some **meaningful objects** (cards) such as pause, start (inbound) and stop (outbound) button cards or special quiz cards that could bring a much more interesting effect and control for the user. The user could also explore more by bringing additional elements that will affect the current 6 cards sequence.

Visual Access- "Can everybody see and follow what 's happening?"

It is not a reciprocal situation where seeing implies being seen. But it is an open game, and everybody can see what is happening between cards and phone. It must require getting closer to understand exactly the interaction and how it works

Full-Body Interaction- "Can you use your whole body?"

Currently, it is a static game that requires you to touch and manipulate the cards only with your hands.

Generate design idea. What could be add and test in workshop? Treasure hunt game concept (see Inhabited Space- body in a context & atmosphere) could be used.
The other design idea is to place the scanning device (tablet) on a stand in order to allow using both hands "To make it more social you need a kind of a tabletop environment in which the tablet sits on a stand […] then more hands could be used" quote by Stefan- Lego Project Manager position

Full-Body Interaction- "Can users take ownership of space by physically moving there?"

Currently this game is not fully-body interaction based, so does not require physical movements.

Generate design idea. What could be add and test in workshop? Treasure hunt game concept allows full body movement (see Inhabited Space- body in a context & atmosphere).

Full-Body Interaction- "Can users be proud of skilled body movement? - Can they develop skill over time?"

Considering the current prototype, the user does not need to make meaningful body movements to accomplish any skills. Instead they can develop knowledge and musical skills over time "By listening to and visualizing different instruments, children will easily recognize the sound the next time they hear it and therefore train their listening skills" quote by Judith – Music teacher position

Performative Actions- "Can you communicate through your body movements while doing what you do?"

While listening to music the current game may cause the user to move/dance on the instrument rhythm's bits.

Performative Actions- "Are actions publicly available?"

The scanning action and the results of the action (AR 3D and GUI elements) can be difficult to be seen by other people around the prototype but instead, it can easily be heard due to the instrument sound sequence. Therefore, it can make aware others about what the main users are doing respectively, creating sequences, and playing with instruments. Also, the game can be played by a maximum of two users. Therefore, from a technical point of view, the best interaction will only happen between a maximum of 2 people. (the main user handling the tablet and secondary user which may be handling the cards)

Generate design idea. What could be add and test in workshop? Make an instrumental card game which could be played in classrooms to invite all the students to play (not applicable yet but it can spark idea of improving the social interaction

<p align="center">Theme- Embodied facilitation</p>

Embodied Constraints-pre configuration of objects- "Is there a physical focus that draws the group together?"

The current prototype does not provide enough tools for several participants to play at once. The game does not request mutual helping or coordination. There is not any pre set-up or configuration of space or objects that could draws the group together. Currently, the user creates its own path by placing the cards on the surface. Through this activity it allows and therefore invites people to look. The size of cards allows to the viewer to embrace an overview of the game. The cards' shape is easily recognizable (square cards), and the location depends on the player. But the current game limits the interaction of a second player and allows only the activity of one player. The second player can only watch, change cards, and ask quiz questions and not bringing suggestions.

Generate design idea. What could be add and test in workshop?
- Provide Social interaction game concepts (see Inhabited Space-social interaction).
- Provide different size of cards; different shapes or even provide physical 3D models (see Lightweight Interaction- allowing experimenting)
- Group discussions and share the vision by bringing geometric shapes (see Lightweight Interaction- conversational style).

All the objects from above could help in providing mutual coordination or cooperation or help between participants.

Embodied Constraints-cooperation/scaffolding- "Does the physical set-up lead users to collaborate by subtly constraining their behavior?"

The current game's activity limits the trajectories of actions thus limiting the providing suggestions from another random user. The game can be played by a maximum of two users. Therefore, the interaction will happen between them. The second user can scaffold by changing the cards while the main user hold the phone/tablet. The second user could also ask question about each instrument.

Generate design idea. What could be add and test in workshop? Provide Social interaction game concepts (see Inhabited Space-social interaction). In this way, the construction of knowledge will proceed as a social and collaborative process where the users will learn together, and each user expertise will help in solving the game in any extend.

Access Points- *"Can all users get their hands on the central objects of interest?"*

Currently the prototype is not a cooperative game, but the users can still experience by observing and interacting in a certain extent with the tangible object but not playing all together. Still the current tool does not provide enough tools/objects to allow several participants to play at all at once, but it can encourage others to participate by observing and manipulate the cards in a certain extent. The game invites a second player to be part of the interaction by grabbing the cards and challenge the main user to respond to the quiz questions from the back side of the cards.

Generate design idea. What could be add and test in workshop? Bring cooperative or competitive game.

Access Points- Can you hand over control anytime, and fluidly share an activity?

The current game encourages the participation and observation of the others. It is hypothetically considered that after users creates their own cards sequence, they can further share it to the next participants which could change the current card sequence by adding or subtracting the cards. They still cannot play all together (full game

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experience only between maximum two) but they can experience the game by bringing suggestions and by observing.

Generate design idea. What could be add and test in workshop? Bring cooperative or competitive game.

Tailored Representations- **"**What is the entry threshold for interaction? - Can you provide a simple syntax of interaction regardless of the semantics?"

The current prototype might bring cognition or knowledge in which the current action of the game allows to acquire knowledge and understand through thought, experience, and the senses. The game contains sound of instruments and sound of different genres that are associated with the AR text. Sound could encourage learning and easily memorize the information. Sacks (2007) believes that "music has a special relationship to memory […] he argues that music embeds and activates sequences of knowledge and action" (Lucille M. Foran 2016. "Listening to Music: Helping Children Regulate Their Emotions and Improve Learning in the Classroom")

<p align="center">Theme- Expressive representation</p>

Representational Significance- **"**Are representations legible, meaningful, and expressive? Are they of lasting relevance?"

The cards are meaningful, and they differ from the digital information or pictures that occurs on the tablet/phone screen after scanning the cards. The existing physical icon shown up on the tokens (cards) will allow to use it also with another purpose such as selecting the desire sound sequence by combining different tokens (cards/instruments).

Generate design idea. What could be add and test in workshop? See Lightweight Interaction-allow experimenting & See Configurable materials- meaningful objects- Bring shapes, sizes, 3d Models, Pause/Stop/Start cards for allowing experiments within the current context and create a better meaningful and expressiveness.

Representational Significance- **"**Are physical and digital representations of similar strength? Can they augment and complement each other?"

The game cannot work without digital source (tablet/phone) that produce digital content (AR text, images) and it cannot work without physical source either (the physical cards). Therefore, the digital with physical, augment each other providing the desire effect.

Externalization- **"**Does the representation give discussions a focus and provide a record (trace)?" and **"**Can users think or talk with/through objects, using them as props to act with?"

Currently, the only trace can be seen in the cards sequence created by the main user or two or more users. The current tangible tool support communication between the users in a certain extent. The game can be played by responding to the quiz questions from behind of the cards. The cards can be also moved by two participants and create a customizable sound.

Generate design idea. What could be add and test in workshop? See tangible manipulation Lightweight Interaction-conversational style. Encourage sketching to "help the user to think and communicate while providing a trace of their discussions" The medium size geometric shapes could also work.

Perceived Coupling and Power- **"**How easy is it to understand the relations between action and effects?"

There is clear link between what the user does and what is happening. The physical elements and digital representations are naturally coupled, and once digital tool interacts with the physical cards, an immediate effect (sound and image) will be visible. Therefore, this combine physical material and digital elements, like a hybrid.

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Also, the users' actions can create different effects. Example- having 6 cards on the table and then remove 2 cards from this set it will change the results and new sound will pop up. (having 4 cards representing 4 instruments).

Conclusion and outcomes from the tangible interaction framework analyze

The tangible interaction framework poses provocative questions that helped in brainstorming on the current prototype design and generate more ideas such as bringing additional elements to the current prototype or use it in a different context of use. There were questions which were not fitting with the current prototype design and interaction, but which managed to inspire and generate new ideas that gave the freedom of thinking "outside the box" and not being stuck with the original design and interaction.

As a result, a few concepts, for testing, came out such as expressive and exploratory tangible systems in which user needs to discover by themselves the model and respectively explore the existing model. Therefore, the goal was to couple the physical objects with digital information to "support users engaged in a diverse range of activities in which "physical objects augmented with digital information" (Paul Marshall, Sara Price and Yvonne Rogers, 2003 "Conceptualizing tangible to support learning")

Therefore, on the next section, as a result, different expressive and exploratory design concepts were developed in which the participants will have the ability to think about the implication of cards in different settings and have the opportunity to explore these possibilities.

In the beginning of the research paper I was interested to challenge the idea of developing a Tangible User interface that support augmented reality and make the interaction of the user with the cyberspace more natural and intuitive. The hypothesis was that in this way users will be able to cooperate more between them by pushing them to become more creative together and make the interaction of the user with the cyberspace more natural and intuitive by using "ready at hand" tangible tools which therefore, "leads to a minimal cognitive effort of the user." (Hiroshi Ishii and Brygg Ullmer 1997)

While designing the concepts I realized that the users could treat the current tangible tools (cards) both as "ready-at-hand" element (working through it to complete a task/ task focused activities) and "present-at-hand" element (focus on the tangible itself/ the object of activity). In the present at hand approach the cards are more expressive, acting more like meaningful objects which could bring more interesting effects and control for the user.

Therefore, the following examples will present expressive and exploratory tangible systems (games) which supports either "present to hand" or "ready at hand" approaches in different settings in which the usability of the cards has been challenged.

Expressive and exploratory game tangible system

Second
Check your findings by scanning the combinations of cards

First
Scan each card and find the AR missing pieces. In this way they will learn about the instruments used in a rock band

This is the puzzle they need to build
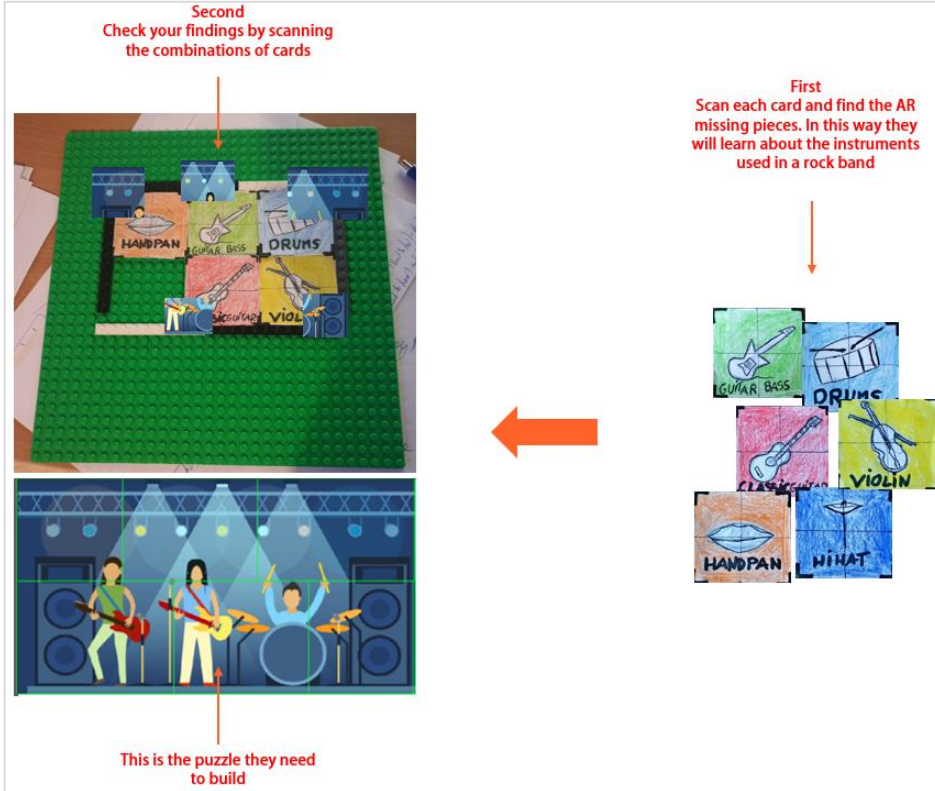
Jigsaw game

The goal of activity is to promote learning. Jigsaw game represented an expressive activity using "present at hand" activity in which the participant is aware about the position of the cards. Here the cards represent the missing parts of a rock band puzzle in which the user needs to be aware about what card to choose. The missing parts will be seen only in AR pictures by scanning the cards. In this way children will learn about the usability of instruments in different genre.

First
Scan the genre cards

Third
You can check if your instruments' combination will sound the same with the genre cards by scanning them

Second
Scan the instrument cards and try to find the instruments played in each genre by listening
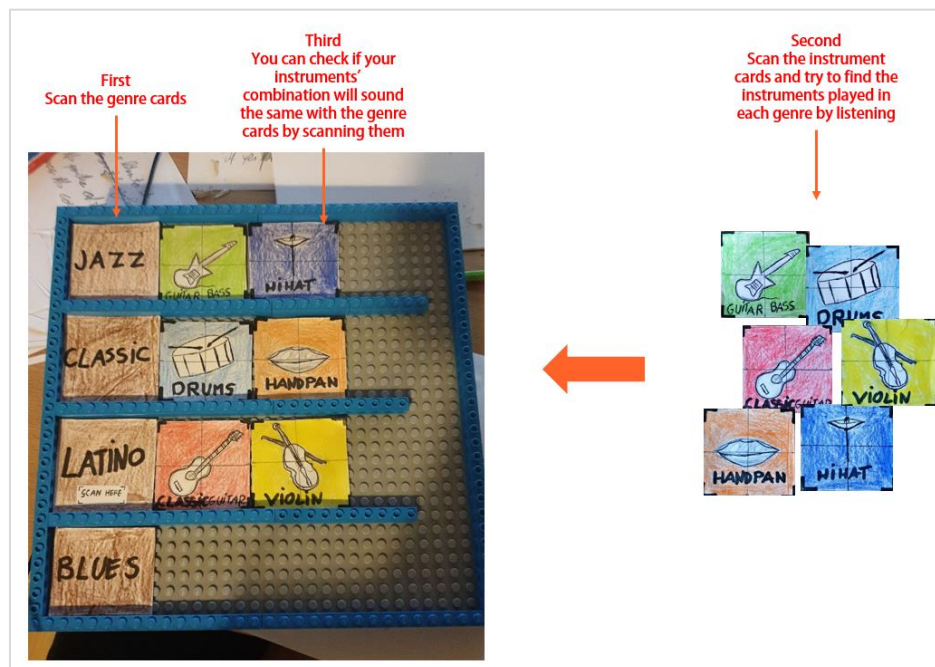
The genre game

Here an additional element was added (genre cards, containing different melodies or combinations of different instruments).

The goal of activity is to promote learning as well by challenging the user to fit the instrumental cards (right side) with the genre cards (left side). This is an expressive and exploratory activity using both "present at hand" and "ready at hand" activity. If in the previous example the user was guided by picture here the user is guided only by sound making the participant sometimes to be aware about the position of the cards and sometimes the cards are not "visible" anymore by the participant. This is an interesting interaction which was tested in the workshops.
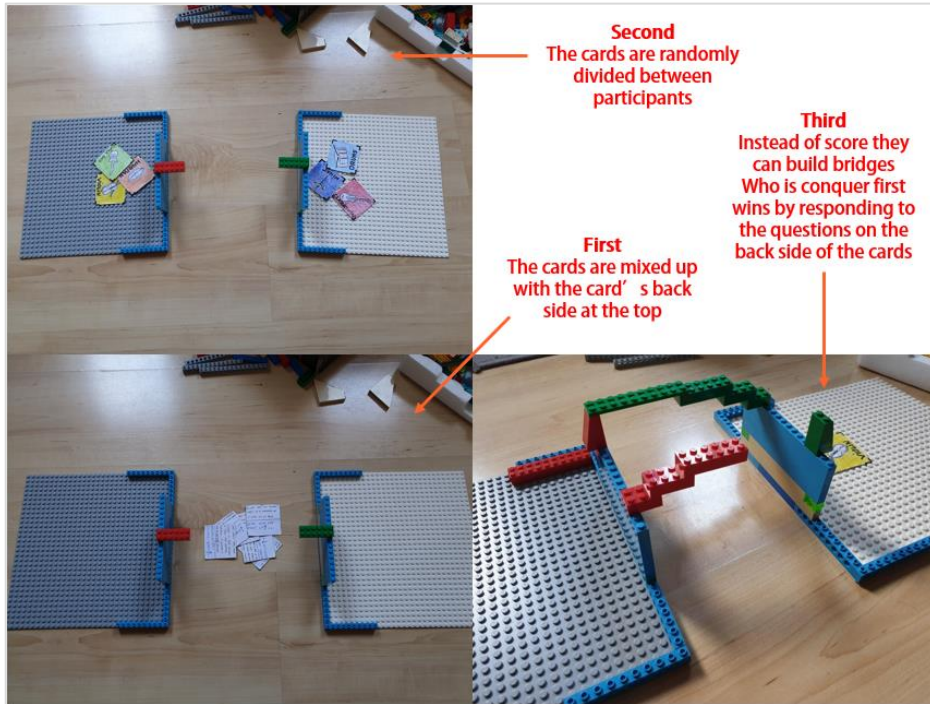
Second
The cards are randomly divided between participants

Third
Instead of score they can build bridges
Who is conquer first wins by responding to the questions on the back side of the cards

First
The cards are mixed up with the card's back side at the top

The quiz game

For this concept, quiz questions were related to each instrument cards. This is an expressive and exploratory in which the cards are characterized as "present at hand" tools in which the participants are aware about the cards and the questions related to the card. This tool was designed to be a competitive game with the purpose of boosting the conversation between participants and learning. How it works? The cards are divided by two participants. Each participant scans the cards and start read about the instruments. Then they need to challenge each other to respond to the question that is related to each instrument. Instead of a traditional score, Lego bricks were chosen for a more playful interaction. The bricks represent the pieces of a bridge in which who is building the bridge first, will conquer and therefore, win the game.
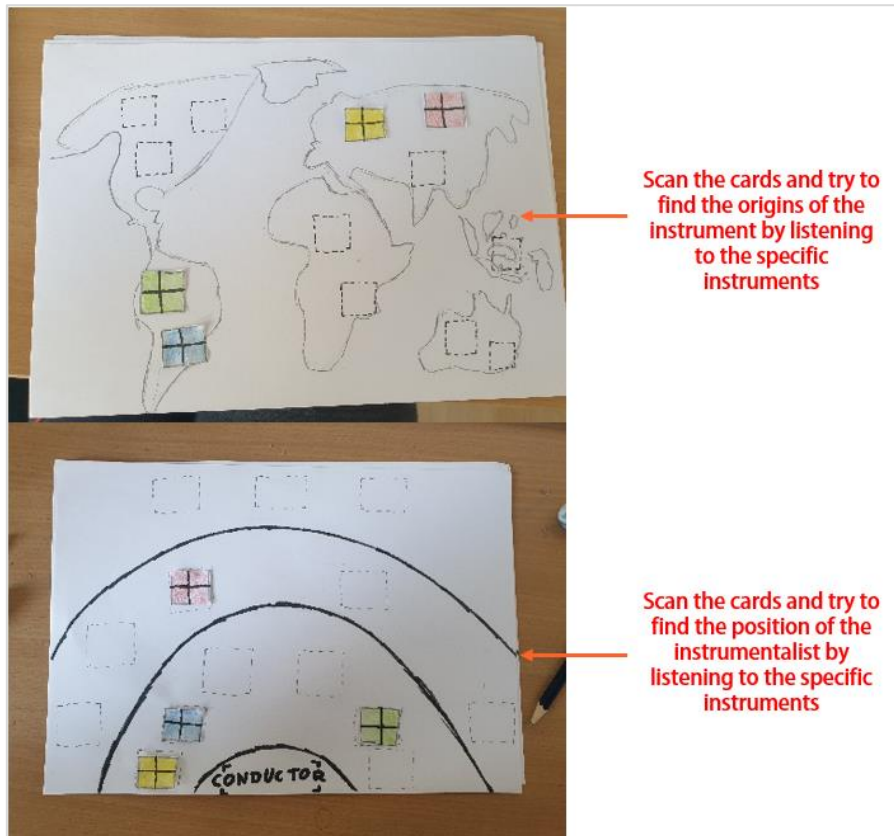
Scan the cards and try to find the origins of the instrument by listening to the specific instruments

Scan the cards and try to find the position of the instrumentalist by listening to the specific instruments

The maps

Exploratory activities. The cards are characterized as present at hand tools in which the user is aware about the position of the card on the maps. The figure shows two maps (a map of the world and a map of the orchestra) both have the same purpose of the learning activity. The world map is a cultural game in which the user must match the instrument with each continent and in this way the user can learn about the history and usability of the instruments.

