COLLABORATIVE MOBILE-LEARNING SYSTEMS

FOR MUSIC EDUCATION AND TRAINING

ZHOU YINSHENG

(B.Sc., Hons, Fudan University)

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Declaration

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Zhou Yinsheng

June 4, 2013

To my loving parents Zhu Daqin and Zhou Boquan.

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Contents

Summary

With recent advances in mobile technology, intelligent user interfaces, and contextual modeling, a new learning paradigm, mobile learning, has emerged. Although this research field is growing rapidly, research into the benefits of mobile learning for music education is still limited [38].

The combination of music and information and communication technology has come to be viewed as a primary catalyst for change. Indeed, mobile technology has become so powerful that people have begun to use the mobile device as a creative and expressive musical instrument, inviting new thinking on music composition. Furthermore, people use the mobile device as a spontaneous, portable, personalized, and interactive digital learning tool. Through mobile learning, present practices in music education can be reviewed, recontextualized, and even transformed and improved.

Since music composition and performance benefit from collaboration among knowledgeable peers, this thesis seeks to understand the human factors involved in collaborative mobile learning of music. It also discusses the philosophy, design, and development of two systems for music education to make mobile learning more usable for music educators and students of different musical and cognitive abilities.

We developed two mobile learning systems to address three special needs of learners. The first system, MOGCLASS (Musical mObile Group for Classroom Learning

And Study in Schools), provides three virtual musical interfaces with various sound and gesture simulations for different kinds of musical instruments. Collaboration is more organized and focused through what is called a virtual sound space, which allows students within a group to hear each other's devices via headphones. Since they do not hear sounds produced by other groups and the sounds they produce are not heard by other groups, noise resulting from different groups playing at the same time is eliminated. Students' activities can be coordinated using the teacher's device, which can also monitor and control students' devices wirelessly.

The second system, MOGAT (MObile Games with Auditory Training), uses three structured musical games to improve aural habilitation through music. Intended for children with cochlear implants, MOGAT has a cloud-based web service that enables special music educators to monitor and design individual training for each child.

This thesis also extends the MOGCLASS system to include an assistive tool for individuals with muscular dystrophy. The pilot study that we conducted to evaluate this system showed that the subjects achieved higher perceived enjoyment, success, and motivation during their group music therapy.

List of Publications

Peer-Reviewed Journal Articles

1. Wang Feng NG, Yinsheng Zhou, Ye Wang, and Patsy Tan. Using the MOG-CLASS in group Music Therapy with individuals with Muscular Dystrophy: A pilot study. In *Music and Medicine 2012* (MMD), SAGE.

Refereed Conference Proceedings

6. Yinsheng Zhou, Khe Chai Sim, Patsy Tan, and Ye Wang. MOGAT: Mobile Games with Auditory Training for Children with Cochlear Implants. *ACM Multimedia Conference*, Oct 29 - Nov 2, 2012, Nara, Japan, ACM, New York, NY, USA. 10 pages.

5. Yinsheng Zhou, Toni-Jan Keith P. Monserrat, Ye Wang. MOGAT: A Cloud-based Mobile Game System with Auditory Training for Children with Cochlear Implants. *ACM Multimedia Conference*, Oct 29 - Nov 2, 2012, Nara, Japan, ACM, New York, NY, USA. 2 pages

4. Yu Yi, Yinsheng Zhou, Ye Wang. A Tempo-Sensitive Music Search Engine With Multimodal Inputs. *MIRUM 2011*, Scottsdale, Arizona, USA. 6 pages.

3. Yinsheng Zhou, Graham Percival, Xinxi Wang, Ye Wang, Shengdong Zhao. MOGCLASS: Evaluation of a Collaborative System of Mobile Devices for Classroom Music Education of Young Children. *In Proceedings of the 29th international conference on Human factors in computing systems*. ACM, New York, NY, USA. 10 pages. (Honorable Mentioned Award)

2. Yinsheng Zhou, Graham Percival, Xinxi Wang, Ye Wang, and Shengdong Zhao. MOGCLASS: A Collaborative System of Mobile Devices for Classroom Music Education. *ACM Multimedia Conference*, October 25-29, 2010, Firenze, Italy.

1. Yinsheng Zhou, Zhonghua Li, Dillion Tan, Graham Percival, and Ye Wang. MOGFUN: Musical mObile Group for FUN. *ACM Multimedia Conference*, October 19-24, 2009, Beijing, China.

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Chapter 1

Introduction

"The old computing is about what computers can do. The new computing is about what people can do." - Ben Shneiderman

1.1 Motivation

The world is now moving from a PC-centric era to a mobile-centric one thanks to the rapid development in mobile devices, wireless technology (e.g., Wi-Fi, Bluetooth, and wireless LAN) and global wireless technologies (e.g., Global Positioning System (GPS), Global System for Mobile Communications (GSM), General Packet Radio Service (GPRS), 3rd/4th Generation of mobile telecommunications technology, and satellite systems). The recent advances in mobile technology, intelligent user interfaces, and contextual modeling have opened up a wide range of possibilities for different applications and user groups. When these technologies were used for education, a new learning paradigm, mobile learning, emerged.

Mobile learning, or m-learning, is defined as "any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies (such as mobile phones, personal digital assistants (PDAs), or laptop computers)" [80].

Although mobile learning using handheld devices is relatively immature in terms of both its technologies and pedagogies, it is growing rapidly [116]. There are already numerous studies in this field that can be further divided into the following categories [14]:

- **Technology-driven mobile learning** - Technological innovation is specifically designed, developed, and deployed in an academic setting to show its technical feasibility and pedagogic possibility. For example, Näsänen et al. [75] examines how the mobile media application, Meaning, which shows kindergarten activities to parents, increases communication within families. Escobedo et al. studied MOSOCO [34], a mobile assistive application that uses augmented reality and the visual supports of a validated curriculum to help children with autism practice social skills in real-life situations.
- **Miniature but portable e-learning** - Mobile technologies replace or recreate e-learning approaches and solutions that desktop technologies use, e.g., adapting virtual learning environments from desktop to mobile devices.
- **Connected classroom learning** - Mobile technologies are used in classroom settings to support collaborative learning. Mobile devices are wirelessly connected to an interactive whiteboard in the classroom. Examples are KidPad [32], Livenotes [59], and vSked [50].
- **Informal, personalized, and situated mobile learning** - Learning is enhanced

by using the additional functionalities available in mobile devices (e.g., location awareness or video capture). Examples are Explore [25], a mobile learning system that helps students access history information related to their current location using GPS; LeafView [123], a tablet PC application that provides automatic identification of botanical species using a camera and which can aid students in field trips; and GreenHat, [96] a smart phone application that uses interactive location-sensitive maps and videos of experts' opinions to help students learn about biodiversity and sustainability issues in their current location.

- **Mobile training or performance support** - This improves mobile workers' productivity and efficiency by delivering just-in-time information and support according to their context, priorities, and needs [42].

- **Remote or rural development mobile learning** - Technologies deliver and support education where conventional e-learning technologies fail due to environmental and infrastructural challenges. One example is Mischief [70], a platform that supports traditional classroom practices between a remote instructor and a group of students. Each student has a mouse but the class shares a single large display. Kumar et al. [64] explores the feasibility of mobile learning in out-of-school settings in rural and underdeveloped areas; researchers have also studied multimedia mobile games for helping improve literacy in children in developing countries such as India [63] and China [112].

We are interested in the use of technology-driven mobile learning for teaching music in the classroom as well as in a rehab setting. M-learning in music education has rarely been studied and understood by researchers. For instance, it is far from sufficient for students to learn music theory through quiz-style applications or to appreciate music merely by storing podcasts or mp3 files in mobile devices such as mp3 players, CD players, iPods, mobile phones, and tablets. In order to allow m-learning to effectively benefit music subject, the conventional music class practices need to be reformed. After integrated into the music curriculum, m-learning has the unique opportunity to change students from "passive recipients of information to active agents in the construction of knowledge" [47, 74].

Mobile learning has the advantages that may facilitate music education. It is:

- **Spontaneous**. Unlike a desktop computer, which experiences latency during startup and shutdown, mobile devices can be immediately activated or put to sleep.
- **Portable, situated, networked, and collaborative**. Mobile devices are very portable and can be used anywhere. Just as learning is now regarded as a situated and collaborative activity, occurring wherever people, individually or collectively, have problems to solve or knowledge to share, so mobile networked technology enables people to communicate regardless of their locations.
- **Personalized and contextual**. Mobile learning is very personalized because it uses information stored in the mobile device (its owner's mobile number, profile, location, and schedule) to provide just-in-time contextual learning and training.
- **Interactive**. Mobile learning can be more interactive, interesting, and fun by leveraging the game factor and the ability of users to interact with a display using multiple sensors.

Technically, mobile devices have the potential to enhance collaborative learning. First, music comes alive through the collaborative processes of a community of knowledgeable peers, e.g., the inherent cooperation between a composer and performers and the collaboration among musicians in an orchestra. Second, collaborative learning offers music education a unique opportunity to increase social capital, expand spheres of influence, develop bands of commonality and community, and have some fun in the process [66]. Third, computer technology can be used in collaborative learning for music education. Hoffmann [52] reviewed computer-aided collaborative learning in a traditional harmony course and noted that "the students reinforce the teacher's instructions, and share in decision-making and in evaluating results. The learning of harmony becomes a shared, ongoing, and externalized process, comparable to a performance" [52]. Therefore, it is highly possible to utilize the core features of mobile devices to enhance collaborative learning in music.

1.2 Research Questions

We sought to solve the following problems:

P1: How should an m-learning system be designed to enhance music education in the classroom for normal children?

P2: How should an m-learning system be designed to be accessible to individuals with disabilities (e.g., children with cochlear implants and individuals with muscular dystrophy), targeting for their special needs?

It poses various challenges for us to solve our research questions. The key challenge of the first research question is how to improve student-student and student-teacher collaboration within the music class. A music class involves not only the 1-to-n communication between teachers and students but also the n-to-n communication among the students. The intrinsic difference in teachers (instructors) and students (learners) distinguishes the two kinds of collaboration between student-student and student-teacher. So how to combine these two kinds of collaboration into one single system remains a challenge. Furthermore, since music education involves both parties, it is imperative to take into account the common practices and scenarios in which teachers and students interact with each other and their needs in the system design.

