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Modular Audio Platform for Youth Engagement in a Museum Context

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Modular Audio Platform for Youth Engagement in a Museum Context

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Abstract

Today, cultural organizations such as museums are seeking new ways to attract and engage audiences. Augmented reality and digital storytelling applications are considered very promising. The target is to provide more interactive experiences for an audience highly familiar with digital interaction. Typically, these experiments utilize separate individual applications. If a cultural institution would like to utilize for example augmented reality and digital storytelling in their service offering they have to acquire, learn and manage each technology and application separately. Indeed, it seems that there is no general-purpose IT platform that is modular and expandable. In addition, visual presentation has been dominant in digital systems. In contrast to this trend, we have chosen to concentrate on audio presentation.

The purpose of this thesis is to support museums and other cultural institutes in their mission to attract young visitors by offering engaging experiences. The main goals of the thesis were to develop a modular and easy-to-use audio story-sharing and audio-augmented reality platform, and evaluate the usefulness of the platform by measuring the level of engagement of participating youth in a workshop context.

Design-science research methodology was used for audio platform component development, and mixed-methods were used to study the utility of platform components as case studies. At a more detailed level this means that the expandable and modular platform was developed incrementally one component at a time. When developing Audio Digital Asset Management, action research was used. For the Soundscape Mixer development, combined action research was used until the software was in the α phase after which a separate evaluation method was used in the β phase. For the Audiostory Sharing development design-science research with separate building and evaluation methods was used. After implementation and testing the audio platform also from the usability angle, we moved on to engagement research. Workshops were organized in order to demonstrate the usage of the audio platform. During the workshops engagement was researched using mixed method, namely quantitative self-report questionnaires and qualitative methods in the form of observations.

We have succeeded in developing a modular and versatile audio platform. All of the hardware is commonly used including Android phones. Software-wise the backend system is based on open

source components. As the backend system provides relevant APIs, new mobile applications can be developed by third parties. In parallel, a concept was also developed, which helps to reach the young target audience and helps to measure the level of engagement. For this purpose, the student engagement structure has been applied in order to find out the level of engagement in workshops where the audio platform is a vital part.

As a final summary, the results are promising. There is a general-purpose audio platform, which is modular, expandable and affordable for cultural institutions, and there is a concept to reach young people and a measurement instrument to measure the level of engagement in an audio-related workshop context.

Computing Reviews (2012) Categories and Subject Descriptors:

- Human-centered computing → Ubiquitous and mobile computing systems and tools
- Human-centered computing → Ubiquitous and mobile computing design and evaluation methods
- Human-centered computing → Empirical studies in ubiquitous and mobile computing
- Information systems → Multimedia information systems
- Applied computing → Sound and music computing

General Terms:
Design and Experimentation

Additional Key Words and Phrases:
Audio Augmented Reality, Soundscape, Mobile Sound Mixing, Audio Story, User generated content, Emotions, NFC, Digital Asset Management, Metadata, Android, User Experience Evaluation, Student Engagement, Extracurricular Activity, Performance profiling, Museum

Acknowledgements

Most of the work in this dissertation (publications II – VI) has been done in the context of The Neighborhood Living Room project, which is part of The People's Smart Sculpture Project (grant agreement 2014-2330) co-funded by Creative Europe. The goal of the project was to study different methods for creating a more dynamic participatory audience relationship with a museum. Thus, the project has dictated the museum context. In addition, it was decided that the project's target audience is young people. My role in this project has been twofold: I was a project manager and mobile application development expert. It was also decided in the project that we would concentrate in auditory presentation.

The first publication was part of the CASS-project's further development. This work was done as a part of the RYM Indoor Environment program (project number: 1064/31/2011, wbs 462054), where Metropolia worked as a subcontractor for the University of Helsinki. The program was funded by Tekes (the Finnish Funding Agency for Technology and Innovation).

I would like to thank my supervisors, Professor Tommi Mikkonen and Professor Giulio Jacucci for their excellent guidance and support during this process. Professor Tommi Mikkonen has been encouraging and guiding me from the beginning. Without the support from Tommi Mikkonen and my collegue Dr. Merja Bauters I would never have been able to finalise this thesis.

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Someone asked why an old man like me would do a Ph.D. thesis. When I was younger I did not have the time, patience or persistence. Now I have more patience and above all, I wanted to prove to myself that I can. Luckily, I have a wife, who has been supportive and tolerant. Thank you Tuula for understanding and tolerating a husband, whose contribution to home activities has been virtually non-existing during the last years.

Tammisaari, January 28, 2019
Kari Salo

Contents

List of Publications

This thesis consists of an overview and the following six publications, referred to by their Roman numerals. The publications are reprinted at the end of the thesis.

I: Salo K., Shakya U., Damena M. 2014. Device Agnostic CASS Client. In: Marcus A, editor. Design, User Experience, and Usability: User Experience Design for Diverse Interaction Platforms and Environments. Switzerland: Springer International Publishing, pp. 334-344

This publication describes how to design and develop a HTML5-based front-end application targeted to different device platforms. We designed and implemented a modular client software architecture. Applying this architecture it was possible to excute basic functionalities in browsers. Hybrid applications were used when media intensive functionalities were required in addition to basic functionalities. From the perspective of the thesis, the discussion of audio capabilities such as W3C documents on Web Audio API and MediaStream Recording were important when deciding **whether we should implement our mobile applications as browser-based using web technologies or as native applications**.

Kari Salo was the main and corresponding author of this publication. He designed the overall front-end software architecture, researched and tested media related JavaScript documents and libraries, and acted as an instructor for the other two writers, who were his students.

II: Salo K., Giova D., Mikkonen T. 2016. Backend Infrastructure Supporting Audio Augmented Reality and Storytelling. In: Yamamoto S., editor. Human Interface and the Management of Information: Information and Knowledge in Context, Part II, LNCS 9735, 1–11. Springer International Publishing, Switzerland.

This article concentrates on describing **the server side of the overall architecture**. It describes design, implementation and testing of an audio-digital asset management system (ADAM), which is portable and based on open-source code. ADAM enables interaction with smart phones and tablets equipped with audio-augmented reality and audio-story applications. This includes researching, selecting and modifying an existing open source DAM system, designing and developing APIs for interaction with client software, and researching and implementing a relevant metadata standard.

Kari Salo was the main and corresponding author of this publication. He designed the overall software architecture, carried out initial studies on relevant DAM systems, researched and selected the metadata standard, organised testing with Museum of Technology staff, and acted as an instructor for Diana Giova, who was his student.

III: Salo K., Bauters M., Mikkonen T. 2016. Mobile Soundscape Mixer – Ready for Action. In: Younas M., Awan I:, Kryvinska N. Strauss C., van Thanh D. (Eds.) Mobile Web and Information Systems, MobiWIS 2016 Proceedings, Lecture Notes in Computer Science 9847 (pp. 18-30). Springer International Publishing, Switzerland.

This article describes how to design, implement and test a smoothly working **Soundscape Mixer application**. We have descibed the design process, development from the requirements into the implementation including functionalities of the application, class diagrams, different user interfaces, **backend interaction using APIs** and selecting (and running) performance tests suitable for Android applications.

Kari Salo was the main and corresponding author of this publication. He defined requirements for the Mobile Mixer application, provided guidelines for the development as several versions of the application were developed by the students participating in Kari Salo's Android Application Development course. Kari Salo also documented class diagrams of selected applications and researched and selected suitable performance testing tools.

IV: Salo K., Zinin V., Bauters M., Mikkonen T. 2017. Modular Audio Story Platform for Museums. In Proceedings of the 22nd International Conference on Intelligent User Interfaces Companion (IUI '17 Companion). ACM, New York, NY, USA, 113-116.

This article describes the functionality and use of **audio story application**. We have described the overall system on the deployment level including Audio Sharing and NFC Writer applications which are together called audio story application. We have also described the functionalities of the audio story application, the user interface of the application utilizing emotions, and backend interaction. In addition, usage of the Soundscape Mixer application for audio story enriching is described.

Kari Salo was the main and corresponding author of this publication. He designed the overall audio story platform architecture, defined requirements for the Audio Sharing and NFC Writer applications, provided guidelines for the development of the applications, and instructed his student Vallo Zinin in application development.

V: Salo K., Bauters M., Mikkonen T. 2017. User Generated Soundscapes Activating Museum Visitors. In Proceedings of the 32nd ACM SIGAPP Symposium on Applied Computing (SAC 2017). ACM, New York, NY, USA, 220-227.

This article again describes the design, implementation and testing of a **Soundscape Mixer application**. However, the main part is the two workshops, where the application was evaluated from the user perspective. The workshops had different target audience and goals. The first one was targeted to youth and we evaluated the ease of use and feelings evoked. The second one was targeted to museum professionals and we evaluated the ease of use and the acceptance of use for other museums than the Museum of Technology, which was our primary design environment. From the perspective of the thesis, **measuring the user experience and the acceptance of use** by other museums are the most interesting points.

Kari Salo was the main and corresponding author of this publication. Together with Merja Bauters he designed the questions for questionnaires. He implemented an online questionnaire system, organized workshops with the help from the Museum of Technology and Finnish Museum Association staff, organized 360 video recordings with his students, and analyzed the collected results.

VI: Salo K., Bauters M., Mikkonen T. 2017. Audio Story and AR Platform for Youth Engagement. In: Younas M., Awan I:, Holubova I. (Eds.) Mobile Web and Intelligent Information Systems, MobiWIS 2017 Proceedings, Lecture Notes in Computer Science 10486 (pp. 18-32). Springer International Publishing, Switzerland.

This paper concentrates on measuring the engagement of **Soundscape Mixer and audio story applications in the context of school extracurricular activities**. We describe the results from two workshops where our platform was used. These workshops were organized as extracurricular activities. We have developed an **instrument to measure the level of engagement** in order to evaluate how participating students experience workshops and our audio platform. Our evalution instrument is based on student engagement research. This instrument enables **analyzing** separately the **behavioral, emotional and cognitive engagement components**. In addition, we asked questions related with the **ease of use of both applications**.

Kari Salo was the main and corresponding author of this publication. He studied student engagement research results and designed the instrument for measuring engagement. He organized workshops together with Gdańsk City Gallery staff, collected user feedback and analyzed the results.

1 Introduction

Storytelling is perhaps the oldest form of human communication. Storytelling has ensured that knowledge, art, ideas and cultural material is received, preserved and transmitted orally from one generation to another. Today, stories are an intrinsic part of movies, books, music, news media, games, social media, business and marketing. Companies need to tell stories in order to attract customers and funding and build their brand. Museums have used storytelling as one way of engaging their audience [1, 2].

Museums and other cultural institutions are seeking various ways in addition to storytelling to attract and engage audiences. There are a lot of experiments based on virtual museums [3, 4], context-aware audio guides [5, 6, 7, 8], augmented reality and 3D modelling applications [9, 10], as well as storytelling in the form of interactive digital storytelling [11, 3]. Typically these experiments utilise separate individual applications. If a cultural institution, like a museum would like to utilise AR and digital storytelling, for example, in their service offering they have to acquire, learn and manage each technology and application separately. It seems, that there is no general-purpose IT platform, which is modular and expandable, and provides increasingly interactive experiences for an audience, which is familiar with the digital world.

In the digital world augmented reality has become a part of everyday life. IKEA [12] and Home Depot [13] let customers place virtual products, such as furniture into the real world. Harley-Davidson shows users how the customised street bike would look parked in their driveway [14]. AR MeasureKit [15] turns your mobile phone into pocket measuring tool and Sky Map [16] displays a star map above your head. Social media tools, such as Snapchat [17] and Facebook [18] allow you to tune photos using special filters. Teachers are using AR applications to illustrate abstract concepts of mathematics, physics and chemistry or visualise the human anatomy or a solar system. In addition to classroom work, digital tools are used as a part of some extracurricular activities.

Several studies have linked participation in extracurricular activities to young people's positive development and positive academic outcomes [19, 20, 21]. According to studies high school students participating in the extracurricular activities have higher confidence, less depression and more friends who plan to attend college. In addition, these students have better grades and test scores, their school engagement is higher, and they have higher educational ambitions. Thus, schools are willingly co-operating with parties who can offer extracurricular activities. Museums and other cultural institutions using, for example, digital storytelling and augmented reality as part of their activities, are willing to co-operate with schools by organizing extracurricular activities as one approach when trying to attract more visitors. Most of the extracurricular activity research concentrates on school-based activities or general trends in different activity categories. So detailed out-of-school extracurricular activity studies, which would address the engagement angle of these activities, are virtually non-existing.

1.1 Research Questions

The purpose of this thesis is to support museums and other cultural institutes in their mission to attract young visitors by offering engaging experiences. In order to reach our purpose we set the following main goals:

1) develop a modular and easy-to-use audio story sharing and audio-augmented reality platform;
2) evaluate the usefulness of the platform by measuring the level of engagement of participating youth in a workshop context.

Based on the research goals, we investigated the following research questions:

1. How do we design and implement a portable modular audio story sharing and audio-augmented reality platform?
    - What kind of overall software architecture is needed?
    - How do we design and implement a modular, smoothly working soundscape mixer and audio story sharing mobile applications?

2. How do we evaluate the audio platform in a workshop context?
    - What is the role of the context?
    - How do we evaluate interaction between user and platform in a workshop context?
    - What is engagement and how do we measure it?

1.2 Research Approach and Methods

In general, this research followed the empirical research approach [22]. The main reason for this is that software development is human intensive, and hence it does not lend itself to analytical approaches. We used mainly research method definitions from Järvinen [22] and Patton [23]. Thus, for audio platform component development we used design-science research methodology, and to study the utility of platform components as case studies we utilized both quantitative and qualitative methods.

On a more detailed level this means that we have developed the expandable and modular platform incrementally one component (such as the soundscape mixer) at a time. Developing ***Audio Digital Asset Management***, we used action research as it contains both building (design and implement system) and evaluation in the same process [23]. ***Soundscape Mixer*** development combined action research until the software was in the α phase and a separate evaluation method in the β phase. The evaluation utilized both a quantitative method in the form of questionnaires and qualitative methods in the form of observations and interviews in order to understand the usability of developed software. For the ***Audiostory Sharing*** and ***NFC Writer*** development we used design-science research with separate building and evaluation methods.

After we had also implemented and tested the platform from the usability angle, we moved on to engagement research. Based on a literature review we defined the engagement structure for our purposes and developed a measurement instrument for measuring engagement on a detailed level. Our target was to organize workshops which demonstrate the usage of our platform. During the workshops we researched engagement using a mixed method, namely quantitative self-report questionnaires and qualitative methods in the form of observations for gaining an in-depth understanding of the quantitative data gathered [23].

Table 1 provides information on what kind of research methods were used in each of the publications and how each publication contributed to the end result. In general, we can say that publications I – IV were addressing the first main research question and publications V and VI the second one.

Table 1: Publication research contribution.

Publication	Research Methods	Contribution
I	Experiment	Are web technologies already mature enough in media intensive (like audio) applications and can they be used instead of native applications.
II	Action research	Describes the design, implementation and testing open-source-based audio digital asset management system, including APIs needed for interaction with client software.
III	Action research	Detailed level implementation of soundscape mixer application including performance evaluation.
IV	Action Research	Describes the audio sharing part of the platform including the discussion on how to include emotions as a part of the stories.
V	Action research Evaluation using both quantitative and qualitative methods	Describes two workshops where the soundscape mixer application was tested. It provides feedback from two types of users: young museum visitors and museum professionals.
VI	Literature review Mixed method: quantitative self-report questionnaires and qualitative method in the form of observations	Describes engagement, how to measure it and provides results from two workshops where the developed engagement measurement instrument was used.

Table 2 describes in more detail which publications contributed into each of the research questions.

Table 2: Research questions addressed by publications.

	I	II	III	IV	V	VI
How to design and implement portable modular audio story sharing and an audio-augmented reality platform?	X	X	X	X		
What kind of overall software architecture is needed?		X	X	X		
How do we design and implement a modular, smoothly working soundscape mixer and audio story-sharing mobile applications?			X	X	X	
How do we evaluate audio platform in a workshop context?					X	X
What is the role of context?					X	X
How do we evaluate interaction between user and platform in a workshop context?					X	
What is engagement and how do we measure it?						X

1.3 Dissertation Structure

This dissertation presents relevant background information in the next chapter, describes the modular audio platform and user interaction in Chapter 3, provides student engagement structure-based contributions in Chapter 4, and draws conclusions in Chapter 5.

2 Background

Museums and other cultural institutions are seeking various ways to attract young visitors. Cultural institutions explore and develop new services and at the same time look for different ways to approach potential visitors. Co-operation with schools in the form of extracurricular activities is one way to attract young visitors. In order to offer engaging services to this customer segment, cultural institutions are testing different technologies, such as augmented reality [9, 10] and digital storytelling [1, 2, 11]. In the next sections we will have a look at these technologies and how they are applied. As the focus of the thesis is in audio presentation, we will cover technologies mainly from that perspective. New technologies as such do not guarantee schools' willingness to co-operate or young visitors' engagement. Therefore, we will also discuss the extra-curricular activities as a co-operation model and its importance to schools and students. Moreover, we will discuss student engagement in order to understand how to organise and measure these extra-curricular activities.

2.1 Audio-Related Technologies

There is a lot of research developing augmented reality (AR) systems and interactive digital storytelling (IDS) systems. In most of the cases the visual presentation has been dominant. We decided to concentrate on auditory presentation as there are not that many ongoing activities. In addition, it was decided within The People's Smart Sculpture Project [24] that we would concentrate on auditory presentation as most of the other partners were developing systems using visual presentations.

2.1.1 Audio Augmented Reality

Augmented reality is nothing new. Myron Krueger has been pioneering this technology already in the 1980s [25]. At that time, he called it artificial reality. He also described how to superimpose synthetized sound on top of the real audio scene in 1991 [26]. The term augmented reality was mentioned in 1992 [27]. Benjamin Bederson introduced the term audio-augmented reality (AAR) in 1995. He described an automated tour guide prototype for a museum. This prototype utilised infrared transmitters to control the location of the visitor and play the relevant pre-recorded audio files [28].

Introducing user modelling to personalise context was the next step for AAR systems. The HIPPIE project used static domain and space models to describe objects and space (in a museum).

The user model was dynamic taking into account the user's interaction with the system and movements in the physical space. The system was utilising infrared transmitters to locate the user and an electronic compass to get the direction of a user. Most of the content was presented in an audio format consisting of pre-recorded snippets. Users were able to add notes and recommendations into the system [7]. The LISTEN project continued the content personalisation theme. This system utilised not just the user's location, but also head orientation in order to produce a binaural soundscape consisting of speech, music and sound effects related to visual objects (in a museum). Location tracking was based on optical position tracking, and head orientation was based on motion sensor attached to headphones [8, 29, 30]. The Cicero project [31, 32, 33] introduced tilt gestures in order to enable the user to control which type of information she would like to get about interesting artefacts. The room-level location inside a museum was based on infrared beacons. In order to get information about particular artefacts/objects inside a room, the user could scan RFID-tags or using tilts. Content navigation was also based on tilt gestures.

As Hippie, LISTEN and Cicero used visual content in addition to audio content, the ec(h)o project was concentrating on audio only content. In order to increase user interaction and moving away from graphical user interface, ec(ho) was using a tangible user interface. The navigation had two levels: macro and micro. On the macro level navigation is based on RFID and optical position tracking. Content on the macro level is ambient soundscapes related to artefacts near the user. On the micro level visitors were using a wooden cube (tangible user interface), which was used to select one of the artefacts in front of the user. Each artefact was presented by playing a preface audio (playful short audio) of the left, centre or right channel of the headphones. Using the video sensing, it was possible to track cube rotations and play content related to the selected artefact [6, 34]. The Corona project was using a similar two-level content. The content theme was a medieval feast where virtual characters were conversing with each other. At the macro level the visitor was able to hear several conversations as a background atmosphere. At the micro level each virtual character's conversation was clear. The location was based on the RFID position tracking. In addition, a compass attached to headphones was used for the head orientation [35].

Some recent research papers have studied whether a mobile phone could substitute the compass attached to the headphones [36, 37] and how to utilise hands tracking and sound or sound and haptic feedback for more interactive user experience [38, 39]. Based on small-scale tests it seems that head tracking is still a better solution compared to device tracking if information about the user's direction is needed [36]. On the other hand, using a mobile devices' microphone as a directional microphone (AudioTorch) could be a promising approach as it reduces the technical complexity of AAR systems [37]. In the AHNE system a special physical space contains virtual audio objects, which can be searched for, grasped and moved. These objects have two-level cues for locating them. The proximity cue is based on the audio feedback, and the target cue on the haptic feedback. The AHNE system uses optical sensing and custom gloves with sensors to track the user's movement and hand movements [38]. The ATSI system contains physical objects, which can be augmented with spatial sounds. These sound objects can be searched for, grasped and moved. The tracking is based on optical tracking of location of hands and head, and head orientation based on an inertial tracker attached to the headphones. User interaction is based on an audio interface as instructions and gestures to attach and move sound objects [39].

As a summary, we could say that the main features of any AAR-system are: user tracking, audio content and user interaction. Table 3 summarises the main features of the previously mentioned systems except those two small-scale tests for tracking.

Table 3: Summary of main features of AAR-systems.

AAR System	User Tracking	Audio Content	User Interaction
Automated Tour Guide	Infrared transmitters	Pre-recorded audio description of each artefact	User movement
HIPPIE	Infrared transmitters + headphones with compass	Dynamic content based on user model, produced from pre-recorded audio files	User movement and direction
LISTEN	Optical tracking + headphones with motion tracking sensor	Dynamic content based on user model, produced as binaural soundscape consisting of speech, music and sound	User movement and head orientation
Cicero	Infrared transmitters and RFID tags	Pre-recorded audios related artefacts and also audio based navigation	User movement, RFID tag scanning and tilt gestures
ec(h)o	RFID and optical tracking (macro level), and video sensing (micro level)	Pre-recorded audio: ambient soundscapes (macro level), and preface and artefact description (micro level)	User movement and wooden cube rotation
Corona	RFID position tracking + headphones with compass	Pre-recorded conversion of virtual characters	User movement and head orientation
AHNE	Optical tracking and custom gloves with sensors	Pre-recorded virtual audio objects and dynamic audio cues	User movement and hand movements
ATSI	Optical tracking + headphones with inertial sensor	Spatial sounds and dynamic directional cues	User movement and hand movements

Audio-augmented reality systems provide a vehicle to consume content. The content can be any type of audio files. Next, more about the audio content called soundscapes will be discussed. As can be seen in the previous table, soundscapes were mentioned in both LISTEN and ec(ho) projects.

2.1.2 Soundscapes

The World Soundscape Project [40] can be seen as the roots of soundscape research. This project was founded in 1969 by a Canadian composer R. Murray Schafer at Simon Fraser University. Schafer has defined soundscape as any acoustic field of study. Soundscape can be a musical composition, a radio program or an acoustic environment [41]. Barry Truax, who was part of the World Soundscape Project, has defined soundscape from the listener perspective as a sonic environment, where the relationship between individual and environment dictates how soundscape is perceived and understood [42]. Soundscape research has been applied in urban planning in order to bring residents' perceptions as a part of the design process. The urban soundscape study (part of the Vivacity 2020 project [42]) article explains Shafer's soundscape building blocks (keynote sounds, soundmarks and sound signals) on a concrete level. In an urban environment the keynote sound is typically noise from traffic, soundmarks are location-dependent components of the soundscape (for example traders calls in the market place), and sound signals being one-off, unpredictable sounds which stand out against the keynote sounds (for example dog barking). Sound walks have been used as a method to gather and understand urban soundscapes [41, 42, 43]. In order to assess soundscape perception and design positive soundscapes there have been projects to model the dimensions of soundscape perception. Axelsson et al. (2010) have categorized sounds into technological, natural and human sounds. Using three perception dimensions (pleasantness, eventfulness and familiarity) they could conclude based on laboratory tests that soundscapes dominated by technological sounds were unpleasant, soundscapes dominated by nature sounds were pleasant, and soundscapes dominated by human sounds were eventful [44]. Davies et al. (2009) have ended up with two perception dimensions (calmness/relaxation and vibrancy) [45]. These two models are quite close to two dimensions: calmness/relaxation is close to pleasantness and vibrancy close to eventfulness. Soundscape perception planning has been experimented with in the State Museum of Contemporary Art in Thessaloniki. They created unpleasant and pleasant soundscapes in order to find out how the experience and behaviour of visitors would change. As a conclusion some changes in behaviour could be found, but the results are uncertain [46].

Location-based soundscapes have been one approach to address how an urban environment can be changed and experienced. Tactical Sound Garden introduced a concept where people could 'plant' sounds to be shared with others using Tactical Sound Garden software [47]. National Mall was an art installation by Bluebrain [48]. Using an iPhone application users could hear composed sounds and music when walking around an outdoor park in Washington DC. These two projects are examples of how to change soundscapes of a certain area. We can also find projects which aim at preserving the soundscapes. In Osaka city, Japan, there is a project and community development activity called Hirano Soundscape Museum. This project has collected soundscapes from an old district called Hirano-go. In addition to soundscapes, also location and description of soundscapes including listener comments are stored. These are exhibited in six different spaces [49]. The Silence of the Lands project has concentrated mainly in collecting wild nature-related soundscapes from the City of Boulder, Colorado, USA [50]. Using sound walks individuals will record soundscapes with location info. These soundscapes will be collected into a web service. This service enables combining individual soundscapes into collective soundscape. This collective soundscape can be used as a tool to facilitate workshops where local residents will create a virtual soundscape describing the ideal soundscape of a particular area.

In some cases, a special space has been built in order to present curated soundscapes. Sound Chamber at the Nordamerica Native Museum in Zurich, Switzerland is designed to present soundscapes related to the culture of North America's First Nations [51]. These soundscapes will support the museum's five cultural spaces. Soundscapes will be presented in educational workshops. Klang.Raise was an audio-visual installation exhibited at Klangturm (part of Landesmuseum Niederösterreich) in St. Pölten, Austria [52]. The installation consisted of video and audio recordings done in five locations in July, November and January. The idea was to demonstrate how the soundscape in each location will change over time. The installation idea was coming from the sound walks. By selecting one of the five places a museum visitor could experience a virtual sound walk in short time.