For the orchestra map, the user will learn how a classical orchestra is organized in a real setting, learning where to place the instruments to make the orchestra work.

Both games come together with an existing map in which is the user task is to explore the possibilities.

From a technical point of view the game concept from above were not functional, and the participants just tested the idea without using a digital input (tablet) to interact with the models. I could characterize the models as Quick-and Dirty-prototypes which were used as "a quick way to communicate the design ideas to the participants" (Milton and Rogers, Making chapter). The concepts were built with inexpensive materials such as paper, glue, tape, and Lego bricks. I focused on speed rather than quality in order to save time and start establishing workshops to test the game scenarios.

These game concepts were chosen as a respond to the Tangible Interactive Framework provocative questions such as

Table 6 Generate design ideas. Game concepts resulting from the provocative questions

Can users experience the interaction straight away, from the start? (Lightweight Interaction-usability)	According to first discussions the interactions seemed to be freely (placing the cards on the table and start scanning). According to the discussions with Stefan he suggested to "bring more restrictions to turn it in an educational tool". To improve the interaction and brig limitations, physical boards (LEGO boards) were brought, in order for the user to play and place the cards in a more controlled setting. In this way we were able exploring other settings as well and make a comparison between them.
Do people and objects meet and invite into interaction? (Inhabited Space-social interaction)	All the game concepts from above were created to invite people to interact with the object. But it was assumed that the quiz game and jigsaw game will generate even more social interaction.
Is there a physical focus that draws the group together? (Embodied Constraints-pre configuration of objects)	The concepts from above tried to enhance the mutual help and coordination in which we have used different pre-setups/ configurations that could draw people together. More players could join (especially in the jigsaw, genre and maps games) and hopefully group discussions will be involved.
Do the physical set-up lead users to collaborate by subtly constraining their behavior? (Embodied Constraints-cooperation/scaffolding)	It was hypothetically considered that the games from above will lead to a social and collaborative process in which each user will use their expertise to solve the game resulting in learning together. Perhaps the best example is the maps game in which each user could come with their own knowledge and therefore subtly use it to explore and fill the maps.
Can all users get their hands on the central objects of interest? (Access Points)	The designed presets could encourage more than two users into play by manipulating the cards in the same time, boosting the cooperation between participants.
Can you hand over control anytime, and fluidly share an activity? (Access Points)	Considering the game interactions, in could represent a sharing activity between participants in which everybody will use their expertise to help in solving the game tasks.

Explore different settings and add elements

The following elements were choses as a respond to the questions

Table 7 Generating design ideas. Objects/probes resulting from the provocative questions

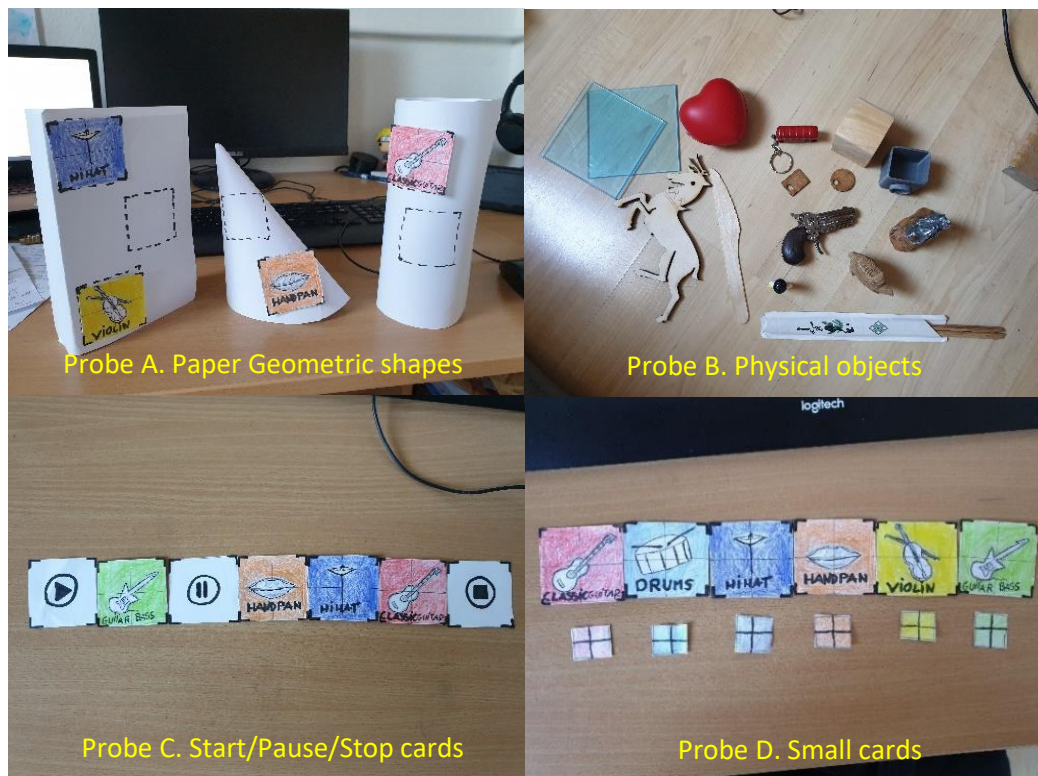| **Can users proceed with small, experimental steps?** (Lightweight Interaction-conversational style)	To explore and experiment the usability of the cards and in which context it could be used, there were brought a few paper geometric shapes (probe a. figure 20) and physical objects (probe b. figure 20) in which the cards could be attached. The shapes and objects were random chosen to provoke the participants imagination, experiment more and create more group discussions and share vision.
Is there rapid feedback during interaction? (Lightweight Interaction-allow experimenting)	In case the participants did not get inspired by the geometric shapes and 3d objects elements, they were encouraged to create sketches in which they had to draw different context of use for these cards. The cards are perceived as ready at hand elements in which the cards are "invisible" to the user. All what matter was to find a context to use the cards.
Does shifting stuff around have meaning? (Configurable materials-meaningful objects)	Meaningful objects such as pause, start, and stop button cards and small cards (probe c. and d. figure 20), were added to bring interesting effect and control for the user. The user could also explore more by bringing additional elements that will affect the current 6 cards sequence. The additional cards were presented to the participants, but it does not have any technical effect instead the participants had to use their imagination (the additional cards elements were not readable by the tablet). The purpose was to spark the conversation and speculate more.

Probe A. Paper Geometric shapes

Probe B. Physical objects

Probe C. Start/Pause/Stop cards

Probe D. Small cards

Figure 20 The elements and objects chose to be tested as a result of Tangible Interaction Framework

Once the technical part, the design of the cards, the game contexts and elements/probs were finalized I chose two methods of testing such as, online testing which was meant for people that I could not reach and physical testing for people willing to test it physically.

Participants such as, Music teacher (online feedback), two Music students (online feedback) and one IBA student (physical testing) have participated in testing sessions (see table 6).

The testing session were divided in 4 workshops. Each participant at the time.

	Online testing			Physical testing
Occupation	Music teacher 2-5-6th grade	Graduated music student	Graduated music student	Top-up Marketing and Sales. student
Institution	Public School Petersmindeskolen, Vejle	–	–	International Business Academy, Kolding
Participant name	Judith	Isabel	Aura	Andrei
Research type	Open discussions and prototype video demonstration (Skype meeting)	Online semi-structured interview and prototype video demonstration (ZOOM meeting)	Online semi-structured interview and prototype video demonstration (ZOOM meeting)	Observing and Intervention (physical meeting)

Table 8 An overview of the participants. Online and Physical testing

Each workshop (online and physical) consists of two parts. In the first part the participants had to interact with the prototype (tablet and cards) and in the second part, together we have explored the possibilities of using the prototype in different game contexts or adding different elements and objects to the existing prototype (see figure 20 elements and objects)

The first part of the workshop consists in evaluate and organizing the participants thoughts. For this part I have asked all four participants to express their opinions about what they Like; Do not like and What they would Improve, regarding the 6 cards prototype. For the physical workshops, post-it notes were used to help brainstorm together with the participant. After the post-it notes were placed on a board, I chose to write them in a digital form for a better visualization of the findings and try to find common findings between participants. For the online participants I have asked them to write their evaluation (digitally in a Word file) and then send it to me.

After gathering participant's evaluation, I have included them in a digital table that helped in better visualizing and find the common thoughts of all participants. (The common thoughts were placed in the centre circle). For each table's quadrant, each participant was assigned a colour such as yellow and red for music students; green for the IBA student and blue for the music teacher. (see Appendix, pages 75 and 76)

For music students, I conducted two semi-structured interviews to compare their students' experience when they were younger with the current tangible musical instrument and try to find out if such a prototype could have helped them. I also asked for suggestions for improvement.

The second part of the workshop consists of challenging the participants to think about how the current prototype could evolve, how they see the future of the current 6-card prototype and how to make it more of a cooperation tool. As mentioned before, to help the participants explore and generate ideas, different game contexts and objects were brought to interact and experiment with. As a result, I created a table (see Appendix, table 2, page 76) that consists of the participant's feedback. Considering the big differences between the participant's suggestions, these could not be clustered together. Therefore, the suggestions were kept and analyzed separately.

The second part of the workshop was conducted for the first time with the IBA student, a music student, and the last session was done with the music teacher. The purpose of having the music teacher as the last participant was to discuss and show the findings got from previous workshops and together find the best possible direction to go for and see the future implications of the prototype and where we could go. (the teacher did not saw the results of the other participants before the workshop and only after the workshop to do not influence the teachers results)

The next section will present and analyze the results of the participants. After analysis, the results helped decide on what tangible interaction I should go.

First part of workshop (like; do not like; improve)

Even if a part of workshops were online and the other part went physical, this did not bring too many differences between participants results (online and physical participants). The physical workshop with the IBA student brought more results due to touching the cards and physical playing with the tablet, but there were no significant differences in answers compared to online workshops.

Semi structured interview – music students

Semi-structured interviews were chosen in order to "allow the interviewees a degree of freedom to explain their thoughts and to highlight areas of particular interest and expertise that they felt they had"(Joanne Horton, Richard Macve and Geert Struyven) Therefore, I brought three general but meaningful questions that helped stimulate the conversation.

The reason for including music graduates in the testing sessions was due to their musical background. They have finished music school and already have knowledge of music and teaching that could help develop the prototype. Even though the music students came from two different schools, the results were similar.

When I asked **What and how they studied in music school**, both students said that their studies refer mainly to music theory, such as musical notes; musical ladder; musical intervals, etc., using composition exercises, practicing the instrument directly or writing the musical notes on paper. They claimed that they had not learned much about the history of music and their lessons were largely traditional. "I have been helped by a mentor in which the teacher draws the notes on the spot, without books containing exercises or drawings, playing the notes directly the piano" music student quote

It seems that they always needed the help of a mentor for practicing music composition or when the mentor is not there they try different checking methods "In order to check how I sound I always recorded myself to see what I can improve […] but recording is better working when you want to check your voice because is easier to observe the voice details and for instruments, the details are harder to be observed, so you need a teacher helping you to observe the mistakes".

When I asked **What they did not like in being music students and what they would improve** they said that everything worked slow. They used to spend hours in learning theory and after one year of practicing, they started to compose a melody "Some things take a too long time. It takes so much time until you will compose a melody because you must learn how to play on an instrument first and then try to build rhythms" and "learn more about how to compose a melody, from where to start and where to finish". They claimed that they would like to move a bit faster and cove more topics such as the history of music or they would be also interested in learning facts about music in general " I would be also interested to learn interesting facts such as how people play the piano depending on the physiognomy of the hand".

The second student argued that she would like to have more interactive and accessible lessons because is hard for a small kid to start learning the music theory from the start.

What caught my attention was when the second music student suggested an introductory method to help children adjust to the music, encouraging them to compose. "We used to get bored, kids get bored with sitting for 50 minutes learning the same thing continuously […] I would rather use a computer or colored books that

would teach me music in a more playful way" She also said that as the first step to enter the world of music, it would be interesting to learn about the differences between musical genre or the history of music evolution.

Also, very interesting is when she claimed that ""everyone teaches you the technical part of the music and how to adjust the notes and how to press the keyboards, but no one teaches you how to transmit the music, the emotional part and how to interpret the music […] authenticity should be promoted more rather than typicality". She said that many students know how to sing and compose but they are not encouraged to promote their own style by interpreting the melody in your own way.

As a last question they were I asked **What they like being music student**. They claimed that they liked to sing in groups and coordinate between them in which everybody had its own musical score and instrument. As they sang, they had to be careful about how agitated or calm the song should be, and therefore, they were communicating through the instruments.

In conclusion, the discussions show that there is a need for a change. According to the discussions, it seems that learning and practicing for hours and hours on the same subject would make things more difficult and students' motivation could decrease sooner or later. The music students were not demotivated to learn but motivated to learn more different music topics such as the history of music, the evolution of music, facts about instruments or the strategies of how to interpret music and not just learning music theory.

What caught my attention was their desire for a more practical tool to explain to them how to compose music from beginning to end. Therefore, an instrument that will initiate every young beginner in music and teaching them how to promote authenticity and not typicality, thinking about himself and what you want to convey by being a singer, is a great request.

Testing the design, interaction, and tangibility of 6 cards prototype

The bellow results represented the feedback of all participants (online and physical) regarding the current design and interaction of the 6 cards prototype. As mentioned in the Prototype Evolution section page 23 the demonstration video of the 6 cards functional prototype can be found here (https://www.youtube.com/watch?v=hS_gOZQL4_w&t=3s)

Strengths ("What did you liked in terms of design and interaction?")

After physical testing and online video demonstrations it seems that participants majority had the same thoughts. They consider the prototype easy to access and easy to understand; easy to interact and moreover the cards seems to be kids friendly "I like it is colored coded and is good because kids can recognize better which instrument belongs to which category and can better differentiate them" music teacher quote. She also said that "this is a new way of teaching kids". The same thoughts have the music student saying that "In terms of design I like that the cards are childish looking, and they are not boring looking"

It seems that music students and music teacher had the same thought about the theory aspect. They like the prototype does not bring too much theory and is focusing more on the practicality (a more active learning tool) "This is a good start in changing the theoretical aspects of learning […] is interactive, practically and not theoretic" music student quote; "I like it because they do not just learn about the instrument itself but also, they can hear the instrument so they can recognize it and it actually is training their listening skills" music teacher quote; "I like that you have to build a melody without thinking of theory and play with the rhythm" quote by second music student.

It seems most of the participants considered prototype a creative tool. When I asked why they considered this prototype being a creative tool they said "the rhythm of your instruments is very interesting because this element of music can develop the creativity" music student; "You train your visual memory; you remember it much easier" music student; "Children would really enjoy it ! Because there is something you can really touch, change the position of the cards, listen to it, and makes you to create different musical patterns" music teacher.
The IBA student only appreciated the sound of the instruments and the GUI sliders.

Weaknesses (What did you find to be unreliable or what confused you?)

While watching the prototype video demonstration the music teacher did not agree with the AR text to be on the same page/side with AR pictures and AR videos due to too much information and "chaos". Instead, she suggested to move the text on the backside of the cards and replace the quiz questions. Moreover, the teacher said that students would never use the info AR text and only just a few of them "There are students that would never use it but there are students that are very curious to learn new thigs and they would definitely use that function" Music teacher quote.

The same impression had also the IBA and the music students which claimed that "is too difficult to focus on text while having both images and videos on the same page" and "Too many things are happening in the same time"(see figure 21)

They also suggested to move and improve the font of the text. For the participants, the most interesting part was the sound rhythm coming from the cards and not the theory/information delivered by the text.

Moreover, the AR text was not visible enough due to the 3D vertical position (see figure 21 and 22) which made hard to be read. "The position of it and the angle of it is confusing, is like playing with "my mind" and I cannot focus […] it should be more stable and more readable […] it took me more than 30 seconds to read 3 sentences […] it was quite challenging and uncomfortable" IBA student' quote.