Secondly, a few specific challenges exist in applying our methodology to the local primary schools in Singapore. For instance, the music class is a dynamic environment that often consists of one music teacher and 20 to 40 students. Unlike in other subjects, music students do not just sit still in front of their desks. They often exchange seats with their classmates for different musical activities arranged by their teachers [131]. So how to manage a group of active children using a m-learning system remains a challenge. Another example is that the music class only contains a limited range of musical instruments and constrains students' music expression. How to design a system for students to create a wide repertoire of music genres or styles? And of course how to design such a system to fit into their music curriculum?

Designing an m-learning system should by no means focus only on the normal users, it should also be accessible to individuals with disabilities such as children with cochlear implants and individuals with muscular dystrophy. However, the difficulty of designing for the disabled is at another level of designing for normal people. For example, besides the factors in music learning, we also need to consider their physical strength, hearing abilities, and cognitive capabilities. More precisely, we need the domain knowledge of their disabilities and special needs.

In the evaluation point of view, since our systems are first such systems, there are no similar systems available for us to use as benchmark. Furthermore, music learning is a multidisciplinary research field in the intersection of music education, human computer interaction (HCI), sound and music computing, learning theory, and psychology. Designing such systems is already quite difficult, which makes it even harder to design the process for evaluating the system effectiveness.

In our work, we designed, developed, and evaluated two m-learning systems: MOGCLASS (Musical mObile Group for Classroom Learning And Study in Schools) and MOGAT (MObile Games with Auditory Training). MOGCLASS focuses mainly on the students' performance using mobile musical instruments. However, voice, mankind's oldest musical instrument, was not used in this project. To fill the gap, we emphasized singing pedagogy in the second research project, MOGAT. MOGAT was implemented on a special user group, children with cochlear implants. Since their level of musical perception and singing performance is much poorer than children who have normal hearing, MOGAT has the potential of providing them timely help in improving their quality of life by enhancing their speech intelligibility and self-confidence. Based on MOGCLASS and MOGAT, we proposed a collaborative mobile-learning technical framework for music education and training (in Chapter 1.3). MOGCLASS and MOGAT showed that the proposed technical framework is useful for music education for grade school children. Then we extended MOGCLASS to understand whether the framework is useful for other user groups as well. So we collaborated with music therapists to enhance regular music therapy sessions of individuals with muscular dystrophy.

The thesis regards users as learners and addresses three special needs based on learner-centered design [103]:

1. Motivation - the need to maintain focus on learning. We developed MOGCLASS to motivate students to learn music.
2. Growth - the need for change in skills and knowledge. We developed MOGAT to improve students' pitch perception and their skill in reproducing the pitch they hear.
3. Diversity - the need to support a wide range of musical abilities and learning styles. Both MOGAT and MOGCLASS support the creation and performance of music using a wide range of instruments as well as the collaboration among teachers and students.

1.3 Proposed Technical Framework

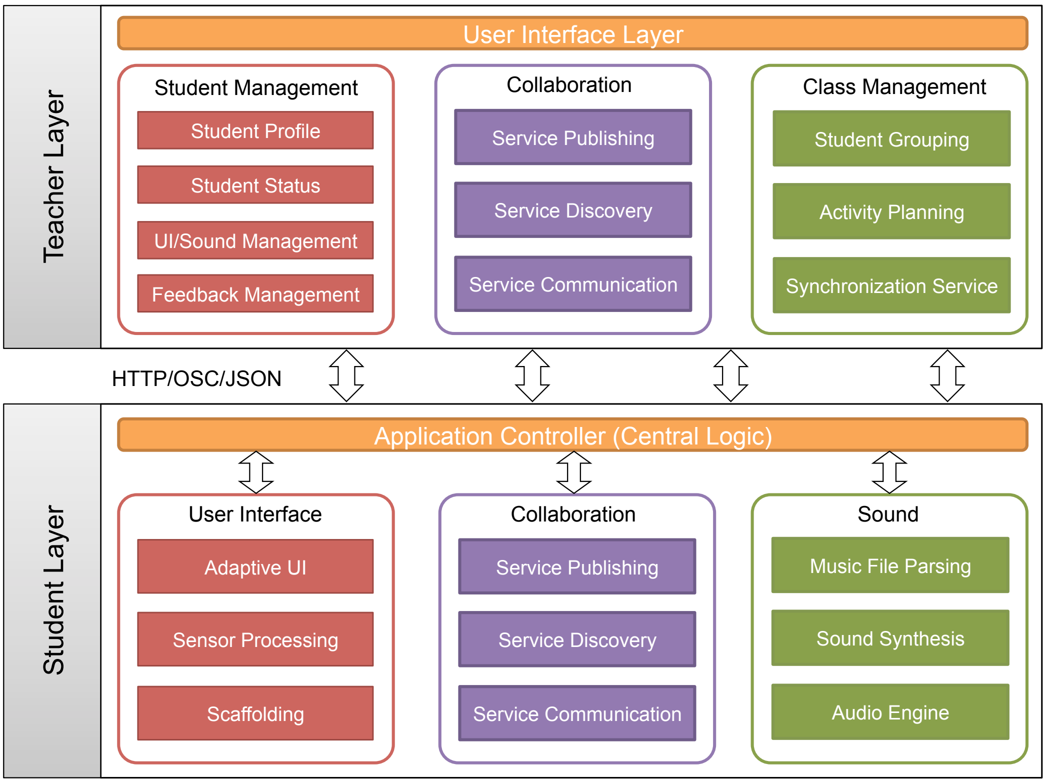


Figure 1.1: Our proposed mobile learning technical framework.

We developed a unified m-learning technical framework based on our experience creating and honing MOGCLASS and MOGAT over the past 4 years (See Figure 1.1). The purpose is to provide a student-centric, teacher-supported framework for music education in both classrooms and distance learning environments. It consists of two layers: the teacher layer and the student layer.

The **Student Layer** consists of the main components of MOGCLASS and MOGAT within the students' mobile devices. It has three modules:

The **User Interface** (**UI**) module provides the interface components by which students compose or perform music. It consists of the following submodules:

- **Adaptive UI**. The system provides a user interface suited to each student's skill level. For example, the number of keys in the Tapper interface of MOGCLASS has five different settings (1, 4, 8, 16, and 36 notes); the size of the note regions in the Slider interface can be adjusted to help students play fretless string instruments. In MOGAT, the games' difficulty level is set according to the individual's skill.
- **Sensor Processing**. The system takes advantage of the sensory capabilities in mobile devices to simulate the performance of a wide range of musical instruments using corresponding body movements. For example, hitting a drum with a stick can be simulated in the accelerometer (MOGCLASS's Hitter); playing on a piano keyboard or the fret board of string instruments can be simulated in the multi-touch screen (MOGCLASS's Tapper and Slider); and using the microphone, a singing voice can be recorded and analyzed based on a reference (MOGAT's *Ladder Singer*).
- **Scaffolding**. Scaffolding guides users in learning new knowledge. For example, the user interface should give effective visual feedback and onscreen hints to help users to perform or sing a new song.

The **Collaboration** module consists of the main components used for teacher-student communication and student-student collaboration.

- **Service Publishing**. Services in the teacher and student devices are published in the local wireless network so that the devices can communicate with each other.

- **Service Discovery**. The student devices search the local wireless network for the service published by the teacher device, and once it is found they automatically resolve the service's IP address and port number. Service publishing, discovery, and address assignment are the part of Bonjour [2], Apple's zero-configuration network service.
- **Service Communication**. Using the address and port number discovered in the previous step, devices can talk to each other in the network. The network protocol is based on the application scenario. For example, MOGCLASS uses Open Sound Control (OSC) to ensure extremely low latency and quick response in music communication among devices, while MOGAT uses HTTP/JSON to provide scalable, secure, and lightweight web service communication.

The **Sound** module consists of three submodules used for sound synthesis and audio playback.

- **Music File Parsing**. The music files in the framework contain MIDI and lyrics files that are used to control the playback of the note animation. Therefore, music files need to be parsed before they can be used for playback and display purposes.
- **Sound Synthesis**. Used to simulate the sounds of a wide range of musical instruments, the module includes a set of methods and algorithms for audio signal processing and MIDI syntheses.
- **Audio Engine**. This is used for managing the playback of audio files.

Lastly, the **Student Layer** has an application controller that manages the **User Interface**, **Collaboration**, and **Sound** modules. Upon receiving messages from the **Collaboration** module, the application controller will check the destination of the message and dispatch it to the corresponding submodules (switching UI or sound). On the other hand, if students change the **UI** or **Sound** on their devices, the application controller will be notified and call the **Collaboration** submodule to send the notification to the **Teacher Layer**.

The **Teacher Layer** consists of one user interface layer and three modules: **Student Management**, **Collaboration**, and **Class Management**.

The **Student Management** module enables teachers to use their devices to manage the information and activities of each student. It contains four submodules:

- **Student Profile**. The teacher device stores student profiles (name, age, gender, grade, and class) into a database. Teachers can access, add, and modify each student's profile through a PC.
- **Student Status**. Teachers can access the student statuses and monitor their progress (e.g., their performance scores). Since some students have better self-control than others, it is indispensable for teachers to monitor their status and take actions accordingly. For example, if a student quits the MOGCLASS application to play games, the status will appear in the teacher device.
- **UI/Sound Management**. Teachers can manage the student user interfaces and the musical instruments they are playing. Depending on the lesson plan, they can set up interfaces and sounds or allow the students to configure them themselves.
- **Feedback Management**. Teachers can give comments and ratings to students' performances and recordings.

The **Collaboration** module in the **Teacher Layer** is almost the same as the one in the **Student Layer** except for specific application programming interfaces (APIs) that enable teachers to send instructions to students.