There have been several projects which have concentrated on the soundscape creation process. The Silence of the Lands project, which was described on the previous page, is one of them. UrbanRemix [53] and SoundScapeTK [54] can be categorised also as location-based soundscape projects. However, their main emphasis is on the soundscape platform. In UrbanRemix users are using mobile software to record a soundscape from some location and this soundscape together with the location info is then uploaded into the platform's content management system. For browsing and remixing soundscapes UrbanRemix provides a browser and map-based tool, which enables users to listen to existing soundscapes and create new soundscapes by defining 'paths' on a map. Mobile software has also a soundscape mixing functionality which combines stored sound files near the user's location. SoundScapeTK is mainly relying on iOS application. The main functionality is location-based mixing, where a soundscape consists of regions. Each region contains a sound file and metadata defining how and when a sound will be played. Depending on the user's location one to several regional sounds will be played. For a sound designer there is a map view to edit metadata and thus modify the soundscape. The same map view can be used for testing by virtually changing the user's location. Both soundscape metadata stored as JSON-file and audio files are stored in the backend system. More advanced soundscape platforms are targeted to professionals, such as sound designers and composers. These platforms create layered and detailed soundscapes from configurable zones, each of which contains a set of sounds with metadata. They take into account the space model and listener position when generating spatial soundscape. The end result, i.e. soundscape will be either produced as a stream, like in the MTG Soundscape project [55] or also as a file, like in the SoDa project [56]. The MTG Soundscape project can use both user-contributed audio and sound snippets from the Freesound database [57].

As a summary, we will categorise earlier mentioned soundscape projects using the following features: type of content, source of sounds, purpose of the soundscape creation, target audience, and technology. Table 4 in the following two pages summarises soundscape projects using these features.

Table 4: Summary of main features of soundscape projects.

Project	Type of content	Source of sounds	Purpose of the soundscape	Target audience	Used technology
The World Soundscape Project	Environmental sounds	Sound walks	Ecologically balanced soundscape	Public	Audio recorders
Vivacity 2020	Urban sounds	Sound walks	City planning	Public, Decision makers	DAT recorders
Positive Soundscape	Urban sounds	Sound walks, Curated sounds	Soundscape perception study	Public	Audio recorders, soundscape sequencer, map-based web site
Principal component model	Urban outdoor sounds	Curated sounds	Soundscape perception study	Public	Binaural recording and reproducing system, semi-echo free room
Soundscape perception planning	Sonic effects, music	Curated sounds	Soundscape perception study	Museum visitors	Sound reproducing system
Tactical Sound Garden	Any sounds	Recorded sounds	Shared soundscapes	Public	Mobile device with headphones, backend system incl. 3D audio engine
National Mall	Composed sounds and music	Curated sounds	Artistic installation	Outdoor park visitors	Smart phone application, Backend system
Hirano Soundscape Museum	Urban sounds	Curated sounds	Preservation history	Museum visitors	CD players, website
The Silence of the Lands	Wild nature soundscapes	Sound walks	Preservation and experiencing natural heritage	Local community	Mobile devices, backend system, desktop client

Project	Type of content	Source of sounds	Purpose of the soundscape	Target audience	Used technology
Sounding Museum	Environmental and artificial sounds	Curated sounds	Support museum artefacts	Museum visitors	Sound Chamber
Klang.Reise	Outdoor sounds	Curated sounds	Raise awareness of environmental sounds	Museum visitors	Ambient cinema
UrbanRemix	Urban sounds	Recorded sounds	Raise awareness of aural environments	Local community	Mobile phones, web based tool, content management system
SoundScapeTK	Any sounds	Recorded sounds	Shared soundscapes	Public	iPhones, Backend system
MTG Soundscape	Any sounds	Curated sounds, recorded sounds	Utilised in games, AR applications, urban design, artistic installations, etc.	Sound designers, composers	Platform incl. format editor, generation module, content management system, streaming service
SoDa	Any sounds	Curated sounds	Utilised in games, AR applications, urban design, artistic installations, etc.	Sound designers, composers	Platform incl. search engine, generation module, soundscape composer, content management system
Freesound	Any sounds	Recorded sounds	Utilised in soundscapes	Freesound community	Content management system

According to Schafer [41] a soundscape can be a musical composition, a radio program or an acoustic environment. Radio programs can be audio stories and can thus be seen as one type of soundscape. Next, we will look at the stories, how storytelling has evolved and what kind of systems are available for digital storytelling.

2.1.3 Digital Storytelling

Digital storytelling has its roots in San Francisco, California, where local media artists and designers explored how digital media tools introduced in the 1990s could be used to empower personal storytelling [58]. Based on these explorations and discussions, a media producer and interdisciplinary artist, Dana Atchley, together with a theatre producer, Joe Lambert, and his wife Nina Mullen, founded the San Francisco Digital Media Center in 1994 [59]. This was the starting point for a series of community workshops called 'Digital Storytelling'. Digital storytelling enabled ordinary people to tell their personal stories utilising digital cameras (and later mobile phones), computers and non-linear editing software. The value of these personal stories was recognised by media houses such as BBC [59] and schools [60, 61].

In a museum environment digital storytelling soon required interaction elements. Bedersen's automated tour guide prototype (discussed earlier) could be seen as a set of linear digital stories, where interaction was based on location [28]. The My Exhibition project developed a prototype, where the audio content provided was based on user preferences. Audio stories were a combination of improvisations, readings and comments related to Jean Froissart's Chroniques exhibited in the Leeds Royal Armouries Museum. The system utilised user movement detection and colour detection of badges. Utilising user location and badge colour, relevant stories were selected utilising metadata linked to stories [62]. The Sarajevo Survival Tools project developed a virtual presentation of Sarajevo Under Siege exhibited in the Historical Museum of Bosnia and Herzegovina [63]. The digital story in this case was a movie, which was divided into segments. The segments were presented in sequential order and each segment provided a possibility to browse through objects related to the segment's theme. More advanced interaction was provided by Holocaust survivor stories [64] and Apartheid-Era narratives [65]. Both projects consisted of personal stories told by persons who had experienced these dark sides of human life. The Holocaust survivor project had stories and answers to questions in video format. Visitors in the Illinois Holocaust Museum could ask questions verbally. Based on speech recognition, the storytelling platform was searching suitable answers or general comments if the search functionality could not find a relevant answer. The Apartheid-Era project implemented a virtual model in the District Six Museum in Cape Town. Both story tellers and visitors were virtual characters. In addition to narratives, the virtual model also contained story-tellers' answers and questions. Thus, visitor interaction consisted of either asking questions of the story-teller or answering the story-teller's question. These questions and answers were analysed and relevant narrative content produced if the content search was successful.

Interactive storytelling research has produced more advanced digital storytelling platforms than the previously mentioned, museum-related projects. Typically, these platforms contain an interactive narrative environment and a virtual environment utilising a game engine. The story plot and characters are the main elements of a (digital) story. Some systems emphasize the plot in order to keep the story well-organised and interesting [66]. Some systems emphasize the autonomous characters and their behaviour [67]. Then, there are hybrid systems which try to balance between character and plot approach [68, 69]. In all these platforms the interactive narrative environment is based on a reasoning component and directed graphs which are used to respond to user interaction, control character behaviour and narrative plans, and interact with the game engine. The Apartheid-Era project contained a game engine producing the virtual environment and reasoning element for controlling narrative sequences, responding to user interaction and interacting with the game engine. It could be categorised as a plot-based story telling platform.

Tangible user interfaces (TUI) have also emerged in the digital storytelling world. The TUI approach allows us to manipulate digital information with our hands using physical objects [70]. There are already several storytelling systems containing TUI. Harley et. al. (2016) have reviewed and categorised 21 tangible storytelling systems [71]. They have found out that most systems targeted to adults provide only the listener role and systems targeted to children enable story creation. Museon in The Hague, Netherlands had the 'The Hague and the Atlantic Wall: War in the City of Peace' exhibition, where tangible replicas were used to control video and audio content. As a part of a smart-replica project, personal stories related to 10 objects were recorded. Each object had three different stories told by a civilian, a civil servant and a German soldier. In addition, all the stories were recorded in Dutch and English. Visitors were offered six different replicas with an NFC tag, where each replica defines which language is used and who will tell the story. By placing a replica on top of an NFC reader, the digital content related to the object will be presented [72].

Only those projects, which were connected to a museum environment will be summarised. Table 5 describes the main features of each project.

Table 5. Summary of the main features of digital storytelling projects.

Project	Story format	Linear / non-linear	User interaction
Automated Tour Guide	Audio	Linear	User movement
MyExhibition	Audio	Linear	User movement
Sarajevo survival tools	Video	Linear	User selection
Holocaust survivor	Video	Non-linear	Speech recognition
Apartheid-Era narratives	Virtual reality, audio	Non-linear	Virtual character
Smart replicas	Video, audio	Linear	Replica movement

So far, we have discussed technologies to consume and create content. These can be used when developing new services for young museum visitors. Typically these tools to address new technologies are separate individual applications. There is no general-purpose IT platform, which would enable a plug-in structure to address several different technologies. Next, we will take a look at how we could approach these young visitors.

2.2 Co-operation and Engagement

In order to reach and attract young visitors we need two different approaches. First of all, we need to reach the young people. One of the easiest ways is to co-operate with schools. This also means

that schools themselves should value the co-operation with cultural institutions. This is where the extracurricular activities play a major role. However, it is not enough that we are able to reach the youth. There must be some motivational factors that encourage the young people to participate. In that case we need to understand the concept of engagement. Let us start with extracurricular activities.

2.2.1 Extracurricular Activities

Young people in the USA and other western nations spend 40 – 50% of their waking hours on leisure activities, adolescents even more [19, 73]. Out of this time organised activities outside of the school day are around 15% [73]. These organised activities include school-based extracurricular activities, after-school programs, community-based programs and youth organisations. They are characterised by structure, adult supervision and skill development. Both sociologists and psychologists have researched the relationships between participation in these activities and social outcomes, academic achievements and educational aspirations [19, 20, 21, 73].

Jacquelynne Eccles is one of the leading researchers in this area [20]. She has studied how youth can be categorised into different clusters based on their involvement in several both organised and non-organised leisure activities [21, 73]. Then all of the clusters were examined using academic performance, emotional (psychological) functioning and behavioural functioning as variables. Results from this study demonstrate that adolescents, who are mostly participating in extracurricular activities (School and High Involvement clusters), typically have high academic performance, high psychological resilience and low problem behaviour [74]. She has also conducted more focused studies related to extracurricular activities. In two studies extracurricular activities were divided into sub-activities, such as academic clubs. These sub-activities were separately analysed. Based on analysis participation in all sub-activities predicted better educational outcomes. Adolescents who participated in academic clubs enjoyed school, had higher grades, were more likely to enrol in college and used less alcohol. These two studies were also discussing the role of peers linking activity participation to positive development. Adolescents in an academic club context reported having more academic and prosocial friends than non-participants. Being a part of a prosocial peer network explained at least partially the positive development, such as school engagement.

Joseph Mahoney is another leading researcher in the youth development field [20]. In one of his studies (together with Eccles and Harris) he was addressing the over-scheduling topic [19]. Some of the researchers have raised concerns that some youth are participating in too many organised activities due to pressure from parents and other adults. According to these over-scheduling researchers this type of excessive participation will create a risk that young people would have adjustment problems and poor relationships with parents as they do not have time for traditional family activities. Based on earlier research reviews it can be seen that youth participating in organised activities have reported intrinsic motivations for participation. In addition, the vast majority of American youth are able to balance their organised activity participation with school work, family time, informal socializing with friends and relaxing. Only 6% of adolescents are spending 20 or more hours per week on organised activities. Findings from several studies do not provide evidence that extreme levels of participation would be harmful.

Reed W. Larson has been mentioned as one of the leading researchers in the youth development field [20]. He has studied youth activities from the personal and interpersonal development angle [75, 76]. Personal development is a combination of identity work, development of initiative and development of emotional, cognitive and physical skills. Interpersonal development consist of team work and social skills development, peer networks and internalization of positive prosocial norm development, and development of adult networks. In two studies organised activities were divided into similar sub-activities to Eccles' sub-activities. These sub-activities, such as academic clubs and organizations were analysed from the angle of personal development, interpersonal development and negative experience. In addition, organised activities were compared to academic class, hanging out with friends and working at a job. In comparison it was evident that all organised activities provided positive developmental experiences in all categories compared to school classes. When analysing sub-activities, it turned out that academic clubs and organizations were providing lower positive developmental experiences than the other sub-activities. This was explained by the fact that this sub-activity contains activities that typically encourage academic development and thus academic achievement is the main driver. Young people report very low negative experiences (stress, inappropriate adult behaviour, negative influences, social exclusion, and negative group dynamics) in academic clubs and organizations sub-activity.

Feldman and Matjasko have published two comprehensive reviews of studies in the field of school-based extracurricular activities and adolescent development [20, 77]. Their first review was looking for relevant research literature in the early 1980s until 2004 and the second one for the next five years. As a summary from the first review consisting of 36 studies, it was found that extracurricular activity participation compared to unstructured activities is linked to positive adolescent developmental outcomes: higher academic performance and attainment, reduced school dropout rate, lower rate of substance use, higher self-esteem, less worry about the future, less social exclusion, and less delinquent behaviour. The newer review with 52 new studies confirmed earlier review findings.

So far, the studies which have been described here are mostly from the USA. In Feldman's and Matjasko's review there were a couple of studies from Sweden and Canada. In order to provide a non-US angle there are two studies, one from Australia and another one from Finland, discussing the extracurricular activities and youth development. The Australian study confirmed mostly the findings described earlier, i.e. adolescent participation in the extracurricular activities was associated with university aspirations, higher level of school belonging and less school skipping [78]. It was also found that participants had more prosocial friends. The Finnish study was targeted on 10-12-year-old children [79]. Participating in extracurricular activities was related to lower levels of internalizing problems, such as depressive symptoms and social anxiety. Participating in academic clubs resulted in higher academic attainments. In addition, longer duration (two to three years) of participation was associated with more positive outcomes.

As a summary, we can assume that participating in organised, structured extracurricular activities in general have a positive impact on adolescents' development. If we look at the participation in academic clubs, then the main positive impact is in academic achievements, such as school grades, school belonging, college and university aspirations. Also, positive developmental experiences compared to school classes. In addition, lower negative experiences and substance use. From the school point of view, it is easy to understand that teachers and other school staff see academic clubs and other extracurricular activities in a very positive light.

How do we know that students will also find these activities attracting? That is covered next.

2.2.2 Student Engagement

There are several definitions of engagement. Some researchers, whose background is typically in motivational theories, such as flow theory, interest theory and self-determination theory, define engagement as a synonym for motivation [80, 81]. In recent years, research on engagement as a separate structure has emerged. Today, most motivation and engagement researchers have come to an agreement that motivation is the antecedent of engagement. According to research motivation is intent and engagement is action [83]. We will use the student engagement definition as our context is extracurricular activities. It is agreed that the student engagement structure has several dimensions. The amount of dimensions vary from two to four depending on the researcher [83]. The vast majority of engagement researchers agree on a three-part typology described by Fredricks, Blumenfeld and Paris [82, 83]. According to Fredricks et al. (2004), student engagement is a multidimensional structure consisting of behavioural, emotional and cognitive engagement components. The behavioural engagement component is typically defined in three ways. We have a positive behavior aspect. Then there is intentness on learning and academic tasks. The third aspect is involvement in school-related activities.

The definition of emotional engagement is based on students' emotional reactions, such as happiness, sadness, interest, boredom, and anxiety. The cognitive engagement component links to students' preference for challenging tasks, attention to tasks, how to master the task, and willingness to go beyond what is required. According to research the engagement components are interrelated. However, there is no clear understanding of how different types of engagement components interact. Based on some research, it seems that emotional engagement leads to increased behavioural and cognitive engagement [82].

There are several student engagement measument instruments and they differ a lot from each other. This differentiation is a result of the student engagement structure's subcomponent definition. Some researchers have defined four subcomponents and some three. Even if using the most common three component structure, researchers have not been able to agree on the content of items describing subcomponents. During the data-gathering phase the most common methods used contain interviews, observations, student self-report surveys and experience sampling. The handbook of research on student engagement contains a comparison of various methods [84]. There are descriptions of 11 self-report instruments. Another study describes 21 instruments including 12 student self-reports, 3 teacher reports, and 4 observational measures [85]. If we take these 12 student self-reports, only 5 include subscales that address all three engagement subcomponents.

As mentioned earlier most of the extracurricular activity research concentrates in school-based activities or general trends in different activity categories. There is a similar situation in student engagement research and especially measuring it. Out of those 5 self-reports, which cover all three dimensions of engagement, none is targeted to only out-of-school extracurricular activity measurement.

3 Modular Audio Platform

The main goal of this thesis was to develop a modular and easy-to-use audio story- sharing and audio-augmented reality platform, which was used in workshops in order to measure the level of engagement of participating youth. This chapter will concentrate on the design and development of a portable modular audio story-sharing and audio-augmented reality platform. In addition, we will discuss the user interaction measurement of the mobile applications developed.

3.1 Platform Architecture

There are several approaches to design software architecture [86]. As described by Hofmeister et al. (2007) despite the different vocabulary used, these methods have a lot in common. Therefore, selecting one approach over another is not a big issue. In this case we will follow the attribute-driven design method which produces a workable architecture early and quickly [87]. First, we will describe the functional requirements (or responsibilities), non-functional (or quality attribute) requirements and constraints. Then we will discuss what the most important requirements or architecturally significant requirements are and what kind of architectural patterns are suitable to address these requirements. Finally, the platform architecture will be described at a sufficient level by using relevant views. Let us start with the requirements and constraints.

3.1.1 Requirements and Constraints

We have divided requirements into functional and non-functional following the guidelines described by Bass et al. [87]. We use the term functional instead of responsibilities as functional requirement is a commonly known term. Non-functional requirements will be called Quality Attribute Requirements.

As a starting point it was clear that we need some kind of content management system to store and distribute audio files. Studying some popular open source content management systems, like WordPress, Drupal and Joomla, it was easy to figure out the basic requirements for such a system. More research related to audio content management and metadata management requirements was done during the design and development of ADAM [II]. Initial mobile application requirements were based on similar application functionalities. Soundscape mixer mobile application was following research-based design approach. During the design phase more detailed requirements for the mobile application and also for the APIs between mobile applications and

ADAM were defined [III]. Similarly during the design of Audio Story applications the requirements were defined iteratively. First requirements were found by studying the functionalities of other digital storytelling applications. After which there were brainstorming and discussion sessions with museum staff and Metropolia students, who present the application target group. Then followed several testing rounds of prototypes, where more detailed requirements were defined.

Table 6. Functional requirements.

General requirements	Detailed requirements
FR1 Manage common audio data	• create, read, update and delete audio and related metadata content • search content based on metadata • metadata should be compatible with unqualified Dublin Core • provide APIs: authenticate, search content, download content, and upload content
FR2 Provide admin console	• manage access groups and rights • manage users • provide easy to use access to metadata management • provide easy to use access to audio data management
FR3 Manage soundscapes	• run on mobile device • Login into common audio data • Search content (common audio data) utilizing metadata • Download, save and play selected files either in MP3 or raw (PCM) format • If needed convert audio file format • Mixing, i.e. define combination of saved files that will played, possibility to loop, change volume, etc. of each audio file separately • Record audio file, convert the audio format and upload together with metadata into common audio data
FR4 Manage audio stories	• run on mobile device • read user id, password, collection id, and artefact title from the NFC tag • decrypt user id and password • login into common audio data • listen to the audio stories related to the artefact • filter the stories based on the emotions • record an audio story • add emotions related to the story • upload audio story and related metadata (incl. emotions) into common audio data
FR5 Manage NFC tags	• run on mobile device • write a user id, password, a collection id, and an artefact title into a NFC tag • encrypt the user id and password

We have defined functional requirements as general and detailed requirements in Table 6. From the general requirements module candidates can be deducted as follows: audio data management, admin console, soundscape management, audio story management, and NFC tag management.

Quality Attribute requirements follow a similar two-level approach such as functional requirements. These requirements are described in Table 7, which covers only those non-functional requirements, which are most relevant to a quite simple prototype system, which we will plan.

Table 7. Quality attribute requirements.

General requirements	Detailed requirements
QAR1 Availability	• Fault detection using mainly exception detection
QAR2 Interoperability	• Audio data management module should enable exchange of assets by supporting Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) • Audio data management module should provide REST API
QAR3 Modifiability	• Different modules needs to be encapsulated in order to reduce coupling of modules • Audio data management module needs to be portable
QAR4 Performance	• Mobile applications' response times should be less than 1 second • Audio data management module should be capable of supporting up to 50 simultaneous mobile applications
QAR5 Security	• Audio data management module should include basic security in the form of authentication and authorisation, access limits, and non-default settings • NCF tag's sensitive content should be secured • Mobile applications should include basic security in the form of authentication and authorisation

The platform customer is typically a cultural institution, like a museum. This means that we can not expect that museums would have a large IT department or resources to acquire some special IT infrastructure in order to support our platform.

As most of the development work has been done as a part of the The People's Smart Sculpture-project, we decided to concentrate on auditory presentation as other partners were focusing on the visual presentation. In addition, the other project partners should be able to use our platform. Thus open-source solutions are recommended when developing software.

The first version of audio data management and access modules should be up and running within 4-5 months.

3.1.2 Architectural Patterns

Let us take into account only the high level functional requirements (FR1 – FR5) and non-functional requirements (QAR1 – QAR5) when considering suitable architectural patterns. According

to Bass et al. [87] software architecture consist of three kinds of structures: module, component-and-connect, and allocation structures. Thus, we will use the same categorisation when looking for suitable architectural patterns. Out of module patterns the very common layered pattern addresses the modifiability quality attribute requirement [87]. Audiostory mobile application, soundscape mobile application and admin console interface with an audio data management layer, which interfaces with the data storage layer. From the component-and-connect category we will select the client-server pattern for the platform level and model-view-control pattern for the mobile applications [87]. The client-server pattern addresses modifiability, performance, interoperability and availability quality attribute requirements. Mobile applications and the admin console can be seen as clients and audio data management as the the server. The model-view-control pattern by separating UI and datamodel addresses the modifiability quality attribute requirement [87]. The shared-data pattern will be useful with the NFC tags as both Audiostory mobile application and NFC management application share data stored into NFC tags. The shared-data pattern addresses the modifiability and performance quality attribute requirements [87]. The multitier pattern as an allocation pattern addresses modifiability, performance, interoperability, security and availability quality attribute requirements [87]. Mobile applications will run as mobile platform processes and the admin console will run as a browser-based application at the client tier. Audio data management will run on the web server at the web logic tier, and data and metadata will run on the database server at the data storage tier.

3.1.3 Platform Level Architecture

The architectural patterns propose that we need to modify our module candidates by separating the audio data management into data storage and data management modules. Thus, the platform level architecture can be divided into the following modules:

- data management module
- data storage module;
- admin console module;
- soundscape management module;
- audiostory management module;
- NFC tag management module.

The data management module provides audio and metadata management functionalities, such as create, read, update and delete audio and related metadata content. It also provides search functionality. In addition, it provides APIs to authenticate, search content, download content, and upload content. The data storage module takes care of data and metadata storage. The admin console module manages users, accesses groups and rights. In addition, it provides access to audio data and metadata management.

The soundscape, audiostory and NFC tag management modules run on mobile devices. All of them access audio and metadata utilising APIs offered by data management module. The

soundscape management module provides audio file manipulaton functionalities, like download, play, record, upload and mix audio files. The audiostory management module offers NFC tag reading, audio story listening, recording and uploading functionalities. The NFC tag management module links stories and artefacts by writing the relevant info into NFC tag.

Let us review whether the selected architectural patterns will address the non-functional requirements. Table 8 will summarise how architectural patterns will address the non-functional requirements. As we can see in Table 8, the selected architectural patterns are in principle capable of addressing non-functional requirements. Thus, we can apply those patterns to define our platform architecture on a more concrete level using relevant views to describe the module, component-and-connect, and allocation structures, and sequence view to describe the behaviour of the architecture.

Table 8. Summary of architectural patterns addressing non-functional requirements.

	QAR1	QAR2	QAR3	QAR4	QAR5
Layered pattern			x		
Client-server pattern	x	x	x	x	
Model-view-control pattern			x		
Shared-data pattern			x	x	
Multitier pattern	x	x	x	x	x

Modules decomposition and their use dependencies are described in Figure 1 using UML2 notation as proposed by Hofmeister et al. [88]. Figure 1 describes how modules are divided into three different layers, where each layer is allowed to use the next lower layer. This means, for example, that the admin console is not able to access the data storage directly. The only way to access the data storage is by using the data management.

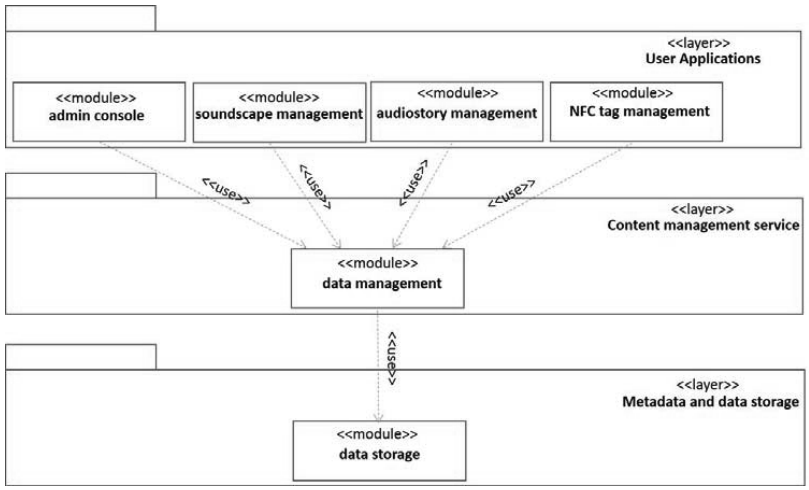

Figure 1. Layered module view.

Figure 2 describes the runtime view of the platform. We will use UML2 components and ports, and connectors defined as associations [88, 89, 90]. As described in Figure 2 there are several mobile applications running simultaneously. These mobile applications are communicating with the data management component using the http protocol. The admin console is also communicating with the data management component using the http protocol. The audiostory management and NFC tag management modules are reading and writing NFC tags using the NDEF protocol. We will assume that audio and metadata are mainly stored in a relational database and the data management module is using MySQLi as communication protocol when accessing the database.