Also, more suggestion of changing the text's content came from participants majority, suggesting including more interesting, funny facts "You should include some interesting facts about the instrument itself. NOT A DRY HISTORYICAL but funny or interesting facts" music teacher's quote or "include more interesting info such as classification, fun facts or usability of instruments" IBA student' quote

Figure 21 Issues with the vertical position of AR Text and Video
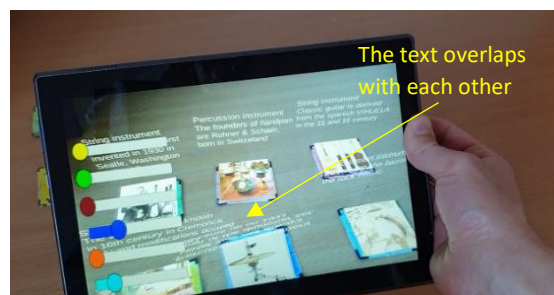
Figure 22 AR info text issues
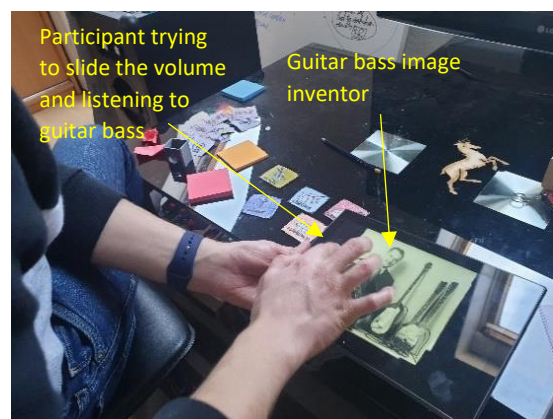
Figure 23 IBA student participant testing the AR pictures

Even if the AR videos were of high interest, it seems that the participants agree with one conclusion. They would prefer the AR images instead, because the entire purpose of the TUI is to compose and not losing time watching videos that could be found on Google (YouTube). One of the participants (music student) had called the current prototype "a mini-google' in which you could find info about instruments and according to the music teacher this could affect the kids and "quickly loose interest" for the prototype.

Another feedback was about the chosen AR images. People considered this element too boring and sometimes it does not make sense to have it there. Even if the images were chosen to fit the text, for example, matching the image with the first inventor of the guitar bass (see figure 23) to the text, it was not fully understood by the participants who asked "Once I see the drawing instrument symbols on the cards, why should I see an AR image with the same instrument, again?" music student quote or "I don't like the AR pictures because are too regular/ serious and children can lose interest easily […] I do not see the point of illustrating twice the same instrument, in physical and digital" IBA student' quote.
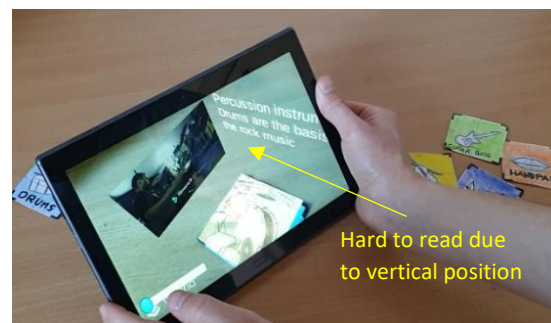
Since, for this prototype session, the IBA student was the only one who tested the cards, physically, I found very interesting his reactions. He said that the cards are difficult to handle and that it is difficult to slide the volume slides with one hand while holding the tablet and, at the same time, handling the cards with the other hand (see figure 24). I did not find such a reaction to online testing.

When I asked him if instead of the tablet, he would use a phone, he had the same opinion "whereas you have to hold the device with one hand this would not make any difference" IBA student quote

Hard to manipulate with one hand

Figure 24 IBA student testing the grasping feeling

Improvements/Suggestions ("Do you have more suggestions from improvement considering the design and interaction?")

For this section, participants were told to think of anything they could imagine. They were encouraged to think ambitiously and explore their ideas by sketching or just discussing. Although the workshops were hosted separately, the participants came up with similar suggestions (see Appendix, table 1.3, page 76). Therefore, I have clustered the suggestions and it resulted in 3 main suggestion categorizes such as More cards; GUI buttons; 3D AR elements.

- **Bring more cards (suggestion)**

An interesting feedback came from a music student saying that "I like it is simple but maybe it is too elementary". This feedback piqued my curiosity and I started to ask myself if I should bring more instrumental cards instead? My thoughts were confirmed when the music teacher said that "You could create different card levels to allow children building an actual melody (intro and outro) […] kids will need more choices and, more choices more interesting for them but this does not mean the game needs to be too complicated".

Moreover Judith (music teacher) brought similarities between the Garage Band app and the Card prototype. "This tool can also train their creativity they have to create their own melody. For example, every melody has an intro, a main part, and an outro. So, they have to practice the structure of the melody". When I asked how she would improve it she suggested to bring more card elements to make the tool more complex but still do not overcomplicate, so keep the tangible interaction simple in order for children to do not lose interest and focus.

When I asked how she would perceive the interaction with the cards considering more students being at the same table she said that "I can't see exactly how we could apply this tool to 25 kids in a class. I only could see it as a competition game where we create groups and therefore, let groups play together […] in which they can create their own sequence and then listen to each other results and give feedbacks and decide what team has the best sequence, but for that you will need more cards with different rhythm".

It seems that the IBA student had the same thoughts, saying that "you should bring a larger diversity of instruments and allow explore more because the current game becomes boring after 10 minutes of play with the same instrument rhythm".

I got the same feedback from a music student suggesting that "It could be much more elaborate, bring more cards but do not bring too many instruments because this can be too overwhelming for children". The same music student elaborates even more upon creating different cards saying that "The children could learn how to combine the instruments by taking into consideration "force" and "piano" elements so, they can train their musical ear".

According to the student, "force" term means louder and complex and "piano" term, means less complex and a more chill sound. When she was asked why to bring such elements she said "There are powerful instruments which usually needs to be played in a "piano" mode and try to do not overcame the other instruments. So, they learn how to combine instruments and which combination works and does not work".

Interesting is that the music teacher had almost the same feedback suggesting to "bring different card levels and the bigger card level is the more complex the rhythm should be".

While online (Skype) discussions with one music student she brought a suggestion being inspired by her wall from the room. As figure 25 shows, the music student pointed toward her wall and showed me a piano drawing that she made a long time go

Therefore, being influenced by her drawing she started to bring an interesting suggestion such as "bring a blank card in which you could draw an instrument by yourself and then it could appear in 3D on the screen" or she also suggested that while drawing different instruments such as piano or guitar, the user could sing to it "The user could draw a piano on the physical blank card. Once the draw is finished you could start using this card as your own customized instrument and start sing by pressing on the drawing piano keys. Also, the piano could be set to play various sounds like a violin, drums and so on. Think about an electronic Organ in which you can set how this could sound and the type of instrument that can be played. So, the piano cards could be the base of different instruments"
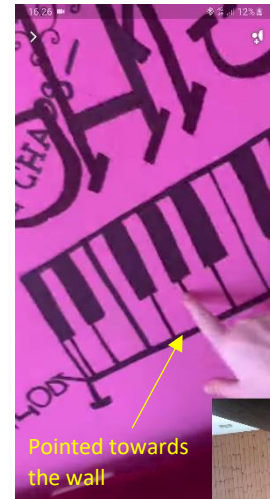
Figure 25 inspired by her wall

When I asked why she suggested such interaction she said that the current prototype needs be more animated and immersive in which the user could interact more with the prototype.

- **Bring 3D AR elements (suggestion)**

The participants were impressed by the AR components and they asked if the current AR pictures and videos could be change with 3D animated models instead. The music students suggested to "Bring 3D animation and interact with it, once you press on it, this could sing or just animated people and musical notes that are dancing on the table or on the physical cards" music students quote.

The same thoughts had also the IBA student saying that he would like to interact more with some 3D animation. When I asked what kind of interaction he thinks of, he said "moving, rotating or zoom in and out the 3D animation" He also continued suggesting even more ambitious interactions "I would like to play with it the drums by touching the 3D drums animation and create my own rhythm or for the violin I would like to try poking the strings"

Since the IBA student is studying sales marketing and management, it was noticed a slight tendency of marketing suggestions when comes the design of the 3D models, recommending the creation of unique 3D animations and therefore, the unique selling point. He gave the example of two similar games but still very different when come the game purpose "Think about *Fort Night* game which is much more popular among youngsters compared to the *PlayerUnknown's Battlegrounds* game which is played more by the adults. Even if both games have the same purpose and idea, they are still different […] this is because *Fort Night* game, is more mystic, cartoonish, and more animated graphics. The *PlayerUnknown's Battlegrounds* game has a too realistic game graphics"

Fort Night (2017) and *Player Unknown's Battlegrounds* (2016) are two multiplayer computer games which have in common the same type of gameplay and game mode respectively a cooperative survival shooter game.

The IBA student participant also came with a very ambitious suggestion saying that would be interesting to create a game that plays with the words instead "you could write by yourself the word "drums" directly on the screen, then the tablet will start to play the sound of the respectively world ("drums") that you wrote. Therefore, he suggested to bring a game that teach kids how to write.

When I asked why he suggested such interaction he said that "the current prototype needs more life and interact more with it". The music student had the same thoughts.

- **Include GUI buttons (suggestion)**

While participants claimed that there are too many things (AR elements), happening on the same time on the screen, the majority suggested to move the text or create buttons in which each button will be attributed to an AR element so "You decide what you want to see" quote "IBA student

The IBA student also suggested bringing a "kill sound" button to turn off all instrument sounds simultaneous "I can no longer find out what instrument is singing in order to turn it off […] Do I need to scan all of them until I will find the instrument?". I found such suggestion interesting and I decided to show it to the music teacher, and she agrees "to bring a general button that stays there (on the screen) no matter what". I found this element interesting because in this way I could improve the user experience even more.

- **Flip the card**

In the physical workshop, it was observed that the IBA student had the tendency to flip the card every time because he was expected something to happen while scanning the backside.
I saw this tendency to the music teacher as well by asking if the backside of the cards has any reaction. As a result, she suggests changing the questions from the backside with info text, instead "This game has a lot of potential. It could also teach about history of the instrument, having the info text on the back side".

When I asked how such change will help the current prototype, she said that "I feel like you should separate playing from learning". I found this suggestion very interesting and I considered it for the next prototype development.

Conclusion of first part of the workshop & potential target group

According to discussions with the music teacher one of the biggest problem she faced by teaching kids, is that "children tend to overcomplicate the whole thing" and "they need someone to tell them to keep it simple" and teach them that "music is not about to be complicate but is about the simplicity of the notes and tones" music teacher quote

Considering the current prototype it was much more appreciated by the participants than expected "Kids will find it very interesting especially the AR elements" or "I like this tool because is simple and it easily allow the user to hear the instruments without making too much effort" quote by Music teacher. She also said that "by listening to and visualizing the different instruments, children will easily recognize the sound the next time they hear it and therefore train their listening skills".

The music teacher focused more on the game itself, instead of suggesting AR 3D animations or GUI buttons. She was more interested in how the cards react to each other and how the sound of the cards was chosen and from where. "How did you choose the sound?" or "Can you bring even more sound?"

After discussions together with the music teacher, questions arose, asking "How should I apply this to 25 kids?" Since the prototype was in the initial phase, I could not respond to the question. Instead, we agree that the potential target could be children from 5 and 6th grades (12 years) because this is the average in which they start to better handle the devices and start pay attention to details "This prototype should definitely not be for the small ones. It would be interesting for the biggest kids like 5 and 6th grades because they know how to handle a phone/tablet and pay attention to details "quote by music teacher.

Also considering the music students feedback this tool could be an initiation method for young beginners, that would help children to accommodate with music, encouraging at the same time to compose or learn about different music genre. According to the music teacher which already is using Garage Band APP on mobile devices, for training the music skills of her students, she claimed that this tool is even more practically and "it actually can help children to visualize the composition of a melody by choosing the cards for intro, middle part, and outro of a melody" resulting to learn about simple steps of music composition.

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I also found very interesting the IBA student feedback, suggesting that the prototype is hard to handle due to uncomfortable position by holding the tablet with one hand and manipulating the cards with the other hand. Such feedback made me think that this tool is not enough tangible as it should. Therefore, I have decided to keep the tablet and the cards and conduct further testing in the next workshops to validate this finding. He also suggested to improve the material of the cards by making them more durable for the kids.

Second part of the workshop (game settings and objects tests)

My purpose for this workshop's part was to explore future prototypes and find how the participants perceive the future of the current card prototype. As described in the previous chapter, the Tangible Interaction Framework provocative questions and the suggestions of the UX Lego department (game suggestions) helped be to bring different game contexts and objects which were included in the second part of the workshops with the purpose of provoking and allowing the participants to explore more.

Therefore, the goal of the second workshop was to "couple the physical objects with digital information to support users engaged in a diverse range of activities in which physical objects augmented with digital information" (Paul Marshall 2003 "Conceptualizing tangible to support learning") and encourage exploration of current prototype in different settings.

I was interested in exploring the social aspects and having a focus on learning activities by

- generating experimental steps to allow discussions (geometric paper shapes and objects)
- generating a rapid feedback to allow experimenting (sketching)
- generating meaningful objects that causes exploration (stop/play/stop and small cards)
- generating social interaction and cooperation through game settings (jigsaw, genre maps and quiz games)

Physical workshop findings- IBA student feedback

Since the second workshop part had the purpose of exploring different tangible interactions, I consider the physical workshop to be one of the most important because the participant had the chance to touch, grasp and feel the game settings and the objects. The IBA student started by looking, touching, feeling the objects placed on the table. He asked to look at the objects and think about how the cards could be attached to the respective objects

The interaction (touching and feeling) the with the provided probs, gave him a better perspective "creating its own perception about the object" (Michael Mascolo 2009) which helped in developing different types of interaction and generate new design ideas.

The IBA student first choice was "the paper book". Experiments and discussions arose after he attached the cards to the "paper book" and started sketching on it (see figure 26). He suggested that the current cards can be used in a story telling context "Would be interesting to integrate the cards in a story telling setting in which the cards could be attached to a book [...] resulting in an augmented reality fairy tale book, helping children to hear and visualize the animals and instruments in 3D animation" IBA student quote

Attaching the cards to the paper book prob

Figure 26 Paper book prob

Soon after choosing the paper book he immediately started to play with a pack of cards that helped him to link the ideas and give him even more inspiration, starting suggesting to change the 6 cards game purpose (making or learning music) into a more complex learning activity "What if you will use more sounds effects such as

animals, cars, city noise and make a learning toy for small children in which they need to discover the sounds of our planet?" IBA student quote

He went even further, and while playing with the pack of cards (see figure 27) he got even more ideas "You could create different e-learning pack of cards with different themes such as animals, nature, city, and instruments themes and start create AR animation stories by combining the cards, helping in this way children to learn about the world's surroundings" IBA student quote
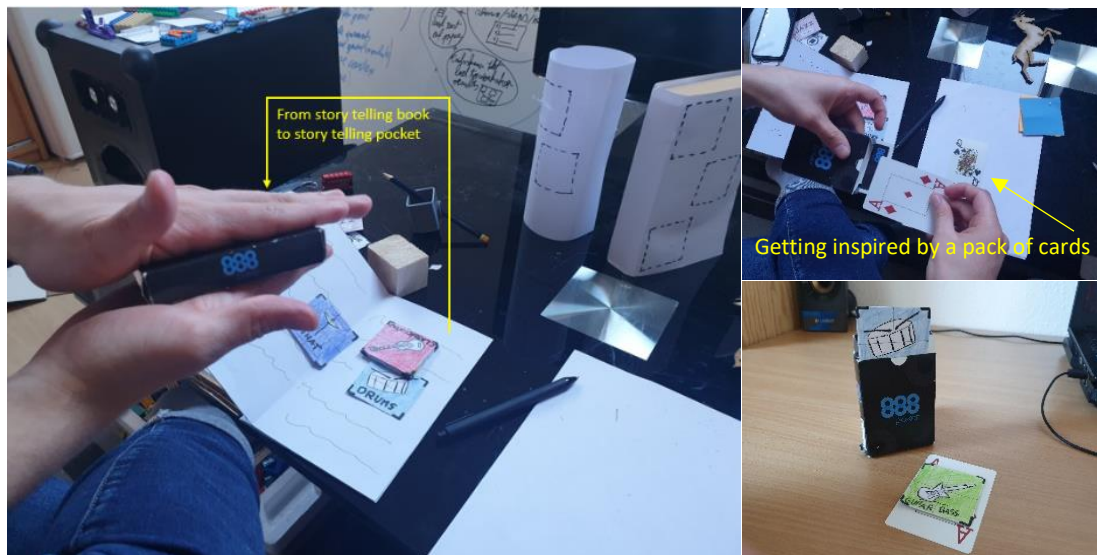
Figure 27 Pack of card prob

After a few demonstrations with the pack of cards, at the same time, he also got inspired by the pre-setup of jigsaw game suggesting two types of game interaction.

Therefore, he suggested to eliminate the "paper book" and use the cards to build stories. He suggested that the current jigsaw game could work as a culture game "For example, if you have different animal cards and start combine the bear card with a fish card, the 3D animation could show how the bear catch the fish […] so, you create your own story combination right on the table" IBA student quote

Another suggestion regarding the jigsaw game was to play with existing melodies or tracks and bring cards that will help to decompose each melody in order to learn about different melody parts and in the same time learn what kind of instruments were used to play the respective melody/track.

When I asked why he chose such setting he said that he got inspired by the genre game setting first, and then slowly he moved to the jigsaw setting. The reason was that "jigsaw gives you the feeling of constructing something, you create something, whereas the genre game is just to test your existing knowledge". Moreover, he admits that such jigsaw setting would allow more participants to play at the same time, due to its complexity, inviting others into play.