The last module in the **Teacher Layer** is the **Classroom Management** module, which allows the teacher to manage group activities. It has three submodules:

- **Student Grouping**. This module enables the teacher to organize students into small groups for group practice and rehearsal (e.g., setting up a *virtual sound space*).
- **Activity Planning**. This module enables the teacher to plan student activities in advance. Afterwards, the servers can push activity notifications to the student devices.
- **Synchronization Service**. Teachers can use their devices to synchronize the internal clocks of the student devices so that students can commence a performance at the same time.

The **User Interface Layer** in the **Teacher Layer** is an important layer as well. It overcomes limited screen resource when, as in MOGCLASS, the status of 20 to 30 students needs to be displayed in small smart devices. It enables teachers to select individual or a group of students. It also has semi-transparent menus that can be displayed and hid immediately after a selection is done in order not to obstruct the display of the student statuses.

1.4 Goals and Contributions

The study has two goals: one, to make m-learning more usable for music teachers and students by enabling them to work more effectively and empowering them to enhance music education; and two, to gain a deeper understanding of the human factors that affect the application of m-learning to common problems in music education (e.g., mastery of technical skills, availability of musical instruments, individual and group activities, and teacher's workload), and in the process contribute to a broader human computer interaction (HCI) perspective on the practice of m-learning.

This thesis has a number of contributions which are briefly noted here. A more detailed discussion of these contributions is provided in Chapter 6. Contributions 1-4 are on the MOGCLASS/MOGAT methodology; contributions 5-6 related to empirical results; and contributions 7-8 are concerned with design recommendations.

Contribution 1: Development of a method for rapid sliding up or down (glissando) the music scale and a slightly tremulous effect (vibrato) as on a violin using a multi-touch screen, whilst provide rectangle note regions to help the amateur to identify the frequency on the simulated violin string.

Contribution 2: Development of a method (scaffolding) for visualizing the music scores to reinforce the user's cognitive mapping between the music notes to play and the locations of the keys on the touch screen, whilst provide a way to synchronize the aforementioned visualization on multiple devices.

Contribution 3: Development of a collaborative interaction method (virtual sound space) that enables users to perform music on mobile devices in a group using head-phones, as their sounds are shared among the group members through wireless net-

work.

Contribution 4: Development of a method (Ladder Singer) for visualizing the music scores to reinforce the user's cognitive mapping between 4 elements that the user needs to perform (i.e., (1) the music note to sing; (2) the syllable to pronounce, (3) the duration to sustain the note; and (4) the direction to adjust the pitch) and the visual feedback on the touch screen, whilst provide a two-stage asynchronous way to learn singing a melody (first listen and then sing A cappella).

Contribution 5: Demonstration, through experimental results, that the motivation and interest toward music subject and the collaboration in students using MOGCLASS method were generally more than those using traditional musical instruments.

Contribution 6: Demonstration, through experimental results, that learning in pitch perception and reproduction can be achieved in children with cochlear implants after using MOGAT for two weeks.

Contribution 7: Derivation of a design recommendation for the singing pedagogical systems on mobile devices to use a two-stage asynchronous way (i.e., listening to the example music followed by singing A cappella) and to provide regions with a minimal size that display note duration, hints for adjusting pitch, and syllables.

Contribution 8: Derivation of an educational recommendation for music educators to use the MOGCLASS/MOGAT method as an alternative way to enhance classroom music education for primary school children.

1.5 Overview

In the following chapter, we provide a literature review of music technology and mobile learning in education to acquaint the reader with relevant background in these fields. Following the literature review, we describe 3 case studies that solved the research questions presented in the Chapter 1.2.

In Chapter 3, we present the MOGCLASS project. In order to enhance classroom music education, we designed MOGCLASS, a multimodal collaborative music environment that enhances students' musical experience and improves teachers' management of the classroom. Utilizing sound synthesis and multi-sensory technology, MOGCLASS is able to provide sound and gesture simulation to various kinds of musical instruments. Compared to acoustic musical instruments, MOGCLASS is simpler to use and easier to experiment with. It is also easier to set up individual and group practice using the *virtual sound space*.

We conducted a two-round system evaluation to improve the prototype and evaluate the system. Improvements were first made based on the results from an iterative design evaluation, in which a trial system was implemented. The system then underwent a second round of evaluation through a three-week-long, between-subject controlled experiment in a local primary school. Results showed that MOGCLASS is effective in motivating students to learn music, improving the way they collaborate with other students, as well as helping teachers manage the classroom.

In Chapter 4, we present the MOGAT project. To improve musical auditory habilitation for children with cochlear implant, we developed MOGAT (MObile Games with Auditory Training). The system includes three musical games built with off-the-shelf mobile devices to train their pitch perception and intonation skills respectively, and a cloud-based web service which allows music therapists to monitor and design individual training for each child. The design of the games and the web service was informed by a pilot survey ($N = 60$ children). To ensure widespread use with low-cost mobile devices, we minimized the computation load while retaining highly accurate audio analysis. A 6-week user study ($N = 15$ children) showed that the music habilitation with MOGAT was intuitive, enjoyable and motivating. It has improved most children's pitch discrimination and production, and several children's improvements were statistically significant ($p < 0.05$).

In Chapter 5, we present the extension of MOGCLASS project. We aim to survey Muscular Dystrophy (MD) clients' perception of enjoyment, motivation and success during music therapy group sessions with the use of music assistive technology, MOGCLASS. Convenience sampling was used to recruit a total of seven subjects with MD and progressive muscle weakness, though only four subjects completed the study. The study design comprised three sessions using acoustic musical instruments, followed by three sessions using MOGCLASS. A board-certified music therapist conducted sessions. All other variables such as MOGCLASS developer, room where sessions were conducted, session plans, and session duration were controlled throughout the study. Repeated-measures ANOVA test was used to analyze the data. Results show that MOGCLASS achieved higher perceived enjoyment, success, and motivation, though the difference was not statistically significant due to the small sample size. The instrument condition received the highest rating. We conclude that music therapy is appropriate and enjoyable for clients with MD. There is a great need for music therapy research for MD clients, with particular emphasis on the use of assistive technology.

1. INTRODUCTION

Chapter 2

Related Work

2.1 Interactive Computer Music

The work presented here was inspired by computer music, a field of study relating to the applications of computing technology in music composition, particularly stemming from the western art music tradition. Computer music has grown dramatically in the past 60 years from the creation of CSIRAC, the world's first computer to play music, dating back to 1950 or 1951 [30]. The decades saw the invention, development, and evolution of MUSIC and its descendants (the MUSIC-N family of programs) [20], Max/MSP [88], and CSOUND [17] to meet the needs of musicians and researchers who wanted their own musical software and computer music compositions. New mechanisms for controlling computer in real time were conceptualized and built, ranging from manipulating graphical user interfaces (e.g., GUIs in Max), to interfaces such as MIDI keyboard, which closely resembled the conventional organ or piano, acoustic instruments augmented with sensors (e.g., hypercello in Paradiso and Gershenfeld's work [82]), and entirely new sensor-based gestural interfaces (e.g., BioMuse, Sound-

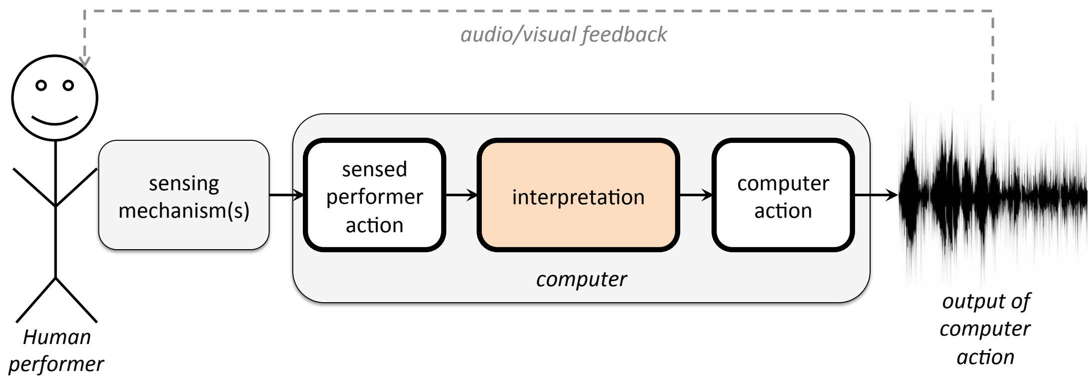


Figure 2.1: Interactive computer system: actions of a human performer are sensed by a microphone, sensor, or other sensing mechanism, and communicated to the computer. The computer interprets these actions, which is used to control/influence its future actions. The output of the computer action provides real-time audio and visual feedback to the human performer. For example, audio feedback includes the changes in the pitch or timbre of its sounds. The real-time visual feedback on some acoustic features is very useful for singing pedagogy [53].

Net, and Global String in Tanaka's paper [109]). The advance of mobile devices has pushed forward the portable and populous computer music performance ensembles such as the Princeton Laptop Orchestra (PLOrk) [120] and the Stanford Mobile Phone Orchestra [119].

Computer music involves a wide range of live performance practices. In an interactive computer music system, a performer can control the pitch, articulation, volume, and timbre of a computer synthesis algorithm through gestures using a hardware controller. The controller, together with the synthesis software, functions as an expressive musical instrument. On the other hand, the computer can listen to the sound of a user playing an acoustic instrument and respond by producing its own musically appropriate output. In this case, the computer may play a role more akin to a human accompanist or collaborator. Figure 2.1 shows the general components and workflow of interactive music systems. Basically, an interactive music system incorporates some mechanisms by which the computer senses the information about the actions of a performer (e.g., accelerometer, multi-touch screen, and gyroscope), interprets the information (e.g., digital signal processing or machine learning methods), and takes some action based on this interpretation (e.g., triggering a sound, or setting synthesis parameters). The computer output is conveyed to the performer in the form of audio and visual feedback. Depending on the feedback, the performer may subsequently interpret and respond to the computer's actions. This interactivity loop captures the essential part of music performance (i.e., "action-sound-action" feedback loop) on conventional musical instruments [83]. In this case, the computer takes the role of an instrument within the interactive computer music context.