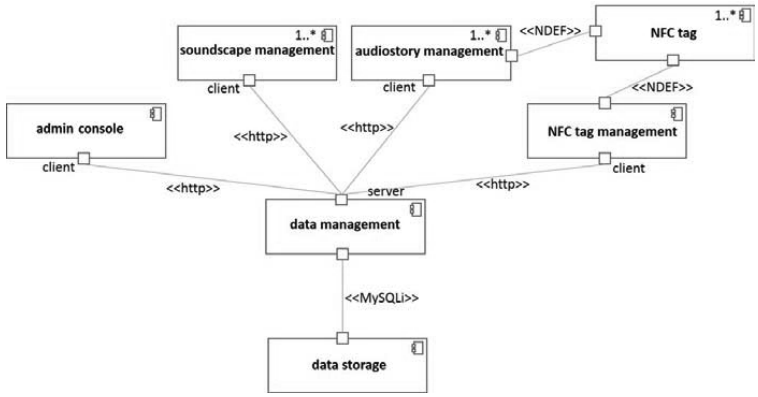

Figure 2. Component-and-connect view.

In order to describe how modules are mapped into the hardware environment we will use deployment view (see Figure 3). In Figure 3 we can see that the soundscape management, NFC tag management and audiostory management modules will run on smartphones. The admin console module will run on the workstation's web browser. The data management and data storage

modules run on application and database servers, which could be separate physical or virtual servers or one server combining both roles.

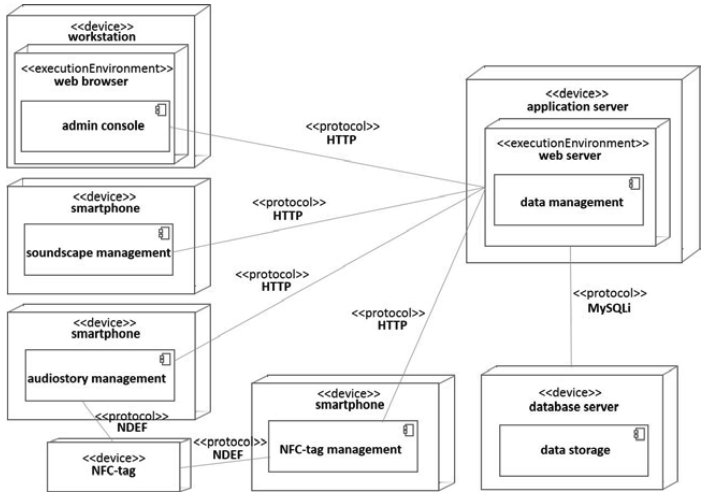

Figure 3. Allocation view.

As modules are decoupled from each other in order to enable modifiability and also the possibility to allocate development of each module for separate teams, we need to define the behaviour between smartphone applications and data management. In Figure 4 we have described on a high level how different APIs need to behave. These APIs are defined as a part of functional requirements (FR1). Mobile clients are soundscape management, NFC tag management and audiostory management modules. We will use basic authentication and authorisation (see QAR5) by forcing mobile clients to send userid and password to the data management module. As a response the data management module will return the API key (or token) (Figure 4 A), which is used when searching (Figure 4 B) or uploading files (Figure 4 C). It is assumed that during authorised search the client will receive a link (or url) as a part of the file list. Thus, the API key is not used during the download (Figure 4 D).

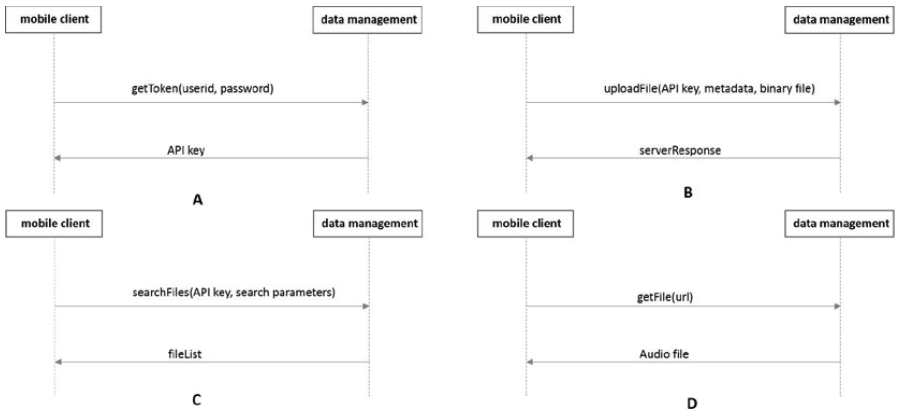

Figure 4. Sequence view.

Next, we will discuss technology selections to define hardware and execution environments in more detail.

3.1.4 Technology Selections

There are two main technology-related selections: which technologies for the backend service (data management and data storage modules) and which technologies for the mobile applications (soundscape management, NFC tag management and audiostory management modules). As described earlier, one of the constraints was to use open-source software and another one was suggesting using common technologies which would be easily available also for small cultural institutions. These constraints and limited time frame were heavily impacting backend service technology selections. The initial idea was to find an existing open source digital asset management system, which would be based on LAMP-stack as Apache is the most common web server [91] and PHP is the most common server-side programming language [92]. In the next chapter we will discuss in more detail the backend service technology selection.

Technology selection for mobile applications needs to address two questions:

1. Should we support several mobile platforms?
2. Are we able to use web technologies or should we develop native applications?

Let us start with the second question. If we are able to use web technologies to develop browser-based mobile applications then we are most probably able to support both iOS and Android platforms. We need to look at the details of functional requirements FR3 and FR4. Based on the Device Agnostic CASS Client-publication [I] we know that the audio recording is the critical issue. This functionality requires that the following APIs are supported by the browser: MediaStream API / getUserMedia method and MediaStream Recording API. MediaStream API's getUserMedia is used for recording from the device's microphone and Stream Recording API for capturing that stream into a Blob object, which can be played or uploaded. In addition, Web Audio API is needed when processing, for example mixing audio streams. Based on our tests during spring 2014 the only browser supporting audio recording was Chrome v. 32 [I]. As of today, iOS Safari 11.2 is still not supporting Stream Recording API [93]. The MediaStream API / getUserMedia method is supported only by the newest mobile browsers: iOS Safari 11.2, Chrome for Android 62 and Samsung Internet 6.2 [94]. So, browser-based mobile applications are not able to support audio recording, which is an essential functionality especially for the audiostory management module. If we look at the NFC and web technology then we have another obstacle. Web NFC API is only a specification draft and the current support is limited to an experimental implementation in Chrome [95]. In addition, iOS 11 finally is supporting NFC tag and NDEF message reading, but not writing [96]. If we want to address the functional requirements FR3 – FR5, we need to develop native applications for the Android platform. This is not that bad a situation as around 80% of the new smartphones are based on the Android platform [97, 98, 99]. This was also the situation in 2015 when the decision was made (see Figure 5).

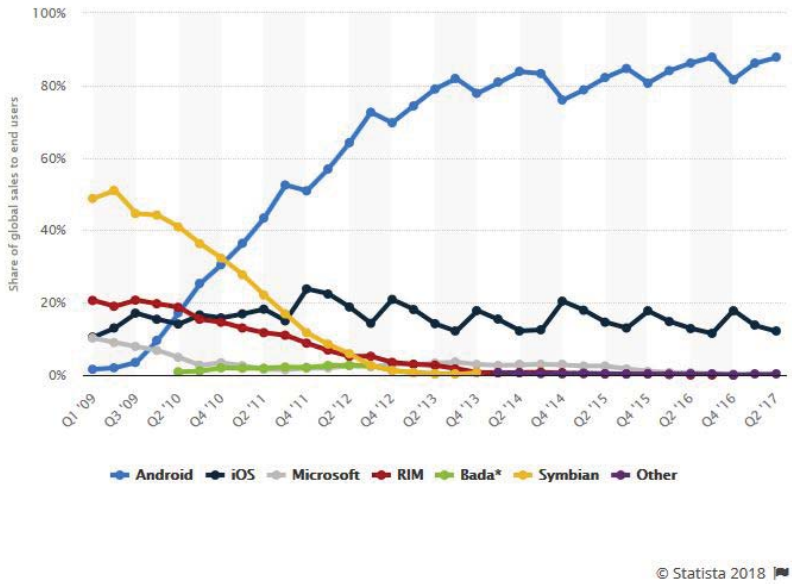

Figure 5. Smartphone sales by Operating System between 2009 and 2017.

Figure 5 describes the new smartphone sales worldwide. We can see that since 2014 the Android platform has taken the major share (around 80%) followed by iOS (less than 20%). Regionally there are some variations in market shares. In any case, the Android platform is the market leader.

3.2 Backend Service

Data management and data storage modules together constitute the backend service, which will provide required services to mobile applications using APIs.

3.2.1 DAM Selection

As described in chapter 3.1.1 there was a time constraint to develop the audio data management part of the platform. Taking into account functional requirements FR1 and FR2 we could easily see that a readymade digital asset management system (DAM) would address most of these requirements. DAM needs to manipulate as well as protect from unintentional alteration those digital assets stored in it. There are two complementary definitions of digital asset. First one defining asset as a combination of a file and metadata. This definition is commonly used by large companies [100]. The second definition states that an asset is a combination of a file and its rights. This definition is based on the idea that content has value only as long as there is the right to utilize it [101]. If we combine these two definitions then a DAM should contain digital files, such as audio files and related metadata as well as usage rights, which could be part of metadata.

There are several types of DAMs. Some of them are designed for a specific file type, while others are designed to cover several file formats. In order to find potential DAM candidates, we did a search for open source digital asset management systems and created a short list of the ones that seemed to be suitable based on descriptions on the web [II, 102]. In Table 9 we list potential open source DAMs and their characteristics.

Based on the web descriptions, we ended up selecting Telemeta [103] and ResourceSpace [104] for further studies. Unfortunately, we did not have time to install and test both DAMs. Based on documentation we could deduce that Telemeta's target users are musicologists. Telemeta utilises the TimeSide audio processing framework. In addition, they have included in the system audio analysis plugins and audio extraction libraries. Thus, the system aims at describing audio files on a detailed level, which is not needed in our case. During our evalution period Telemeta was still in development mode. In addition, it was not compatible with Windows systems. Thus, we ended up using ResourceSpace as the basis for data management, data storage and admin console modules. The ResourcSpace selection was also supported by the availability of a large number of students with PHP skills.

Table 9. Potential open source DAMs.

Software name	Features	License	Language
Telemeta	• open source • web audio archiving software • metadata • user management • English and French support • REST API • Dublin Core compatibility	CeCILL	Python and JavaScript
ResourceSpace	• fully featured DAM system • user management • API available • plugins available • metadata • many file types	BSD	PHP and SQL
Phrasenet	• DAM system • user management • images/video/documents support	GPL3	PHP
EnterMedia	• typical DAM system • uses XML, but database possible • plugins available • metadata	LGPL	Java

3.2.2 ResourceSpace Modifications

In order to fulfil the requirements described earlier the following modifications were needed:

- Admin console configuration.
- New metadata fields added.
- Existing API modified and new ones developed.

ResourceSpace's standard admin console is fairly straightforward to understand and use. The Team Center functionality enabled necessary changes to exclude other than audio content and modify the look and feel. The same Team Center functionality enabled adding the necessary metadata fields. Originally there were already some metadata fields. First, we added some more metadata fields in order to address initial requirements. After researching metadata standards there was a need to comply with unqualified Dublin Core to enable the exchange of assets in the future by supporting Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) [105, 106]. Thus, more metadata fields were added. A more detailed discussion about metadata can be found in the publication Backend Infrastructure Supporting Audio Augmented Reality and Storytelling [II].

ResourceSpace from the box provides two built-in APIs, an upload and a search API. Both of these APIs were tested to check if they comply with the requirements. The upload API satisfied our requirements with a few minor additions. Unfortunately the search API did not address our requirements. Thus, we had to develop our own search API and an authentication API. The search API implicitly also enables downloading functionality as it also returns a link to audio content. A more detailed description about these APIs can be found in the publication Mobile Soundscape Mixer – Ready for Action [III].

We will call the modified ResourceSpace including audio content audio digital asset management (ADAM). ADAM is an implementation of Data management and data storage modules. In addition, modified ResourceSpace also implements the admin console module.

During the ResourceSpace modification several user tests were done from the different roles: admin role, ADAM maintenance role, and client developer role. Based on the tests, bugs were corrected, some functionalities were changed, and user-guide documents improved. Before testing we produced five user guides. The installation guide was used to define the server environment in the Museum of Technology, install ADAM and run basic functionality tests to ensure successful installation. The admin guide was given to two persons from the museum staff (non-IT-staff), who were testing the system as administrators. Their response was that the system works and the admin guide is sufficient to handle the tasks. After that the admin guide was given to a few sound design students with basic IT-skills. They were testing audio files and metadata upload functionality. These files were used as soundscapes building blocks in a museum environment. The sound design students were able to accomplish their task using the guidelines from the admin guide. The only complaint was related to manual input of metadata fields, which was slowing the upload process. Using three API guides,the Authentication, Search and Upload APIs were tested first by using Chrome Advanced REST Client and a simple Android app. After this preliminary testing, the API guides were given to a group of Android developer students. These students were developing apps which needed access to ADAM. The students were able to develop the required functions based on the API guides. During the testing there was one change request: the search API should return an empty array in JSON if the results for the search were null. This change was implemented. Otherwise all APIs were working as defined. More detailed testing description will

be provided in the publication Backend Infrastructure Supporting Audio Augmented Reality and Storytelling [II].

3.2.3 ADAM Addressing Requirements

As ADAM was ready to be used as the backend system serving mobile applications, we could summarize that so far, we have succeeded in addressing the backend-related requirements as expected (Table 10).

Table 10. Backend and admin console requirements.

Functional Requirements	**Yes/No**
create, read, update and delete audio and related metadata content	Yes
search content based on metadata	Yes
metadata should be compatible with unqualified Dublin Core	Yes
provide APIs: authenticate, search content, download content, and upload content	Yes
manage access groups and rights	Yes
manage users	Yes
provide easy to use access to metadata management	Yes
provide easy to use access to audio data management	Yes
Quality Attribute Requirements	**Yes/No**
Fault detection using mainly exception detection	Yes
Audio data management module should enable exchange of assets by supporting Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)	Yes
Audio data management module should provide REST API	Yes
Audio data management module needs to be portable	Yes
Audio data management module should be capable of supporting up to 50 simultaneous mobile applications	Partially tested later
Audio data management module should include basic security in the form of authentication and authorisation, access limits, and non-default settings	Yes

As described in Table 10, we have succeeded in fulfilling most of the requirements. The only exception is the scalability of the system. So far, we have had a maximum of 30 users using 11 mobile devices simultaneously. In a lab environment we tested with 20 mobile devices without any hiccups. If we look at the constraints, then the portability and open-source constraints have been met. The only drawback was the two-week delay in installing the final system in the museum's server. To summarize, we have succeeded in providing the backend system as expected. Next, we will have a look at the mobile applications using the backend system.

3.3 Soundscape Mixer

The idea behind the soundscape mixer application is a mobile tool that enables users to create soundscapes from the building blocks (=audio files) located in ADAM.

3.3.1 Soundscape Mixer Development

The design and development of the soundscape mixer application was given to engineering students, who were participating in a design-oriented course called Usability and Interface, and a programming course called Android Advanced Application Development. The students were divided into teams consisting of designer and programmer sub-teams. All teams were given functional requirements (FR3) as a starting point.

The research-based design approach [107] was used for designing the soundscape mixer application. The research-based design is an iterative process consisting of the following phases: contextual inquiry, participatory design, product design and prototype as hypothesis. The design process produced different levels of prototype granularity, ranging from low fidelity prototypes to a running prototype. The prototypes that were created were tested with users, who belonged to our target group of 15-24-year olds. Since the students themselves also belonged to the defined target group, they could pre-test their ideas with each other. The design process details are described in the publication Mobile Soundscape Mixer – Ready for Action [III]

We provided development guidelines to Android programming teams in order to coach teams towards the target:

- Iterative/agile development process;
- Support Android 5.0 and newer version;
- Follow Google's material design guidelines;
- Support MP3 and/or PCM/Wave-format;
- Utilize Soundpool or Audiotrack classes for playing audio files;
- Utilize AudioRecord for recording.

The design and programmer students had five organized meetings to present, organize, and test their intermediate outcomes. Between these joint meetings, the sub-teams of designers and programmers were working on their own fields. Four of the teams were able to provide a fully working and tested application within the given timeframe. We will describe only the SoundSpace application, which was the preferred application defined by the museum staff. More about these four applications and selection of SoundSpace as preferred soundscape mixer toll can be found in the publication User Generated Soundscapes Activating Museum Visitors [V].

3.3.2 Soundscape Mixer Implementation

The SoundSpace implementation followed the Android best practises as described on the developer.android.com website. At the time of development the MVC architecture was the closest that could be followed [108, 109]. The View can be seen as layout files containing graphical components in XML-format. Activities and Fragments can be seen as Controller, which handles events from user actions and communicates with Model. The model is logical associated with the application data, such as classes defining ADAM audio and metadata, API processing classes and local database. A class diagram describing the structure can be found in Appendix 1. More detailed implementation including class diagrams can be found in the publication Mobile Soundscape Mixer – Ready for Action [III].

The SoundSpace application provides the following functionalities: login, searching and listening to audio files, recording your own audio building blocks, uploading recordings, creating soundscapes and saving them locally.

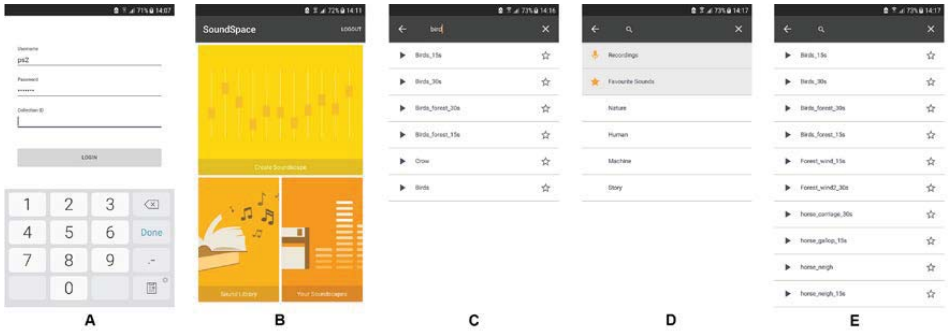

Figure 6. Soundscape login (A), landing page (B), free search (C), search by metadata (D), and search results (E).

Login into the backend system before doing anything else (Figure 6 A). After successful login the user will see a landing page, where it is possible to create a soundscape or browse and listen to audio files or retrieve an existing soundscape from the phones memory (Figure 6 B). The search is either a free search (Figure 6 C) or an assisted search from the user's own recordings or favourite sounds or based on metadata (Figure 6 D). Search results will provide the possibility to play individual audio files and toggle some of them as favourites (Figure 6 E).

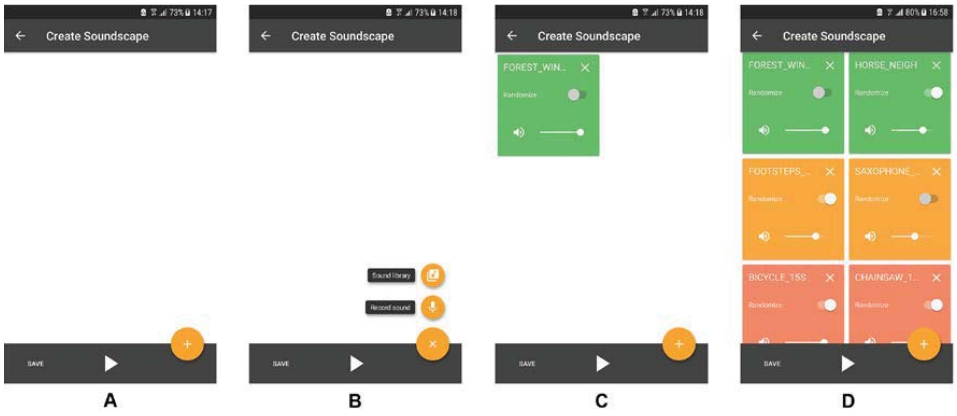

Figure 7. Soundscape create (A), Select source (B), Sound file added (C), and soundscape ready (D).

Figure 7 describes how to create a soundscape from scratch. First, there is a blank dashboard (Figure 7 A). By clicking the plus-button, the user can either record a sound or select a sound from the sound library (Figure 6 D, E). After recording or selecting a sound, it will appear as one soundscape component in the dashboard (Figure 7 C). When repeating this selection process, the user is able to create a soundscape, where each component can be controlled separately by defining the volume level and randomising, when this particular sound will be played.

Figure 8 describes how a user is able to add his or her own sounds if suitable sounds from the backend system, i.e. sound library cannot be found. Recording is quite simple. Just click the record-button and start recording (Figure 8 A). When this has been done, a user can listen to his or her recording and if satisfied, save the recording (Figure 8 B). The saved recording will appear in the dashboard (Figure 8 C). When the user is satisfied with the soundscape, he or she is able to save it into the device's memory.

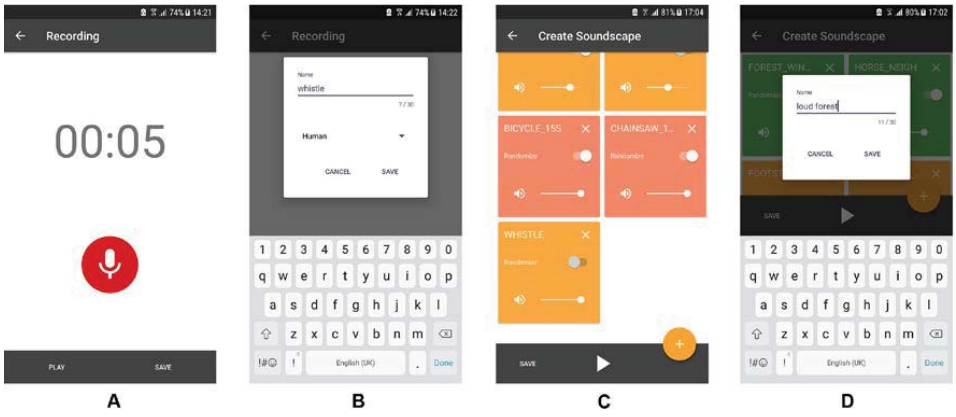

Figure 8. Record your own sound (A), Save recording (B), Recorded sound added (C), and soundscape save (D).

3.3.3 Soundscape Mixer Performance

When evaluating the user experience, the application's performance is one of the main characterictics. There are virtually no existing testing approaches to check the presence and effects of poor responsiveness in Android applications. There is some research carried out and approaches proposed [110, 111]. As the approaches are pretty immature we decided to use those tools that are part of Android Studio [112]. Static code analysis based on lint tool is used to find potential bugs and optimization improvements in source files [113]. We run lint code analysis to get an overall picture of potential problems. Lint exposed no problems. Thus, the common Android development pitfalls related to performance were avoided. According to research the GUI lagging is the most common performance bug [111]. In our case GUI performance was tested using the Hierarchy Viewer tool and GPU monitor. The Hierarchy Viewer tool visualizes the application's UI component (=view) hierarchy and profiles the relative rendering speed for each UI component. As described in the Android Studio user guide [114], potential problem nodes could be spotted using the following criteria:

1. red dots in leaf nodes or view groups with only a few children;
2. a view group with many children and a red measure phase (left dot);
3. a leaf node in a tree with 20+ views has a red draw phase (right dot)

In Figure 9 we present a visualisation of SoundSpace relative rendering.

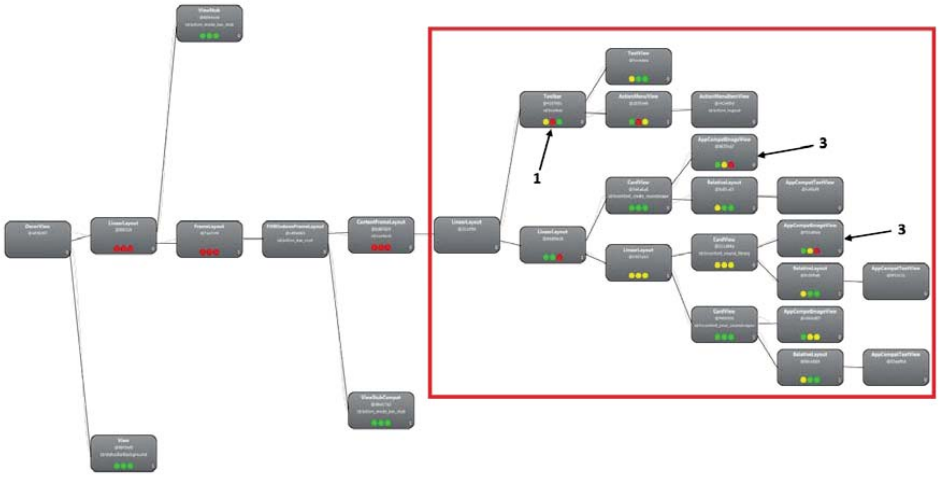

Figure 9. Soundscape Mixer Hierarchy View.

In Figure 9 there are 8 system generated views on the left (outside red box), like DecorView, containing the standard window frame/decorations and zero-sized ViewStubs for lazily inflate layout resources at runtime. Inside the red box there are the real content views which need to be analysed. As seen in the Figure, there are three potential problem areas: the toolbar has a red dot in the layout phase (number 1 in Figure 9) referring to criteria 1 and two imageviews have a red dot in the draw phase (number 3 in Figure 9) referring to criteria 3. When running on a device, they seem to work smoothly. Analysing static information using lint and hierarchy viewer tools did not reveal any problems. The next step was to test run-time information using the GPU

Monitor, which gives a quick visual representation on how much time it takes to render the frames of a UI window. We have run SoundSpace in Samsung Galaxy S7. By analysing the GPU Monitor results we found some potential code blocks where the user may see slower response than expected (see Figure 10).