Before, in the first part of the workshop (see page 39), the participants were allowed to move the cards freely, more natural and intuitive on the table. Results from the first part of workshop shows that the participants began to be unaware of the cards, but more of the content of the cards resulting in a ready-at-hand interaction, leading to "a minimal cognitive effort of the user." (Hiroshi Ishii and Brygg Ullmer 1997)

On the other hand, the current workshop shows that a certain limitation is always welcome. The game's setting chose for this workshop contained a LEGO board as a limitation. None of the participants claimed that the board is distracting, and it should be removed, but on the contrary, it helped them to play with the cards in a more logical way.

Therefore, it was observed that a more controlled environment in which the participants place the cards in a narrowed place makes them to perceive the cards as "present-at-hand" elements in which the participants are aware of the usability of the cards.

Another interesting observation came when the IBA student, while looking at the Quiz game, he got a new idea and starting to take the Lego bricks (of the bridge) apart, starting to explore by touching and feeling the bricks together with sketching (see figure 28) thus creating even more discussion and shared vision.

Figure 28 LEGO bricks inspiration

"You could build some instruments from LEGO and then find info about the instruments that you have built on the tablet's screen in order to feel that you have co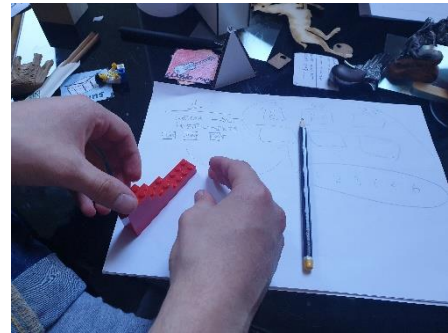ntributed to the construction of the instrument […] so you can make mini instruments models using the same Lego pieces" IBA student quote. Therefore, the participant suggested even a more tangible and graspable interaction by using LEGO pieces taken from the Quiz game and use them for the Jigsaw game instead in which the cards will work as "support" for the LEGO pieces.

When asked why he did such a move he said that "I think children, while building by themselves, will remember easier the instruments then trying to respond to some quiz questions". Therefore, he suggested that Lego bricks could be used as a visual physical tool helping children to faster memorize the instruments by physically constructing them. Considering the first part of the workshop the same constructing tendency of the IBA student was noticeable as well when he suggested to bring 3D animations "You could play with the drums by touching the 3D drums animation and create your own rhythm or for the violin I would like to try poking the strings" (see page 43). This suggests that there is a need for a more immersive experience such as a 3D element that would better help the participant to faster memorize the content.

When I asked why he did not choose the other objects from the table he said that the objects did not inspired him and moreover he really enjoyed the cards idea. So, he would prefer to keep this design and bring improvements for the current cards. So, the workshop results shows that the current cards can be characterized as meaningful objects and we don't need to bring additional elements such as pause, stop, play or smaller cards in order to create interesting effects "I would stay with the current cards instead and I would try to bring more cards elements, having same purpose […] I could not imagine how the other cards (pause/start/stop and small ones) could be used here" IBA student quote.

Online workshop results - Music students' feedback

Even the other workshops took place online, the results were considered as well. I was aware that, through online workshops, I could not bring the same qualitative results found in physical workshops, this representing the biggest disadvantage.

But I was still interested in the other participants' opinions to the game settings and the objects in order to make a comparison between the thoughts of the participants and try to find similarities. Moreover, I was interested in showing the result of the music teacher and together deciding in which direction we should go, given her experience in teaching music to children.

I was surprised to see almost the same results. The music students considered that keeping cards should be enough for bringing the learning experience and boost cooperation between the future users. The online participants brought just a few thoughts about the game and objects elements.

If for the IBA student, the paper book represented the objects of inspiration for the music students, the cube probe represented the element of inspiration that provoked them to explore other kind of tangible interactions. Surprisingly, both music students got inspired by the cube probe, suggesting the cards could be attached to the object and create a game "your card prototype could be transformed into a cube tool" (see figure 29).

First music student suggested that "You could bring two cubes with different instruments and rhythm and play with these by rolling the cubes in order to start compose a melody". Again we saw the same tendency in the first

workshop in which the first music student suggested that the current prototype is too elementary suggesting to bring more aspect of music such as "force" and "piano" aspects in which the children could learn how to combine the instruments by taking into consideration force and piano elements "so, they can train their musical ears and build a melody" music student quote
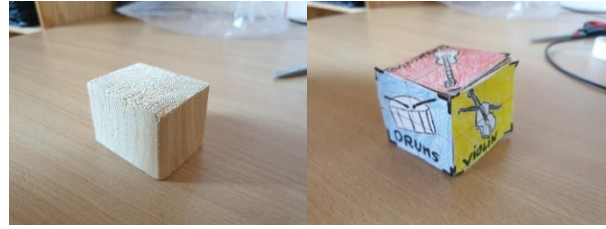

Figure 29 Cube inspiration

So, for the current workshop, the same music student continued with the same idea suggesting changing the tangible interaction by using two cubes as a more interesting game and effect. On the other hand the second music student considered that two cubes would be too distracted and instead she suggested to bring only one cube "get something out of the cube, like a 3D hologram and sounds"

Again, the same tendency of 3D animation was noticed in the first workshop in which the same music student suggested to "change the text and the pictures and include the 3D components of an instrument, explaining for example, what does a violin bow means and how is that bow used […] I see your game as a Google or Wikipedia device". So as a result, she characterizes the cube as a "learning box tool" from which children will learn the culture of music.

I decided to ask both music students why they chose such element (cube) and how they got inspired.

The first music student claims that she got inspired by the jigsaw puzzle setting. So, she tried to evolve it by coming up with the cube tangible interaction idea "create two cubes in which you have to match different instruments and rhythm (the faces of the cubes) and therefore, create different melodies". The second music student claimed that the cubes gave her the feeling of a more tangible tool where the user could better visualize the instruments and "by scanning the cube, some 3D animation could pop up from the cube" resulting for a more immersive experience.

Despite the cube choices the music students agreed that the cards have enough potential. Also the teacher did not consider the cubes being necessary as well, because the children will not use such tool wisely "I remember playing with some cubes in an English class but until the end they ended up just playing and throwing the cubes in another group. They like teasing each other. So, the cards will better work for them", music teacher quote. Moreover, she said that the tangible interaction should be simple in order to stimulate the children interest.

The music students also suggested to improve the current quiz game by changing the quiz cards with rhythm cards instead, that could be scanned by the tablet/ phone device and produce different rhythms sound.

Again, it was noticed a negative feedback towards quiz questions cards, even in a game setting. It seems the game questions are not playful enough and this is not inviting people to interact as it should. I decided to exclude the quiz questions from the tangible interaction especially when I tried the game together with the IBA student. While playing the quiz game together with the IBA student I was surprised to see that after only 5 minutes I had nowhere to go. The quiz questions were not joyful, and the participant could not remember nothing due to the AR text position (vertical) which made difficult for him to read. The same feeling has also the music students, even they did not have the chance to touch and play with it.

Music teacher feedback

The last online workshop took place with the music teacher with the reason of showing and discussing the results and together decide what could be tested as a next step and which direction I should go. The results of the IBA and music students participants were presented in the end of the workshop in order to do not influence the teacher's own findings.

Considering the teacher is using different active learning activities/methods in the music class to teach 6 graders, she was more interested into the game settings.

The objects/probes brought for this workshop, did not represented an inspirational source for her and she could not see the objects to be used in a social context. Moreover, she suggested the tangible interaction with the current cards should be simple "music is about simplicity, and not complexity", music teacher quote. Therefore, the recommendation of the schoolteacher is that it is important that the interaction of the prototype be simple to allow children to focus and learn.

Considering the game settings, she was inspired by the Genre and Jigsaw games, suggesting the kids could learn more about music genre while using more cards than existing ones and place the cards in a more controlled setting "Your cards could be used to introduce different kinds of music genre, helping them understand the formula of the genre and from where the respective music genre is coming from". She also said that "is very beneficial for children to concentrate and to improve their listening skills while playing the genre game by listening to the genre cards and trying to find and collect the respective instruments"

The same tendency of suggesting more cards elements, was noticed in the first workshop part as well suggesting creating different card levels to allow children building an actual melody while having more cards rhythm choices. For the current workshop, the teacher suggested again to bring more cards elements to make the tool more complex but still do not overcomplicate. Therefore, the tangible interaction needs to be simple and the content of the tangible object should be more complex to allow children curiosity and therefore, explore more.

The Quiz game managed to generate some ideas as well. The teacher was inspired by the competitive activity offered by the Quiz game, so she decided to elaborate even more on this idea by enhancing, even more, the social interaction and learning. Hence, more suggestions coming from the teacher consists of changing the backside of cards (quiz questions) with a scanning code instead "Once the user scans the code, he/she will be redirected to the Kahoot game website" music teacher quote.

The teacher mentioned already the Kahoot game in the beginning of this paper (page 16) when I asked what kind of learning activities she uses in class. "I already use Kahoot game to monitor the kids […] this is not an evaluation this is more like a feedback for me to see if the students understood the lessons or not".

When I asked how she would apply such game setting in the class she said "This can be played in small groups […] the game could contain 5 questions per each card. The first group can dive more into guitar instrument and the second can dive more into drums, for example […] and they can give a presentation in the end to each other or test each other".

Conclusion of second part of the workshop- Findings' summarize and further decisions

The results were summarized and placed in the table 7 for a better visualization of the results that will help to further develop the interaction of the prototype

IBA student	
NAME OF TANGIBLE TOOL	**THE INTERACTION**
The story telling book	Bring Augmented Reality fairy tale book, helping children to hear and visualize the animals and the instruments in 3D animations.
AR cards packages story telling	Bring cards with different themes such as animals, nature, city, and instruments themes and start create AR animation stories by combining the cards.
Decomposing melodies- jigsaw game	Bring cards with different melodies/tracks and start decompose each of them in order to learn about different melody parts and in the same time learn what kind of instruments were used to play the respective melody/track.
The Lego bricks instruments	You could build some instruments from LEGO and then find info about the instruments that you have built on the tablet's screen in order to feel that you have contributed to the construction of the instrument […] so you can make mini instruments models using the same Lego pieces.

Music students	
TITLE	**TANGIBLE INTERACTION**
The cube/cubes	Bring two cubes in which you must match different instruments and rhythm (the faces of the cubes) by rolling the cubes and therefore, compose different melodies by combining instruments" Bring one cube that works as a "learning box tool" from which children will learn the culture of music and better visualize the instruments in AR 3D models By scanning the cube, some 3D animation could will pop up from the cube.
Rhythm cards	Bring different cards with different rhythm sounds and start combine them

Music teacher	
TITLE	**TANGIBLE INTERACTION**
Genre game	"Your cards could be used to introduce different kinds of music genre, helping them understand the formula of the genre and from where the respective music genre is coming from". She also said that "is very beneficial for children to concentrate and to improve their listening skills while playing the genre game by listening to the genre cards and trying to find and collect the respective instruments"
scanning codes	"Once the user scans the code, he/she will be redirected to the Kahoot game website.

Table 9 Game setting & Objects workshop results. An overall view of participants suggestions

The second workshop helped in finding other types of tangible interaction by inviting the participants to interact (physical workshop) and observe (online workshop).

The workshop showed that the experimental prototype (AR 6 cards) was treated by the participants being almost invisible in which the users were focusing on the task that the prototype is used for (listening to the sound, reads the text, watch the video and pictures). Therefore, was observed that the cards were perceived by the participant

as a "ready to hand" tool in which does not matter how you place the card because the participants will have the same results (Paul Marshall 2003). Currently, all the cards produce the same rhythm on the same BPMs as a result and you cannot see the difference between them.

The participants suggestions were to bring more card's elements and jigsaw games which allow for doing more experiments and exploring more the tangible tool. Therefore, we understand that the tangible interaction should address interaction and encourage cognition or shared cognition between users in which "knowledge is constructed via dialogic thinking in which ideas are shared and pondered in a group" (William Roy and Timothy Dowd, 2010). Cognition is "the mental action or process of acquiring knowledge and understanding through thought, experience, and the senses" (Lucille M. Foran 2009)

Therefore the workshop findings showed that there is a need for a "present at hand" tool in which the cards should be more meaningful, acting more like meaningful objects which could bring more "interesting effects and control for the user" so people focus more on the tool for a better tangibility interaction and learning in which different card elements action resulting in acquiring knowledge.

Besides the cards which are not diverse, the freely way of manipulating the cards on the table should also be changed by considering a more controlled environment of manipulating the cards such as different pre-setups/ configurations which could bring people together and allow for mutual help and coordination in which group discussions will take place.

I noticed this inclination in the second part of the workshop where the participants chose the Jigsaws and Genre game as an inspirational element. Both games settings came with pre-setup boards, helping the game's steps to make much more sense, facilitating the participant to explore even more. In the beginning of this paper I believed that a freely environment will bring much more creativity and will allow people to explore but the workshop showed that free handling of cards can be a weakness.

The results of the workshops also showed that the current AR elements (video, text, and images) can disturb the participants and therefore, make the participant to do not focus on the tangible tool anymore. The IBA student claimed that he "cannot focus on the cards due to the tablet and the enormous AR information that is appears on the tablets screen" making him to perceive the current cards as "ready at hand" elements which does not allow him to experiment and explore. Therefore, he chose the "AR story telling playing cards" or "paper book" or the "jigsaw game", in order to give a meaning to the cards, transforming them in a more "present at hand" tool, thus, allowing him to explore more.

As a further research I have decided to keep the current 6 cards and the freely tangible interaction and instead focus on the AR elements to validate the findings from the previous workshops and conduct further testing sessions with more people.

I also was not convinced by the current AR elements so I have decided to improve the AR content with the purpose of better enhancing the learning activity and to find possible learning benefits while using AR content.

Second functional prototype (AR improvements)

In the beginning if this paper I came with an hypothesis in which I wanted to create a Tangible User Interface that support AR and make the interaction of the user with the cyberspace more natural and intuitive using "ready at hand" tangible tools that leads to a minimal cognitive effort of the user. (Hiroshi Ishii and Brygg Ullmer 1997). The hypothesis was that in this way users will be able to cooperate more between them and push the users to become more creative together. Therefore, I have asked myself what is the value of grasping and manipulation? And how can I use tangible objects (physical environment) together with digital (cyberspace) that supports learning and moreover cooperation between users?

The functional prototype evolution (first and second functional prototype) represent an interative process. Generating ideas and "think outside the box" helped to look for different ways to explore the problem and identify new results. Therefore, different experimental workshops were included to identify the best possible solutions and allowed me to investigate the prototype elements weaknesses and strengths.

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The results from the previous workshops lead to another iterative process. The accumulated feedback made me go back and start improving the prototype again. Therefore, in the next chapter, I will discuss improvements to the AR and GUI elements in order to enhance learning.

Prototype evolution

Therefore, AR text, and images have been replaced with a simple 3D animation illustrating the musical instruments of that card and only one card was chosen to have AR video instead (the demonstration video of the improved 6 cards functional prototype can be found here https://www.youtube.com/watch?v=0wKAJoJidd0).

The next page illustrates a comparison between the previous (old) prototype with the improved (new) prototype.

- The handpan instrument card (figure 30- orange quadrant) is the only instrument that contains an AR video instead of 3D animations. As figure 30 shows, AR image and AR text were used before to the "handpan" card. Now, these elements were replaced by an AR video having a horizontal position to improve visualization. The reason for changing with video was because I wanted to further test people's reaction and make a comparison between the AR elements.
- For the rest of the instruments (hihat, violin, bass guitar, classic guitar and drums) I chose to use 3D animation.
- All the cards contain the same interface in which included GUI buttons for a better user experience and interaction. The buttons have the purpose of killing the sound (kill sound button,) and show or hide info text (info text button,). Regarding the AR info text, I opted for a GUI text, that can be seen on the tablet's screen for a better view. If users no longer want to read the text, now they can always hide the information by pressing the "info text button".
- As I noticed in previous workshops, the sliders helped in mixing the sounds of different instruments resulting in interesting effects, so I found it interesting to keep and conduct further testing.
- I still chose to keep the current physical cards because for this step, I was interested in improving the AR and GUI elements.
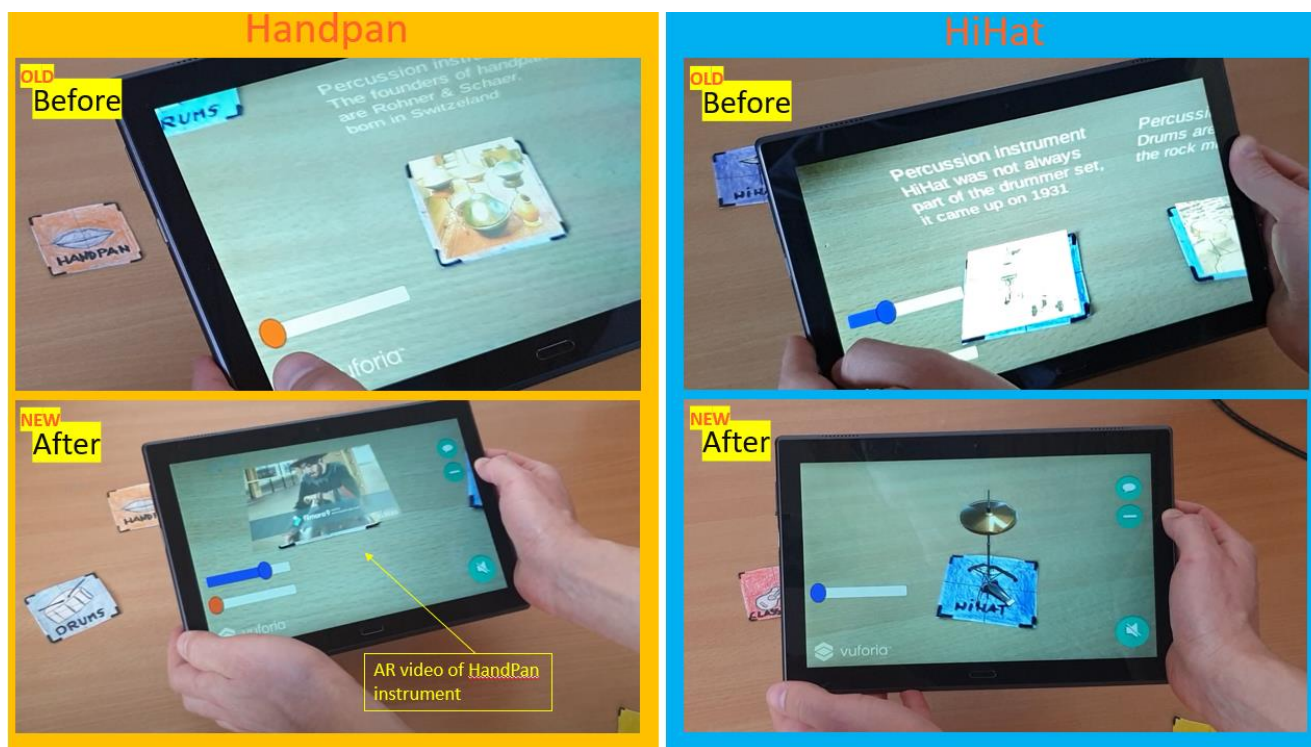