Making music with mobile devices such as personal digital assistants (PDAs), smartphones, and electronic music players is a hot topic in current research. There are two conferences, NIME (New Interfaces for Musical Expression) [8], which regularly includes papers about mobile phones with customized hardware, and MMW (Mobile Music Workshop) [7], which is devoted entirely to this subject. Prime examples of such work include Shamus [35], the combination of a Nokia 5500 with an additional accelerometer with higher fidelity, and Audioscape [125], a combination of mobile devices that create shared 3-D virtual environments.

Numerous commercial applications transform a mobile device, such as the Apple iPhone, into a virtual musical instrument. For example, Cosmovox [5] allows the user to play notes with 45 different musical scales. Smule's Ocarina [118] mimics the ancient flute of the same name, allowing users to play with four tone holes. Recently, Bauer [15] presented a summary of iOS-based applications for mobile learning and music.

2.2 Computer Technology in Music Education

Computer technology in music education has been growing rapidly over the last few decades. Programs such as GNU Solfege [3] and Practica-Musica [10] can be used for ear training and teaching music theory, while systems like i-Maestro [76] and the Digital Violin Tutor [127] provide interactive self-learning environments for playing an instrument. Many schools teach composition using notation programs [93], which allow students to hear their scores without the need for live musicians, while Hyperscore [4] teaches students to create music through intuitive visual cues. However, most of these tools are geared towards non-performance activities (theory and composition) or were created for specific instruments (like violin). They are not suitable for classroom music education, which involves the use of a wide variety of instruments.

A few computer technology projects (excluding m-learning) for classroom music education have been attempted in recent years; a good survey is presented in [122]. Students have considerable interest in technology-enhanced music lessons, as shown by a recent survey of almost two thousand students in Shanghai secondary schools [51]. The Princeton Laptop Orchestra (PLOrk) [120] teaches undergraduates a combination of computer programming and music. However, few technology-enhanced projects involve young children performing instruments; most focus on composition, listening, or instrument-neutral performance skills. One rare example of instrument performance (which still includes a strong component of composition and listening) is the Continuator [37]: a student plays a short musical phrase, then the computer plays a "continuation" of that phrase.

One solution is to create non-standard physical interfaces to act as controllers for synthesizers (e.g., Toy Symphony [114]). However, customized hardware limits the potential for widespread adaptation by schools. We adapted current mobile interfaces, especially since these devices are increasingly powerful and affordable. One example of this approach is MoPhO [119], a new repertoire-based ensemble using mobile phones as primary musical instruments. Other projects have focused on accelerometers within commercial mobile phones [22, 29] or the Wii remote [124], using gesture recognition as input methods for musical instrument applications. Nevertheless, very few attempts to translate this approach for application in large classrooms.

2.3 Auditory Habilitation and Its Applications

For children with cochlear implants (CI), auditory habilitation is critical to their hearing and speech development [126]. Due to the spectrally degraded signal pattern provided by the implant and the interpersonal variability (e.g., nonverbal intelligence, gender, implant characteristics including the length of time using the newest speech processing strategies, and educational programs) [113], passive adaptation via long-term use of the devices may not be adequate. However, active learning via auditory habilitation has been shown to be effective in speech recognition and production of the hearing impaired [19, 26, 108]. Auditory training with music stimuli can help to improve music recognition and production for CI users [13, 44, 54]. However, due to time and cost considerations, it is almost impossible to provide extensive and intensive auditory therapy to CI recipients [41].

Recently, computer-assisted speech training (CAST) system has been developed to facilitate auditory habilitation approaches by providing greater flexibility with minimal costs and supervision. Research shows that moderate amounts of auditory training at home with CAST software resulted in significant improvements in speech recognition for both adults [40, 41] and children with CI [126]. A typical example is the Sound Express Auditory Training (SEAT) system [110], a self-directed auditory training program on personal computers. Although it has some useful features (e.g., interactive interface and feedback) to help CI users to practice their perception of spoken sounds, it is not optimized for musical habilitation and lacks teacher guidance.

Unlike speech perception, music perception relies more strongly on pitch perception. Due to the cochlear device limitation, implant listeners are reported to have great difficulty with complex pitch perception in comparison with speech perception [69]. Unfortunately, relatively few studies have explored the effects of auditory training on CI users' music perception or production. The only system for this purpose was designed for post-lingually deafened adults [44, 45]. However, music perception by pre-lingually deafened children with CI is very different from post-lingually deafened adult CI users [54] who have experienced acoustic sound before their deafness. Pre-lingually deafened children don't begin to form their concept of sound until implantation, and all their central speech and music patterns are developed in the context of electric hearing. Therefore, it is essential to develop a musical auditory system specifically for children with CI.

We also examined existing applications for auditory training whose objectives, however, are not compatible with our purpose. Most vocal training applications (e.g., [68, 87, 115]) were designed to develop specific professional listening and performing techniques for users who already have decent hearing acuity (e.g., recognition of chords, harmonics, and development of unique vocal style or instrument skills). Therefore, the components of these applications are not suitable for children with CI, for their habilitation focuses on completely different aspects, namely, pitch and rhythm perception and basic singing ability. Although Karaoke games [60, 90, 102] seem to aim in learning songs through real-time visual feedback and machine scoring, our study shows that it is harder for children with CI to understand and use this kind of Karaoke games than our singing game. Family Ensemble [81] and MySong [99] use automatic accompaniment generation technique to motivate users to sing and play piano. MOGCLASS [130, 131] provides a collaborative system to enhance the music class experience. However, all of the projects mentioned above are designed for normal people, and will not be suitable for our special user group.

Freitas and Jarvis [28] have proposed a framework for developing serious games to encompass learner needs and target learning outcomes, and they analyzed how to apply the framework into the case study of training nurses for infection control. Ritterfeld's book [117] on serious games focuses on the desirable outcomes of digital game play and covers a broad range of topics on serious games' definition, theories, effectiveness, and innovative research methods. However, to date no attempts have been made to use a game to train children with CI. In the MOGAT project, we explored the training need involved in auditory habilitation and the possible games for children with CI at the Canossian School with the hearing impaired in Singapore.

2.4 Music Therapy and Muscular Dystrophy (MD)

From as early as the 1950s, music therapy has been seen as an appropriate treatment modality for individuals (particularly children) with MD [36]. Subsequently, in the music therapy literature, occasional references seem to acknowledge that music therapy services can help individuals with MD to the same extent as other orthopedic impairments such as arthrogryposis and cerebral palsy [16, 62]. More recent contributions were the case studies made by Kennedy and Kua-Walker [61] and Dwyer

[39]. Kennedy and Kua-Walker [61] examined whether skills trained during music therapy sessions transferred over to regular classes, while Dwyer [39] explored the use of song-writing with an adolescent with MD. To date, however, researchers have not given much attention to music therapy work with individuals with MD, especially work involving the use of technology.

Music therapy can meet the multifaceted needs of individuals with MD and various treatment domains have been articulated by authors [84, 111], for example, motor, communication, cognitive, social, emotional, and musical skills [111]. Some of the areas mentioned above apply more to children than to adults, due to the particular developmental needs of children.

Peters [84] highlighted the need for individuals with MD to be encouraged to exercise regularly to maintain or improve physical functioning. Movement to music and movement through music, such as playing instruments, can help strengthen or maintain muscle tone, range of motion, and coordination. Moreover, as individuals with MD may be excluded from various social activities due to their restricted mobility, they often need to decrease isolation, improve their social skills, boost their self-confidence, and build/restore their self-esteem. Indeed, Korson Herman [36] pointed out that children with MD often lack independence and confidence as a result of overprotective parents and thus tend to become inactive and lose interest in work and play. Musical activities (e.g., participating in a music group) can invite individuals with MD to make contact with others.

Furthermore, individuals with MD often cannot express their emotions adequately through physical motion and are prone to frustration and psychological stress [84]. Therapeutic music experiences can also offer a medium to meet their emotional needs and relieve the frustration and tension they experience. It is also important to recognize that individuals with MD have needs common to their non-impaired peers, including needs of independence, a feeling of accomplishment, opportunities to participate with others in meaningful activities, enjoyable leisure and recreational experience. In particular, they may have a greater need for opportunities for aesthetic experience and expression as they seek ways to add meaning, fulfillment, and quality experiences to their lives [84]. The development of musical skills can also have a normalizing effect [111].

2.5 Technology for Muscular Dystrophy Clients

Though there is some literature about the use of technology in music therapy [73, 105], only limited research has focused on clients with muscular dystrophy (MD). The use of technology for individuals with MD is also a relatively unexplored area, but one that has massive implications for their music-making experience.

For individuals with MD, traditional musical instruments must be adapted to facilitate their music participation. For example, instruments may be mounted on wheel chairs or tray tables to be more accessible to wheelchair-bound clients. Manuals also give instructions regarding the basic physical abilities required to play various instruments and inform therapists to make appropriate instrument selection for individuals with various abilities [84]. However, certain instruments such as the tone chimes would be difficult for a client with very weak muscular control to manipulate without adaptation.

2.6 Assistive Technology (AT)

Music therapists may often encounter AT in their work, when serving a wide range of client populations with unique needs. A broad definition of AT is “the use of devices and services to help people with disabilities of all ages in their daily lives” [56]. Such devices include but are not limited to computer technology, and also the approaches and methodologies that accompany the technology [58]. Since clients with physical limitations have limited ways for musical expression, the use of technology can make the music-making experience more accessible and direct [57] (i.e., increase the width of clients’ musical expression [67]).

Generally, two kinds of technology have been applied in music therapy to facilitate client participation: nondigital and digital. Music therapists and their clients use a myriad of nondigital technology applications involving some modification of traditional instruments. Indeed, the adaptation of acoustic instruments for therapeutic use has been driven not only by client needs but also by the creativity of music therapists [98]. However, musical improvisation with acoustic instruments remains a challenge, as they cannot provide a wide range of possibilities in musical interaction [72]. Even the theremin could potentially be explored for use with clients with physical limitations as there is nothing to hit. Since not only music therapists and clients but also music technology designers and engineers should be involved in the process, music technology applications may be more difficult to apply. As a result, music therapists have been using commonplace technology (e.g., amplification and recording devices [67]) in their work with individuals with less complex needs.