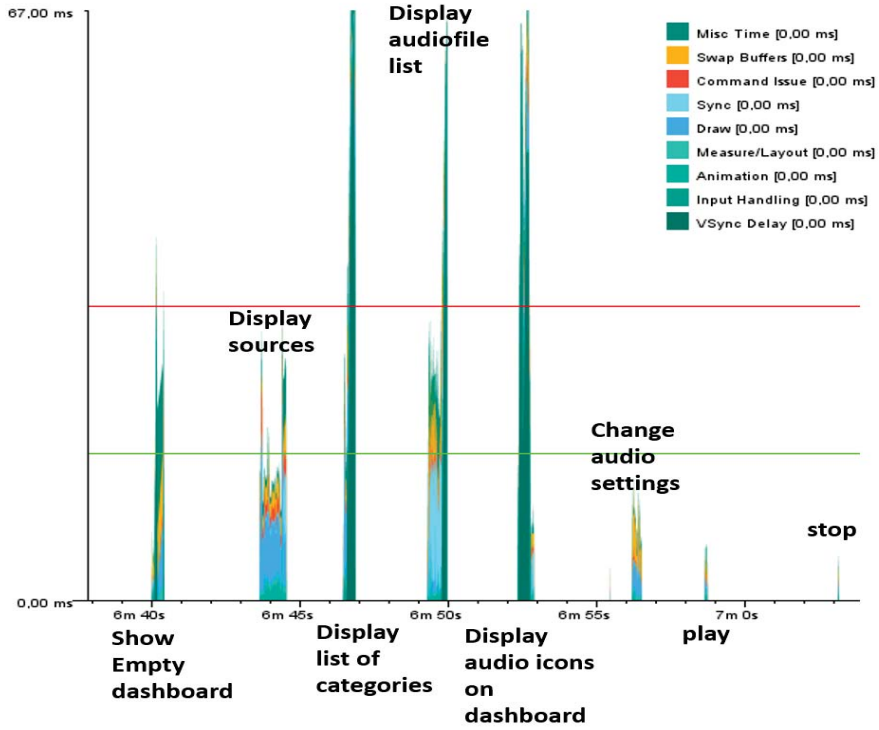

Figure 10. Soundscape Mixer GPU Monitoring.

In Figure 10 we will see that only a few frames are exceeding the green line. This green line demonstrates the 16 ms frame duration calculated from the recommended frame rate 60 frames per second. The recommended frame rate ensures very smooth user interactions with the application. Based on Figure 10, we can see that displaying lists and grid of audio icons is slower than expected. We could improve list and grid processing by simplifying grid and list elements if needed. The responsiveness is at a good level most of the time and only on some occasions slowness could be seen. Therefore, we were confident enough to put this application into the hands of real users.

3.3.4 Soundscape Mixer Addressing Requirements

Let us look at the soundscape management-related functional and quality attribute requirements. In Table 11 there are the requirements and description of how the SoundSpace application will satisfy those requirements.

Table 11. Soundscape management requirements.

Functional Requirements	**Yes/No**
run on mobile device	Yes
Login into common audio data	Yes
Search content (common audio data) utilizing metadata	Yes
Download, save and play selected files either in MP3 or raw audio (PCM) format	Yes
If needed convert audio file format	No
Mixing, i.e. define combination of saved files that will played, possibility to loop, change volume, etc. of each audio file separately	Yes
Record audio file, convert the audio format and upload together with metadata into common audio data	Yes
Quality Attribute Requirements	**Yes/No**
Fault detection using mainly exception detection	Yes
Different modules needs to be encapsulated in order to reduce coupling of modules	Yes
Mobile applications' response times should be less than 1 second	Yes
Mobile applications should include basic security in the form of authentication and authorisation	Yes

The SoundSpace application satisfies almost all functional requirements except audio format conversion. It plays audio files both in WAV (raw audio with headers) and MP3 formats, but records audio only in WAV format as Android devices typically only have an MP3 decoder and not an encoder. Encapsulation is supported by utilising MVC-architecture. Response times are typically less than 1 second, which can also be seen in Figure 10. Longer response times are possible when communicating with the backend. This is addressed by implementing progress bars, when there is a possibility for slow response. In order to use the application, the user has to log in using user id, password and collection id. This ensures that only authorised users have access to a particular sound library. Next, we will discuss two mobile applications which are needed when sharing audio stories.

3.4 Audiostory Applications

As a part of storytelling we will use NFC tags [115]. Cultural institutions need to configure tags. For that purpose, we need an NFC tag management module. An audience visiting a cultural institution will use an audiostory management module. The next chapters will describe these two modules.

3.4.1 NFC Writer Development

Near Field Communication (NFC) is a standards-based short-range wireless connectivity technology [115]. In our case NFC allows to share small payloads of data between an NFC tag and an Android-powered device [115, 116]. The NFC Writer application's main functionality is to store relevant data into NFC tags in order to link the tag and a collection of audio files in ADAM. There are several existing Android applications, which could be used to read and write NFC tags. We could not use those applications because of security reasons. The NFC writer application needs to authenticate the user using ADAM's authentication API and it also needs to encrypt data before storing it into an NFC tag. Thus, we had to develop our own application instead of using some existing Android application.

The NFC Writer application is rather simple (Figure 11). It asks a user to login and check the credentials from ADAM. It encrypts the user name, password and collection id and asks the user to provide the artefact title. It creates an NDEF message consisting of one NDEF record, which includes encrypted info, artefact title and Android Application Record (AAR). AAR contains a package name of the Audio Sharing application, which ensures that the Audio Sharing application is started when an NFC tag is scanned. Finally, all this information is written to an NFC tag.

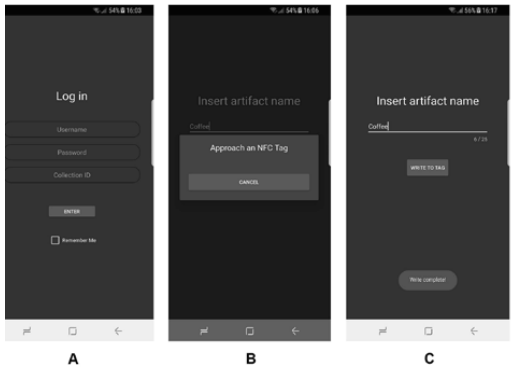

Figure 11. Login info (A), Artefact title (B), and write to tag (C).

In Figure 11 you can see that this application is very basic from the UI perspective as it is targeted to museum staff for admin purposes. The user will input user credentials and collection id and touch the Enter button (Figure 11 A). Next, he or she will define the artefact title, which is limited to 25 characters, and touch the write to tag button (Figure 11 B). The application will ask the user to touch the NFC tag (Figure 11 B). When the NFC tag is recognised by the phone, then information of NDEF message is written into the tag's memory (Figure 11 C).

We have used low-end NFC type 2 tags, which are based on the NTAG203 chip. These tags have 137 bytes of available memory, which has been sufficient for the five strings that are saved into the tag's memory. The limited memory size is the reason why the artefact title is limited to 25 characters.

3.4.2 NFC Writer Addressing Requirements

There were not too many requirements for the NFC Writer. Both functional and quality attribute requirements and how the developed NFC Writer is able to fulfil these requirements are described in Table 12.

Table 12. NFC Writer requirements.

Functional Requirements	**Yes/No**
run on mobile device	Yes
write a user id, password, a collection id, and an artifact title into a NFC tag	Yes
encrypt the user id and password	Yes
Quality Attribute Requirements	**Yes/No**
Fault detection using mainly exception detection	Yes
Different modules needs to be encapsulated in order to reduce coupling of modules	Yes
Mobile applications' response times should be less than 1 second	Yes
NCF tag's sensitive content should be secured	Yes
Mobile applications should include basic security in the form of authentication and authorisation	Yes

As can be seen in Table 12 the application was able to fulfil all these requirements. Encapsulation is supported by utilising MVC-architecture. Due to a very simple UI, response times are less than 1 second. In order to use the application, the user has to log in using user id, password and collection id. This ensures that only authorised users have access to ADAM. Sensitive content is encrypted using a simple encryption functionality. Thus, this info is not in understandable format if read from the tag using some NFC tag reading application. Next, we will discuss the audiostory sharing application which is utilising these NFC tags.

3.4.3 Audiostory Sharing Development

An Audiostory Sharing application contains two main functionalities: recording audio story and listening to audio stories from other users. These audio stories are linked to some object, such as an artefact in a museum. In order to link a story to some object, we need a collection in ADAM and NFC tags attached to the object. An NFC tag will contain user credentials and collection id as described in subsection 3.4.1. Using information from the NFC tag, the Audiostory Sharing application will store recorded stories in the right collection and search object-related stories only from the respective collection.

In order to categorise stories, we decided to use emotions. In addition, our idea was that stories would be more interesting and attracting if people explicitly thought about emotions related to their stories. Transportation theory focuses on how individuals may become transported into a narrative world when experiencing a story. Emotions are an important part of the transportation process [117]. Emotions have been researched from different perspectives for years. Unfortunately, there is currently no accepted definition for emotion. Some researchers, like Carroll

Izard claim that there are some basic (primary) emotions out of which all other emotions are built [118, 119]. Others claim that there are no basic emotions and proposed their own model of how to describe emotions [120, 121]. As we are not researching the importance of different emotions, we decided to select 9 positive (pleasant) and 9 negative (unpleasant) emotions. These emotions are based on Robinson's basic emotions list [123] and are described in Table 13. We decided to exclude Robison's social emotions, such as charity, sympathy, greed, envy, jealousy and cruelty, in order to limit the amount of emotions.

Table 13. Story related emotions.

Positive emotions	**Negative emotions**
Love	Hate
Pride	Frustration
Relief	Shame
Joy	Sorrow
Gratitude	Anger
Hope	Fear
Surprise	Indifference
Attraction	Disgust
Interest	Panic

As described in Table 13 emotions include the four basic emotions commonly agreed upon: anger, happiness (or joy), sadness (or sorrow) and fear. It could be argued whether surprise and interest are emotions at all and if they are what their valence is [120]. In order to visualise these emotions, we considered using colours. As the relationship between colours and emotions is not clear and is culture- and context-dependent [121], we ended up using text and colours to separate emotions from each other. The emphasis is on text as colours may be associated with several different emotions.

The Audiostory Sharing application implementation followed the Android best practises in a similar way as described in subsection 3.3.2. The architecture is based on the MVC pattern [87, 122]. The View can be seen as layout files containing graphical components in XML-format. Activities can be seen as Controller, which handles events from user actions and communicates with Model [124]. The model is logically associated with the application data, such as classes defining user credentials, API processing classes, local storage, and emotions and related colours. A class diagram describing the structure can be found in Appendix 2.

The AudioStory Sharing application provides the following functionalities: reading NFC tag, decrypting NFC tag content, searching and listening to stories, login, recording your own story, defining story-related emotions and uploading the recorded story.

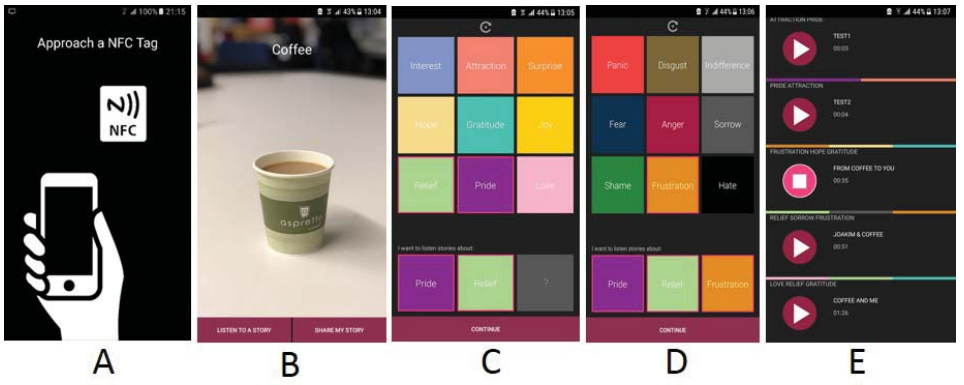

Figure 12. Splash screen (A), Landing page (B), Positive emotions (C), Negative emotions (D) and List of stories (E).

When the AudioStory Sharing application is launched, the user will see an animation asking to approach the NFC tag (Figure 12 A). After touching an NFC tag with the phone, there is a landing page displaying an image of an artefact and providing two alternatives: listening to stories or recording stories related to the artefact (Figure 12 B). Before displaying a landing page, the application reads the contents of the NFC tag, decrypts information and based on user id, password and collection id, retrieves the artefact image from ADAM. When the user decides to listen to audio stories, he or she will be asked to select emotions in order to provide stories which contain those emotions (Figure 12 C and D). After selecting at least one emotion, a list of stories will be displayed and the user can listen to them by touching a play button of individual titles (Figure 12 E).

In addition to listening to stories, the AudioStory Sharing application also provides the possibility to share the user's own story related to a particular artefact. In that case the user will select the share my story option on the landing page (Figure 12 B). In order to record, the user will be asked for user id and password, which will be compared to information retrieved from the NFC tag (Figure 13 A).

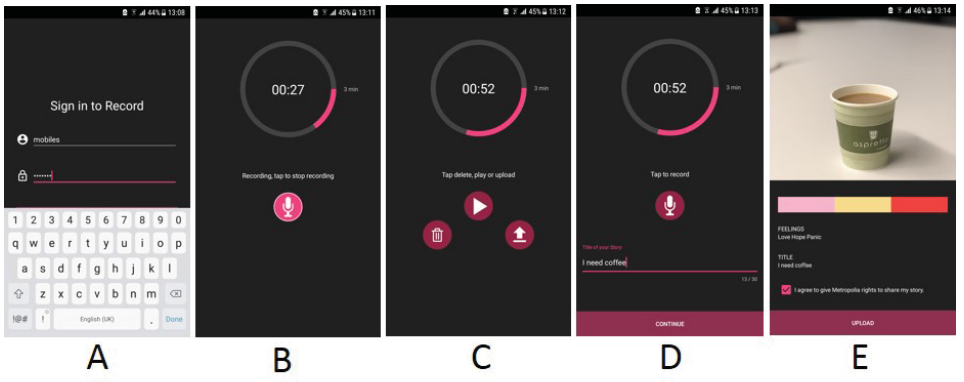

Figure 13. Login screen (A), Start recording (B), Recording ready (C), Add title (D) and Upload story (E).

After successful login, the user is able to record his or her story. The length of the story is limited to three minutes and the user will see his or her recordings length status from the progress spinner (Figure 13 B). After the story has been recorded, the user is able to listen to it (Figure 13 C). If he or she is not satisfied with the story, it can be deleted and recorded again. If the user is happy with the story, he or she can start the uploading process (Figure 13 C). Before uploading the story, the user needs to give a title to the story (Figure 13 D), define emotions related to the story (Figure 12 C and D), and agree to share the story with other users (Figure 13 E). After these steps the story with metadata will be uploaded into ADAM.

3.4.4 Audiostory Sharing Performance

We used Android Studio's existing tools to analyse potential problem areas related to performance. Static code analysis based on the lint tool gave 10 performance-related warnings: 9 due to unused resources and one possibly useless layout. The last warning was not correct as that layout was needed. Unused resources were removed. Then we were ready to use the Hierarchy Viewer tool, applying the same three criteria as mentioned already in section 3.3.3.

In Figure 14 there is a visualisation of the AudioStory Sharing application's relative rendering.

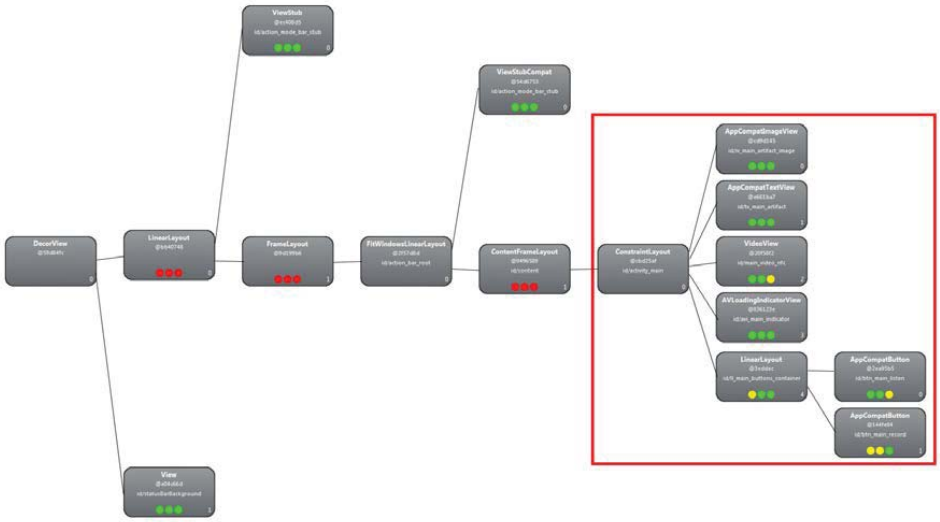

Figure 14. Audiostory Sharing hierarchy view.

In Figure 14 there are 8 system generated views on the left (outside the red box), such as DecorView, containing the standard window frame/decorations and zero-sized ViewStubs for lazily inflating layout resources at runtime. Inside the red box there are the real content views which need to be analysed. As seen in the Figure, there are no potential problem areas. So far, there is no indication that there would be problems with performance. Let us use the GPU Monitor in the same way as with the SoundSpace application. We have run the AudioStory Sharing application in Samsung Galaxy S7. Using GPU Monitor's data we found some code blocks where the user

may see slowness. In figures 15 and 16 there are visual representations of how much time it takes to render the frames of a UI window in case of listening to an audio story (Figure 15) and recording an audio story (Figure 16). In both cases the frame rate exceeds the 16 ms (green) line or recommended 60 frames per second whenever a list or grid of visuals elements is displayed. If we look at Figure 12 B, C, D and E, and Figure 13 A, B and E, we can see that these are the screens, which will be displayed with slower frame rate. Luckily the drawing of a full screen will take in total just a fraction of a second, so it seems that the user is not disturbed by the slowness too much. As Jakob Nielsen has pointed out, by keeping a response time to less than a second, the user's flow of thought is seamless [125].

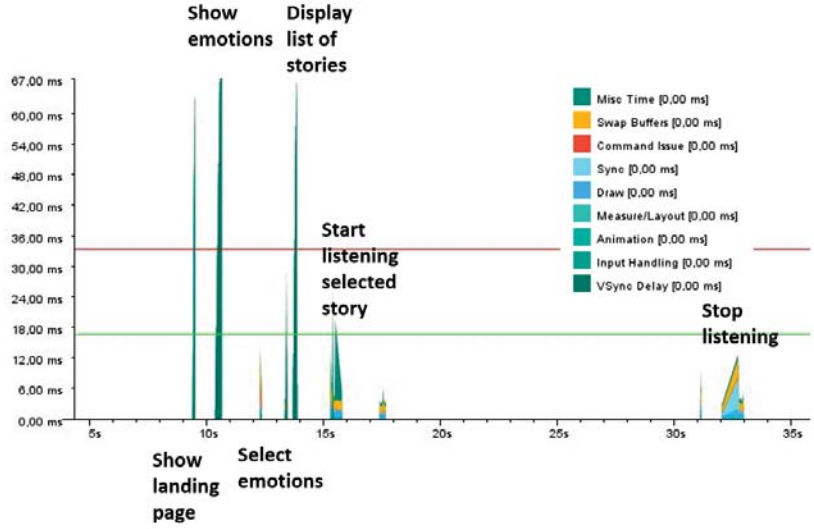

Figure 15. GPU monitoring of audio story listening.

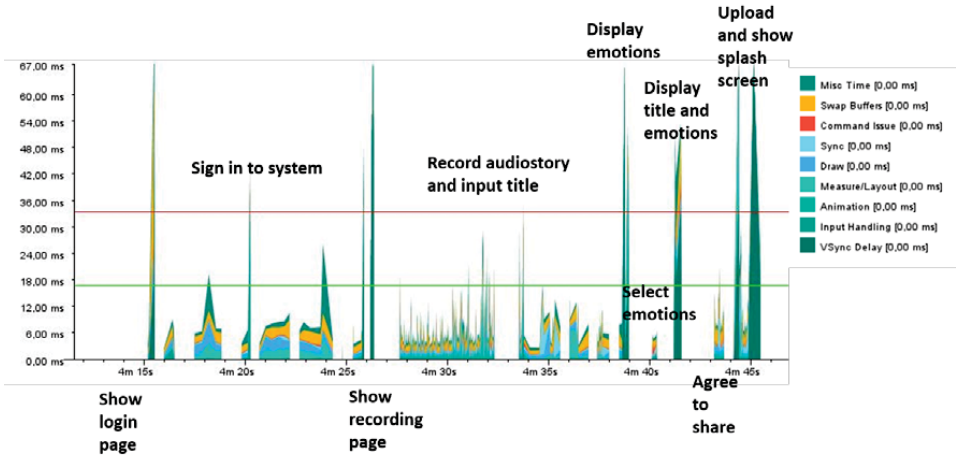

Figure 16. GPU monitoring of audio story recording.

When looking for the whole cycle of the listening or recording task, the frame rate is below the 16 ms green line. Thus, the interaction with the application is smooth at least from the rendering perspective. We will discuss interaction with applications in section 4.

3.4.5 Audiostory Sharing Addressing Requirements

Let us look at the audiostory management-related functional and quality attribute requirements. Table 14 shows the requirements and how the AudioStory Sharing application will satisfy those requirements. As can be seen in the table, the AudioStory Sharing application developed in this study was able to fulfil all these requirements.

Table 14. AudioStory Sharing requirements.

Functional Requirements	**Yes/No**
Run on mobile device	Yes
Read user id, password, collection id, and artifact title from the NFC tag	Yes
Decrypt the user id and password	Yes
Login into common audio data	Yes
Listen to the audio stories related to the artefact	Yes
Filter the stories based on the emotions	Yes
Record an audio story	Yes
Add emotions related to the story	Yes
Upload audio story and related metadata (incl. emotions) into common audio data	Yes
Quality Attribute Requirements	**Yes/No**
Fault detection using mainly exception detection	Yes
Different modules needs to be encapsulated in order to reduce coupling of modules	Yes
Mobile applications' response times should be less than 1 second	Yes
NCF tag's sensitive content should be secured	Yes
Mobile applications should include basic security in the form of authentication and authorisation	Yes

As described in Table 14, encapsulation is supported by utilising MVC-architecture. UI response times are less than 1 second. In order to use the application, the user has to log in with user id and password. This ensures that only authorised users have access to ADAM. Sensitive content is in encrypted format in the NFC tag and it is decrypted by the application.

3.5 Contribution

We have succeeded to develop a modular and versatile audio platform. This platform does not require any special hardware components, so there are no user or user head location tracking

devices. No special rooms or spaces in order to use the platform. All of the hardware is commonly used including Android phones, which typically come with the standard headset. Software-wise our backend system is based on open source components, so there are no license fees to be paid by the institute that would like to install and use this system. The same applies to existing mobile applications as they have been developed for the Android platform. Typically, Android applications are free to use. As we have developed relevant APIs between mobile applications and the backend system (ADAM), new mobile applications can be developed by third parties for new services or other mobile platforms. One main reason for our success has been the idea to keep the content for the audio file simple and immutable. This means that we are not aiming at splitting or annotating the content of existing audio files. The other reason for the success is the use of metadata. The rest is architectural decisions and software development.

Thus, our contribution to the community is developing a general-purpose audio platform, which is modular and expandable.

Next, we will discuss how different parts of the audio platform were designed and developed by several teams.

3.6 Acknowledgements

There has been several people contributing to Audio Story Sharing and Audio Augmented Reality Platform development. During the backend service (ADAM) development Ms. Diana Giova was doing her Bachelor's thesis under the author's supervision. She carried out a more comprehensive study of available open-source DAM solutions, implemented modifications into ResourceSpace and wrote user guides.

Development of Soundscape Mixer applications were the result from two courses. Design and user testing were carried out during a Usability and User Interface -course. Senior lecturer Merja Bauters was in charge of this course. Android application development was done during the author's Android Advanced Application Development course. Students from these two courses were working as teams and together with Merja Bauters the author was guiding these teams. Senior lecturer Aura Neuvonen and her sound design students created audio files, which were used as building components for soundscapes. Sound design students also tested the usability for both ADAM and Sound Mixer applications. The SoundSpace application, which was selected as the most suitable soundscape mixer application was originally developed by Mr. Mikko Piuhola and Mr. Petri Rautiainen.

Both Audiostory applications are implemented by Mr. Vallo Zinin as part of his Bachelor's thesis under the author's supervision. The author has guided the design and development of these applications. Senior lecturer Ulla Sederlöf has guided the visual design of the AudioSharing application.

3.7 Discussion

At the time of writing this document there are two parallel platform implementations up and running. One is running in the Museum of Technology's server in Helsinki, Finland and the other

one at Metropolia UAS's server in Espoo, Finland. The Museum of Technology is offering soundscape-related workshops as a service. This means that museum staff is administrating ADAM, and using SoundSpace applications, which are running on their own Android tablets.

Metropolia UAS's implementation of the platform has been used for different experiments. In June 2016 we participated in the Public Urban Lab Bremen in Bremen, Germany, where we organised a workshop on Soundscapes in an urban planning context together with local sound artist Kevin Kerney [126]. ADAM was running on the Espoo server and we published the SoundSpace application temporarily in Google Play, so workshop participants could download the application onto their own Android devices. ADAM and SoundSpace worked smoothly during the workshop.

In October 2016 there was the Puhdas vesi / Clean Water event in Taidehalli, Helsinki, Finland, organised by Huili-lehti. SoundSpace was modified in a way that it could be used in Kiosk-mode. SoundSpace's kiosk version was installed onto Android tablet and users were able to use it during the event. During the event there was a collection of sounds related to water available from ADAM. Thus, participants were able to create their own water related soundscapes.

In March 2017 we organised two workshops in Gdansk, Poland together with Gdańsk City Gallery [VI]. ADAM was running in Espoo. The SoundSpace and Audio story applications were preinstalled into Metropolia's Android phones, which were given to participants at the beginning of the workshops. During the first workshop participants were using the AudioStory Sharing application. The application was fine, except that there were uploading problems due to the congestion when the wireless router was communicating with ADAM over the cellular network. This upload problem has been analysed and AudioStory Sharing application's code improved by modifying Retrofit2 library's timeouts. During the second workshop participants were using the SoundSpace application and there were no problems with the platform.