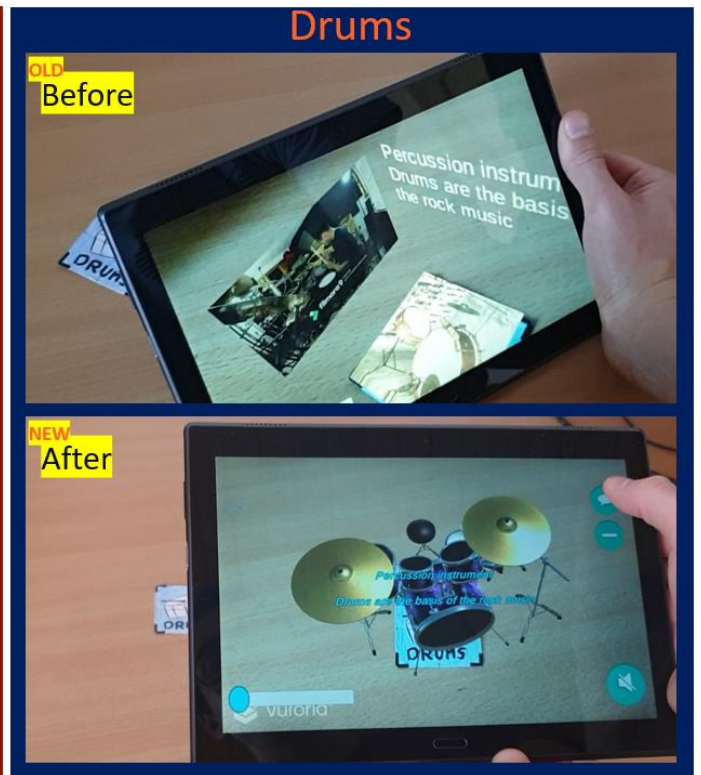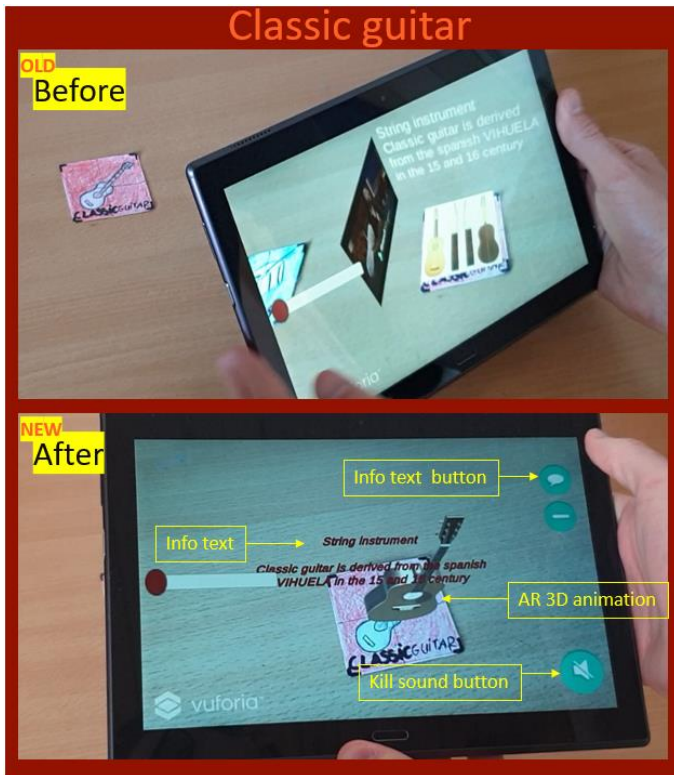*Figure 30 Percussion instruments. Old vs New design and interaction*

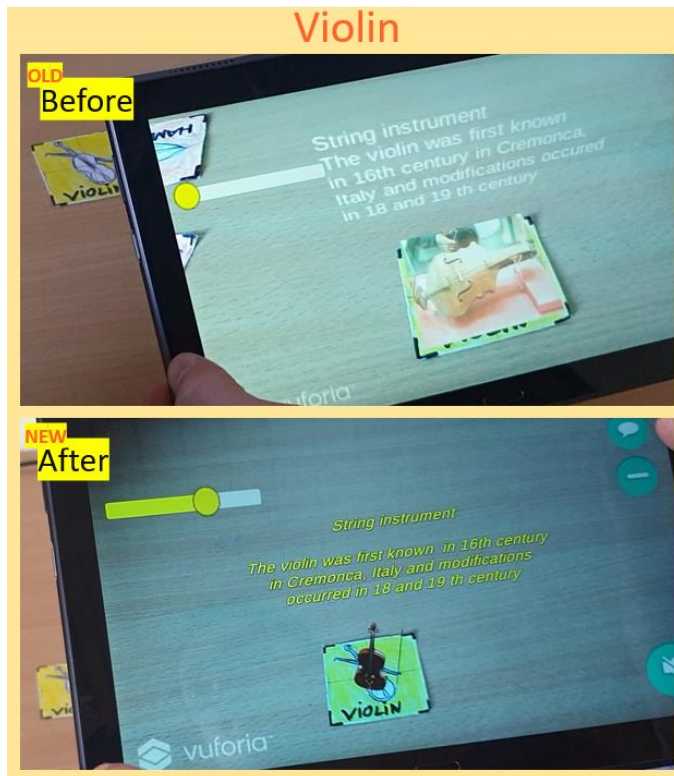*Figure 30.1 String instrument (left) and Percussion instrument (right). Old vs New design and interaction*

Figure 30.2 Strings instruments. Old vs New design and interaction

	Physical testing			**Online testing**
Occupation	Top-up Marketing and Sales. student	Master student	Graduated Master student	Music teacher 2-5-6th grade
Institution	International Business Academy, Kolding	South Denmark University, Kolding	South Denmark University, Kolding	Public School Petersmindeskolen, Vejle
Participant name	Andrei	Jasmin	Alex	Judith
Research type	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting)	Open discussions and prototype video demonstration (Skype meeting)

Table 10 An overview of the participants. Online and Physical testing

After improving the AR and GUI elements I have decided to conduct further tests in which two SDU design students and one IBA marketing student participated in physical test and music teacher in an online test.

The observations show the IBA student was much more interested in the AR 3D animation and GUI elements besides the SDU students which focused more on the sound element and purpose of this prototype. Regarding the AR and GUI elements I got good feedback saying that the instruments has a good size, allowing to see the details of the instruments as well. I got the same feedback from the music teacher saying that "kids will love it, is really joyful to see the instruments in 3D, because they can see the details".

Considering the IBA student when he interacted with the 3D animations, I observed a tendency toward joyfulness /playfulness and not on learning. He was focused more on the animation saying that he would love to interact with it even more. "could be displayed people singing to the instruments in 3D […] make it more active and once you stop the sound of the instrument, the animation stops as well, so, it interacts with you […] give more life to it" IBA student quote

I saw the same tendency in the previous workshop when the same participants asked if I could include animation for a more immersive experience. This made me to question the implication of 3D AR elements which might be distracted for the user.

On the previous workshop the IBA student also claimed that the tablet represents an obstacle, making the cards to do not feel that tangible and he suggested the elimination of the tablet. For the current workshop I have observed a different perspective. This time he suggested to keep the tablet and eliminate the cards for a better visualization and interaction of the 3D models "Once you scanned the card, I feel you do not need the cards anymore […] you can take the 3D animation and place it everywhere you want in the room on any surface". Very interesting is that once the 3D animation appears, the users does not appreciate anymore the physical cards' interaction.

Later he said "I know you want to use the cards but is still a bit harder to manipulate the 3D animation while moving the cards and holding the tablet" making him wish the cards to be eliminated. This was a big concern for me, and I started to ask myself if the 3D animation decrease the value of the physical card.

The elimination of the tablet was also proposed by the two SDU students. Alex, one of the SDU student said that "The interaction should be more freely […] and I don't think is convenient to have one tablet for more than 2 persons […] also this is not that physical for me […] would be much more interesting if I could build
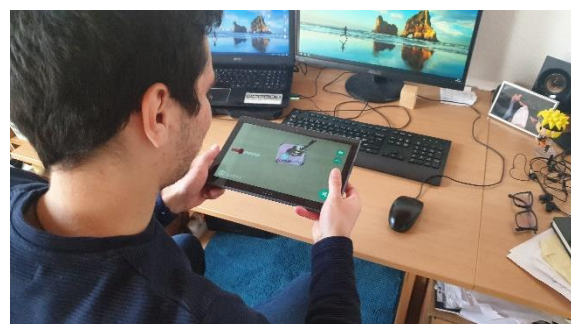

Figure 1 IBA student testing the prototype

something on the table/surface with my both hands." In meantime Jasmin, the second SDU student had the same opinion saying that " I had to look through the screen in order to see where my cards are placed and visualize the 3D animation, making the interaction with the cards a bit uncomfortable me […] a phone will not help either".

For this workshop I specially chose the two SDU students (Alex and Jasmin) to test the prototype together. The tests show that users cannot even cooperate between them and it turned that each user was using the prototype individually while the second participant was watching and not even helping to change the cards. While the main user was busy to arrange or change the cards on the table/surface the second user was busy watching the 3D animation.

The scope of this research paper is to bring a tangible user interface that encourages people to get creative, cooperate and explore. Another interesting aspect emerged during the testing. The two SDU participants felt these cards already feature a melody that won't let you explore "it feels like it is already decided what songs is this […] so it seems that you are building an already established song and you cannot build a customizable one" Jasmin, SDU student quote.

When I announced that this song was supposed to let you create your own sequence and there is no pre-set song in the background, Alex, the second SDU student, also reacts by saying,

"What?! Is it not an existing song? It reminds me of an existing melody. I also though this is a piece of music and you must dissect it […] I thought there is already a recorded melody and you start dissecting it by using cards"

Immediately I have realized the cause. It was because, while choosing the instruments loops in the Music Maker software, for the cards, I selected the same BPMs of 120/ minute (beats per minute) and the same Pitch (the harmony) for each instrument to facilitate the composition and make this activity easier for the participants. According to the feedback the users are not able to explore and make their own combinations anymore while having these two aspects (BPMs and Pitch) for the same instrument cards.

This represented a huge breakthrough which lead to change the prototype by creating and bringing more card elements with different BPMs and rhythms. Moreover, I got the same feedback in the previous workshops in which the participants asked for more instrument's cards as well. Until this current workshop I could not realize why people felt a need to bring more cards.

The SDU students suggested even a genre game "a Genre game would be nice, so take different famous genre tunes and decompose the melodies in different parts, so you have to find the right instrument to the specific genre. For example, you cannot use a handpan instrument in this specific jazz melody. So, teach them the importance of each instrument in a specific genre" Alex quote

Jasmin, the second SDU student participant supported Alex saying, "from a learning perspective, you could dissect melodies like taking an already known track and dissect it using the cards […] so maybe there is a person which is very interested intro a song and instead of reading how this was made they can build it by moving the cards and listening to the instruments "

Discussions with SDU students shows almost the same results with the previous workshops results (Tangible Interaction framework outcomes) on which music students and IBA student showed that there is a need for a "present at hand" tool in which the cards should be more meaningful, acting more like meaningful objects which could bring more "interesting effects and control for the user" resulting to an expressive activity.

Both SDU students focused on an expressive activity as well that focus on construction of an actual model or representation suggesting that cards could be used expressively by combining them together to create

Figure 2 SDU students testing the prototype

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interesting patterns such as deconstructing or constructing a melody (similar to the jigsaw game suggestion of previous workshops). The SDU students showed that there is a need for a present at hand tool in which they are aware about the usability of the cards and place them on the table with a purpose, compared to a ready at hand tool in which the user just throw the cards randomly on the table and start create sequences using the same BPMs with same Pitch and Rhythm.

Conclusion of the second functional prototype

Paul Marshall (2007) in his paper "Do tangible enhance learning" raised the question "is unclear which elements of tangible interface designs are critical in supporting learning activities and the roles played by the physical and digital elements in different design remain to be mapped out". I also encountered this problem in my prototype and, due to the process of iterating the prototype, I concluded that

- AR 3D elements can sometimes represent a distraction from learning and physical interaction making the cards to act as a ready at hand tool
- Too much freedom on the table (no boards) makes the cards to lose the purpose and instead lead the user to focus more on the AR elements, perceiving physical cards as a ready at hand tool
- Low diversity of cards does not allow exploration and learning
- The same BPMs and Pitch of the instruments cards does not allow exploration and learning
- The tablet constrains users and prevents them from cooperating

Moreover the paper "Do tangible enhance learning" by Paul Marshall (2007) suggested that "a present to hand approach lead to increased planning and reflection, which in turn lead to improved learning compared to easy manipulation of concrete objects (ready at head) could lead to decreased reflection, planning and learning". So, there is a need for concrete materials for expressive learning. Therefore, for the next prototype (third functional prototype) I decided to include more card elements and eliminate the tablet to increase the tangibility and challenge the user to be more aware about the usability of the cards.
After physical workshops, an online discussion with the music teacher was settled in which I have presented the results of the SDU student participants with the purpose of deciding the direction of the prototype.

The discussions confirm the findings and she agree with a larger diversity of the cards, but the music teacher reminded me again that "music is about simplicity, and not complexity" because "children tend to overcomplicate the whole thing" and "they need someone to tell them to keep it simple" and teach them that "music not about to be complicate but is about the simplicity of the notes and tones" music teacher quote.

In the beginning of the research paper (semi-structured interview page 16) I have asked the teacher once, What is the biggest struggle you faced by teaching kids?", She answer that, quote "The biggest trouble is the self-discipline, they do not take any responsibility for music/composition lessons". The teacher was afraid that once creating more cards elements the children will not be able to learn to understand the game and will start just play around without learning nothing.

In the earlier workshops the teacher even suggested to bring different cards level to make the game more logical in which the children are aware about the usability of the cards (present at hand) allowing in this way to bring a larger diversity including more complex content of the cards but in a more controlled environment. Such a suggestion was also taken into consideration.

In conclusion the purpose of the workshop was to improve the learning experience and test and find possible learning benefits while using the AR and GUI elements. The workshop did not show promising results and it did not confirm the usability of the AR and GUI elements. Moreover, the workshops did not confirm if such elements could enhance learning. Therefore, for the next workshops I have decided to keep the AR and GUI elements for further testing in order validate the current findings.

Third functional prototype (tangible interaction improvements)

Therefore, before starting to test the prototype with the possible end users (5 and 6 grades children) I have decided to go back and improve the interaction and the design of the 6 cards by bringing 20 cards instead.

As mentioned before, together with the music teacher we agree of a potential target group which should be children from 5 and 6th grades (12 years). According to the teacher this is the average in which they start to better handle the devices and start pay attention to details. "This prototype should definitely not be for the small ones. It would be interesting for the biggest kids like 5 and 6th grades because they know how to handle a phone/tablet and pay attention to details "quote by music teacher. Moreover, the earlier workshops findings showed that the current prototype could be characterized as an initiation tool for young beginners, that would help children to accommodate with music.

Prototype evolution

Interaction of the cards (first step)

As a first step I decided to improve the interaction of the 6 cards and as a second step to improve the design and content. Therefore, as a first step, I chose to change the interaction using a webcam instead of a tablet (see figure 33). I chose a full tabletop interaction, allowing the user to utilize both hands for a better grasping and manipulating feeling of the cards.

In order to make the interaction work, I chose a webcam, a computer, and speakers. As you can see in figure 33 the webcam position was placed on the top, having the role of filming/scanning the cards from the surface. The webcam (which is connected to the computer), in my case represent the input which scan the cards; the computer screen representing the output showing the AR 3D elements on the screen and the speakers of the computer representing the output for the cards' sound.

The technical test worked well and I decided to continue with this type of interface and start designing the cards and conducting further tests with a few IBA and SDU students (physical tests) and finally organizing online discussions with the online teacher..
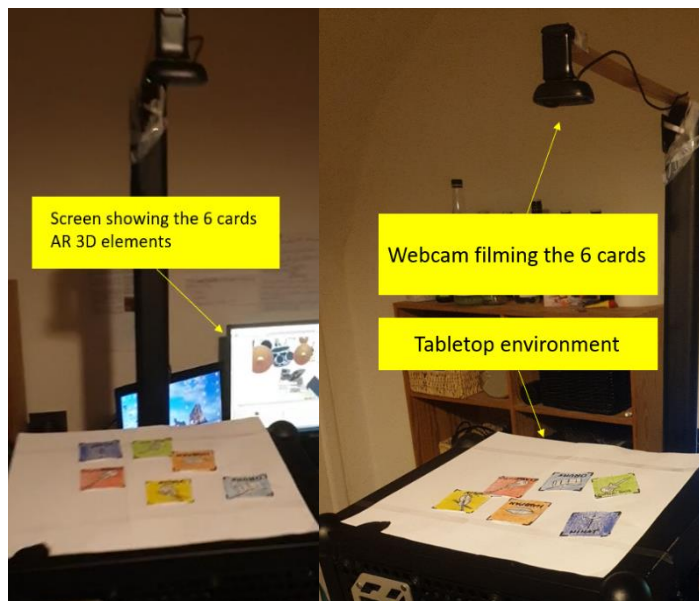
Figure 33 Full tabletop experience

Design & Configuration of the cards (second step)

As a second step, I decided to improve the design and the structure of the cards such as the material they were made and the icons. There are two reasons why I changed the icons and the material of the cards.