Digital music technology applications that are useful for music therapy are summarized as follows:

In Toy Symphony [55], Beatbugs are hand-held percussive instruments that allow users to create, manipulate, and share rhythmic motives through a simple interface. At the same time, multiple Beatbugs can be connected in the network to form a larger scale collaborative composition. Music Shapers are soft, squeezable instruments allowing players to mold, transform, and explore musical material and compositions. Music Shapers allow access to high-level parameters, e.g., contour, timbre, density and structure. Drum machines [91] generate percussion accompaniment to the performance of a song, which has the following benefits: 1. developing aural acuity and recognition of different percussion sounds; 2. recognizing beat patterns, developing an awareness for loud/soft concepts on a machine with velocity-sensitive pads; 3. programming beats to match current rap/pop/rock songs; 4. improving eye-hand and fine motor coordination.

MidiCreator [92] creates an array of innovative switches that allow clients to control a variety of sound choices through simple physical actions and gestures. Two additional devices, MidiGesture and MidiSensor, are used to detect body movement in either individual or group settings. MidiGrid [92] is a program that controls MIDI synthesizers and tone cards/modules via a unique system of on-screen boxes. It handles complex sound relationships graphically by organizing the boxes on a user-configured grid, and the resulting sound programs are played by MidiCreator.

In the U.S., legislation makes AT available to individuals with disabilities and their families. AT "may be provided as part of special education, as a related service, or as a supplementary service" [56]. In Singapore, the Ministry of Education has provided the FM system, an assistive hearing equipment, to hearing-impaired students since 1999. In 2000, visually handicapped pupils (in designated secondary schools) were equipped with assistive devices such as Braille Notebook Computers, talking calculators, voice synthesizers, and specialized computer software [77]. The Ministry of Community Development and Sports (now Ministry of Community Development, Youth and Sports) “launched the Assistive Technology Fund aimed to help individuals purchase the assistive equipment necessary for employment and educational purposes” [77].

Although AT has helped individuals with various disabilities, few studies have been conducted with the MD population. Thus, the purpose of our study is to survey MD clients’ perception of enjoyment, motivation, and success during music therapy group sessions with the use of the music assistive technology, MOGCLASS.

2.7 Summary

All the literatures presented in the related work are relevant to my work with respect to different angles. Here I identify which papers are more significant than others in the following four perspectives.

- Mobile music making and interactive computer music: Princeton Laptop Orchestra (PLOrk) [120], Stanford Mobile Phone Orchestra [119], Shamus [35], and Smule’s Ocarina [118].
- Computer technology in music education: GNU Solfege [3], Practica-Musica [10], i-Maestro [76], Digital Violin Tutor [127], Toy Symphony [55], and MoPho [119].
- Auditory habilitation: CAST [40, 41, 126], SEAT [110], and the systems for CI users’ music perception or production [44, 45].
- Muscular Dystrophy: Two papers [84, 111] that point out that music therapy can address the needs of individuals with MD; and two papers [57, 58] that introduce

the concepts of integrating computer technology into music therapy. These four papers have paved the way to our work - using m-learning systems for the music therapy of individuals with MD.

This chapter summarized the relevant literature for interactive computer music and reviewed various computer technology used in music education for normal children, auditory habilitation for children with cochlear implants, and assistive technology for individuals with muscular dystrophy. Developers and computer music researchers have developed various mobile systems for music making, focusing on specific technical solutions from sensor processing and sound synthesis to intuitive user interface. Mobile systems intended for music education and training are rare. Many mobile music applications are fun and interesting to play but lack the real-time collaboration and teacher management functions that are critical in music education. Their user interfaces were also designed for normal people, which cannot be easily adapted to people with weak upper-limb motion ability. Existing computerized auditory habilitation programs are focused on post-lingually deafened adults and hence are not suitable for children with CI. However, mobile devices possess some features that could potentially enhance music education and training, e.g., affordability, portability, interactivity, and wireless connectivity for collaboration. It is thus promising to build mobile systems for music education, but more research work are needed to identify the requirements, validate the design, and evaluate the results.

Designing such systems for music education and training is challenging. The remainder of this thesis focuses on two innovative pedagogical systems (MOGCLASS and MOGAT) of networked mobile clients for music class of young children, music habilitation of children with CI, and music therapy of individuals with MD, respectively. They are designed to take advantage of lessons learnt from this literature review and to overcome many of the aforementioned shortcomings of existing approaches.

Chapter 3

Classroom Music Education of Young Children

3.1 Introduction

Music education for young children integrates composition, listening, and performance. Performance and listening enrich students' repertoire of musicianship, allowing them to perform creatively and construct their ideas into new shapes and meanings. However, interaction among these musical activities is optimal only when students have mastered the necessary technique to accomplish different tasks [107].

Conventional classroom music education constrains the development of students' musical skills [71]. Most instruments require years of practice to achieve competency, a technical demand too high for most students. The limited number of instruments available also restricts students' artistic expression. Furthermore, not only does cacophony during class-wide practice make listening and self-analysis difficult, much of the class time intended for teaching instrumental skills or musical expression is sacrificed just to maintain classroom order.

After careful analysis of current practices in the musical classroom, we designed MOGCLASS (Musical mObile Group for Classroom Learning And Study in Schools) [130], a collaborative system and multimodal music environment based on networked mobile devices. It enhances music experience for students and helps teachers manage the classroom. It enhances active listening, composition, and performance, which stimulates creative music making and makes lessons engaging, fun and effective.

Taking advantage of the sound synthesis technology and sensory capabilities in mobile devices, we were able to simulate the performance of a wide range of musical instruments through appropriate body movements. Since the sounds were simulated, we could carefully control the level of complexity required to produce them. Extraneous movements were eliminated, allowing students to focus on musical understanding. It also allows teachers to assist students through "scaffolding", a set of visual hints that guide students through a piece of music.

To support peer collaboration during practice sessions, we designed *virtual sound spaces*, allowing students to hear, via headphones, only the sounds produced by their own group. Consequently, students can collaborate better without disturbing others. Their devices can also be switched to *public performance mode* in which loudspeakers play their sounds for everybody in the classroom to hear.

The teacher can manage the classroom through a device that remotely controls all student devices. It can automate tasks for different instructive and disciplinary purposes such as changing sounds, interfaces, statuses (activated or deactivated) for student devices, and setting up group practices (through *virtual sound space*) or class rehearsal (using *public performance mode*).

Designing MOGCLASS required a significant understanding of the teachers' and students' characteristics (e.g., musical skills) and the requirements and workflow of music classes. Two rounds of evaluation were conducted to refine and validate the design. The first round of evaluation consisted of an iterative design process with four separate music lessons given to three classes (see Chapter 3.5). The improved system was then evaluated in a between-subject controlled study of two groups of primary school students, one using MOGCLASS and the other using the recorder (a commonly-used music instrument), taking the same five-lesson course (see Chapter 3.6).

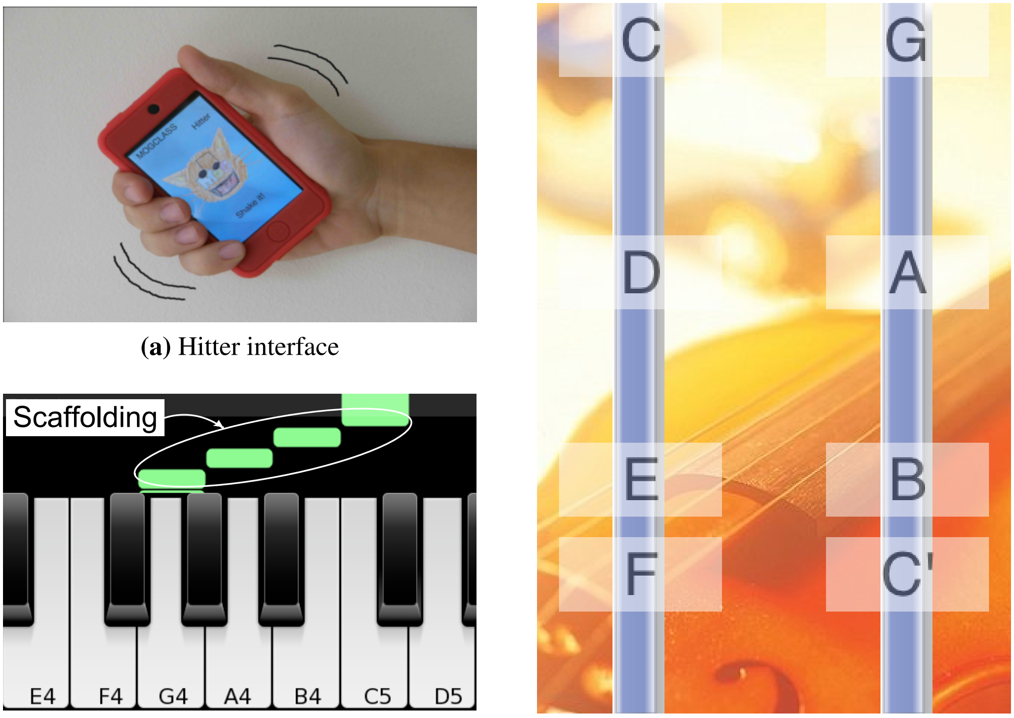
Our work makes the following contributions: 1) general design objectives that will be useful for creating collaborative systems for improving classroom music education, 2) identification, through the iterative design evaluation, of specific challenges that these systems must meet, and 3) a tool for learning music that has a measurable impact on students.

3.2 Usage Scenario

To illustrate the various functionalities of our system, let us imagine MOGCLASS being used to teach a Grade 5 class (students aged 10-11 years).

At the beginning of the lesson, the teacher configures the student devices to show a piano-like interface (Figure 3.1b) by pressing a few buttons on her device. To help the students learn a musical piece, she enables scaffolding to provide extra visual cues. A set of bars drop down from the top of the screen on all devices. The location and size of each bar indicates a note and the duration it should be played. Students can press the key/note indicated by the bars allowing them to focus on the interface instead of splitting their attention between an instrument and a sheet of printed music.