During February 2018 we organised two more workshops, one audio story workshop for Metropolia UAS's first year international engineering students and another soundscape workshop for cultural management students at Humak University of Applied Sciences in Jyväskylä, Finland. In Jyväskylä we had a memory overflow problem, when one team decided to use 15 separate components to create a soundscape. Other teams did not have any problems with fewer audio files. This problem was analysed. Based on the analysis we found a bug in the Android platform. A report describing a problem with releasing timely AudioTrack instances was issued (using Google Issue Tracker) to the Google and Android community. At Metropolia, our platform and the AudioStory Sharing application worked well. There were no more problems with the audio story uploading.

Based on previous examples we can see that there is a possibility to use either the soundscape mixer functionality or audio story sharing functionality or both. In addition, modifying the soundscape mixer into kiosk mode did not require any changes into ADAM. Therefore, it can be concluded that the selected architecture is modular enough in case we need to use part of the platform or if we need to make some changes in the platform's individual components.

Then there is the question whether the soundscape mixer can be categorised as an augmented reality application and in which context. Craig (2013) has defined augmented reality as a medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in real time [127]. He explains that augmented reality means those applications that rely on spatial, and when appropriate, temporal registration with the physical world. The spatial registration can be either absolute (specific place) or relative (with respect to some entity). In our case we will enhance the physical world

with a soundscape that will be created by the user. The Soundscape will be registered to some location in a museum (such as living room from the 1960s) or to some object (such as historical photo from Helsinki city centre). The Soundscape will change in real time depending on user interaction. Thus, we could say that user-created soundscapes which are related to some location or object can be seen as (audio) augmented reality. On the other hand, if we just listen to a soundscape without the possibility to change it and not relate it to some location or object, then we are not talking about augmented reality. So, when using SoundSpace to create soundscapes for some location or objects we can say that SoundSpace is an audio-augmented-reality application.

Let us clarify the role of NFC in connection with audiostory applications. Why did we select NFC tags instead of using barcodes, like QR code to link artefacts and audio collections? Implementing a QR code reader is rather simple as there are libraries providing the basic functionality. We discussed this option with the Museum of Technology's staff. Their opinion was against using QR codes as QR code could be a visually disturbing element near museum artefacts. An NFC tag is easy to hide as it does not require a direct line-of-sight from the mobile device. Thus, we ended up using NFC tags.

All in all, we can say that we have successfully designed and implemented a Modular Audio Story Sharing and Audio Augmented Reality Platform. Next, we will discuss the most important research projects, which have helped us to develop our platform.

3.8 Related Work

There is a lot of research, which relates to some part of our platform, such as soundscapes, audio augmented reality, digital storytelling or digital asset management. This has been discussed already in the background chapter. So far, we have not found a similar project, which would address the full scope of our project. However, there are several audio platform research projects, which have been relevant to our platform design and development.

There are the Telemeta [103] and GlobalMusic2one [128] projects, both of which have been relevant when planning the backend service (ADAM). Telemeta is an audio digital asset management system as well as an audio analysis and annotation tool. Telemeta is targeted to music researchers. It utilises Django for data management and TimeSide Engine for audio processing, audio analysis and automatic extraction. Telemeta supports Dublin Core and OAI-PMH metadata standards. The GlobalMusic2one annotation tool has the same target group as Telemeta, i.e. musicologists. The audio annotation tool aims at describing audio file on a very detailed level. Our backend system is targeted to non-music professionals. Thus, there is no need to split audio files into segments. However, we have similar needs to utilise metadata to describe (annotate) audio files in order to provide good search functionalities. Similar to Telemeta we have implemented the digital asset management features provided by ResourceSpace.

If we reduce our scope from any type of audio to soundscapes only, then we have six research projects, which have discussed IT platforms specifically targeted to soundscapes. Each of these platforms have somewhat different approaches. The Sound Design Accelerator (SoDA) project provides a combination of digital asset management (incl. annotation of audio files and semantic search) and soundscape composer. Soundscape composer produces a three-dimensional audio stream or audio file based on a user-defined space model, listener model and audio format. the SoDA platform is basically a fast prototyping tool targeted to sound designers [56]. We have

a similar need to provide a soundscape composer component in addition to digital asset management. The difference is that our system is targeted at cultural institution visitors. We do not expect visitors to be familiar with reverberation, resonance, acoustic absorption, bit depth and other acoustic terms. UrbanRemix [53], Tactical Sound Garden [47] and SoundScapeTK [54] are targeted to ordinary people, so basically the same target audience as ours. In addition, they utilise mobile devices as part of a platform. All of them use the location of a user to play soundscapes. UrbanRemix and Tactical Sound Garden allow users to share their recordings. UrbanRemix also provides a browser-based tool, which enables creating (mixing) new soundscapes by graphically combining audio file locations as a path on a map. This path on a map combines existing recordings as a new soundscape. As a future option we have added location metadata into ADAM. In addition, we have included the possibility to add the user's own sound files as soundscape building components. If we take into account the museum context, there are two research projects targeted to museum visitors: ec(h)o [6, 34] and Klang.Reise [52]. Klang.Reise is an installation of video and audio recordings inside a closed spherical space in Landesmuseum Niederösterreich. The goal is to demonstrate to museum visitors different sounds of a selected place and how these soundscapes change over the time. The ec(h)o system plays ambient soundscapes related to artefacts near the visitor. Visitors are tracked using a combination of RFID tags and optical positioning. When a visitor is close to an artefact he or she can listen to one of the three related audio files by rotating a wooden cube. Both these system rely on curated soundscapes, which are related to particular artefacts. In our system we expect visitors to create soundscapes related to artefacts.

Next, let us move from soundscapes to audio stories. The My Exhibition [63], Holocaust survivor [64] and Smart replicas [72] projects have developed a platform for interactive storytelling in a museum context. All of them are relying on curated content, which will be personalised for each visitor. These projects have been described already in the background chapter. From My Exhibition and Holocaust survivor projects we have learned that stories containing personal touch are well-appreciated. Smart replicas project implemented an idea of using NFC tag to link a story and artefact. Another perspective to stories is discussed in Tag-IT [129], Object stories and 100toys [130] projects. The last two projects are using web-based tools for collecting and sharing visitors' own stories related visitor's personal objects or favourite toys. Tag-IT project has developed a simple device which is able to record and play audio content stored into an NFC tag. We have implemented a similar idea to invite visitors to participate by telling their own story and sharing it with other visitors.

Next, we will discuss what kind of experiments we have done with our platform and what kind of feedback we have received from different types of users.

4 Evaluation of Audio Platform

The evaluation of the audio platform has been done in a workshop context. Workshops were planned in the way that they could meet the characteristics of extracurricular activities. As described in section 2, extracurricular activities are organised activities, which are characterised by structure, adult supervision and skill development. In addition, we decided that workshops should include pedagogical objectives, which is partly overlapping with the skill development characteristic. The reason for this extracurricular approach is twofold: a positive impact on adolescents' development, and motivating schools to co-operate in order to reach young people. The evaluation itself is divided into two parts: evaluating the interaction between users and mobile application, and evaluating how engaging the workshops are, where the audio platform will be utilized.

4.1 Workshops

We will describe six workshops, which were the most interesting and useful from the evaluation perspective. First two workshops were pilots in Finland, where we observed how the soundscape mixer application and backend system worked, whether our workshop concept was feasible and how the interaction with the mobile application was perceived. The next two workshops were organised in Poland to check if the workshop concept was culture independent. At the same time, we introduced a student engagement instrument and observed not just the soundscape mixer, but also an audio story sharing application. The last two workshops were organised in Finland again. This time we observed both a soundscape mixer and an audio story sharing application in student interaction and student engagement perspectives in university premises instead of cultural institution premises. These last two workshops will be described in detail as they are not described in the publications.

In Table 15 we have summarised the main characteristics of these six workshops. It should be noted that even if we mainly evaluate a mobile application, such as a soundscape mixer application, the backend system (ADAM) is always needed as well. Thus, the backend will be evaluated implicitly.

Table 15. Workshops for the evaluation.

Workshop	Location	Participants	Audioplatform components	Interaction evaluation	Engagement evaluation
WS1	Helsinki, Finland	Secondary school students	Soundscape Mixer application	Yes	No
WS2	Helsinki, Finland	Museum professionals	Soundscape Mixer application	Yes	No
WS3	Gdansk, Poland	Secondary school students	Audiostory Sharing application	Yes	Yes
WS4	Gdansk, Poland	Secondary school students	Soundscape Mixer application	Yes	Yes
WS5	Espoo, Finland	University students	Audiostory Sharing application	Yes	Yes
WS6	Jyväskylä, Finland	University students	Soundscape Mixer application	Yes	Yes

Next, we will discuss how each workshop was organised, what were the pedagogical objectives, and the outline of the workshop.

4.1.1 Soundscape Mixer Workshop with Students

The first objective of the WS1 workshop was to research which soundscape mixer application would be the most prefered one by the participating students. The second objective was to study the easiness of the interaction with the application.

The workshop was organised in the Museum of Technology in Helsinki, Finland. A secondary school class with a teacher and 24 students was invited to take part in the workshop. The class was from Helsinki, Finland and fitted the target group that the museum wants to engage well.

Pedagogical objectives for the soundscape workshop were to understand that:

- a soundscape is typically a composition of several sounds;
- the city soundscapes have changed due to urbanization and introduction of new technologies;
- a soundscape is a subjective experience.

The outline of the workshop was as follows:

1. An introduction was given to workshop objectives, soundscape and soundscape mixer tools
2. In groups, students created a soundscape using three different tools, a photo that reflected the exhibition topics of the Museum of Technology, and an adjective that described an atmosphere in the selected photo

3. All the soundscapes were listened to and discussed
4. Student groups filled in the questionnaire (see Appendix 3)

More detailed description of the workshop can be found in the publication User Generated Soundscapes Activating Museum Visitors [V].

4.1.2 Soundscape Mixer Workshop with Museum Professionals

In the WS2 workshop our target was to understand whether the SoundSpace application was simple enough to be used and suitable in various kinds of museums.

The workshop was organised in the Museum of Technology in Helsinki, Finland. The ten participants were museum professionals from different Finnish museums (4 persons), university researchers specialized in museology (2 persons) and other culture sector professionals (4 persons). The workshop was similar to the first one. Thus, both pedagogical objectives and the outline of the workshop followed the description in the previous sub-chapter. At the end, both museum professionals and university researchers filled in a questionnaire (see Appendices 4 and 5).

A more detailed description of the workshop can be found in the publication User Generated Soundscapes Activating Museum Visitors [V].

4.1.3 Audiostory Workshop with Polish Students

The WS3 workshop's main goal was to evaluate the level of engagement during the workshop as students recorded, shared and listened to audio stories. Another goal was to study the easiness of the interaction with the Audio Sharing application.

The workshop was organized in the Gdańsk City Gallery, Poland. Workshop participants were 30 students from three different classes from a local secondary school. They matched our target group well as their age was between 13 and 16 years.

We defined the pedagogical objectives for the workshop as follows. After the workshop students will undertand that:

- when someone shares a memory or a story about oneself, it could strengthen the view of one's personality or others could see one's personality in a new light;
- sharing stories and ideas provides learning experiences;
- emotions are subjective and context sensitive.

The platform and its usage were described in advance to teachers and gallery personnel. This enabled teachers to link the workshop to school work by asking students to prepare stories already before the workshop.

The outline of the workshop was as follows:

1. Introduction was given to workshop objectives, storytelling and audio story sharing tool. After this, the students were divided into three-person groups.
2. Each group recorded two audio stories, listened to stories from two other groups and took notes about stories and related emotions.
3. The most impressive stories were listened to by all and discussed.
4. Students filled in the questionnaire (see Appendices 6 and 7).

A more detailed description of the workshop can be found in the publication Audio Story and AR Platform for Youth Engagement [VI].

4.1.4 Soundscape Mixer Workshop with Polish Students

During the WS4 workshop the main goal was the same as in the WS3 workshop, i.e. evaluate the level of engagement. The second goal was to verify if the easiness of the interaction with the Soundscape Mixer application was experienced similarly as in the Finnish museum context.

Like the previous workshop, WS3, also this workshop was organized in the Gdańsk City Gallery, Poland. The 12 secondary school students participating in workshop came from three classes. The local school was different than in WS3 workshop. The age range was 13 – 16 years.

The workshop was similar to the previous two soundscape mixer workshops (WS1 and WS2). Thus, both pedagogical objectives and the outline of the workshop were the same as earlier. The only differences were that the workshop was bilingual in the sense that a short intro was done in Polish and the rest of the workshop was in English, and the questionnaire was modified for soundscape workshop purposes (see Appendices 8 and 10)

A more detailed description of the workshop can be found in the publication Audio Story and AR Platform for Youth Engagement [VI].

4.1.5 Audiostory Workshop with International University Students

The aim of the WS5 workshop was the same as in the WS3 workshop in Poland, i.e. to measure the level of engagement during the workshop and study the easiness of the interaction with the Audio Sharing application.

The workshop was organized at Metropolia University of Applied Sciences, Espoo, Finland. The participants were 16 first year international IT-students coming from 10 different nationalities. The age distribution was wide: 50% 20 – 25 years, 12,5% between 26 – 30 years, and 37.5% over 30 years.

We modified the pedagogical objectives of the WS3 workshop in order to better adapt to the current context. We expected that participants were to understand that:

- user experience is a vital element when developing mobile apps;
- when someone shares a story with emotions, it could strengthen the view of one's personality or others could see one's personality in a new light;
- sharing stories and ideas provides learning experiences;
- emotions are subjective and context sensitive;
- an artefact can be described from many different angles.

Students were given three consecutive pre-tasks:

1. They were asked to select two objects inside the Metropolia building, so that they could come up with a short story related to the object. The objects could be any concrete objects inside Metropolia, like a favourite table or sofa, statue or painting or poster. In addition,

it was required that there should be good Wi-Fi-coverage near the object and they should take a photo of each object.

2. All participating students were asked to select three objects out of all those objects that they found as individuals. The selection was based on the idea that each student could come up with a story, which somehow relates to one of these three objects.
3. Each participant should plan a story which relates to one of the three selected objects. It could be a memory related to the object. It could be a story how to use that object. It could be a story describing that object. It could be a story how to design that object. It could be a story why this object is fascinating, etc. In addition, they were asked to think about emotions which were related to their story by picking 1 to 3 positive and/or negative emotions from a list (see table 13).

Our plan for the workshop was based on the experiences gained from the WS3 workshop. Thus the outline of the workshop was pretty similar to the WS3 outline. There were just a few modifications.

The workshop objectives were described followed by a discussion about storytelling in general and personal experiences. After this a short demonstration of the Sound Sharing application and dividing students into three teams based on their object selection. (30 min)

Each team was asked to move to the location of the selected object inside the university building. There they could find an NFC tag on the wall. Students were supposed to record their own stories and then listen to stories from other students from the same group. While listening, the students were asked to take notes which story was the most fascinating one. The students were given an Android device equipped with a Sound Sharing application, and they were provided with user credentials in order to log into ADAM. (40 min).

In the end, each group selected the most fascinating story, which was listened and discussed. At the end of the workshop each student filled a questionnaire. (30 min).

The questionnaire was the same as in the WS3 workshop (see Appendix 7). A detailed description of the questionnaire can be found in the publication Audio Story and AR Platform for Youth Engagement [VI].

4.1.6 Soundscape Mixer Workshop with Finnish University Students

The aim of the WS6 workshop was the same as in the WS4 workshop in Poland, i.e. to measure the level of engagement during the workshop and study how easy or difficult the interaction with the Sounscape Mixing application was.

The workshop was organized at Humak University of Applied Sciences, Jyväskylä, Finland. The participants were 8 Finnish Cultural Management students. The age of the participating students was 20 – 30 years.

We slightly modified the pedagogical objectives of the WS1 workshop:

- different types of new digital services and products, like soundscape mixer apps will emerge into the culture sector;
- a soundscape is typically a composition of several sounds;
- the city soundscape have changed due to urbanization and introduction of new technologies;
- a soundscape is a subjective experience.

Students were given a pre-task to find two old photos from their home town and bring them to the workshop.

We used the term researcher of the person who was leading and guiding the workshop. This researcher was introduced to students earlier by one of teachers. We adapted the outline of earlier workshops as following:

1. The researcher welcomed students and explained the objectives of the workshop. He also explained what a soundscape is, after which there was a discussion about soundscape components and how soundscapes are time and context dependent. The SoundSpace application was introduced and demonstrated. Then the students formed pairs and the task was provided for each pair. (30 min)
2. The task was to select one photo out of four photos that each pair had. After that each pair would create a soundscape for the selected photo. For creating the soundscape, the students were provided with an adjective, like quiet, lively, calm or noisy, which exemplified the atmosphere of the selected photo. The students were provided with user credentials and a sound collection identifier in order to use ADAM and the relevant sound library. Each pair was given an Android device where the SoundSpace application was installed, two headsets and a headset splitter. (60 min)
3. In the end, all the soundscapes were listened to and discussed. At the end of the workshop each student filled a questionnaire. (20 min).

The questionnaire was the same as in the fourth workshop, WS4 (see Appendices 9 and 10). A detailed description of the questionnaire is in the publication Audio Story and AR Platform for Youth Engagement [VI].

4.2 Interaction with Applications

In each workshop we studied the easiness of the interaction with the mobile applications. With interaction we mean interaction with the application, how this felt in combinations with the task. As Dourish [131] and Paay and Kieldsjkov [132] argue, it is never the application alone that provides the feeling but the tasks and environment are also involved.

4.2.1 Interaction with Soundscape Mixer Application

A Soundscape Mixer application was used in four workshops described in Table 16. We have used observations, informal discussions and questionnaires in all workshops to get feedback related to interaction. In addition, in the first two workshops we had interviews and in the first three also video recordings. We have used three different questionnaires during these workshops. However, all these questionnaires have included a common part. This common part covered:

- which type of phone users were familiar with;
- three basic questions on the usage of the application;
- whether users were familiar with a similar application;
- is the application viable also in other contexts;
- were the icons clear enough;
- two questions about how the application was used;
- Did users succeed in creating a soundscape and did they record new sounds?

Based on observations the interaction with Android devices and the Soundscape Mixer application was smooth in all workshops. This was expected especially with the young participants as they use smart phones on a daily basis. It should be noted that also adult users in the second workshop were very fluent with application usage. If we look at Figure 17 we will notice that not all users have an Android phone in their private use. Thus, the ease of use of the Soundscape Mixer was remarkable – even more so because all of the users noted that they had never used similar applications before (see Figure 19).

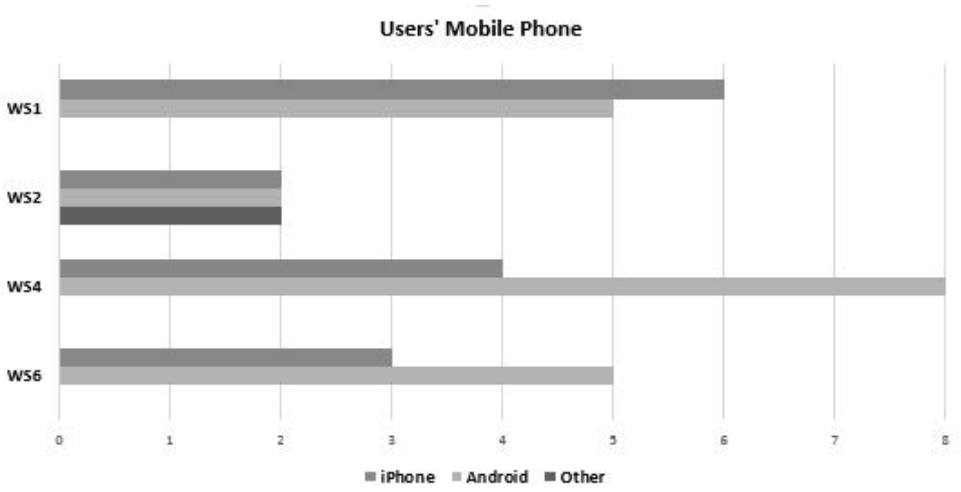

Figure 17. Mobile phone owned by the soundscape workshop participants.

In Figure 17 we see the distribution of mobile platforms. In the first two workshops (WS1 and WS2) iPhone was as common as Android or even more common. In the next workshops (WS4 and WS6) the Android phone owners were in the majority.

Table 16. SoundSpace usage statistics.

Workshop	N	Usage	Mode	Min	Q1	Median	Q3	Max	IQR
WS1	22	Was fitting to the task	2	1	1	2	2	4	1
		Worked well	1	1	1	2	4	4	3
		Pleasant to use	2	1	1,5	2	2,5	4	1
WS2	6	Was fitting to the task	1	1	1	1,5	2	2	1
		Worked well	2	1	1,25	2	2	2	0,75
		Pleasant to use	1	1	1	1,5	2	2	1
WS4	12	Was fitting to the task	1	1	1	1	2	2	1
		Worked well	2	1	2	2	2	3	0
		Pleasant to use	1	1	1	2	2	3	1
WS6	8	Was fitting to the task	1	1	1	1	2	2	1
		Worked well	2	1	1,75	2	2,5	4	0,75
		Pleasant to use	2	1	1	2	2	2	1

In Table 16 there are SoundSpace statistics calculated from the four workshops. Because we have used the likert-scales using words (ordinal scale), non-parametric statistics have been applied. Thus, there are mode, median, minimum, maximum, 25% quartile (Q1), 75% quartile (Q3), and Inter-Quartile Range (IQR). We have used the scale strongly agree (=1), agree (=2), undecided (=3), disagree (=4), and strongly disagree (=5). We will mainly look at the median (a measure of central tendency) and IQR (a measure of dispersion) calculated for each usage related answers. Most respondents in all four workshops indicated agreement with the idea that the application was fitting to the task, worked well and was pleasant to use (median ≤ 2, IQR$\leq$1). The only exception is the WS1 workshop, where the opinion seems to be divided with regard to the worked well question (median=2, IQR=3). In addition, if we look at the Q3 values over 2, we can say that in the WS1 and WS6 workshops the results related to the pleasant to use and worked well questions could have been better.

In Figure 17 and Figure 18 it should be noted that in the WS1 workshop these answers are common to all three Mobile Mixer applications. In addition, 11 pairs answered the questions, so there were no individual answers. Thus, the answers do not fully correlate with the answers from the other three workshops. Based on the answers we could see that the mobile application was

pleasant to use and was fitting to the task. There were some crashes during the first and last workshop. In the first workshop it was mainly other than the SoundSpace application which crashed. Based on observations and the open-ended question, only one pair had problems with the SoundSpace application. During the WS6 workshop one pair crashed the application as their soundscape consisted of 15 different components. Adding and removing a lot of sound files resulted in memory overflow. In addition to crashes there were moments of frustration in some workshops caused by limited amount of sounds (there were 142 sound files), and the fact that some sounds seemed to be too quiet. This frustration could be partially the reason why the answers are not even more positive.

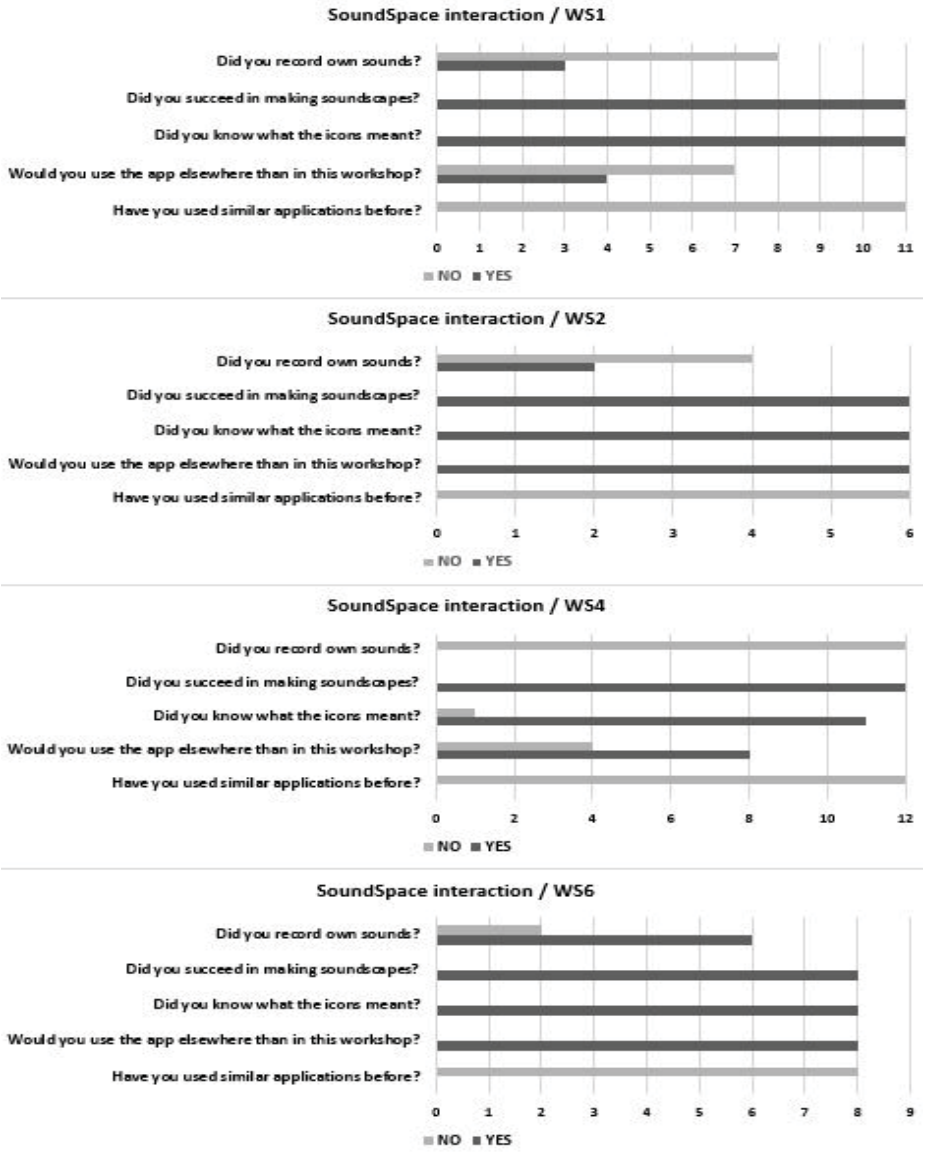

Figure 18. Interacting with SoundSpace during the workshop.