- The first card prototype was made by paper and it could have been easily bent, leading to the risk the user to break the cards by mistake. Moreover, the bending issue did not allow the camera to perfectly scan the cards leading to scanning issues, leading further to poor user experience. Therefore, I decided to use plastic cards instead which are more durable.

- The symbols of the old instrument cards were colored by hand (see figure 34). Due to too frequent use of cards, the symbols began to fade. Such an issue lead to camera scanning issues and the camera could not read the cards anymore. So, I decided to create new symbols in Adobe Illustrator and then use a sticker machine to print high-quality symbols that will allow camera for a faster tracking of the images. Also, colors and the names were changed (see figure 34).

  As can be observable in figure 34 the new cards' classification of the instruments are matched to a color code. For string instruments (violin; classic guitar; bass guitar) I chose more warm colors (yellowish-orange); for percussion instrument (hand-pan; drums; timpani) I chose more cold colors (blueish-purple) and for keyboard instrument (piano) I chose green color in order to differentiate them.

  Also, to spark the interest of the user the name of the instruments was eliminated and instead replaced with a general classification name (string, percussion, and keyboard). If the user wants to know the name of the instrument, now they must scan the cards and find the name in the info text.

Figure 34 An overall design comparison between old and new cards (tracking images)

The structure of the cards was changed as well resulting in two sides, front and back side.

- The backside of the card is meant to learn about the instruments' facts for those which are interested in learning more about the instrument itself. Therefore, on this side of the card the user can find the AR 3D elements together with GUI buttons and the info text (see figure 34.1). This side of the card does not contain any sound/noise to do not distract the user while reading.

- I decided the elimination of the hi hat instrument because the drum set already contain hi hat instruments. This card was replaced by a timpani instrument instead

- I chose to keep two types of AR elements. All the cards contain 3D AR models except the two of them (handpan and timpani) which contains AR videos representing the usability of the instruments. The reason of keeping the two types of AR elements was because I wanted to see what people find more interesting and what aspects better enhance learning

- The front side of the card is meant to play/compose different sequences, taking into consideration different rules such as BPMs, Rhythm and level of the card. As figure 34.2 shows, the card's levels are illustrated with numbers. The bigger number, the more complex the rhythm will be, and the as lower number, the cooler the rhythm will be. Each card contains also sounds waves symbols of the rhythm for a better visualization of the card complexity in which the number match the rhythm waves.

  Such improvements were included to allow user to experiment more and allow to compose different sequences. I also decided to include one more instrument such as Piano (green card) for a greater diversity, resulting in 7 instruments. Since I brought so many changes, I decided to do not include more instruments cards or rhythms and test the new interaction and structure & design. Also, in order to indicate the sound is working, I chose to include small AR 3D green dots for each card (see 34.2)

- Due to the new interaction (tabletop), I did no longer need the volume sliders and the "kill sound" button because now the sounds go on (when the camera detects the tracking image) and off (when the camera does not detect the tracking image) automatically.

Below can be observable an overview of the new cards and a few pictures' demonstration of the AR elements (for a video demonstration click here https://www.youtube.com/watch?v=46fZRL1s6Q0)
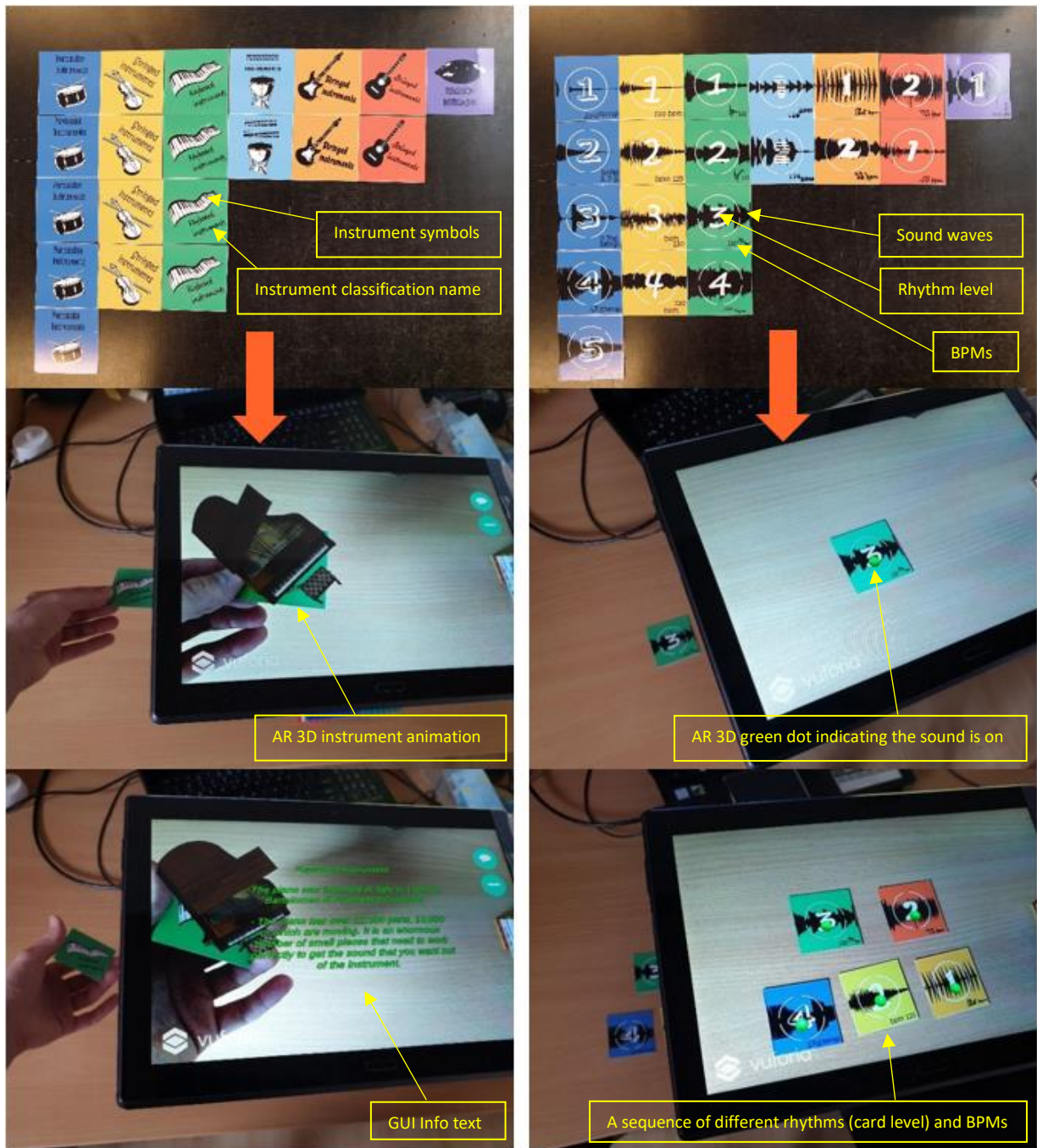
Figure 34.1 Back side (learning mode)

Figure 34.2 Front side (playing mode)

Back side (Learning theory purpose)

Contain

- 2D symbols of each instrument category
- Name of each instrument classification
- Some cards contain AR 3D Animation, and some contain AR Video of the instruments
- One GUI button for showing or hiding interesting facts about and usability of the instruments
- This card's side does not contain any sound

Front side (Composing sequences purpose)

Contain

- Sound waves symbols of the rhythm (drawings)
- Cards are noted from minimum level 1 to maximum level 5 representing the complexity/difficulty of the rhythm
- Some cards are noted with 120 and others with 125 BPMs to teach the user the importance of the BPMs when trying to compose music
- AR green dots indicating the sound is on

Third functional prototype workshop results

After improving the cards and before start to test with the potential end users (children) I have decided to conduct a last prototype tests with two SDU students ; 2 IBA students and the music teacher in order to find the gaps and bring suggestions of improvement.

Physical testing							
Occupation	Master student	Graduated Master student	Top-up Marketing and Sales student	Top-up Marketing and Sales student	Music teacher (2-5-6th grade)	Three Pupils (age 6; 9 and 11)	12 pupils Music class 6th grades
Institution	South Denmark University, Kolding	South Denmark University, Kolding	International Business Academy, Kolding	International Business Academy, Kolding	Public School Petersmindeskolen, Vejle	Public school, Esbjerg	Public School Petersmindeskolen, Vejle
Participant name	Jasmin	Alex	Cristina	Andrei	Judith	*Confidential* (the parent did not agree to expose the names)	Unknown
Research type	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting)	Observing and Intervention (physical meeting	Observing and Intervention (physical meeting	Music teacher observation and intervention
Testing & Developing the prototype						End-user tests	

Table 11 An overview of the participants Physical testing

SDU and IBA students' tests

The tests worked well. The participants enjoyed using both hands, leading to a more joyful experience. The new cards were highly appreciated as well especially the tone color of each instrument category "The first thing you see is the color then the symbols of the instruments, the color is important to differentiate the cards, but the image symbols are important to define the instruments" SDU student quote.

Small suggestions arose such as

- The cards level numbers are confused. They said the number does not make that much sense because there are empty numbers. "Since the numbers represent the card level, would be nice to write the "level" word on the card as well" IBA student quote
- "The BPMs are not visible enough and it should be bigger" SDU student quote

- Bring guidelines explaining the elements from the backside of cards "Bring a legend that explain the BPMs, the cards level's numbers and the waves symbols" IBA student quote
- Interesting is that participants felt a need for a board in order to keep the cards more organized on the table starting suggesting to bring "a frame which will contain spots for each card […] like a board with 6 or 8 places for each card" IBA student quote or "you can easily get confused on the cards, I think a board will be necessary in order to keep it organize" SDU student
- Also, the users claimed that the composition music part (front side of the card) is much more interesting than the theoretical part (back side of the cards).
- Considering the card's backside, the participants find AR videos much more interesting than the AR 3D animation because the videos shows the usability of the instruments and not just a static 3D instrument.
- All the participants suggested to bring even more rhythm cards and not necessary more instruments.
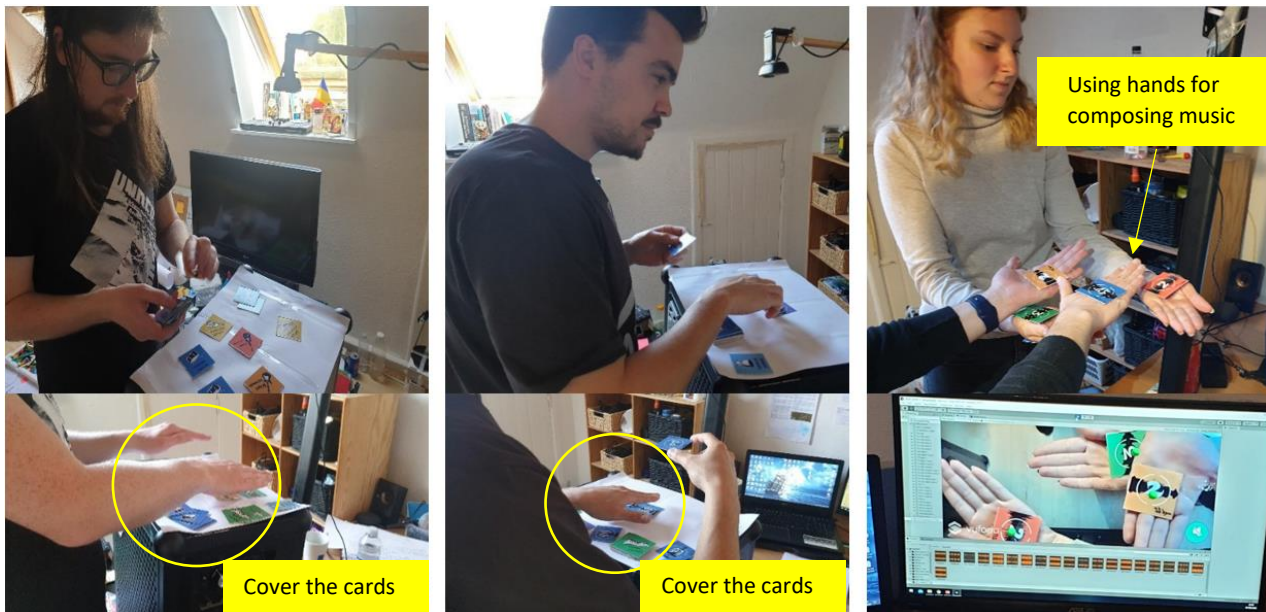
Figure 35 New tabletop interaction. The participant's hands motion. SDU (left and middle) and IBA (right) students participants.

For this workshop I specially chose two participants (IBA students) to test the prototype together in order to explore the social interaction. The usability of both hands has raised interesting interactions that I would not think of and that was worth studying in the future. While using the cards more interaction occurred. The two IBA students while manipulating the cards they began to put the cards on their hands and make music with the hands' movements (see figure 35- right side). I was surprised by this interaction I decided it was worth studying in the future.

Also, the figure 35 (left and middle) shows the two SDU students started to place more cards on the surface and cover with their hand allowing to create music. I found interesting such interaction because the participants claimed that "I feel like I am using a DJ tool, but I do need to touch the buttons" or "this reminds me of a DJ controller but a much more easier interaction" SDU students quote. But for now, I have continued to test the current tabletop interaction.

Music teacher meeting' findings

After finishing the testing with the SDU and IBA students I have decided to meet with the music teacher and together to discuss and decide the last improvements, before meeting with the potential end users and conduct further testing. Therefore, together we decided upon a few changes such as

Make it portable

The prototype should be potable in order to allow testing in in schools and/or at children homes. For making the portable possible the webcam and the computer were eliminated and instead I replaced it with the tablet which was placed on the top of a support/stand. Therefore, the stand needed to hold the tablet so, I used LEGO pieces that allows me to build a customizable stand for the device (see figure 36)
(for a video demonstration of third functional portable prototype click here for part 1
https://youtu.be/XCk9q6b3WtY and https://youtu.be/HmQSzwrSsvE for part 2

Bring a board

We decided to include a paper "board" with the purpose of helping the user to pay more attention to the cards and keep them organized. The paper board was divided in 3 quadrants (see figure 37). Each quadrant of the board is attributed to an instrument category (strings, percussions, and keyboards). In this way the visualization and the awareness of the instruments will be improved, making the user aware of what instruments are playing on the background and keep the cards organized.

In this way the prototype will increase the awareness of using cards and challenge the participant to create a melody structure (intro; middle part and outro) at the same time, being aware of the cards.

Create a task

Together with the music teacher we have decided to focus on "composing melody" exercise. We agreed that the level of the cards is good enough to create a task "You can feel the small level cards are hitting a few notes compared to the bigger level which has more complex notes and rhythm" music teacher quotes

Therefore, the exercises aimed to ask children to create a sequence by building the "stairs" of a song that contains the intro, middle and part.

We also agree that the BPMs represent an obstacle (in a good way) for the children allowing them to make mistakes by not matching the correct BPM cards, making them think about the usability of the cards.

Distribute questionnaire

After children's tests I decided that a questionnaire could be distributed in which the children should express their opinion by responding to each question. (see Appendix page 77)

The questionnaire will help in defining whether the current music system is working well for the children and if they wish to use the system in the future as well.
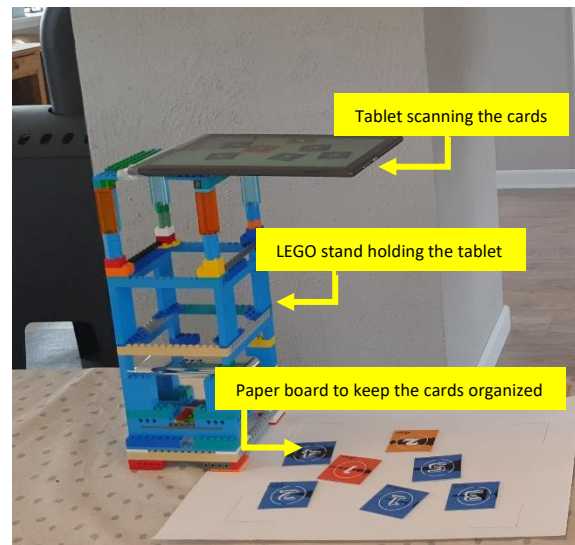
Figure 36 The LEGO stand holding the device
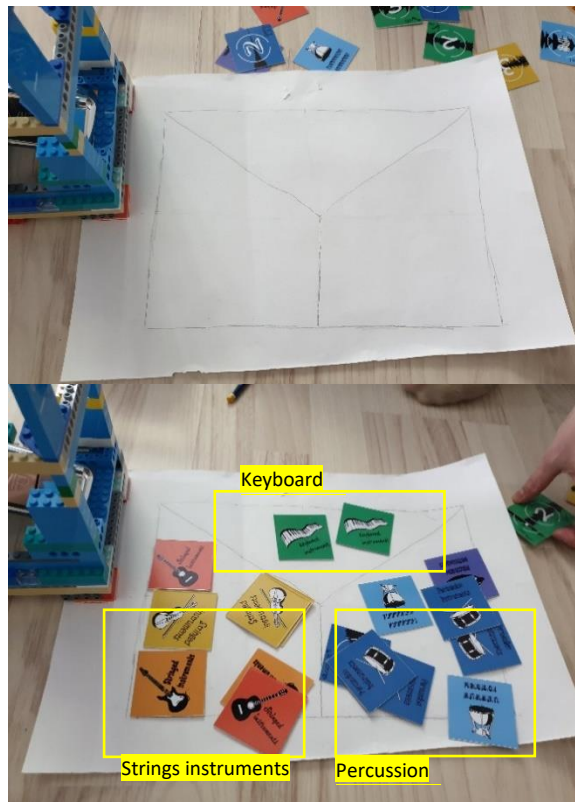
Figure 37 The paper board' quadrants

Keep the current design

We have decided to do not change design of the cards and keep the current elements of the cards (AR elements and 2D symbols) to ask the opinion of the children as well.

The potential end user tests (Three children)

After last improvements I decided to conduct a field visit and together with 3 children to test the third functional portable prototype

Finally, a field visit played a crucial role in understanding children's behaviour towards the TUI prototype system, helping to identify how children cope with digital and physical representations in their natural environment. The test was conducted with 3 children with three different ages such as 6; 9; and 11. For this experiment I chose to do not include the quadrant board and just a piece of paper indicating where to place the cards.