After learning how to play the song on their devices, the students improvise in



(a) Hitter interface

(b) Tapper interface with scaffolding

(c) Slider interface

Figure 3.1: Student interfaces in MOGCLASS

groups. The teacher enables the headphones so that students within a group can hear each other's devices. She allows them to choose their instruments, and turns off the visual cues. Students who choose percussion instruments produce sounds by shaking their devices (Figure 3.1a). Students playing the melody can make it more expressive using glissando ("swooping in between" normal notes) made possible by the Slider interface in Figure 3.1c. The Slider is easier to play than a real violin because of the "note regions" [1], yet is much more difficult than the other interfaces.

Five minutes later, the teacher enables the loudspeakers, and each group takes turns performing before the rest. However, while she is grading the first performance, some students in other groups are very excited and continue playing. The teacher identifies

[1]The sound frequency within the note region is preset to help beginners to play in tune

the misbehaving students through her device, and mutes their devices so that they cannot disrupt the class.

3.3 Design Method

We followed the *classroom-centered design* suggested by Loh [65]. This approach is aimed at "inquiry-oriented" education, which fits well with the current music curriculum in local primary schools [12]. It takes four factors into consideration: student collaboration, student-student and student-teacher communication, teachers as facilitators or guides, and the influence of the curriculum on the use of the tool.

We conducted several field trips and interviews in order to understand conventional music class practices. We visited three local primary schools, observed five classroom sessions in Grades 3-6, and interviewed four music teachers. The research consent form is provided Appendix 1, and the example of interview protocol and questionnaire is provided in Appendix 2 and 3. Each class had 40 to 45 students, with a total of approximately 200 students. To support this project, we put together a multi-disciplinary team consisting of experts from HCI, sound technology, and music education. Paper prototypes were used to test designs within the team and with two music teachers.

To facilitate widespread deployment in public schools, the system has to be robust. It should, after a short period of training, be maintainable by music teachers who do not have a technical background. Setting up the system in the classroom and packing it away at the end of a class must be fast, and any problems during the class should be easy and quick for a teacher to solve.

3.3.1 Music Class Practices

We identified several essential music class practices that are common in classroom music education but are inadequately supported by existing learning tools.

A. Mastery of technical skills: Recorders are relatively easy to master at a basic level, but students still need to spend a significant amount of time learning and developing the physical skills required to play them.[1] Students must learn those skills in conjunction with music theory, collaboration, and composition. Since none of the objectives of the music subject [12] is instrument technical skills, we could simplify them so that students would be able to spend more mental effort on the other three activities (i.e., music theory, collaboration, and composition).

B. Availability of instruments: For practical reasons, the use of musical instruments in the classroom is often restricted to simple percussion instruments (e.g., handbell) or affordable wind instruments (e.g., recorder or harmonica). Due to budget constraints and the lack of expertise in a wide range of instruments (be it Western classical or world music genres), music teachers introduce other instruments or genres through audio/visual samples such as YouTube videos [11], without giving students the ability to play and experiment with the instruments themselves.

C. Individual and group activities: Music classes frequently switch between individual practice, group activities, and class rehearsals. When students are allowed to practice on their own, cacophony ensues. This makes it difficult for each student to focus on the sound he is producing, reducing the effectiveness of solo practice. One teacher noted that this is the most terrible part of music class because it is too noisy, and looked to technology to solve this problem.

[1] These skills include hand position, fingering types, and breath control. Although the recorder is pre-tuned, it is very easy to change the pitch by over- or under-blowing. These often result in an unpleasant sound.

D. Teacher's workload: Teachers handle many tasks, sometimes concurrently, such as giving musical instructions, organizing activities, guiding different students and groups, conducting performances, and maintaining classroom discipline. One particular challenge in music education for children is classroom management. Unlike in other school subjects where students sit at desks, music classes generally involve sitting on the floor in rows or in small groups. This freedom of movement, especially when combined with the opportunity to produce sounds with instruments, makes students excited and harder to manage. The teacher often spends a significant amount of time giving warnings or punishments to noisy students.

3.3.2 Design Objectives

Through our observations of the classes, we arrived at a set of core design objectives which became the basis for the final design of MOGCLASS.

A. Minimize instrument technical demands. Entry barriers such as the technical difficulty of music instruments should be reduced, allowing students to focus on musical creativity and improvisation. Lowering the technical demands of music increases the probability that children can organize and execute a course of action required to complete the designated performance, thereby enhancing their perceived competence and self-esteem in playing music.

B. Support a wide range of instruments and interactions. In order to adapt to a diverse musical repertoire and allow creative exploration, the system needs to simulate a variety of musical instruments for children to actively explore and create with. The music curriculum allows time for such creative exploration; we should give students more sounds to discover.

C. Improve collaboration by separating performance and practice. To avoid disruptions in class, students should use headphones when practicing alone or in groups and use speakers when performing. The wireless network allows students to be interconnected, supporting collaborative music making.

D. Facilitate teachers' task. Some activities can be automated: the teacher can carry out different classroom activities (e.g., group performance, solo practice, and changing their instruments) through her device. She can also get students' attention by sending a notification to their devices. The design should help the teacher accomplish tasks as she moves from group to group.

3.4 The MOGCLASS System

This chapter describes only the features of MOGCLASS after the iterative design evaluation. For a discussion of the interim features, see Iterative Design Evaluation. For technical details, see MOGCLASS [130]. The system diagram is in Figure 3.2.

3.4.1 Student and Teacher Interface

We implemented our system on the iPod Touch, a device with a multi-touch screen and an accelerometer. These two features are relatively new in commercial mobile devices, but we expect them to become widely used in the next few years.

Interfaces designed for young children should use intuitive metaphors as design elements [106], so we developed three user interfaces (Hitter, Tapper, and Slider; Figure 3.1) based on the metaphors of drum, piano, and violin. Hitter uses the accelerometer. When the device detects a hand-shake, it produces a sound whose volume is proportional to the strength of the shake. Tapper and Slider are controlled with the

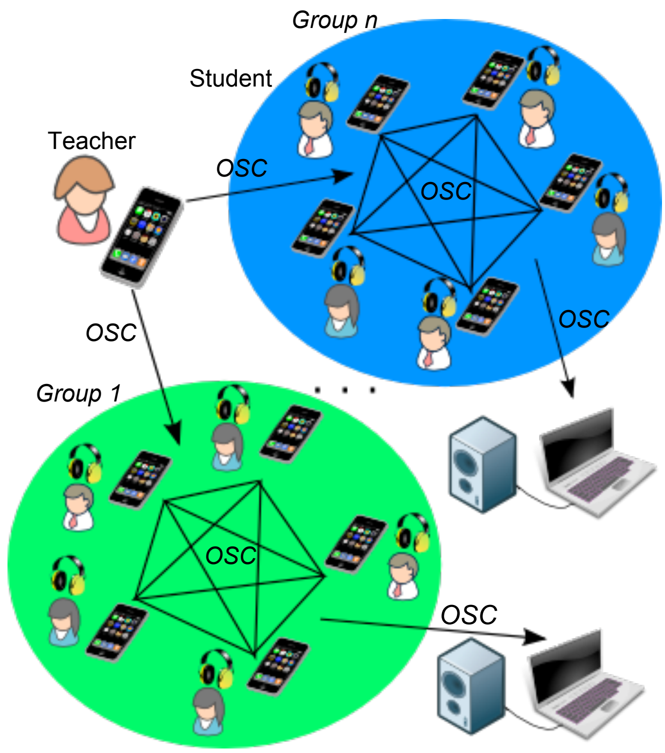


Figure 3.2: System diagram

multi-touch display; Tapper is played using discrete buttons, while the vertical position of a finger on the Slider plays its note. Details about 3 interfaces are as follows:

3.4.1.1 Hitter

This interface uses accelerometer data to trigger an event: students use the iPod like a drum stick. The first version was implemented using threshold-based detection, but we discovered that students naturally had stronger or weaker shaking. Tuning the threshold for individual students would require too much setup, so we chose to employ a machine learning method to train a generic model to recognize shakes.

Figure 3.3 shows the acceleration (in one axis) of a typical series of shakes. We define a_t as the acceleration at time t along that axis. h is a threshold value; we only

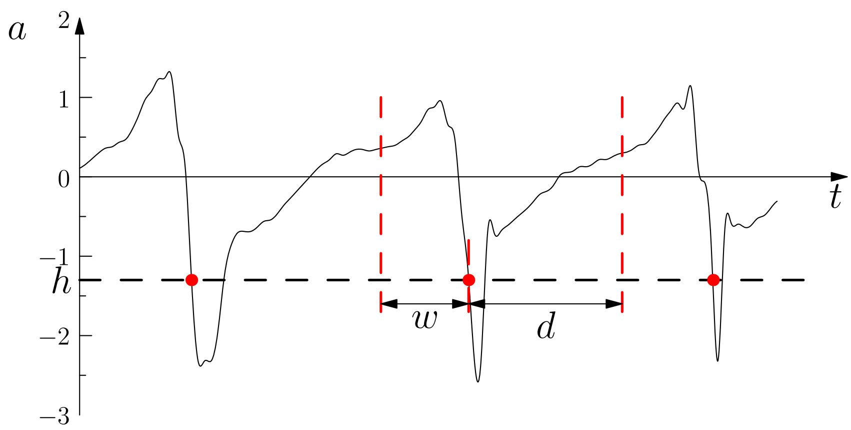


Figure 3.3: Analysis of accelerometer data for shake detection

test for a shake when a_t passes from above h to below h. Once that condition is met, we examine the previous w samples as a vector $\boldsymbol{s_t} = [a_{t-w+1}, a_{t-w+2}, \ldots, a_t]$.

We extract the mean, variance, maximum, minimum, and energy of $\boldsymbol{s_t}$ as the feature vector $\boldsymbol{x_t}$, which is fed into the kernel function $K(\boldsymbol{w}, \boldsymbol{x_t})$. After several experiments, we chose to use a linear kernel in the trained SVM model. This algorithm is expressed in Equation 3.1.

$$(a_{t-1} \geq h) \wedge (a_t < h) \wedge (K(\boldsymbol{w}, \boldsymbol{x_t}) + b > 0) \tag{3.1}$$

The trained SVM model detects a shake point slightly ahead of the "bottom" of the shake. However, this "pre-detection" combines nicely with unavoidable sound synthesis and network delay, resulting in barely any perceptible lag.