According to Figure 18 none of the users had used a similar application and still all of them were able to create soundscapes. This was confirmed by the observations. All but one participant understood what the icons meant. Recording particpants' own sounds varied a lot between workshops. In the WS4 workshop no one recorded their own sounds. They decided to use only the ones which were available in ADAM. On the contrary in the WS6 workshop three pairs out of four decided that they would need to record more sounds in order to create just the right atmosphere to their photo. There was also a wide contrast between participants if they used the Soundscape Mixer application in another context than the existing one. Younger participants in the WS1 and WS4 workshops were more hesitant compared to older participants in the WS2 and WS6 workshops. Also, it should be noted that in the WS1 workshop these answers are common to all three Mobile Mixer applications. Thus, they do not fully correlate with answers from the other three workshops.

To summarise, there was no controversy between the observations and the questionnaire feedback. The interaction with the application was smooth except for those few crashes.

4.2.2 Interaction with Audiostory Sharing Application

The Audiostory Sharing application was used in the WS3 and WS5 workshops described earlier. We have used observations, informal discussions and questionnaires in all workshops to get feedback related to interaction. We used the same questionnaire in both workshops. This questionnaire included almost the same questions as the soundscape common part described in the previous chapter. The only difference was the last two questions, which were modified to the audio story context. We asked if users succeed in listening to audio stories and if they were able to record their own story.

Based on the observations, interaction with Android devices and the Audiostory Sharing application was quite smooth in both workshops even if there were problems in the WS3 workshop. This ease-of-use was expected especially with the youth as they use smart phones on a daily basis and most of them own an Android phone (see Figure 19). On the other hand, most of them had not used a similar application (see Figure 20).

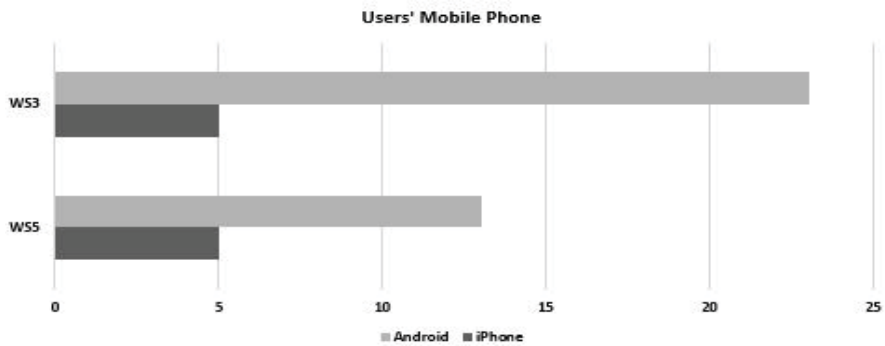

Figure 19. Mobile phone owned by the audio story workshop participants.

In Figure 19 we see the distribution of mobile platforms. In both workshops the Android phone owners were the majority.

Table 17. Audiostory Sharing usage statistics.

Workshop	N	Usage	Mode	Min	Q1	Median	Q3	Max	IQR
WS3	30	Was fitting to the task	2	1	1	2	2	5	1
		Worked well	3	1	2	3	3	5	1
		Pleasant to use	2	1	2	2	2	5	0
WS5	16	Was fitting to the task	1	1	1	1	2	2	1
		Worked well	1	1	1	1	2	3	1
		Pleasant to use	2	1	1	2	2	3	1

In Table 17 we can see the difference between two versions of the Audiostory Sharing application. In the WS3 workshop we had problems with the uploading functionality. We fixed it and in the WS5 workshop also that part was working smoothly. Thus, the answers in the WS5 workshop are clearly more positive. It should be noted that most of the users in the WS3 workshop still considered our application to be fitting for the task and pleasant to use (median=2, IQR≤1) even if one third of them had problems with the uploading. This uploading problem was mainly indicated in the 'worked well' question, where the median was 3, the most common answer being 3 (undecided). In the WS5 workshop most respondents indicated agreement with the idea that the application was fitting for the task, worked well and was pleasant to use (median ≤ 2, IQR=1). The scale was the same as in table 15: strongly agree (=1), agree (=2), undecided (=3), disagree (=4), and strongly disagree (=5).

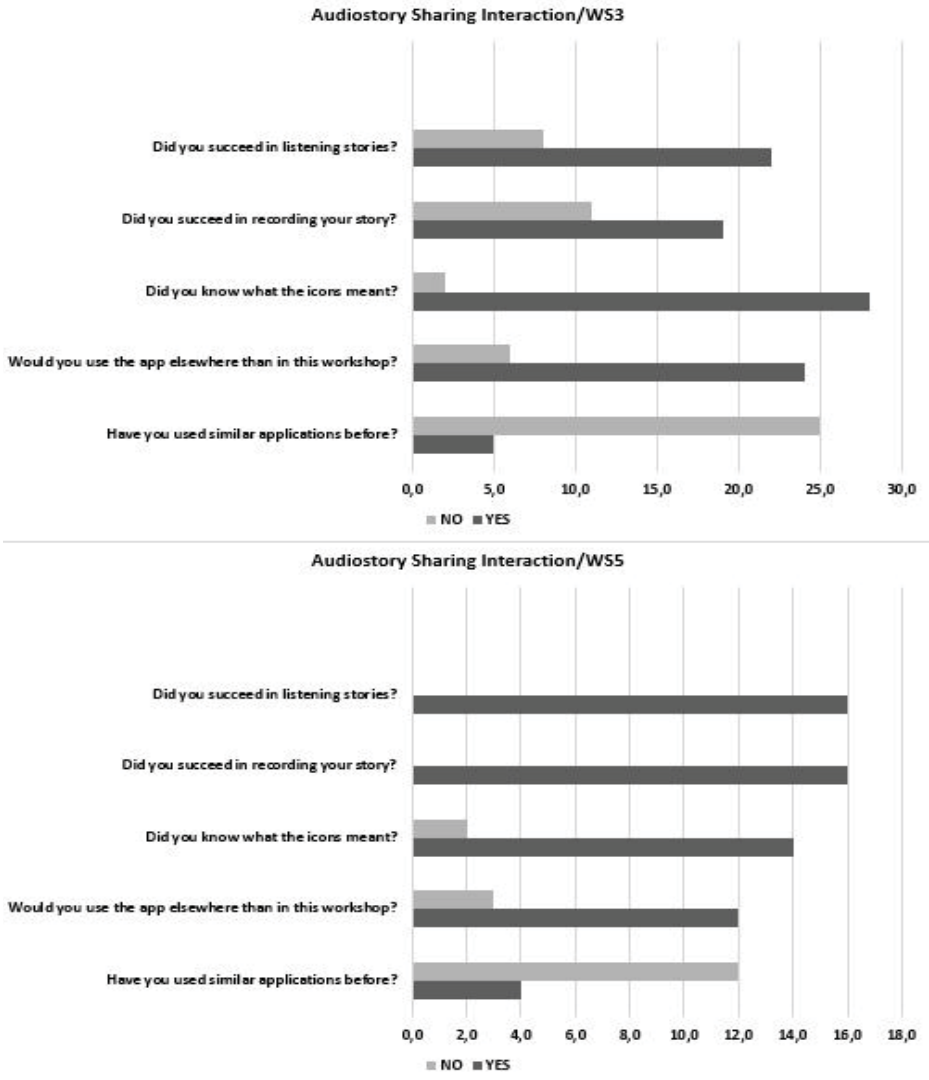

Figure 20. Interacting with Audiostory Sharing during the workshop.

As described earlier, we had problems in the WS3 workshop and Figure 20 describes that in more detail. At least 11 out of 30 students could not upload their story. We asked if they succeeded in recording their story. Based on observations all of them were able to record, but upload problems prevented them finalising this task. They were very persistent in trying to upload, which resulted in a situation where several students did not have time to listen to other students' stories, which is seen in the questionnaire results stating that 8 students did not succeed in listening to the stories from others. In the WS5 workshop we had a fixed version of the application and all students were able to listen to and record stories. It is a bit unsettling that three students out of 46 did not understand the meaning of icons. We could not confirm this by observations or discussions

with students. Most of the students would use this type of application also in another context, and some of the students have already used similar applications before.

As a whole we could say that there was no controversy between our observations and the questionnaire feedback. The interaction with the application was smooth after fixing the problem found in the first workshop.

4.3 Workshop Engagement

In previous chapters we have studied the interaction between the user and the mobile applications mainly from the application characteristics perspective taking into account the task and context. The next step is to research how engaging the workshop (including our audio platform) experience was for the user. Even if we would have liked to study the engagement of our audio platform as a separate entity it is not possible. The role of context, action and user has been studied intensively for the last 20 years. In the early 2000s when ubiquitous computing or context-aware computing was emerging, researchers discussed how technology and context cannot be separated anymore. Dourish [131] based his research on phenomenological theories. He claims that context and action cannot be separated and that they are mutually constitutive. Paay and Kjeldskov [132] based their research on gestalt theory when explaining how users experience the interaction between context and technology. They have the same claim as Dourish, namely that we cannot separate context and technology. Lately the User Experience (UX) research has tackled this same topic. Although there are different opinions about the nature and scope of UX [133X] the most commonly accepted definition of user experience by Hassenzahl and Tractinsky [134, 135] defines:" UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organisational/social setting, meaningfulness of the activity, voluntariness of use, etc.)". Based on these studies we ended to evaluating how users experience workshops (and an audio platform as a part of it).

4.3.1 Engagement measurement

As our workshop setup was to fulfil characteristics of extracurricular activities, and the participants were typically students, we decided to base our engagement measurements on student engagement research. In section 2.2 we have described the current status of student engagement research. We will use the student engagement definition from Fredricks, Blumenfeld and Paris [82]. As described earlier, the behavioural engagement component is typically defined in three ways. We have a positive behaviour aspect, such as following the rules. Then there is intentness on learning and academic tasks including behaviours, such as effort, persistence, concentration and attention. The third aspect is involvement in school-related activities.

The emotional engagement component definition is based on students' emotional reactions, such as happiness, sadness, interest, boredom, and anxiety. The cognitive engagement component links to students' preference for challenging tasks, attention to tasks, how to master the task, and willingness to go beyond what is required.

There are several student self-report surveys [84, 85]. Only a few of them cover all three components of engagement. Our target is to use both observations and self-report questionnaires. Self-report methods are useful for assessing emotional and cognitive engagement components, which are not directly observable [83]. The behavioural engagement component is observable. Thus, we use observational methods to assess behavioural engagement. In addition, behavioural engagement assessment will be complemented by using self-report questionnaire as observations can not dive into participants' thinking or quality of effort or feelings during their activities.

As there was no existing self-report questionnaire suitable for our purposes, we decided to develop our own, which rely on three-dimensional student engagement [82]. The questions are modified from three existing questionnaires, which are targeted to the school and classroom environment: School Engagement Scale [136], Student Engagement in Schools Questionnaire (SESQ) [137] and School Engagement Survey (SES) [138]. They contain questions for behavioural, emotional and cognitive engagement components. School Engagement Scale, developed by Fredricks, Blumenfeld and Paris, provides a basis for us. SESQ divides emotional engagement questions into liking for learning and liking for school, which is not relevant for us. The SESQ behavioural engagement component covers extracurricular activities as a general concept. When filtering out direct classroom and school related questions, SESQ and SES complement our basis in all three engagement areas. After combining and modifying these three existing questionnaires we ended up with six questions for each engagement component. As our context is two different extracurricular activities, we have modified the questions addressing these activities.

4.3.2 Soundscape workshop engagement

We measured the engagement during the WS4 and WS6 workshops. In the WS4 workshop, we had 12 students from three different classes in a local secondary school. Their age was between 13 and 16 years. Based on observations students enjoyed, were interested, concentrated, paid attention and finished the tasks. Enjoyment was observed from laughter. Interest could be seen in the discussions, comments and questions asked. Concentration and attention could be detected from to the point questions and keen faces when explaining the idea of the workshop and demonstrating the application. There was one student, who was bored part of the time and not that interested in the workshop activity. This could be detected from her behaviour as she was using her own phone for non-related activities. Although students were answering the questionnaire anonymously, there was one student whose answers were somehow different from the others, which most probably confirmed the observed behaviour of lack of interest and boredom. In Table 18 there are statistics calculated from the questionnaire. A more detailed analysis from the WS4 workshop can be found in the publication the Audio Story and AR Platform for Youth Engagement [VI].

Table 18. WS4 workshop Soundscape engagement statistics.

		Min	Q1	Median	Q3	Max	IQR
1	I tried my best in the workshop	3	4	4	5	5	1
2	I paid attention during the introduction	3	4,75	5	5	5	0,25
3	During the workshop, I just pretended I am working	1	1	1	1	1	0
4	I just did enough to get by	3	3,75	4,5	5	5	1,25
5	During the workshop my mind wandered	1	1	1,5	2	5	1
6	I tried hard to do my part during the recording, listening and discussion	3	4	5	5	5	1
7	I felt happy in the workshop	3	4	5	5	5	1
8	I felt bored in the workshop	1	1	1	2	3	1
9	I felt excited by the work in the workshop	2	4	4	5	5	1
10	I was interested in the tasks done during the workshop	3	4	5	5	5	1
11	I enjoyed learning new thing in the workshop	2	4	4	5	5	1
12	I enjoyed working with other students in the workshop	3	4	5	5	5	1
13	During the workshop I discussed with other students to make sure I understood what was expected from us	1	1	2	3	4	2
14	When I listened to the introduction, I tried to understand information better by relating it to things I already know	1	3	3,5	4	5	1
15	When I listened to the introduction, I tried to figure out how the information would be useful in real world	2	3	3	4	5	1
16	When I was recording and listening stories I tried to figure out how this would be useful in real world	1	2,75	3	4	5	1,25
17	Tasks done during the workshop were challenging	1	1,75	3	4,25	5	2,5
18	I tried to see similarities and differences between things I learned in the workshop and things I already know	1	2	3,5	4	5	2

In Table 18 there are non-parametric statistics: median, minimum, maximum, 25% quartile (Q1), 75% quartile (Q3), and Inter-Quartile Range (IQR). We have used the scale never (=1), on occasion (=2), some of the time (=3), most of the time (=4), and all the time (=5). We will mainly look at the median (a measure of central tendency) and IQR (a measure of dispersion) calculated for each engagement related answers. The first six answers are related to behavioural engagement. Half of them are related to positive behaviour and questions 3, 4 and 5 were control questions defining negative behaviour. Based on the answers most respondents indicated behavioural engagement at least most of the time. The only exception is the question 'I just did enough to get by'. The answers are totally contradicting other answers. We will discuss the possible explanation on this controversy later. Questions 7 to 12 are related to emotional engagement. Five questions are checking positive emotions and question 8 is a control question describing negative emotion. Based on the answers most respondents indicated emotional engagement at least most of the time. The last six questions are related to cognitive engagement. Answering questions 14 and 15 most respondents indicated engagement some of the time (median ≥ 3, IQR=1). There were more divided opinions when answering the rest of the questions (median ≥ 2, IQR ≥1,25). Thus, respondents were cognitively engaged only some of the time.

In the WS6 workshop we had 8 students from the Humak University of Applied Sciences, Jyväskylä, Finland. Their ages varied between 20 and 30 years. We had similar observations as in the WS4 workshop. Students enjoyed, were interested, concentrated, paid attention and finished the tasks. Based on observations, two students seemed to be less interested to put full effort into workshop tasks. However, this was not confirmed by the answers to the self-report questionnaire.

Table 19 presents the statistics from the WS6 workshop. Based on the answers most respondents indicated behavioural (questions 1 – 6) and emotional (7 – 12) engagement at least most of the time. Similar to the WS4 workshop, the cognitive engagement was different compared to the other two engagement components. The tasks were not challenging according to most respondents. There were more divided opinions when answering the rest of the questions (median ≥ 3, IQR ≥1,5). Thus, respondents were cognitively engaged only some of the time, as in the WS4 workshop.

Table 19. WS6 workshop Soundscape engagement statistics.

		Min	Q1	Median	Q3	Max	IQR
1	I tried my best in the workshop	4	5	5	5	5	0
2	I paid attention during the introduction	4	5	5	5	5	0
3	During the workshop, I just pretended I am working	1	1	1	1	2	0
4	I just did enough to get by	1	1	1	1	2	0
5	During the workshop my mind wandered	1	1	2	2	3	1
6	I tried hard to do my part during the recording, listening and discussion	4	4	5	5	5	1
7	I felt happy in the workshop	4	5	5	5	5	0
8	I felt bored in the workshop	1	1	1	1	1	0
9	I felt excited by the work in the workshop	4	4,75	5	5	5	0,25
10	I was interested in the tasks done during the workshop	4	4	5	5	5	1
11	I enjoyed learning new thing in the workshop	3	4	4,5	5	5	1
12	I enjoyed working with other students in the workshop	4	5	5	5	5	0
13	During the workshop I discussed with other students to make sure I understood what was expected from us	1	1,75	3,5	4,25	5	2,5
14	When I listened to the introduction, I tried to understand information better by relating it to things I already know	2	2,75	3	4,25	5	1,5
15	When I listened to the introduction, I tried to figure out how the information would be useful in real world	2	3	3,5	5	5	2
16	When I was recording and listening stories I tried to figure out how this would be useful in real world	2	2,75	3,5	5	5	2,25
17	Tasks done during the workshop were challenging	1	1	1	2	2	1
18	I tried to see similarities and differences between things I learned in the workshop and things I already know	1	2	3,5	4	5	2

The comparison of the medians in both workshops (WS4 and WS6) can be found in Figure 21.

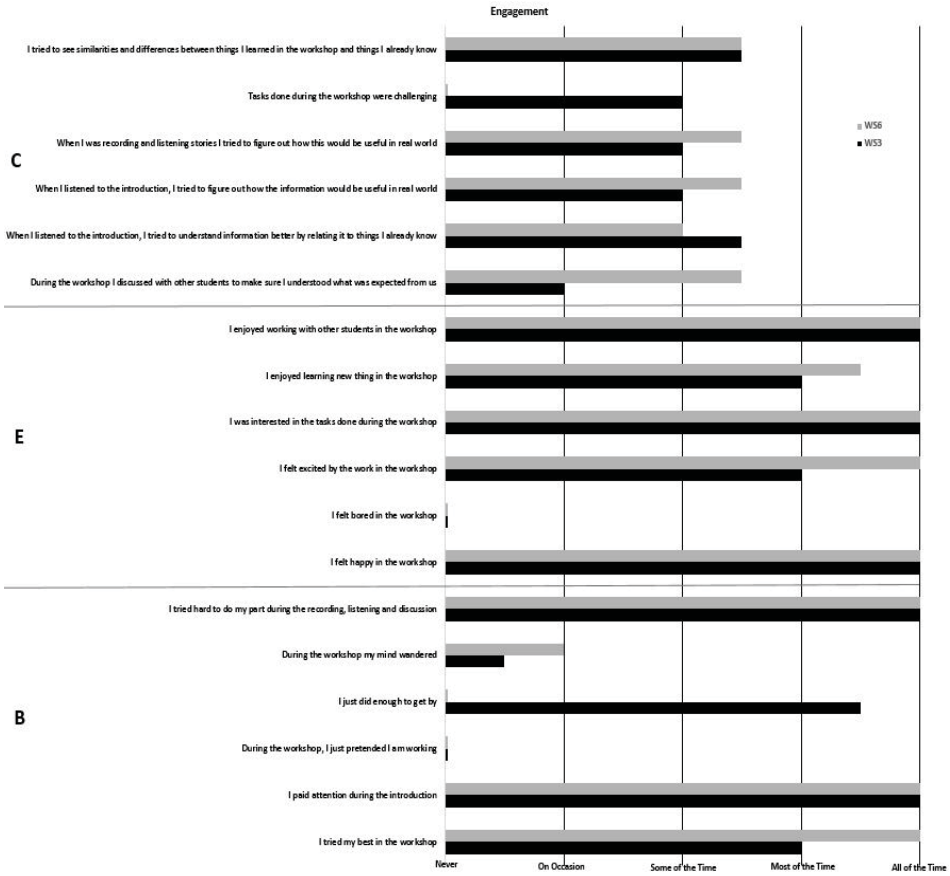

Figure 21. Soundscape workshop engagement.

In Figure 21 we have three sections describing the three engagement components. If we look at the behavioural engagement first (Figure 21 B), we will see that students in both workshops were putting effort into and paying attention to the workshop most of the time. As a cross-check we asked if participants were just pretending to work or if their mind wandered during the workshop. Answers to these cross-check questions confirmed that participants were really concentrating and doing their best. An interesting result is that in the WS4 workshop they did just enough to get the work done. On the other hand, in the WS6 workshop also answers to this question confirmed that students were doing their best. One explanation to this difference could be that the translation from English to Polish was not that accurate in relation to this particular question. All in all, we could see that students were behaviourally engaged most of the time in both workshops. Emotional engagement (Figure 21 E) related answers indicated that students were happy, excited and enjoying themselves most of the time. Only occasionally did they seem bored in Gdansk. Thus, emotionally they were also engaged. This confirms the behaviour that was observed. Students were happy and laughing. They expressed interest and attention through discussions and relevant questions without negative comments. The third component, cognitive engagement (Figure 21 C) was not as positive as the others. It can be seen that students paid attention to the task and to some extent to task mastery, but they did not invest much in tasks relating to a

larger context in the WS4 workshop. The level of challenge for completing the tasks was not high in the WS4 workshop and was very low in the WS6 workshop, which could be a reason why students were cognitively engaged only for some of the time. This assumption is supported by other research where they have found a relationship between challenging tasks and higher behavioural, emotional and cognitive engagement [82].

As a whole we could see that the engagement in both workshops follows the same pattern. Emotionally and behaviourally students were engaged most of the time. The cognitive engagement level was not as high as the other two components.

4.3.3 Audiostory workshop engagement

Engagement was measured in both audio story workshops, the WS3 and WS5 workshops.

In the WS3 workshop we had 30 students from three different classes in local secondary school. Their age was between 13 and 16 years. Based on our observations, students enjoyed, were interested, concentrated, paid attention and finished the tasks. Enjoyment was observed from laughter and happiness. Students were expressing interest by willingly discussing and asking questions. Concentration and attention could be detected from the silence and keen faces when explaining the idea of the workshop and demonstrating the application, and on the other hand from relevant questions and serious discussions when it was time for discussions. In Table 20 there are statistics calculated from the questionnaire. A more detailed analysis from Gdansk workshop can be found in the publication Audio Story and AR Platform for Youth Engagement [VI].

Table 20 presents the statistics from the WS3 workshop. Based on behavioural engagement related answers 1, 2, 3 and 5 most respondents indicated behavioural engagement at least most of the time. The answer to the 6th question divided opinions (median=4 and IQR=2). However, the median still indicated behavioural engagement at least most of the time. The only exception is question 4, ‘I just did enough to get by’. The answers are totally contradicting other answers. This contradiction supports the explanation that was offered earlier, i.e. the translation from English to Polish was not that accurate. Based on answers to emotional engagement most respondents indicated emotional engagement at least most of the time. The last six questions are related to cognitive engagement. Answering questions 14, 15 and 18 most respondents indicated engagement some of the time (median = 3, IQR=1). The opinions were more divided when answering rest of the questions (median $\geq$ 2, IQR $\geq$2). Thus, respondents were cognitively engaged only some of the time.

Table 20. WS3 workshop Storytelling engagement statistics.

		Min	Q1	Median	Q3	Max	IQR
1	I tried my best in the workshop	3	4	4	5	5	1
2	I paid attention during the introduction	4	5	5	5	5	0
3	During the workshop, I just pretended I am working	1	1	1	1	4	0
4	I just did enough to get by	2	4	4,5	5	5	1
5	During the workshop my mind wandered	1	1	2	2	5	1
6	I tried hard to do my part during the recording, listening and discussion	2	3	4	5	5	2
7	I felt happy in the workshop	3	4	5	5	5	1
8	I felt bored in the workshop	1	1	2	2	4	1
9	I felt excited by the work in the workshop	2	4	4	5	5	1
10	I was interested in the tasks done during the workshop	3	4	5	5	5	1
11	I enjoyed learning new thing in the workshop	1	4	4	4	5	0
12	I enjoyed working with other students in the workshop	3	4	4	5	5	1
13	During the workshop I discussed with other students to make sure I understood what was expected from us	2	3	4	5	5	2
14	When I listened to the introduction, I tried to understand information better by relating it to things I already know	1	3	4	4	5	1
15	When I listened to the introduction, I tried to figure out how the information would be useful in real world	1	3	3	4	5	1
16	When I was recording and listening stories I tried to figure out how this would be useful in real world	1	1,25	3	4	5	2,75
17	Tasks done during the workshop were challenging	1	1	2	3	5	2
18	I tried to see similarities and differences between things I learned in the workshop and things I already know	1	3	3	4	5	1

In the WS5 workshop there were 16 first year international IT-students coming from 10 different nationalities. Age distribution was wide from 20 to 38 years. Based on observations, the students were interested in this workshop, they had fun and they finished the tasks. Some of the students finished their tasks quite fast, which resulted in a situation where they had to wait for the rest of the students. Thus, there was some frustration to be seen. This was confirmed by the questionnaire.

Table 21. WS5 workshop Storytelling engagement statistics.

		Min	Q1	Median	Q3	Max	IQR
1	I tried my best in the workshop	3	4	4	5	5	1
2	I paid attention during the introduction	3	4	5	5	5	1
3	During the workshop, I just pretended I am working	1	1	1	1,25	2	0,25
4	I just did enough to get by	1	1	1,5	2,25	5	1,25
5	During the workshop my mind wandered	1	2	2	3,5	5	1,5
6	I tried hard to do my part during the recording, listening and discussion	3	4	4	5	5	1
7	I felt happy in the workshop	3	4	4	5	5	1
8	I felt bored in the workshop	1	1	1	2	3	1
9	I felt excited by the work in the workshop	2	3	4	4	5	1
10	I was interested in the tasks done during the workshop	3	3,75	4	5	5	1,25
11	I enjoyed learning new thing in the workshop	2	4	5	5	5	1
12	I enjoyed working with other students in the workshop	2	4,75	5	5	5	0,25
13	During the workshop I discussed with other students to make sure I understood what was expected from us	2	3	4	5	5	2
14	When I listened to the introduction, I tried to understand information better by relating it to things I already know	2	3	4	4	5	1
15	When I listened to the introduction, I tried to figure out how the information would be useful in real world	3	3	4	5	5	2
16	When I was recording and listening stories I tried to figure out how this would be useful in real world	2	3	4	5	5	2
17	Tasks done during the workshop were challenging	1	2	2	3	4	1
18	I tried to see similarities and differences between things I learned in the workshop and things I already know	3	3,75	4	4,25	5	0,5

Table 21 presents the WS5 workshop statistics. Based on behavioural engagement-related answers 1, 2, 3 and 6 most respondents indicated behavioural engagement at least most of the time. The answer to questions 4 and 5 divided opinions (median≤2 and IQR≥1,25). However, even these answers supported the conclusion of behavioural engagement most of the time. Based on answers to emotional engagement, most respondents indicated emotional engagement at least most of the time, except the answers to question 10, where there were more divided opinions

(median=4, IQR=1,25). Answering questions 14 and 18 most respondents indicated engagement most of the time (median = 4, IQR≤1). Most of respondents were also of the opinion that the tasks were not challenging. There were more divided opinions when answering the rest of the questions (median = 4, IQR =2). However, the median indicates that the respondents were cognitively engaged most of the time.