As a first step, I asked the children to play freely, without being given information about cards and without being given any task. It was observed that they did not used the learn mode and just the composing mode. Such a test also showed the importance of a guideline or a person to explain the basics of building a song in order to start using the cards appropriately, in the same time, taking into account the symbols on the cards, to make sense of the use of the card.

Observations have shown that, without giving guidance, children will only start playing, chaotically mixing the rhythms of the cards. During the tests I noticed children began to behave like being a DJ, placing the cards randomly on the table and trying to figure out how to match the rhythm of the cards. They also did not pay attention to the "theory" side and started directly to play with the rhythms (front side).

As a second step, children were asked to build/ compose the intro, middle and outro part in order to create a melody. Before starting I only gave them a few hints about the card's level numbers. All three children started to play and contribute to building the intro part of the melody. I was impressed to see that they took into consideration the numbers starting with a level 1 card for the intro part. As figure 38 (next page) shows they started with a level 1 card continuing increasing the complexity of the sequence adding 3 more rhythm cards indicating the intro of the melody. Soon, the middle of the melody contained even more instruments starting to mix the rhythms. The cards were placed everywhere and soon it become a small chaos (see figure 38- third quadrant) Soon they started to check all the cards and listen to the sound without even looking at the numbers or taking into consideration the BPMs.
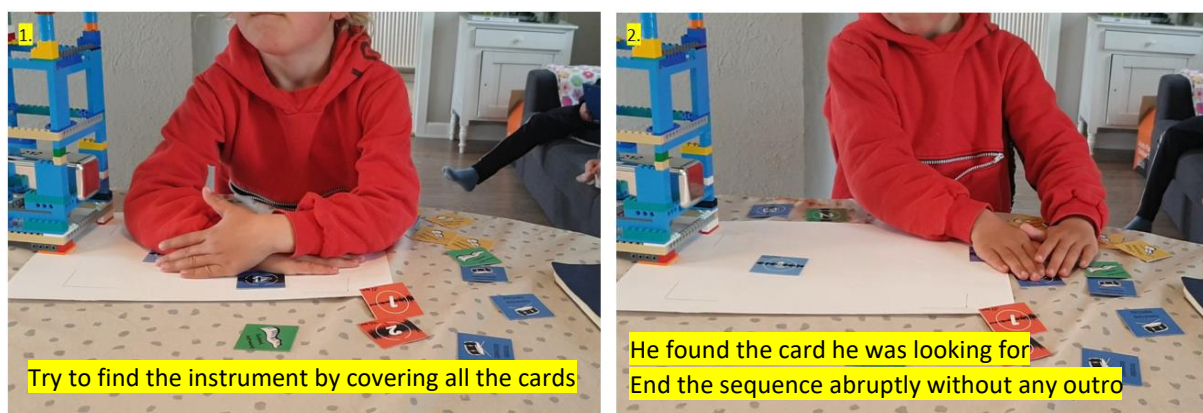
Figure 38.2 Finding the instrument sound. Children interrupting the sequence
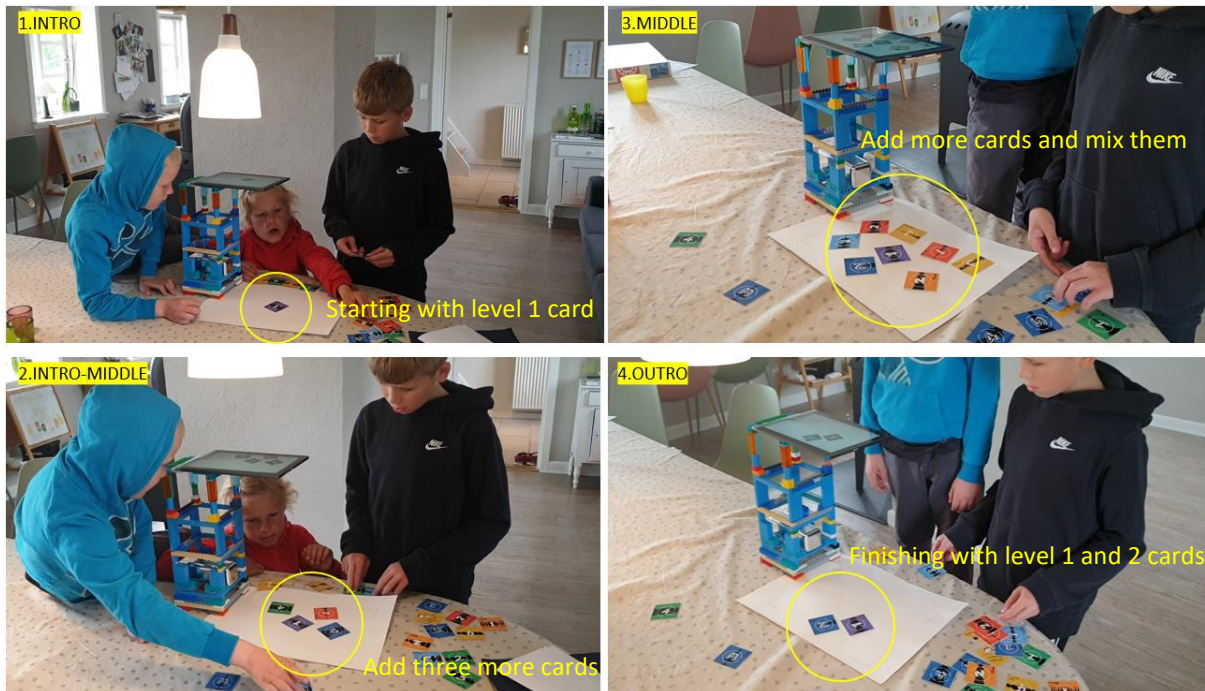
Figure 38 Building a melody exercise- Children cooperation

When I asked them to build the outro they did better. They started to subtract cards by being aware of the level of the cards, resulting with only 2 cards end (level 1 and level 2 cards) in the end (see figure 38- fourth quadrant). During the creation process I also observed that the small kid (6 years old, red shirt) soon become bored to cooperate and left the table right in the middle of the melody, leaving his bigger brothers to cooperate between themselves. His bigger brothers (blue and black shirt) had the patience to finish the melody.

I observed that when children wanted to find a specific instrument card or rhythm of an instrument from the current playing sequence they were covering all the cars in order to find the one they were looking for interrupting in the same time the sequence, leading to finishing the game earlier/ abruptly, without any outro part (see figure 38.2). The participant was previously constantly watching the tablet screen and tried to find the cards by looking at the AR 3D green dots, but this did not help either. This was happening due to the chaos that was created on the board by placing the cards randomly without having a structure. It has been observed that the chaos created on the board causes children not to understand what instruments are played and where the sound comes from.

I was also interested to see how children act alone rather than in groups to make a comparison. It was observed that the 11 years old kid was acting differently by being alone and start organizing the cards to make sense for him by creating his own strategy. He started to place the percussion instruments on the sides and the strings instruments in the middle (see figure 38.3) Previously, in groups, the same participant was not focusing on organizing the cards and only by playing.

As an observer I tried to do not interfere too much and let the children to experiment and discover the game by themselves Soon it seems they needed someone to explain then the steps. The children's mom started to explain (acting like a mediator between the TUI and users, see figure 38.4) them again the elements from the cards (the level numbers, BPMs and waves) that allows to create the melody. This situation showed that game needs some guidelines explaining how cards works. This workshop confirmed the findings from previous workshops with IBA and SDU students in which, the same "guidelines" recommendations were advised as well by the IBA and SDU student participants.
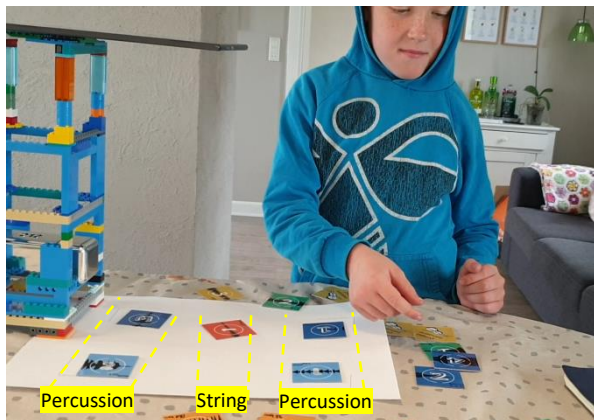
Figure 38.3 Organizing the card instruments

Figure 38.4 Mediator mom

Moreover, the board was also recommended before by the SDU, IBA participant and music teacher and the workshop showed the importance of such a board. There was a need to a more detailed and structured board that will help children to keep the cards more organized.

In the previous discussions with the music teacher, initially we thought that the backside of the cards (illustrating the information about the instrument) will represent a kick start heling children to understand the instruments and catch their attention. For the current worship, the children seemed disinterested from the AR part (theory side) and found much more interesting the composition part. The same feedback I got from the last workshops with IBA and SDU students as well.

The children only found the videos of the instruments much more interesting than the AR 3D animation because it showed how the instruments are used. Also, the children never tried to read the GUI info text. Therefore, such findings, question whether augmented reality could really enhance learning or not. I still chose to keep the AR elements for the next workshop in order to confirm/validate the findings.

The potential end users test (Music class environment)

The test was conducted only by the teacher in her class from Public School Petersmindeskolen, Vejle. In total 25 children participated to the test (5 and 6th graders). For this experiment I chose to include the quadrant board indicating where to place the cards and conclude if whether such board will enhance learning or not.

As a first step the teacher was curious if the children would recognize the instruments without looking at the cards. The teacher played the instruments one by one while children had to listen. Feedback shows that the participants easily could recognize the instruments sound. The only instruments that was not recognized by the listeners was the Hand Pan instrument. The hand pan instrument represents a rarely instrument which is not used in schools. This instrument was specially chosen to spark different reactions and see how children cope with such instrument. Depside the fact that children could not recognize the instrument, results from previous and current test shows that children find this instrument very interesting "This is something new for me, I never played with such instrument" children participant quote and they even recommended to bring more rarely instruments.

After testing the instrument sounds, **as a second step**, the teacher made a small demonstration of how the cards works explaining at the same time the elements symbols (BPMs, level numbers, waves drawings) from the cards. According to the last meeting, together with the teacher, we decided to include the demonstration step in which we agreed to let the kids know how to use the prototype before starting to play with it. This is because I was interested to see children exploring the game and not discovering it. I was interested to find if such a game represents a challenge for them and if they can cope with physical and digital interaction. Moreover, I was interested to see if such an interaction could stimulate and motivate learning and spark creativity.

After demonstration **as a third step** the teacher invited small groups (3-4 children per group) to test the prototype "After explaining how the cards works I organized the tests, to try in small groups, so three to four children to come out and start compose by giving them a guideline in which I have told them to build a melody considering few rules such as the intro; middle and outro part and taking into consideration the complexity of the rhythm and try to start in a smooth way and slowly increase the complexity of the melody" music teacher quote. The figure 39 shows an example of a team exercise in which they started smoothly (intro), leading to more complex rhythms but organized cards (middle) and ending smoothly again (outro). I was pleased by the results and teacher claimed that children were able to understand the exercise.

The tests have shown that kids enjoy not making major mistakes and they were glad that the only "mistake" or challenge the prototype provides, stands in the rhythms. They paid more attention to the rhythm and slowly started to match the cards numbers with the complexity of the rhythm, being able to realize how important is the usability of the instruments and rhythm when comes to compose.

The feedback shows that children enjoyed creating and do not make mistakes like in real life. It was enjoyment and learning of combining "Is great because I do not need to touch any instrument because I am afraid to play piano and make mistakes". This game gave them the courage to combine and make small mistakes that can be solved easily.
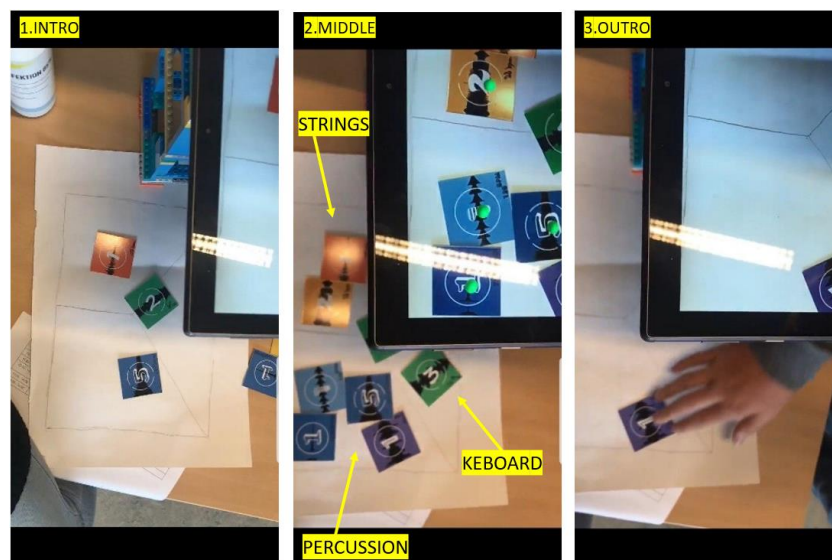
Figure 39 First time try – respecting the rules and keep organized
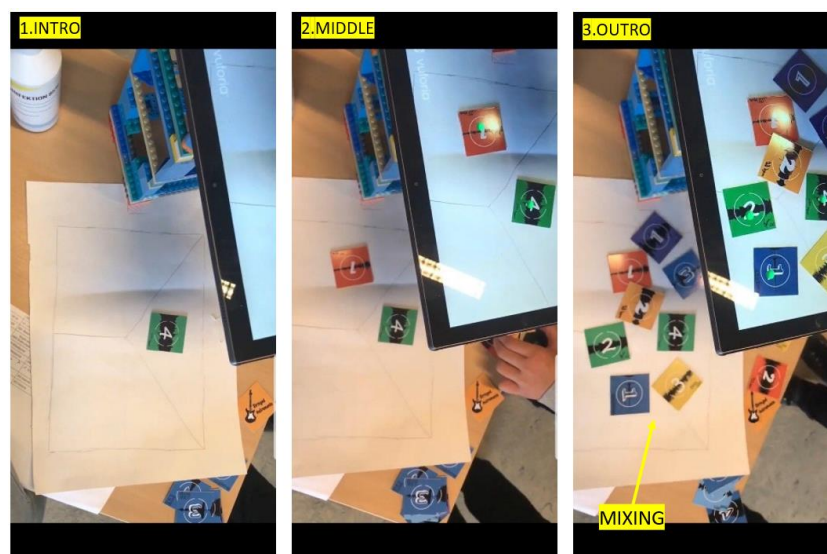
Figure 40 Second time try- mixing the instruments on the board

According to the videos provided by the teacher, some children started to lose the essence of the game soon. The figure 39 represent the first part of the test in which the children kept the cards organized on the board respecting the quadrant delimitation. Soon (figure 40) the same group of kids started to throw the cards on the board and begin creating a melody without taking into consideration the board delimitation or even the numbers of the cards anymore. Figure 40 shows the children started with a level 4 card (intro) and finishing the outro by mixing all of them "Some children started to act like DJs perceiving the cards more like a DJ mix game, than a composition game. These kids started to do not follow the level and the BPMs of the cards" music teacher quote.

According to discussions with the music teacher such attitude happened in both classes (5 and 6 grades) but the professor claimed that a slightly difference between the children age was visible. "I have noticed a small difference between 5 and 6 graders […] for the 6 grades I could see that they were able to perceive the details better and faster noticed the intensity of the rhythm (card level) and the BPMs […] they had more patience […] they also created strategies between them of how to start the intro and how to finish the melody" music teacher quote . Moreover, the teacher observed that 6th graders tend to collaborate and communicate more than 5th graders.

In the end of the test the children were asked for a feedback indicating what they liked, did not like and what suggestions for improvement (qualitative data) they have together with a questionnaire (quantitative data) . The bellow section contains the children suggestions for improvement.

Suggestions for improvement (music class children)
Qualitative data

The Board - The Feedback shows that would be much easier for children if the paper board would be colored to easily indicate the quadrants for each category of instruments. Moreover, the teacher suggested that the board should be bigger to allow more cards to be played "I could the see the quadrants are too small for the size of the cards. […] the children felt a need to use more blue cards in the percussion quadrant and they had to place them on top of each other instead" teacher quote

AR 3D elements & GUI text - regarding the AR elements from the backside of the cards the children found the AR videos much more interesting because it shows the usability of the instruments "It was useful when they saw the video with the hand-pan and timpani instrument, because they could better understand how to use the instrument […] the 3D animation is nice and you can see how the instruments are built but the children spent no more than 5 second inspecting it" music teacher quote

Regarding the GUI info text, the children did not have any suggestions but according to the teacher's observation the text seems to be too general. The current research showed that in order to enhance the learning the text should be more specific "Would be nice if the info text will explain the formula of the rhythm that are used in the cards" music teacher quote

Split the cards - A very interesting feedback shows that the children would prefer the cards to be split up. They said would be better if the cards would be not flappable and therefore, create two packs of cards such as theoretical and practical cards "I also noticed that children seemed distracted by having two sides cards" music teacher quote

Bring more instruments and rhythm - Children wished for both more instruments and more rhythms and BPMs to play and challenge them. "The current number of cards can't cover a full music lesson due to too less examples of instruments and rhythms" music teacher quote. She also suggested that 20 cards are not enough for a group of 4 students to compose a melody "There are 4 students with 8 hands for 20 cards […] they do not have too many choices to be challenged".

Make it more obvious- The children claimed that the cards level could be even more clear by writing the "level" word on the cards to make it more understandable.

Questionnaire results (music class children)
Quantitative data

Given the large number of children (25 participants), the questionnaire was a quick way and therefore an advantage for data collection. At the end of the testing day I have asked the teacher to share with the children a questionnaire (see Appendix, page 77) with the purpose to measure the usability of the prototype. It consists of 6 questions with five response option; from Strongly Disagree to Strongly Agree.

This disadvantage on the other hand consists of random choice by responders without properly reading and understanding the question, especially the children are 5 and 6 graders. Therefore, the teacher played a crucial role in explaining each question to the children and make sure that they understood the nature of questions.