Training was performed by two subjects who imitated various types of shakes and indicated the "bottom" of a shake by clicking a button on the touchscreen. We used libSVM[21] to train the model. Our dataset contained 1083 features; 503 features are positive examples while 580 are negative. The average precision of the 10 folds cross-validation is 97.8%.

To reduce CPU consumption, we ignore the next d samples after a shake was detected. We determined that children cannot shake faster than 10 Hz, so since the accelerometer gives us 100 Hz, we set $d = 10$.

3.4.1.2 Tapper

The Tapper interface is presented in Figure 3.1b. The metaphor is a piano keyboard. In order to support collaborative music composition with five students at once (the default setting in *Virtual Sound Space*, see Chapter 3.4.2 for more details), we cache sound buffers in memory to lower the CPU load.

3.4.1.3 Slider

The Slider interface aims to simulate instruments with variable pitch, such as bowed strings or certain wind instruments. For string instruments and non-conical wind instruments, the frequency f of the sound depends on the vibrating length L, the wave's

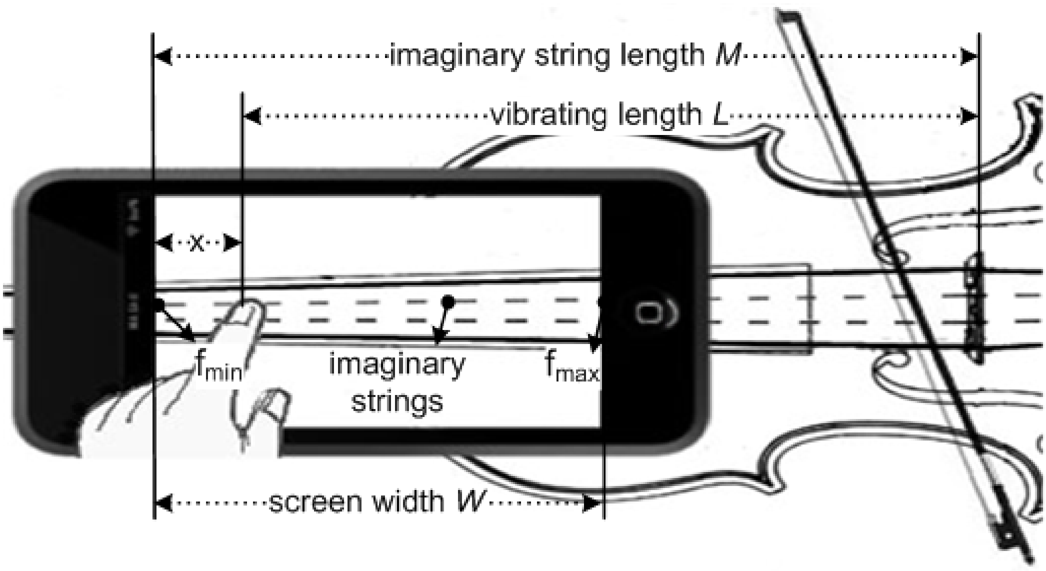


Figure 3.4: The idea of the imaginary string

velocity v, and a constant $1/2$ or $1/4$. Since the velocity does not change significantly during normal playing, we can replace it with a constant K. The frequency is changed by the finger position x, which reduces the total length M of the vibrating body.

$$f = \left(\frac{v}{2L} \text{ or } \frac{v}{4L}\right) = \frac{K}{L} = \frac{K}{M - x} \tag{3.2}$$

To create such an instrument on the iPod, we imagine an imaginary string such as in Figure 3.4. K can be calculated by setting our desired maximum and minimum pitches (f_{max} and f_{min}), and using the screen width W.

$$\begin{aligned} f_{min} &= K/(M - 0) && (3.3) \\ f_{max} &= K/(M - W) && \\ \therefore \quad M &= W \cdot f_{max}/(f_{max} - f_{min}) && (3.4) \end{aligned}$$

We calculate K from (3.3) and (3.4). For MOGCLASS, we decided that one screen-width should span the musical interval of a fifth. From basic acoustics, this gives $f_{max} = \frac{3}{2} \cdot f_{min}$ (in just intonation), which simplifies (3.4) to $M = 3 \cdot W$.

Fretless string instruments are notoriously difficult for beginners to play in tune. We therefore added "note regions" (as shown in Figure 3.1c) which apply to the initial "finger-down" touch. If the iPod is touched inside one of these note regions, that note's pitch will be played. We define an "ideal" frequency f_i according to (3.2). The relationship between f_i and the "real" frequency f_r is shown in Figure 3.5.

To ensure that students can still play smooth glissandi and vibrato – arguably the most important attributes of variable-pitch instruments – the calculation of a *sliding*

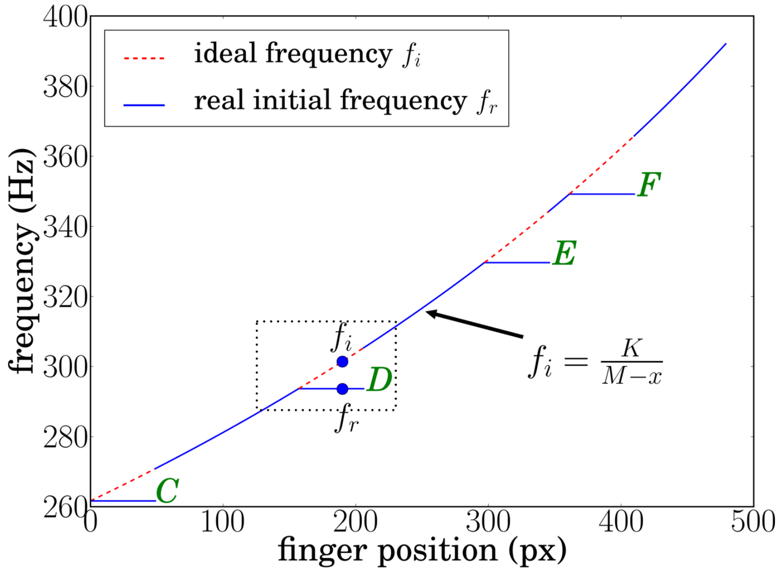


Figure 3.5: Initial touch, showing note regions. The vertical blue dots indicate the touch location x. Without the note regions, the pitch would be above 300 Hz (f_i); with the note regions, the pitch corresponds to a D (f_r).

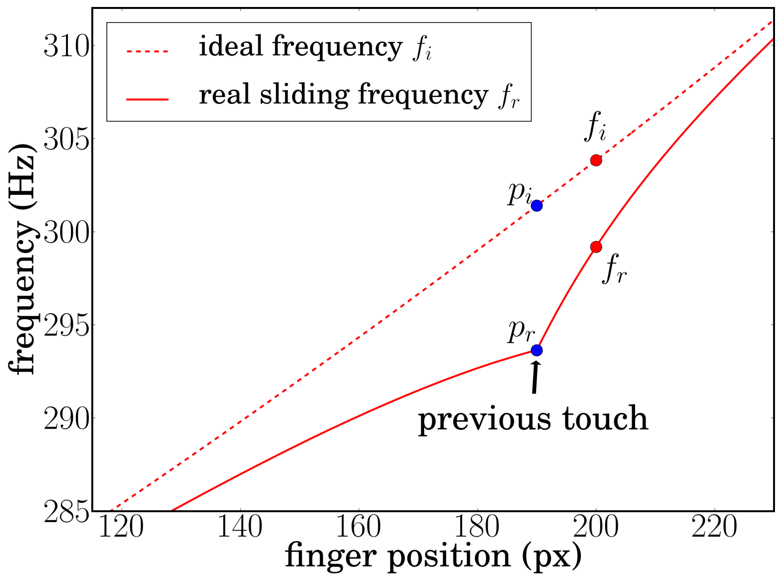


Figure 3.6: Sliding touch, showing glissando. The current position of x is indicated with the vertical red dots; the previous position is indicated with blue dots. Note that f_r converges to f_i as the sliding touch moves further away from the previous position.

touch (i.e., not a “finger-down” touch) is based on the previous “real” and “ideal” frequencies. We set $p_r \leftarrow f_r$ and $p_i \leftarrow f_i$. The new f_i is calculated according to (3.2), and the new f_r is calculated according to (3.5). This is shown in Figure 3.6.

$$f_r = f_i - \tau \cdot (p_i - p_r) \tag{3.5}$$

Listening and playing experiments produced the most “natural” pitch response when τ was set to 0.95 when the position is increasing, and 0.98 when the position is decreasing.

3.4.1.4 Teacher Interface

To help teachers monitor student statuses and manage their interfaces simultaneously, we designed an interface that integrates the teacher functions in single display (Figure 3.7). Selecting individual students is done by dragging the finger to select the student icons (A) on the touchscreen, and then clicking the “instrument” button in the pop-up menu. The teacher may allow students to choose any instrument (H), or specify their interface (I), sound (J), and starting note (K). The teacher may also disable or mute the student devices (C). A corresponding student icon flashes (D) when a device is being played, so the teacher always has class feedback.

Selecting an entire group (e.g., all Yellow ipods) is done by doing a long press in the group area (B). This lets the teacher choose between *public performance mode* (speakers) and *virtual sound spaces* (headphones). Scaffolding is enabled on all devices in the class (E), with the option of allowing students to practice by themselves, or having an ensemble practice. All devices can be selected with (F) for global administration. The teacher can also switch to display the other half class with (G).