The comparison of the medians in both workshops can be found in Figure 22.

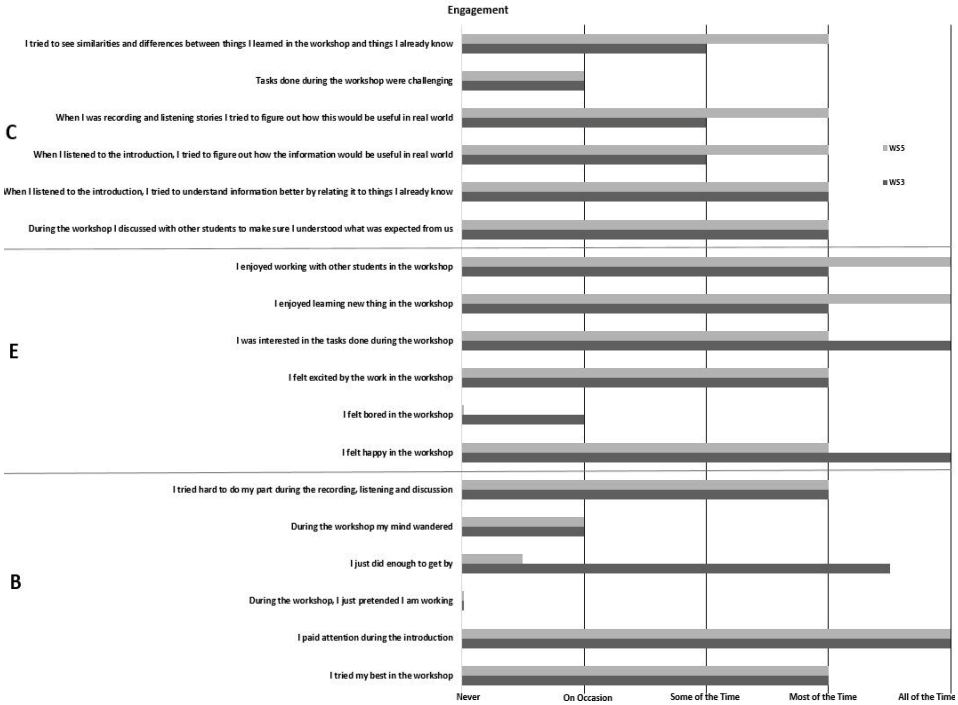

Figure 22. Audiostory workshop engagement.

Figure 22 is similar to Figure 21 containing three engagement components. If we look at the behavioural engagement first (Figure 22 B), we will see that students in both workshops were putting effort and paying attention to the workshop most of the time. In both workshops, the participants reported that their mind wandered during the workshop on occasion. This could be explained in the WS5 workshop due to the waiting periods as some students were progressing much faster than others. In the WS3 workshop students were waiting due to upload problems. The only exception is the question 'I just did enough to get by'. This exception was potentially explained earlier. All in all, we could see that the students were behaviourally engaged most of the time in both workshops. Emotional engagement (Figure 22 E) related answers indicated that students were happy, excited and enjoying themselves most of the time. Only occasionally did they feel bored in Gdansk. Thus, emotionally they were very engaged. Our observations also confirms the behavioural and emotional engagement. There was a difference in cognitive engagement (Figure 22 C) in the WS3 and WS5 workshops. In the WS3 workshop they paid less attention to tasks relating to a larger context, which might be at least partially explained by the age difference. In both workshops, the participants paid attention to task and to task mastery. The level of

challenge for completing the tasks was not high. As a whole, the participants in the WS5 workshop were cognitively engaged most of the time, while participants in the WS3 workshop were cognitively engaged only for some of the time.

4.4 Contribution

We have developed a concept which helps to reach our target audience and helps to measure the level of engagement. As our audio platform aims at activating young people, we need to reach that audience. For this purpose, we need to co-operate with and motivate schools and teachers. Thus, workshops which fulfil extracurricular characteristics will serve this purpose. In our case we have developed two different workshops, which have a clear structure, are supervised by adults, and have pedagogical objectives for the participants' skill development. The leading researchers in the youth development field have stated that extracurricular activities have a positive impact in general on adolescents' development. Thus, teachers and other school staff see extracurricular activities in a very positive light.

The second part of our concept is addressing the question of how young people experience our workshops. For this purpose, we have applied the student engagement structure in order to find out the level of engagement in workshops where our audio platform is a vital part. By observing participants and utilising a questionnaire which we have developed it is possible to measure the level of three engagement components. The behavioural engagement finds out the positive conduct and involvement in learning and academic tasks. The emotional engagement concentrates on participants' affective reactions. The third component, cognitive engagement focuses on attention to task, task mastery, a willingness to go beyond what is required and a preference for challenging tasks. By analysing measurements from each component separately it is easier to improve specific characteristics of the workshop. For example, we could increase the task challenge if the cognitive engagement component is not up to the expected level. The task challenge could be increased by modifying pedagogical objectives to be more challenging, for example.

As a whole our contribution to the community is a concept to reach young people and a measurement instrument to measure the level of engagement in an audio related workshop context.

Next, we will discuss how several people were supporting our concept development and testing.

4.5 Acknowledgements

Organising a workshop typically requires more than one person. The first and second workshops in the Museum of Technology in Helsinki were organised by a team of five people: Ms. Outi Putkonen and Ms. Riina Linna from the Museum of Technology and Senior Lecturers Merja Bauters and Aura Neuvonen, and myself from Metropolia University of Applied Sciences. In addition, Ms. Pauliina Kinanen from the Finnish Museums Association was helping with arrangements in the second Helsinki workshop.

Ms. Marta Wróblewska from Gdańsk City Gallery was a key person, when we organised two workshops in Gdansk. She arranged the venue, contacted local schools and invited teachers and their students to join our workshops. In addition, she translated all the relevant material to Polish and together with Senior lecturer Aura Neuvonen and myself facilitated both workshops.

Senior Lecturer Tuula Salo from Humak University of Applied Sciences organised the Jyväskylä workshop together with me.

When studying how easy/difficult the interaction with the mobile applications was, we needed to observe participants, design and implement questionnaires, and analyse results. Senior Lecturer Merja Bauters helped me a lot with these activities.

PhD Arto O. Salonen from Metropolia University of Applied Sciences provided valuable comments during the engagement instrument development.

Next, we will discuss what we have accomplished together.

4.6 Discussion

We have organised six workshops using the same format but different environment, and partially different objectives. The same format means that there were pedagogical objectives defined and the structure of the workshop followed the same pattern: introduction, practical tasks, reflection, and feedback. Table 22 presents the main characteristics of each workshop.

As can be seen in Table 22, the first two workshops were organised in the Museum of Technology, in Helsinki, Finland. The participants were Finns. In order to find out if culture makes a difference, we organised the next two workshops in Gdańsk City Gallery, in Gdansk. The participants were Polish secondary school students. In other words, the first four workshops were organised outside an ordinary workplace. When the students' workshop was outside the school, this could increase positive feelings towards the workshop. Thus, we wanted to change the venue back to a school environment in the last two workshops. In the WS5 workshop we had first-year students from different nationalities on their own campus, which they were already familiar with. In the WS6 workshop we had Finnish students in their normal classroom.

Table 22. The main characteristics of workshops.

Workshop	Objectives	Theme	Participant Age	Participant Nationality	Venue
WS1	Evaluate interaction with three mobile mixer applications	Soundscape	14 – 15	Finnish	Museum of Technology
WS2	1) Evaluate interaction with SoundSpace 2) Soundscape applicability in other museums	Soundscape	Adults	Finnish	Museum of Technology
WS3	1) Evaluate interaction with Audiostory Sharing 2) Evaluate workshop engagement	Audiostory	13 – 16	Polish	Gdańsk City Gallery
WS4	1) Evaluate interaction with SoundSpace 2) Evaluate workshop engagement	Soundscape	13 - 16	Polish	Gdańsk City Gallery
WS5	1) Evaluate interaction with Audiostory Sharing 2) Evaluate workshop engagement	Audiostory	20 - 38	10 nationalities	Metropolia University of Applied Sciences
WS6	1) Evaluate interaction with SoundSpace 2) Evaluate workshop engagement	Soundscape	20 – 30	Finnish	Humak University of Applied Sciences

In all workshops we have taken into account four components of conceptual modelling of engaging school and out-of-school contexts [139]. Both teachers and staff have been supportive, the workshops have been adequately structured, and we have done our best to create tasks that were interesting and meaningful to be accomplished in teams. In all cases the peer context has been positive due to similar educational background, willingness to ask questions and co-operate with others.

As said earlier, the evaluation was divided into two parts: evaluating the interaction between users and mobile application and evaluating how engaging the workshops where the audio platform will be utilised are. The first part of the evaluation used three different angles to explore how the user experienced the application in the task context:

1. Application suitability for a task.
2. Application functionality.
3. Feeling of the usage.

Both applications succeeded in the suitability aspect. In the first workshops (soundscape mixer in the WS1 workshop and audiostory sharing in the WS3 workshop) there were functional problems, which clearly had an impact on the answers. Even if there were problems with the applications, users still agreed that the applications were fitting for the task. This was clearly seen in the WS6 workshop where users had problems and that did not affect the answers about suitability. Suitability was also seen from the fact that most of the users would use applications also elsewhere than the workshop.

Looking for the functionality aspect it seems that the soundscape mixer application does not work as well as the audiostory sharing application when taking into account the problems mentioned earlier. The difference between the applications' functionalities can also be seen in the results as all the users succeeded in listening to and recording stories (after a bug fix). On the contrary, only some of the users recorded their own sounds when creating the soundscapes. Maybe we did not encourage users enough to utilise this feature. Another reason for the difference in functionality could be that the soundscape mixer application requires a lot of downloading. The network traffic could be slow depending on the quality of the network. We need to research this aspect more.

The results were promising in the third aspect, i.e. how users experienced the usage of the application. Both applications were seen as pleasant to use if we take into account the impact on the functional problems in the first workshops of each application type. The pleasantness of use could have a positive impact on the result obtained that most of the users would use the applications also elsewhere than the workshop.

As a conclusion from the interaction evaluation, we can say that the results were very promising, especially, if we take into account that none of the users had used a soundscape mixer-type application before, and only a few had used a similar application to the audiostory sharing. However, we need to further develop the soundscape mixer application. This requires that we study in detail, which parts of the application should be modified in order to satisfy users' expectations of smooth functionality. As a part of this further study we need to revisit the soundscape mixer application and requirements. However, it seems that we have succeeded with ADAM and the audiostory sharing application requirement definitions based on interaction evaluation results. In addition, we need to review our workshop introduction in order to encourage users to utilise all application features.

Our approach to evaluating workshop engagement could be categorised as a user experience evaluation method. Vermeeeren et al. have published research containing 96 different methods [140]. Some of the existing methods, such as Experience Sampling Method (ESM) or Intrinsic motivation inventory (IMI), have similar features as ours. However, their theoretical roots are different. So far, we have not found a UX evaluation method that is based on the student engagement structure.

When applying our engagement evaluation approach we were expecting more variation on engagement results due to different cultures, age groups and venues. If we start with emotional

engagement, we can see that the results in all four workshops are quite similar. Participants were happy, excited and enjoying the workshop. It did not matter if the workshop was outside the school or in the school premises. In any case, the activities during the workshops were different compared to ordinary school classes. The students from different nationalities and age groups were positively engaged most of the time whether it was a soundscape or an audiostory workshop.

Behaviour-wise there were some differences. During the audiostory workshops there were moments when some of the participants were having some unrelated thoughts instead of concentrating on the workshop topics. This could be due two different reasons. In Gdansk they had problems with uploading. This resulted in a situation that one of the groups was trying to upload while others were waiting. A similar waiting situation happened in Espoo as some of the students were much faster to accomplish the task. Otherwise participants in all workshops paid attention and tried hard most of the time during the workshop, which was confirmed by observations and self-report questionnaire results. In order to get rid of unwanted waiting periods we need to revisit audiostory workshop guidelines and structure.

Most of the differences could be seen in cognitive engagement. The level of challenge in the soundscape workshop was felt to be higher by young participants. However, this did not result in higher overall cognitive engagement as was expected from earlier research [82]. On the contrary, older participants' cognitive engagement was higher even if the challenge was felt to be very low. This was also true for the audiostory workshop, where the challenge level was the same in both workshops independent of the nationality or the age group or the venue. The older students were relating the contents of the workshop to a larger context, which resulted in higher cognitive engagement independent of nationality.

Because our workshops require intense work, they do not have many participants which makes it hard to generalize the findings. In addition, the number of workshops was limited. From these few workshops we gathered quantitative data mostly using likert-type scales. Qualitative methods (observations, interviews and discussions with participants) were used to understand the quantitative data gathered. Using a qualitative paradigm illuminates the people behind the numbers and helps to understand what is observed, it provides richer understanding that mere statistics [23]. The qualitative methods also support the three measurement components: observation allows studying of the behavioural aspect especially when mixed with self-reporting questions related to behaviour and cognitive aspects. The questionnaires allow us to understand the emotional aspects of the users that cannot be seen in their behaviour. Although our questionnaire was based on the earlier tested three questionnaires developed by leading engagement researchers, it is not evident that our questionnaire would be most suitable for the task. We did the basic validation of the questionnaire using a few experienced researchers. However, we were relying on the fact that the original three questionnaires were developed by professionals. Thus, we need to validate more thoroughly the questionnaire including different language versions.

Based on engagement results we could say that our workshop concept including the developed audio platform is an engaging experience for youth. This is true especially whenregarding emotional and behavioural engagement. We need to improve the audio story workshop in order to avoid waiting times. Similarly, we need to further research how to encourage younger participants to think about larger contexts in order to increase the level of cognitive engagement. Moreover, there is a need to raise the challenge of the workshop tasks, which has an impact on all the engagement components.

4.7 Related Work

We have combined youth development research and student engagement research to create a workshop concept, where the young participants' engagement could be measured. By adding the context related research from the user experience field, we have evaluated the interaction between users and mobile applications as well as evaluated how engaging the workshops where the audio platform will be utilised are. So far, we have not found a similar evaluation approach, where these three research areas will meet in the IT domain. However, there are several research projects in each field, which have been relevant to our evaluation approach development.

Out of several studies related to organized activities and youth development these three have been the most inspiring: Extracurricular Activities and Adolescent Development by Eccles et al. [21], Differing Profiles of Developmental Experiences Across Types of Organized Youth Activities by Larson et al. [76] and Organized Activity Participation, Positive Youth Development, and the Over-Scheduling Hypothesis by Mahoney et al. [12]. Based on these studies it is obvious that participation in organised youth activities have a positive impact in both psychological and academic development. Eccles has studied the relation between extracurricular activities and academic development. Larson and Mahoney have a wider perspective by researching the general youth development, not just educational development. From these studies we have adopted the idea of arranging workshops in the form of school-related extracurricular activities. Thus, we will involve teachers in the arranging of workshops, define pedagogical objectives, define a clear structure for a workshop and involve also other adults than teachers for supervision of workshops. These workshops are the context where our audio platform is used.

The relationship between the context and interaction with an IT system has been studied more intensively since ubiquitous computing has emerged. The same phenomenon has been tackled also by user experience (UX) research. If we look at the studies by Dourish [131] and Paay and Kjeldskov [132] it is clear that we cannot separate interaction and context. This is confirmed by UX research. The most common UX-definition says: UX is a consequence of a user's internal state, the characteristics of the designed system and the context within which the interaction occurs [135]. Based on these studies it was obvious that we needed to take into account the context if we wanted to evaluate the interaction between audio platform and user. The same also applied to the evaluation of how users experience the platform.

The user experience was measured as engagement with the workshop. Fredricks et al. have described student engagement consisting of three components [82]. Most researchers in this field agree with this three-component definition [83]. However, there is no common agreement on how to operationalize three components into items and scales for measurement. Operationalization of components in the form of questionnaires is defined in School Engagement Scale [136], Student Engagement in Schools Questionnaire (SESQ) [137] and School Engagement Survey (SES) [138]. By accepting the definition by Fredricks et al., we decided to develop our own questionnaire, which was based on these three existing questionnaires. By combining results from these five studies we ended up evaluating the user experience as student engagement using observations and self-report questionnaires as proposed in [83].

5 Conclusions

We will conclude this document by summarising our findings and their meaning in order to answer the question why it was important to carry out this research. After that we will revisit the publications and research questions, and finally discuss how to move on.

5.1 Summary

The aim of this dissertation has been to develop a modular and easy-to-use audio story sharing and audio-augmented reality platform for museums, which has been used in workshops in order to measure the level of engagement of participating youth.

By dividing the overall audio platform into six modules and then applying relevant architectural patterns, such as layered, client-server, model-view-control, shared-data and multitier pattern, we ended up in manageable design and development phases. In the first phase, the audio digital asset management (ADAM) system including relevant APIs was developed. After that a mobile soundscape mixer (audio- augmented reality) application utilising APIs was developed. Finally, a mobile NFC writer and audiostory-sharing applications were developed. To sum up, we have succeeded in developing a modular and versatile audio platform. This platform does not require any special hardware components. Software-wise our backend system is based on open source components, so there are no license fees to be paid by the cultural institutions that would like to install and use this system. The same applies to existing mobile applications as they have been developed for the Android platform.

As we have developed relevant APIs between mobile applications and ADAM, new mobile applications can be developed by third parties for new services or other mobile platforms. Modular architecture means that only those (existing or new) mobile applications could be selected, which are relevant to the cultural institution's service portfolio.

There are two main reasons for our success: keeping the audio file's content simple and immutable, and the use of relevant metadata. The rest is architectural decisions and software development.

The limitation of the audio platform is the immutable audio files. If there is a need to analyse and annotate some parts of the audio content then our platform is not the right choice.

In order to reach youth and measure the level of engagement we have developed a concept consisting of a special type of workshop and engagement measurement instrument. As our audio platform aims at activating young people we need to reach that audience. For this purpose, we need to co-operate with and motivate schools and teachers. Youth development researchers have stated that extracurricular activities have a positive impact on adolescents' development in general. Thus, teachers and other school staff see extracurricular activities in a very positive light. By

applying extracurricular characteristics into a workshop, we will serve this purpose. In our case we have developed two different workshops, which have a clear structure, are supervised by adults, and have pedagogical objectives for the participants' skill development. Cultural institutions are able to create their own workshops by applying the extracurricular characteristics guidelines.

The second part of our concept is addressing the question of how young people experience our workshops. For this purpose, we have applied the student engagement structure. Our engagement measurement instrument is based on workshop participant observations and developed a self-report questionnaire. By using our instrument, it is possible to measure the level of three engagement components during a workshop where our audio platform plays a vital part. The behavioural engagement finds out the positive conduct and involvement in learning and academic tasks. The emotional engagement concentrates on participants' affective reactions. The third component, cognitive engagement, focuses on attention to tasks, task mastery, a willingness to go beyond what is required and a preference for challenging tasks. By analysing measurements of each component separately, it is easier to improve those parts where the workshop is not up to the expected level.

As a whole this is a concept that cultural institutions could utilise when trying to reach young people through school, and which provides a measurement instrument to check the level of engagement in an audio-related workshop context.

This concept assumes organising an extracurricular activity, which limits the usefulness of the engagement questionnaire.

Did we meet our objectives? Yes, we have described how to develop a modular and easy-to-use an audio story-sharing and audio-augmented reality platform. Also, we have described the concept of how to reach youth through schools and how to measure the level of engagement in workshops where the audio platform is utilised. Next, we will revisit our publications.

5.2 Publications revisited

I: Salo K., Shakya U., Damena M. 2014. Device Agnostic CASS Client. In: Marcus A, editor. Design, User Experience, and Usability: User Experience Design for Diverse Interaction Platforms and Environments. Switzerland: Springer International Publishing, pp. 334-344.

This article discusses how to implement a front-end application, which needs to run in different platforms. A software architecture that is based on HTML5 and web technologies is described. This architecture enables basic functionalities to run in browsers and media-intensive functionalities to run as native applications

This publication was important for the audio platform architecture design. The article discusses media-related APIs which was the corner stone when deciding whether we should implement our mobile applications as browser-based using web technologies or as native applications.

II: Salo K., Giova D., Mikkonen T. 2016. Backend Infrastructure Supporting Audio Aug-mented Reality and Storytelling. In: Yamamoto S., editor. Human Interface and the Management of Information: Information and Knowledge in Context, Part II, LNCS 9735, 1–11. Springer International Publishing, Switzerland.

This publication concentrates on describing the server side of the audio platform architecture. It describes design, implementation and testing a portable open-source-based audio digital asset management system (ADAM), which supports interaction with phone applications. This includes researching, selecting and modifying an existing open source DAM system, designing and developing APIs for interaction with client software, and researching and implementing relevant metadata standards. The overall audio platform architecture was initially described in this article.

III: Salo K., Bauters M., Mikkonen T. 2016. Mobile Soundscape Mixer – Ready for Action. In: Younas M., Awan I:, Kryvinska N. Strauss C., van Thanh D. (Eds.) Mobile Web and Information Systems, MobiWIS 2016 Proceedings, Lecture Notes in Computer Science 9847 (pp. 18-30). Springer International Publishing, Switzerland.

This article describes how to design, implement and test a smoothly working Android application. We have described the design and development process of the soundscape mixer application. This article contains a description of requirements, functionalities, backend interaction using APIs and relevant performance tests suitable for Android applications. The role of this article was to two-fold: describe the soundscape mixer application (including the integration into overall architecture) and describe how to ensure that an Android application works smoothly.

IV: Salo K., Zinin V., Bauters M., Mikkonen T. 2017. Modular Audio Story Platform for Museums. In Proceedings of the 22nd International Conference on Intelligent User In-terfaces Companion (IUI '17 Companion). ACM, New York, NY, USA, 113-116.

This article describes the functionality and use of Audio Sharing and NFC Writer applications. We have described the audio platform architecture on the deployment level. In addition, we have described the use of NFC tags, application functionalities, user interface of the Audio Sharing application utilizing emotions, and interaction with ADAM. The role of this article was to demonstrate that we could add different types of mobile applications into our modular platform and find out if these mobile applications could be used separately and could they also interact with one another.

V: Salo K., Bauters M., Mikkonen T. 2017. User Generated Soundscapes Activating Museum Visitors. In Proceedings of the 32nd ACM SIGAPP Symposium on Applied Computing (SAC 2017). ACM, New York, NY, USA, 220-227.

This article describes two workshops, where the soundscape mixer application was evaluated from the user perspective. The workshops had different user groups and goals. The first one evaluated ease of use and feelings evoked in the young audiences. The second workshop had museum professionals as participants. The goal of the second workshop was to evaluate the ease of use of the application and at the same time check if this type of application could be used also in other museums than the Museum of Technology. Thus, the evaluation of interaction between different user groups and the soundscape mixer application, and the testing of the soundscape workshop generalizability in the museum sector are the most interesting points in this article.

VI: Salo K., Bauters M., Mikkonen T. 2017. Audio Story and AR Platform for Youth En-gagement. In: Younas M., Awan I:, Holubova I. (Eds.) Mobile Web and Intelligent Infor-mation Systems, MobiWIS 2017 Proceedings, Lecture Notes in Computer Science 10486 (pp. 18-32). Springer International Publishing, Switzerland.

This paper concentrates on measuring the engagement of the Soundscape Mixer and Audiostory Sharing applications in the context of workshops. These workshops follow the characteristics of extracurricular activities. To evaluate how students experience workshops (and audio platform) we have developed an instrument to measure engagement. Our instrument is based on student engagement research. The description and usage of this instrument is described. The role of this article is very important as it describes both the workshop concept and engagement evaluation framework.

Next, we will revisit research questions.

5.3 Research Questions Revisited

As described in the Introduction, we defined the following research questions:

1. How do we design and implement a portable modular audio story sharing and audio augmented reality platform?
    a. What kind of overall software architecture is needed?
    b. How do we design and implement modular, smoothly working soundscape mixer and audio story-sharing mobile applications?
2. How do we evaluate an audio platform in a workshop context?
    a. What is the role of context?
    b. How do we evaluate interaction between user and platform in workshop context?
    c. What is engagement and how do we measure it?

The first question has been discussed in chapter 3. The overall software architecture has been divided into six modules: data management module, data storage module, admin console module, soundscape management module, audiostory management module and NFC tag-management module. Modules are decoupled from each other in order to enable modifiability and also the possibility to allocate development of each module for separate teams. We have applied some common architectural patterns. We used a layered pattern for the module structure, client-server pattern for the component-and-connect structure, and multitier pattern as an allocation structure. Figures 1 – 4 provide a good overview of the overall architecture.

Designing and implementing smoothly working mobile applications has been based on three corner-stones: following the selected architectural patterns, iterative design process and following the Android best practises during implementation. In order to verify the smoothness we tested the performance first and then asked the users to evaluate the interaction with the applications. For the performance testing we used existing Android Studio tools: static code analysis based on the lint tool and GUI performance using the Hierarchy Viewer tool and GPU monitor. Interaction with the applications has been discussed in chapter 4. To sum up, we can say that after fixing the bugs most respondents indicated agreement with the idea that the applications were fitting for the task, worked well and were pleasant to use.