- Question 1 (Q1) "I think I would like to use this music system more often"

The average response was between 4 and 5 suggesting they strongly agree. According to the teacher, the children even asked if they could use the prototype in future lessons and start creating lyrics while getting inspired by the rhythm of the cards. According to the teacher "they even asked if they could take prototype home and start to explore even more the combinations of the rhythm". They also were interested in watching the AR videos wishing to spend a little bit more time on it.

- Q2 "I found the music system too complex"

The average response was between 1 and 3 suggesting they disagree. Respondents were able to deal with TUI in an easy manner and quickly adapted to it. But the current study shows that some of the children failed to decipher all the elements drawn on the cards and sometimes these elements did not make sense to them "the numbers from the top if the cards was confusing for some of them", quoted by the music teacher. So, the prototype becomes a bit too complicated for them.

- Q3 and Q4 "The music system was easy to use" and "I felt confident using the music system"

The average response was between 4 and 5. The children did not need much help from the teacher to figure out how to use the system. The tangible interaction was intuitive, and the children began to experience the rhythm of the cards, without fear of making dramatical mistakes.

- Q5 "I think I would need the support of another person to be able to use it"

The average score was between 2 and 4. Here the respondents answered considering the exercise given by the teacher in which they needed support from the teacher to follow the steps of the game. Therefore, from this point of view, they needed someone to explain the roles of the game to them. The children also said they needed someone to explain the meaning of the card numbers. On the other hand, after understanding all the elements (BPMs, cards level and sound waves symbols), they said that they will not need someone to explain the technical part, because it is simple to use already.

- Q6 "I would imagine that most people would learn to use this music system quickly"

All of them respond with 5 (strongly agree) suggesting that after 5 minutes of use the system become easy and intuitive to use.

Conclusion of end user tests

The third functional prototype brought significant improvements. The usability of both hands raised interesting interactions and helped in creating a full tangible interaction with the physical tools resulting to a full tabletop experience. Such changes helped to conduct further testing with the end user (children) in order to test the usability of the prototype in its natural environment.

The first end-user tests (field research - home test) included 3 children. This workshop showed the importance of having a board to keep the cards more organized and to start building a melody in a more logical manner. The same workshop showed the importance of a mediator who should provide some exercises and some guidelines for children to test the potential of the prototype.

One of the tests in the first workshop was to let the children play freely with the cards without giving them rules or explaining how the cards work. I chose only to observe their behavior. I noticed that they soon got bored of the game and could not find any meaning, but only mixing the rhythms. Only after explaining the rules of the cards and giving them a little task, they find the prototype interesting, allowing the children to start composing.

The second test was conducting by the professor in two separate classrooms (5 and 6 grades) with a total of 25 participants.

It seems that the teacher operates as a facilitator or coach who designs learning activities for the kids to maintain the control. The teacher said that at some point it was necessary to give some guidelines to the participants by acting as a mediator between the user and the tangible user interface. She says that "kids really felt they build something, but they needed a mediator to teach them how to do this".

Scaffolding occurs to make the task more manageable in which "the teacher is viewed as a facilitator or coach who supports the deployment of a learner's attention, helps to manage frustration and so forth." (Michael Mascolo 2009).

According to Michael Mascolo in his paper "Beyond student-centered and teacher-centered pedagogy: Teaching and learning as guided participation" says that are seven types of support/scaffolding.

According to the first discussions from the first workshops with the teacher she used do adopt scaffolding strategy before in the Garage Band composing activity in which she had to give many explanations in order to make sure they are using the app properly and therefore "provide explicit and specific direction about how to perform an action or procedure […] in which novice follow the explanations" (Direction scaffolding strategy)

This time the teacher claimed there was no need for such controlled action. Instead she was distance motivating the participants by interference when needed and create dialogues with children to make sure they understand the usability of the cards in relation to the task. While children were building a melody and the teacher noticed something wrong she started to interfere, starting to give hints to the children by asking "conflict-inducing questions" (Michael Mascolo 2009) such as "can a complex rhythm be used in the intro?" or "is it a complex drum working well with a smooth piano?" or "is 120 BMPs matching the other cards sound?"

The teacher claimed that the game represented a soft start of the music lessons opening the appetite for music and make the children become more curious.

Since they are used to create lyrics and improvise in their music classes the children also suggested vocals and started to ask if they could register their lyrics or even their own rhythm on the cards. Such feedback showed a wish for more and is was a sign that the prototype was meaningful for the participants. Their feedback will be taken into consideration for a future iterative prototype process.

Discussions and Evaluation

In the current research paper, I tried to provide an effective TUI system that improves learning for children, that provides an active collaboration method, which also allows the sharing of knowledge between participants (sharing cognition). I believed in improving the current learning activity in the music teacher's classroom and I tried to bring a handier solution when it comes to composing music activity in the classroom. Despite many prototype iterations processes, the last functional prototype does not seem to provide new knowledge to participants and instead it seems to provide more playfulness feeling.

My first hypothesis was that by providing a tabletop AR TUI system users will be able to cooperate more between them by pushing them to become more creative together and make the interaction with the cyberspace more natural and intuitive by using both "ready at hand" tangible tools which, therefore, "leads to a minimal cognitive effort of the user." (Hiroshi Ishii and Brygg Ullmer 1997)

After few interaction processes I come up with a second hypothesis in which I switched to a present at hand approach in which the cards are more expressive, acting more as meaningful objects which could bring more interesting effects and control for the user, so people focus more on the physical tool usability for a better tangibility interaction and learning resulting in acquiring knowledge.

Maybe the results do not confirm or deny my hypotheses, but it does rise further questions that should be further investigated.

I remember the first online demonstration with LEGO UX department (Stefan and Thomas) in which the they saw videos of the first functional 6 cards prototype. According to them the prototype "reminds and look like a Music Maker" associating it with a DJ card game in which you play with different melodies called Dropmix. What they have tried to do is warn me that if I do not bring a limitation of interaction, this game will be perceived as an enjoyment and funny way of mixing music and not enhancing learning or providing knowledge.

I found interesting that while I was focused on enhancing the learning aspect and bring constrains that will allow children to focus on the usability of the cards I have seen certain DJ aspects inclination toward my prototype in which participants felt like this prototype is a DJ mix tool having the purpose to only mix the rhythms. Such findings raised questions toward the implication of my TUI prototype which does not seems to provide knowledge as it should. Instead, the prototype does provide enjoyment and playfulness (which is good) but offers only a little knowledge about the composition of music and, in some cases, the educational aspect is not seen at all.

I only managed to bring curiosity as an aspect of my prototype and little of knowledge considering the music composition rules. It (TUI) did not provide enough knowledge to make the teacher accept the game in the classroom as a future teaching/learning tool. The teacher considered this tool (TUI) to be just a soft start of the music lessons that opens the appetite for music and make the children become more curious.

Therefore I have asked myself, If this TUI prototype is perceived as a non-limitation game which provides joyfulness and an easy understanding of the content and if this prototype allows natural interaction which does not require complex operations, why should I not change the prototype physiology and instead of acquiring knowledge about music, this tool could be used by the teacher to improve the her teaching skills and methods and help the teacher to express her ideas? Therefore, what if this would represent a conversational tool instead?

Until now my mindset was on delivering a tool dedicated to children to learn different aspect of composing musing through a practical way. But recently, after final discussion with the music teacher she claimed that it was much easier for her to express her own explanation and not necessary focusing on the prototype content.

In order to respond to such question, future workshops with teacher in classroom should be organized and observe and analyze the teacher way of teaching and find wherever this prototype or the elements of this prototype will represent a supplement tool for teachers that helps them to communicate with students.

I also found interesting the third functional prototype workshop results respectively the usability of both hands which raised interesting interactions. Participants started to use their own hands by putting the cards on the hands and make music with their hands' movements leading to a body interaction. Therefore, as a second future research I would focus studying this aspect as well.

Regarding the instrumental cards, while testing with the music teacher I found that the current prototype interaction it could be used for a larger target group as a well. An idea for the future would be to focus on singers/musicians, in which the prototype will allow them to record their own instrumental rhythms on the physical cards and start mixing it.

Considering the research methods, I was not able to participate to the school classroom research due to the current global situation of the Corona Virus, which represented a big disadvantage of the research and therefore, had some limitations when it comes to conduct testing.

Again, due to the Corona Virus situation, I had to limit myself to just a few physical tests. I still did not have the change to test the prototype with the LEGO department, but I would like to test it in the future research.

Regarding the IBA and SDU workshops I wished for a better planification and organization. Again, due to the Corona Virus situation the participant schedule did not seem promising as well. Some of the participants managed to be present for the entire research process and some of them managed to be part only at the beginning, and some of them were part of the final workshops.

I would also like to explore more the power of Unity program and bring more interactive 3D models and conduct additional tests.

Main conclusion

In the beginning of the research paper I was interested to challenge the idea of developing a Tangible User Interface that support augmented reality and make the interaction of the user with the cyberspace more natural and intuitive. The hypothesis was that in this way users will be able to cooperate more between them by pushing them to become more creative together and make the interaction of the user with the cyberspace more natural and intuitive by using "ready at hand" tangible tools which therefore, "leads to a minimal cognitive effort of the user." (Hiroshi Ishii and Brygg Ullmer 1997)

Because, I was trying to find a natural and intuitive TUI, I first found music an incredible source that stimulates people's creativity and imagination. Listening, exploring, and analysing represent fundamental activities at the basis of the development of meta-cognitive skills such as attention, concentration, and control" (Luca A. Ludovico 2017)

The very first workshops, Lego bricks sessions helped define the main aspects of the prototype. Colors and instrumental sounds represented two important elements that helped the participants to get creative, be able to combine and intrigued them to build more and therefore, I decided to include such elements to my prototype.

As research methods, qualitative data such as video recording, observation and semi-structured interviews and quantitative data such as questionnaire, were used to find solutions and suggestions for improvements; Finally, a field visit played a crucial role in understanding children's behaviour towards the TUI prototype system, helping me to identify how children cope with digital and physical representations.

The music teacher and the music students represented two of my important stakeholders that helped in sharing key findings.

When I asked the music students What they did not like in being music students and what they would improve they said that everything worked slow. They used to spend hours in learning the theory and composition principles and only after one year of practicing, they started to compose a melody. They did not have any method allowing them to practice a full composition exercise.

What caught my attention was when music students asked for an introductory method to help children adjust to the music, encouraging them to compose. Very interesting is when a music student suggested that such method

should also promote more the authenticity and not typicality. She said that many students know how to sing and compose but they are not encouraged to promote their own style and interpret the melody in your own way. The music student feedback showed that as a kid you need a more practical and smoothly way of learning music.

Compared to the traditional teaching methods that music students went through, I found interesting the music teacher new way of teaching, using digital learning content, such as websites and online games, to teach children about music. Moreover, recently, the teacher began to use a more practical way of teaching music using a telephone application called Garage Band app, to teach children about the rules of composition and how to create melodies.

But new technology brings new problems. Findings shows that the teacher had a rush time by getting the children do cooperate, saying that the "phones and tablets are sometimes a great distraction for them and cannot complete the task in time". Research showed that "digitalization may be a distraction in the classroom" (William F. Crittende 2019) in which children can get distracted by a fully digital activity and therefore, there was a need for an even more practical way of teaching by combining digital representations with physical representations.

The main object of the my research paper was to find a more physical and practical way to improve the cooperation and the creativity of children by offering them an easier way of composing music, allowing students to combine instruments in a smoother and easier manner. Moreover, the current research shows that there were children that had a wish to compose music, but they did not have the right skills to do it by using real instruments.

Methods such as sketching modeling, paper prototyping represented the first methods that helped me to build a functional TUI prototype music composition system, helping the children to compose music in an easy manner requiring a minimal theoretical skills such as BPMs and Rhythms.

The functional prototype went through many iterative processes in which different design and marketing students together with music teacher, music students and LEGO UX department helped with suggestions for improvements.

In this way I chose to build three functional prototypes which uses augmented reality as digital output and instrument cards as physical input, that helped to experience and "demonstrate what is like to actually use a product in a given situation and provide findings that can help develop a product through an interactive prototyping process" (Milton and Rodgers, Making chapter) in which I constantly refine and improve the design and interaction, in order to continue to create the best value for the end-user.

The Tangible Interaction Framework represented a strong analyze that helped in the evolution of the prototype which managed to inspire me and generate new ideas that gave me the freedom of thinking "outside the box" and "not being stuck with the original design and interaction" (Eva Hornecker and Jacob Buur 2006).

After the analyze I have asked myself what is the value of grasping and manipulation? And how can I use tangible objects (physical environment) together with digital (cyberspace) that supports learning and moreover cooperation between users?

The results coming from the Tangible Interaction Framework analyze were significand. The findings showed that there is a need for a "present at hand" tool in which the cards should be more meaningful, acting more like meaningful objects which could "bring more interesting effects and control" for the user so people focus more on the tool for a better tangibility interaction and learning in which different card elements action resulting in acquiring knowledge.

Another interesting finding is represented by the strategy of the teacher's scaffolding strategy which is an important aspect that stimulate children to cooperate and learn, in which "the teacher is viewed as a facilitator or coach who supports the deployment of a learner's attention, helping to manage frustration and so forth." (Michael Mascolo 2009).

The results show that the musical TUI prototype (third functional prototype) needs a facilitator or coach who designs learning activities for the kids to maintain the control. Furthermore, the feedback shows that it is necessary to provide some guidance to the participants, in which the facilitator will act as a mediator between

the user and the tangible user interface (TUI) and therefore promote learning through play in which children are offered the best opportunity to fulfil their potential to become creative, engaged and allow the construction of knowledge in different types of actions.

Acknowledgment

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Appendix

Legend:
- **IBA STUDENT** (green)
- **Music student** (magenta)
- **Music student** (yellow)
- **Music teacher** (blue)

Quadrant contents:

- You train your visual memory; you remember it much easier
- A good start in changing the theoretical aspects of learning. It is interactive, practically and not theoretic
- Easy to access
- I like that the cards are childish looking, and they are not boring
- the rhythm of your instruments and is very interesting because this element of music can develop the creativity.
- build a melody with without thinking of theory
- Is simple and easy to understand
- Simple to interact/scan
- Easy to play with the volume sliders and moving the cards
- Once you set the volume, I like it stays there and not changing
- It is colored coded and is good because kids can recognize better which instrument belongs to which category and can better differentiate them.
- they do not just learn about the instrument itself but also, they can hear the instrument so they can recognize it
- Children would really enjoy it ! Because there is something you can really touch, change the position of the cards, listen to it
- A new way of teaching!
- Is nice to have the info on the back side
- A good music introduction tool for 4 graders but I don't think they can handle the tablet. 6 graders will handle the tablet better.

Table 1 Like

Legend:
- **IBA STUDENT** (green)
- **Music student** (magenta)
- **Music student** (yellow)
- **Music teacher** (blue)

Quadrant contents:

- Hard to distinguish the AR elements
- The font of the text
- Once you see the drawing instrument why should I see an AR picture with it?
- I like it is simple but maybe too elementary
- Too many things are happening in the same time
- Position of text makes it hard to read (because of the angle)
- To much historical info in the text
- The cards are hard to handle
- Videos are difficult to watch
- You can lose the cards easily
- AR pictures to serious
- Hard to hold the tablet and move the cards
- I don't like the violin sound that you chose. Same for the bass. Rhythm issues.

Table 1.2 Do not like

75

Table 1.3

Legend:
- 🟢 IBA STUDENT
- 🟣 Music student
- 🟡 Music student
- 🔵 Music teacher

Yellow quadrant (Music student):

Change the text and the pictures and include the 3D components of an instrument.
"What does that bow of the violin mean, how is that bow used". I see your game as a Google or Wikipedia device

Pink quadrant (Music student):

Do not bring too many instruments because this can be too overwhelming for children.

It could be much more elaborate, bring more cards

The children could also learn how to combine the instruments by taking into consideration "force" and "piano" elements.

Bring 3D animation and interact with it, once you press on it, this could sing. Or just animated people and notes that are dancing

Green quadrant (IBA STUDENT):

Too short text, include more info such as Classification, fun facts or usability of instruments

Change font of text

Create more buttons, each for one AR element. You decide what you want to see.

Bring more instrument cards

Eliminated pictures keep videos

Include animated 3D instruments. Interact with AR 3D models (move, rotate, zoom in and out)

Bring a button to kill the sound

Bring more durable cards

Flip the card, expected something to happen

create a tutorial of how to play with different instruments (AR video)

Blue quadrant (Music teacher):

You should include some interesting facts about the instrument itself. NOT A DRY HISTORYICAL but funny or interesting facts.

Create different card levels to allow them build a melody (intro and outro). Kids will need more choices. More choices more interesting for them but not too complicated. So, it can be complex but still simple.

Table 1.3 Suggestions for improvements

Table 2

Legend:
- 🟢 IBA STUDENT
- 🟣 Music student
- 🟡 Music student
- 🔵 Music teacher

Yellow quadrant (Music student):

A cube will be interesting to use. Combine it with a jigsaw

Be more physical. No tablet. Get something out of the cube, like a hologram and sounds.

Pink quadrant (Music student):

Bring a blank card in which you could draw an instrument by yourself and them in 3D the instrument could pop up and star sing

The competitive game is very interesting. Perhaps the Lego pieces that you play with should do something else as well. You could scan them and play something

Competitive game upgrade.

Would be nice to play more with the rhythm. For example, Ana gives to Alex a rhythm to reproduce instead of playing with the questions.

your card prototype could be transformed into a cube tool. You could bring two cubes with different instruments and rhythm and play with these. But I still think the cards have enough potential.

Green quadrant (IBA STUDENT):

Bring more sounds (animal sounds)

You can make mini games

Make some instruments from LEGO and scan them

Bring children book, story telling learning book

Play with words game!

Jigsaw game. Take an existing melody and decompose it in order to learn about the intro middle and ending of it

Jigsaw game. Build stories using cards. In which the cards influence between them in order to make a story.

e-learning packages of 100 cards each (animal package, nature, package, city package instruments package

Blue quadrant (Music teacher):

They could learn about the genre of the music

When they flip the card, they could scan the code and direct them on the kahoot game. This can be also played in small groups. And the game could contain 5 questions per each

Instead of the small cards bring "funny task" cards which could contain some funny exercises the kid needs to accomplish

Table 2 Game and Elements suggestions

Figure 1 Questionnaire- usability test