The second question has been discussed in chapter 4. In order to evaluate the developed audio platform we need to define the context. As described in chapter 4, the role of context, action and user has been studied intensively the last 20 years. When ubiquitous computing or context-

aware computing was emerging researchers discussed how the technology and context cannot be separated anymore. Similar discussion has been seen in the UX research. UX is a consequence of a user's internal state, the characteristics of the designed system and the context (or the environment) within which the interaction occurs. Thus we will evaluate how users experience workshops (and the audio platform as a part of it).

We have used observations, informal discussions and questionnaires in all workshops to get feedback related to interaction. This approach is following a mixed methods design. On a more detailed level we have used a concurrent triangulation type of mixed methods design according to Creswell's classification [141]. The interaction evaluation used three different angles on how the user experienced application in the task context:

1. Application suitability for a task
2. Application functionality
3. Feeling of the usage

Both applications succeeded in the suitability aspect and were seen as pleasant to use if we take into account the impact of the functional problems in the first workshops of each application type. Functionality-wise it seems that the soundscape mixer application does not work as well as the audiostory sharing application when taking into account the problems mentioned earlier. As a conclusion from the interaction evaluation we can say that the combination of qualitative and quantitative methods seems to be the right approach as our workshops require intense work and thus are not large in participant numbers.

In order to evaluate how engaging the workshop (and audio platform as a part of it) was we needed to define our interpretation of engagement. We selected the most common student engagement structure as a basis. Then utilising existing student engagement self-reports we developed our own questionnaire. By combining qualitative methods (observations and informal discussions) and quantitative methods (likert-type questionnaires) we were able to evaluate the engagement in detailed level, i.e. behavioural, emotional and cognitive engagement. According to Morse [140] a triangulation type of mixed methods design provides a more comprehensive picture of results than only qualitative method results or quantitative method results could do alone. In addition, during the analysis phase we have used more than one reasearcher to provide more accurate results.

Did we find answers to our research questions? Yes, we have covered our research questions. As discussed earlier there are limitations, such as immutable audio files and workshops organised as extracurricular activities. However, as a whole the results are promising. Next, we will discuss how to move on.

5.4 Future Work

There are several avenues for how to continue our research:

- Apply mobile applications in different domain, such as urban planning
- Create new mobile application-based services in the cultural sector

- Enhance existing application features, like recognising user emotions or predicting the most suitable sub-set of sounds.
- Further development of the engagement measurement instrument
- A mixture of the previous approaches

The European Environmental Noise Directive [142] requires member states to prepare and publish noise management action plans. During this process the authorities are required to involve the public. These plans are required for larger cities with over 100,000 inhabitants. In order to inform and involve citizens, city planning authorities need new approaches and tools. Our audio platform and especially the soundscape mixer application could be utilised in this context.

New audio-based services can easily be developed for different cultural institutions. A lot of existing art and artefacts in galleries and museums are visual, which leaves the visitor's auditory sense in passive mode. Audio-based services could support the visitor experience. For example art galleries would benefit from inspiring soundscapes, which would relate to the art pieces displayed in the gallery. Artefacts in museums could trigger audio storytelling when visitors are located near by the artefact.

Our existing applications could be enhanced by introducing new features. For example, we could develop user emotion detection into the Audiostory sharing application. This would provide an interesting research topic by comparing emotions the user herself reports and emotions detected from facial expressions [143] or heart rate [144] or speech [145]. The user experience of the Soundscape mixer application could be improved by offering only relevant audio files. This would require the capability of predicting which sounds are relevant. One approach would be using machine learning for environmental sound classification [146].

Our workshop engagement measurement instrument could be further developed. There is a need to further analyse the realibility and validity of the questionnaire by a larger pool of experts with the behavioural science background. At the same time we need to arrange sevaral workshops in order to get more measurement results. An interesting research topic would be longitudinal studies where we could study the correlation between the level of engagement and repeat visitors in cultural institutes.

The most interesting approach for the time being seems to be using the soundscape concept in city planning. There we could further develop our soundscape mixer tool to be used in workshops where noise management action plans are discussed with citizens. Part of the further development could include machine learning predicting urban sounds.

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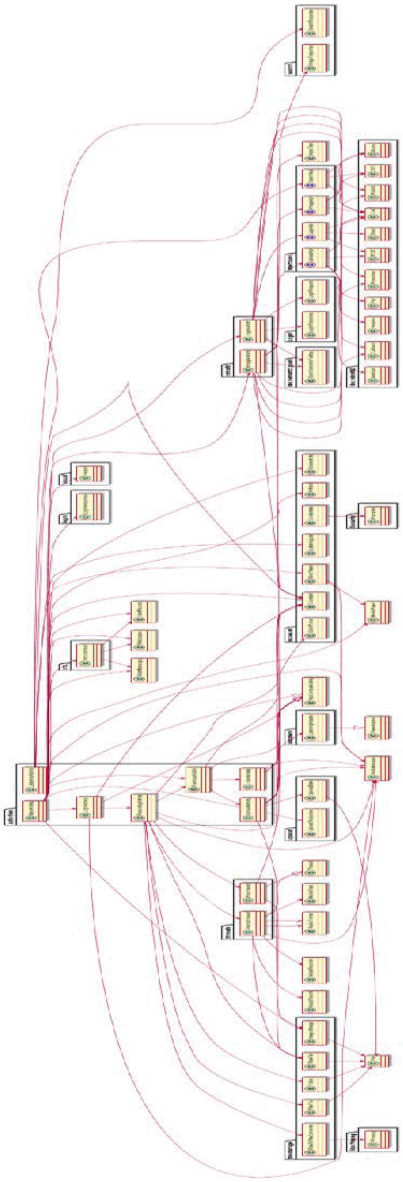
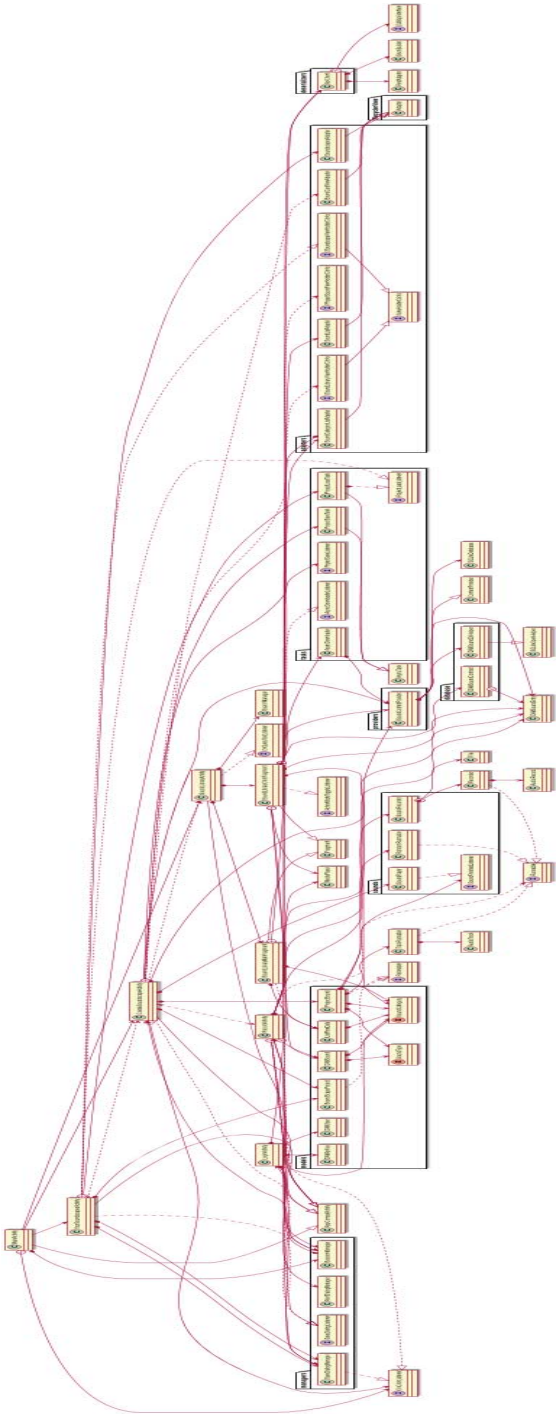
Appendices

Appendix 1
Soundscape Mixer Class Diagram



Appendix 2
Audiostory Sharing Class Diagram



Appendix 3
Questionnaire in Finnish used in the WS1 Workshop

Kyselylomake, sovelluksen toiminnasta

Mitä puhelinta itse käytät? HTC

Minkä arvosanan antaisit sovellukselle Sound Bubbles?

	Hyvä 1	Melko hyvä 2	En osaa sanoa 3	Melko huono 4	Huono 5
Mukava käyttää	○	○	○	○	○
Toimi hyvin	○	○	○	○	○
Sopi tehtävään	○	○	○	○	○

Minkä arvosanan antaisit sovellukselle SoundSpace?

	Hyvä 1	Melko hyvä 2	En osaa sanoa 3	Melko huono 4	Huono 5
Mukava käyttää	○	○	○	○	○
Toimi hyvin	○	○	○	○	○
Sopi tehtävään	○	○	○	○	○

Minkä arvosanan antaisit sovellukselle SoundScape?

	Hyvä 1	Melko hyvä 2	En osaa sanoa 3	Melko huono 4	Huono 5
Mukava käyttää	○	○	○	○	○
Toimi hyvin	○	○	○	○	○
Sopi tehtävään	○	○	○	○	○

Miltä sovellusten käyttö tuntui?

	Paljon 1	Jonkin verran 2	En osaa sanoa 3	Vähän 4	Ei ollenkaan 5
Herätti tunteita	○	○	○	○	○
Tuotti kokemuksia	○	○	○	○	○
Nosti muistoja	○	○	○	○	○

Oletko käyttänyt samanlaista sovellusta aiemmin?	○ Kyllä	○ En
Käyttäisitkö sovellusta muuallakin kuin museossa?	○ Kyllä	○ En
Tiesitkö mitä ikonit merkitsivät?	○ Kyllä	○ En
Onnistuiko äänimaiseman teko?	○ Kyllä	○ Ei
Äänitittekö itse lisää ääniä?	○ Kyllä	○ Ei

Ihan mitä muuta vaan mikä tulee mieleen/jäi mieleen työpajasta

Lähetä vastaukset

Appendix 4
Questionnaire in Finnish used in the WS2 Workshop

Kyselylomake, sovelluksen toiminnasta

Mitä puhelinta itse käytät? HTC

Minkä arvosanan antaisit sovellukselle SoundSpace?

	Hyvä	Melko hyvä	En osaa sanoa	Melko huono	Huono
	1	2	3	4	5
Mukava käyttää	○	○	○	○	○
Toimi hyvin	○	○	○	○	○
Sopi tehtävään	○	○	○	○	○

Miltä sovelluksen käyttö tuntui?

	Paljon	Jonkin verran	En osaa sanoa	Vähän	Ei ollenkaan
	1	2	3	4	5
Herätti tunteita	○	○	○	○	○
Tuotti kokemuksia	○	○	○	○	○
Nosti muistoja	○	○	○	○	○

Oletko käyttänyt samanlaista sovellusta aiemmin?	○ Kyllä	○ En
Käyttäisitkö sovellusta muuallakin kuin museossa?	○ Kyllä	○ En
Tiesitkö mitä ikonit merkitsivät?	○ Kyllä	○ En
Onnistuiko äänimaiseman teko?	○ Kyllä	○ Ei
Äänitittekö itse lisää ääniä?	○ Kyllä	○ Ei

Ihan mitä muuta vaan mikä tulee mieleen/jäi mieleen työpajasta

Lähetä vastaukset

Appendix 5
Questionnaire in English used in the WS2 Workshop

Soudscape Query

What mobile phone do you use? HTC

How would you grade SoundSpace application?

	Strongly Agree 1	Agree 2	Undecided 3	Disagree 4	Strongly Disagree 5
Pleasant to use	○	○	○	○	○
Worked well	○	○	○	○	○
Was fitting to the task	○	○	○	○	○

How did you feel using SoundSpace application?

	A lot 1	Somewhat 2	Neutral 3	Very Little 4	Not at All 5
Evoked emotions	○	○	○	○	○
Provided experiences	○	○	○	○	○
Evoked memories	○	○	○	○	○

Have you used similar application before?	○ Yes	○ No
Would you use the app elsewhere than in this workshop?	○ Yes	○ No
Did you know what the icons meant?	○ Yes	○ No
Did you succeed in making soundscapes?	○ Yes	○ No
Did you record own sounds?	○ Yes	○ No

What else comes to you mind related to workshop?

Submit answers

Appendix 6
Questionnaire in Polish used in the WS3 Workshop

Ankieta na temat aplikacji „Opowieść dźwiękowa”

Twój telefon komórkowy

	iPhone	Telefon z systemem Android	Telefon z systemem Windows	Inny	Nie mam telefonu
Jakiego telefonu komórkowego używasz?	○	○	○	○	○

Zastanów się nad warsztatem od początku do końca (od wstępu do momentu dyskusji) podczas odpowiadania na poniższe pytania:

	Nigdy	Rzadko	Czasami	Często	Zawsze
Na warsztatach bardzo się starałem / starałam	○	○	○	○	○
Podczas warsztatów byłem zadowolony / byłam zadowolona	○	○	○	○	○
Podczas warsztatu konsultowałem / konsultowałam się z innymi uczniami, żeby upewnić się, co mam robić	○	○	○	○	○
Słuchałem / Słuchałam uważnie podczas wstępu	○	○	○	○	○
Warsztaty mnie nudziły	○	○	○	○	○
Gdy słuchałem / słuchałam wstępu, starałem / starałam się go lepiej zrozumieć poprzez porównywanie przedstawianych informacji do rzeczy, które już znam	○	○	○	○	○
Tylko udawałem / udawałam, że pracowałem/pracowałam podczas warsztatów	○	○	○	○	○
Praca podczas warsztatów była dla mnie ekscytująca	○	○	○	○	○
Podczas słuchania wstępu zastanawiałem / zastanawiałam się, w jaki sposób informacje przeze mnie słyszane przydadzą mi się w praktyce	○	○	○	○	○
Angażowałem / Angażowałam się na tyle, na ile to było konieczne	○	○	○	○	○
Interesowały mnie zadania wykonywane podczas warsztatów	○	○	○	○	○
Kiedy nagrywałem / nagrywałam i słuchałem / słuchałam opowieści, zastanawiałem / zastanawiałam się, w jaki sposób przyda mi się to w praktyce	○	○	○	○	○
Podczas warsztatów myśli uciekały mi gdzie indziej	○	○	○	○	○
Z przyjemnością nauczyłem / nauczyłam się czegoś nowego na warsztatach	○	○	○	○	○
Zadania wykonywane podczas warsztatów były dla mnie wyzwaniem	○	○	○	○	○
Bardzo się starałem / starałam podczas nagrywania, słuchania i dyskusji	○	○	○	○	○
Dobrze pracowało mi się z innymi uczniami podczas warsztatów	○	○	○	○	○
Starałem / Starałam się dostrzec podobieństwa i różnice pomiędzy rzeczami, których uczyłem / uczyłam się na warsztatach, a rzeczami, które już znam	○	○	○	○	○

Jak oceniłbyś / oceniłabyś aplikację “Audio Story”?

	Zdecydowanie zgadzam się	Zgadzam się	Niezdecydowany	Nie zgadzam się	Stanowczo się nie zgadzam
Fajna w użyciu	○	○	○	○	○
Dobrze działa	○	○	○	○	○
Pasowała do zadania	○	○	○	○	○

Czy kiedykolwiek wcześniej używałeś/ używałaś podobnej aplikacji?	○ Tak	○ Nie
Czy użyłbyś / użyłabyś tej aplikacji gdzie indziej, poza tymi warsztatami?	○ Tak	○ Nie
Czy wiedziałeś / wiedziałaś, co oznaczają ikonki?	○ Tak	○ Nie
Czy udało Ci się nagrać własną opowieść?	○ Tak	○ Nie
Czy udało Ci się wysłuchać opowieści?	○ Tak	○ Nie

Appendix 7
Questionnaire in English used in WS3 and WS5 Workshops

Audio Story Query

Your mobile phone

	iPhone	Android phone	Windows phone	Other	I don't have a phone
What kind of mobile phone do you use?	○	○	○	○	○

think about the workshop from start to end (from introduction to discussion) when you answer the questions below

	Never	On Occasion	Some of the Time	Most of the Time	All of the Time
I tried my best in the workshop	○	○	○	○	○
I felt happy in the workshop	○	○	○	○	○
During the workshop I discussed with other students to make sure I understood what was expected from us	○	○	○	○	○
I paid attention during the introduction	○	○	○	○	○
I felt bored in the workshop	○	○	○	○	○
When I listened to the introduction, I tried to understand information better by relating it to things I already know	○	○	○	○	○
During the workshop, I just pretended I am working	○	○	○	○	○
I felt excited by the work in the workshop	○	○	○	○	○
When I listened to the introduction, I tried to figure out how the information would be useful in real world	○	○	○	○	○
I just did enough to get by	○	○	○	○	○
I was interested in the tasks done during the workshop	○	○	○	○	○
When I was recording and listening stories I tried to figure out how this would be useful in real world	○	○	○	○	○
During the workshop my mind wandered	○	○	○	○	○
I enjoyed learning new thing in the workshop	○	○	○	○	○
Tasks done during the workshop were challenging	○	○	○	○	○
I tried hard to do my part during the recording, listening and discussion	○	○	○	○	○
I enjoyed working with other students in the workshop	○	○	○	○	○
I tried to see similarities and differences between things I learned in the workshop and things I already know	○	○	○	○	○

How would you grade the Audio Story application?

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Pleasant to use	○	○	○	○	○
Worked well	○	○	○	○	○
Was fitting to the task	○	○	○	○	○

	Yes	No
Have you used similar applications before?	○	○
Would you use the app elsewhere than in this workshop?	○	○
Did you know what the icons meant?	○	○
Did you succeed in recording your story?	○	○
Did you succeed in listening stories?	○	○

Appendix 8
Questionnaire in Polish used in the WS4 Workshop

Ankieta na temat aplikacji „Pejzaż dźwiękowy"

Twój telefon komórkowy

	iPhone	Telefon z systemem Android	Telefon z systemem Windows	Inny	Nie mam telefonu
Jakiego telefonu komórkowego używasz?	○	○	○	○	○

Zastanów się nad warsztatem od początku do końca (od wstępu do momentu dyskusji) podczas odpowiadania na poniższe pytania:

	Nigdy	Rzadko	Czasami	Często	Zawsze
Na warsztatach bardzo się starałem / starałam	○	○	○	○	○
Podczas warsztatów byłem zadowolony / byłam zadowolona	○	○	○	○	○
Podczas warsztatu konsultowałem / konsultowałam się z innymi uczniami, żeby upewnić się, co mam robić	○	○	○	○	○
Słuchałem / Słuchałam uważnie podczas wstępu	○	○	○	○	○
Warsztaty mnie nudziły	○	○	○	○	○
Gdy słuchałem / słuchałam wstępu, starałem / starałam się go lepiej zrozumieć poprzez porównywanie przedstawianych informacji do rzeczy, które już znam	○	○	○	○	○
Tylko udawałem / udawałam, że pracowałem/pracowałam podczas warsztatów	○	○	○	○	○
Praca podczas warsztatów była dla mnie ekscytująca	○	○	○	○	○
Podczas słuchania wstępu zastanawiałem / zastanawiałam się, w jaki sposób informacje przeze mnie słyszane przydadzą mi się w praktyce	○	○	○	○	○
Angażowałem / Angażowałam się na tyle, na ile to było konieczne	○	○	○	○	○
Interesowały mnie zadania wykonywane podczas warsztatów	○	○	○	○	○
Kiedy nagrywałem / nagrywałam i słuchałem / słuchałam opowieści, zastanawiałem / zastanawiałam się, w jaki sposób przyda mi się to w praktyce	○	○	○	○	○
Podczas warsztatów myśli uciekały mi gdzie indziej	○	○	○	○	○
Z przyjemnością nauczyłem / nauczyłam się czegoś nowego na warsztatach	○	○	○	○	○
Zadania wykonywane podczas warsztatów były dla mnie wyzwaniem	○	○	○	○	○
Bardzo się starałem / starałam podczas nagrywania, słuchania i dyskusji	○	○	○	○	○
Dobrze pracowało mi się z innymi uczniami podczas warsztatów	○	○	○	○	○
Starałem / Starałam się dostrzec podobieństwa i różnice pomiędzy rzeczami, których uczyłem / uczyłam się na warsztatach, a rzeczami, które już znam	○	○	○	○	○

Jak oceniłbyś / oceniłabyś aplikację "Audio Story"?

	Zdecydowanie zgadzam się	Zgadzam się	Niezdecydowany	Nie zgadzam się	Stanowczo się nie zgadzam
Fajna w użyciu	○	○	○	○	○
Dobrze działa	○	○	○	○	○
Pasowała do zadania	○	○	○	○	○

Czy kiedykolwiek wcześniej używałeś/ używałaś podobnej aplikacji?	○ Tak	○ Nie
Czy użyłbyś / użyłabyś tej aplikacji gdzie indziej, poza tymi warsztatami?	○ Tak	○ Nie
Czy wiedziałeś / wiedziałaś, co oznaczają ikonki?	○ Tak	○ Nie
Czy udało Ci się stworzyć pejzaż dźwiękowy?	○ Tak	○ Nie
Czy nagrywałeś / nagrywałaś swoje własne dźwięki?	○ Tak	○ Nie

Appendix 9
Questionnaire in Finnish used WS6 Workshop

Äänimaisema kysely

Puhelimesi

	iPhone	Android puhelin	Windows puhelin	Muu	Minulla ei ole puhelinta
Millainen puhelin sinulla on?	○	○	○	○	○

Kun vastaa alla oleviin kysymyksiin, niin mieti koko työpajaa (johdannosta keskusteluun)

	Ei koskaan	Satunnaisesti	Jonkun aikaa	Suurin osa ajasta	Koko ajan
Yritin parhaani työpajassa	○	○	○	○	○
Tunsin itseni iloiseksi työpajan aikana	○	○	○	○	○
Työpajan aikana keskustelin muiden opiskeljoiden kanssa varmistaakseni, että olin ymmärtänyt, mitä minulta odotettiin	○	○	○	○	○
Keskityin johdantoon	○	○	○	○	○
Työpaja tuntui tylsältä	○	○	○	○	○
Kuunnellessani johdantoa yritin ymmärtää sisällön paremmin vertaamalla sitä asioihin, jotka olivat ennestään tuttuja	○	○	○	○	○
Työpajan aikana ainoastaan teeskentelin työskenteleväni	○	○	○	○	○
Olin innostunut työpajatyöskentelystä	○	○	○	○	○
Kuunnellessani johdantoa yritin miettiä, miten hyödyntäisin tietoa käytännössä	○	○	○	○	○
Laitoin vain minimipanoksen työskentelyyn	○	○	○	○	○
Työpajan tehtävät olivat minusta kiinnostavia	○	○	○	○	○
Äänimaisemaa koostaessani yritin miettiä mihin voisin hyödyntää oppimaani	○	○	○	○	○
Ajatukseni vaeltelivat työpajan aikana	○	○	○	○	○
Nautin oppiessani uusia asioita työpajassa	○	○	○	○	○
Työpajan tehtävät olivat haasteellisia	○	○	○	○	○
Tein parhaani äänimaisemien rakentelussa ja keskustelussa	○	○	○	○	○
Nautin siitä, että sain toimia yhdessä muiden opiskeljoiden kanssa työpajassa	○	○	○	○	○
Yritin löytää samankaltaisuuksia ja erilaisuuksia asioista, joita opin ja jotka tiesin ennestään	○	○	○	○	○

Miten arvioisit SoundSpace sovellusta?

	Täysin samaa mieltä	Samaa mieltä	Ei mielipidettä	Eri mieltä	Täysin eri mieltä
Miellyttävä käyttää	○	○	○	○	○
Toimi hyvin	○	○	○	○	○
Sopi tehtävään	○	○	○	○	○

Oletko käyttänyt samanlaista sovellusta aiemmin?	○ Kyllä	○ Ei
Voisitko käyttää sovellusta muuallakin kuin tässä työpajassa?	○ Kyllä	○ Ei
Olivatko ikonit ymmärrettävät?	○ Kyllä	○ Ei
Onnistuitko rakentamaan äänimaiseman?	○ Kyllä	○ Ei
Nauhoititko oman äänitiedoston?	○ Kyllä	○ Ei

Appendix 10
Questionnaire in English used in WS4 and WS6 Workshops

Soundscape Query

Your mobile phone

	iPhone	Android phone	Windows phone	Other	I don't have a phone
What kind of mobile phone do you use?	○	○	○	○	○

think about the workshop from start to end (from introduction to discussion) when you answer the questions below

	Never	On Occasion	Some of the Time	Most of the Time	All of the Time
I tried my best in the workshop	○	○	○	○	○
I felt happy in the workshop	○	○	○	○	○
During the workshop I discussed with other students to make sure I understood what was expected from us	○	○	○	○	○
I paid attention during the introduction	○	○	○	○	○
I felt bored in the workshop	○	○	○	○	○
When I listened to the introduction, I tried to understand information better by relating it to things I already know	○	○	○	○	○
During the workshop, I just pretended I am working	○	○	○	○	○
I felt excited by the work in the workshop	○	○	○	○	○
When I listened to the introduction, I tried to figure out how the information would be useful in real world	○	○	○	○	○
I just did enough to get by	○	○	○	○	○
I was interested in the tasks done during the workshop	○	○	○	○	○
When I was mixing soundscape I tried to figure out how this would be useful in real world	○	○	○	○	○
During the workshop my mind wandered	○	○	○	○	○
I enjoyed learning new thing in the workshop	○	○	○	○	○
Tasks done during the workshop were challenging	○	○	○	○	○
I tried hard to do my part during soundscape mixing and discussion	○	○	○	○	○
I enjoyed working with other students in the workshop	○	○	○	○	○
I tried to see similarities and differences between things I learned in the workshop and things I already know	○	○	○	○	○

How would you grade the SoundSpace application?

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
Pleasant to use	○	○	○	○	○
Worked well	○	○	○	○	○
Was fitting to the task	○	○	○	○	○

Have you used similar applications before?	○ Yes	○ No
Would you use the app elsewhere than in this workshop?	○ Yes	○ No
Did you know what the icons meant?	○ Yes	○ No
Did you succeed in making soundscapes?	○ Yes	○ No
Did you record own sounds?	○ Yes	○ No