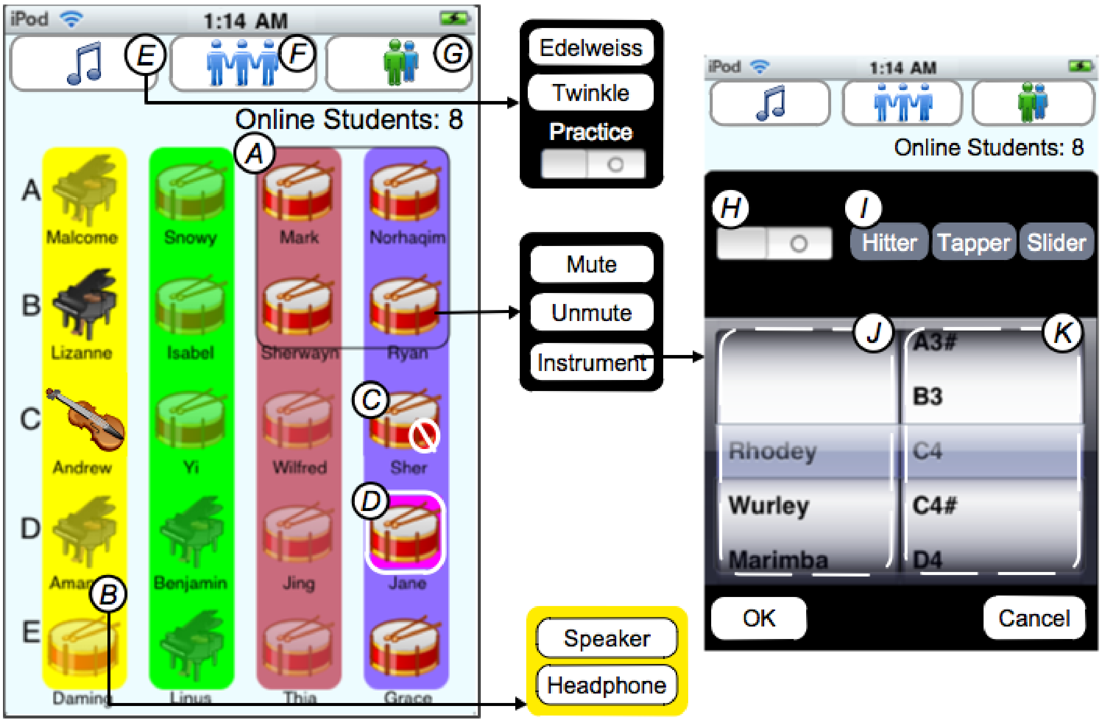


Figure 3.7: The workflow of the teacher interface: the student icon represents Hitter (drum), Tapper (piano), Slider (violin) that the student is using. Icons for students who are online are highlighted while the ones for those who are offline are semi-transparent. The student names are displayed under each icon.

3.4.2 Virtual Sound Space

Virtual sound space provides a way for student devices to share their sounds within their groups. The student devices (typically 5 devices) are grouped by the teacher device in the following process (See Figure 3.8):

- When the system starts, all the addresses of student devices are identified by the Bonjour service [2] in the teacher device.
- When *virtual sound space* is enabled for the group, the teacher device sends the IP addresses of all student devices in each group to all the devices in this group.
- Each student device then stores all the group members' addresses and sets up

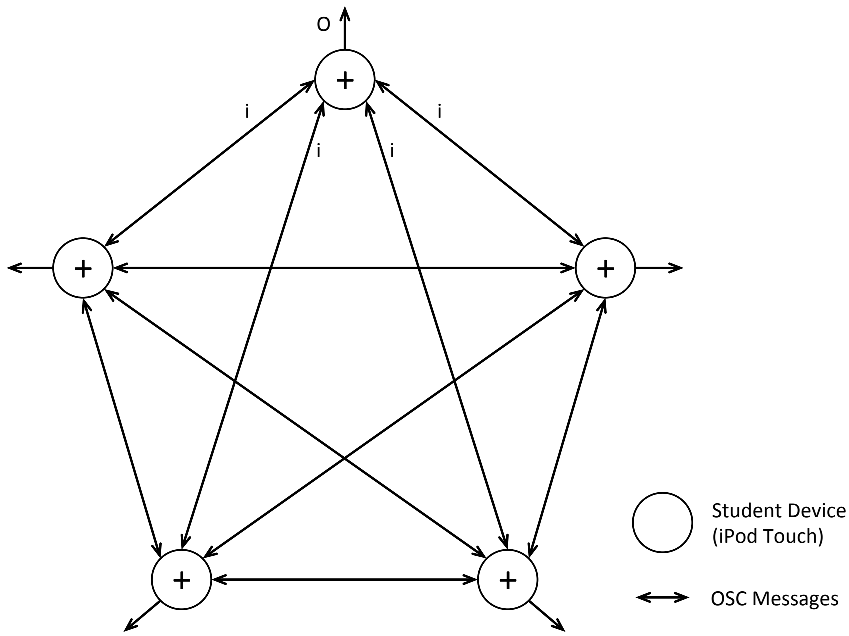


Figure 3.8: Virtual Sound Space.

UDP sockets for sending Open Sound Control (OSC) messages to their peers.

- Upon receiving the OSC messages from other group members, each student device would synthesize the sound and mix all the peers' sounds in the output.

In order to keep the minimal network throughput and delay, the student devices are only sharing the OSC messages and synthesizing the sounds based on them. The format of the OSC message in the system is a beginning message representing its purpose followed by a list of its arguments with a predefined order. This way, the receiver of the message can parse the message to get the ordered arguments according to the message type. For example, the message for playing a note is as follows:

"\action" + device ID (e.g., 2) + note frequency (440.0) + amplitude (1.0)

The message for changing the instrumental sound is as follows:

Figure 3.9: Students working with MOGCLASS in a *virtual sound space* under the teacher's direction.

"\instrument" + device ID + instrument sound

The message for updating student status with the teacher device is as follows:

"\sstatus" + device ID + interface view + interface details + permissions + instrument sound + starting note

Here the interface view is an integer that represents the Hitter, Tapper, and Slider interfaces; the interface details is an integer that indicates the type of notation displayed on the screen (be it western musical notation, numbered musical notation, or solfège); the permissions is an integer that means whether the student device is muted, the *public performance mode* is enabled, and the *virtual sound space* is enabled; the instrument sound is an integer that represents the instrumental sound (e.g., 1 is the sound of snare drum); and the starting note is the lowest note in the Tapper interface as in the MIDI note number;

We choose OSC over MIDI for the communication protocol for its superior speed and throughput, internet connectivity, and data type resolution, and the comparative ease of specifying a symbolic path. In contrast, MIDI requires that all connections be specified as 7-bit numbers with 7-bit or 14-bit data types.

Figure 3.9 shows the *virtual sound space* at work in a real classroom. A room full of students can now play music in small groups without disturbing each other. Without using multiple practice rooms, this was an impossible feat prior to MOGCLASS.

3.4.3 Public Performances

In *public performance mode*, each group has a loudspeaker attached to a laptop for receiving music messages, sound synthesis, and playback. After the teacher device sends the group the IP address of the laptop, the loudspeaker will be enabled so that the group can perform their composition to all the students.

3.4.4 Scaffolding

The scaffolding is useful in guiding students through unfamiliar pieces of music. This gives students a chance to develop the necessary techniques to perform compositions in a consistent and developed manner [107]. The basic idea is similar to karaoke: students perform preset songs guided by the visual cues.

When the whole class performs music together, all student devices must be synchronized. As the teacher device initiates a class-wide performance, all clocks are

Figure 3.10: Students learning with MOGCLASS in the first 3 lessons

synchronized to ensure that the students all see the cues at the same time. To accomplish this, the teacher device sends 10 timestamps to the student devices. Each student device calculates the difference between its local time and the time sent by the teacher. We consider the minimum of all those time differences to be the amount of the clock drift. The average delay in our wireless network is 2.6ms, a negligible difference for visual cuing. After clock synchronization, the teacher device sends all students the starting time, which is equal to its local time plus two seconds. This gives the network (and student devices) time to receive the message and get ready. The scaffolding currently only supports the Tapper interface, and the scaffolding support for the Hitter and Slider interface will be implemented as the future work.

3.5 Iterative Design Evaluation

We conducted four lessons to test the usability of the initial prototype (see Table 3.1). Each lesson contained up to 5 different modules, which presented music from various cultures, using different instruments, and with varying degree of difficulties. Lesson

Figure 3.11: Students learning with MOGCLASS in the final lesson

Table 3.1: Classroom lesson plan. A: Bell pulling (Hitter); B: Mechanical bells (Hitter); C: Kangding Qing Ge (Tapper); D: Frere Jacques (Tapper); E: Kangding Qing Ge (Slider)

Grade	Time (min)	Lesson modules	Other activities
C-3A	50	A, B	Playing with animal sounds.
C-3A	50	C	Choosing new sounds to use. Practice with headphones.
C-6	90	A, B, C, D, E	Practice with headphones. Be free to use any interface and any sounds.
C-3B	50	A, C	No.

modules A, B, and E introduced each music-making interface. Lesson modules C and D allowed students to play more challenging music that requires more coordination among different groups of students. The first three lessons were taught by a member of the research group who has experience in teaching music (see Figure 3.10). The 2 actual teachers were thus spared of the exposure to an incomplete version of MOG-CLASS. They observed and gave comments after the lessons. The final lesson was taught by one music teacher, in order to test whether the system could be used effectively by a music teacher with no technical background (see Figure 3.11).

A total of 104 students and 2 music teachers participated in our evaluation. Working closely with the teachers, we created a lesson plan to evaluate the effectiveness of the system. We divided students into two groups in classroom environment. Group 1 consisted of students aged 8 to 9, a key stage of music development where they can benefit from this type of technological enhancement [12]. Group 1 included two classes: C-3A with 44 students and C-3B with 42 students. Group 2 consisted of 18 students aged 11 to 12 years from one class C-6. They represented the higher end of our target users, with more advanced musical and analytical skills. Group 2 allowed us to collect more feedback for improving the system. All classes were roughly balanced in gender with 80% of the students having had some experience with mobile devices. The first two lessons were carried out with class C-3A, the third lesson with C-6, and the final lesson with C-3B.

During each lesson, student feedback was collected via direct observation, video recordings, and questionnaires. We also conducted semi-structured interviews with the observing teachers. The samples of 2 student questionnaires are provided in Appendix 4 and 5, and the one for the teachers is in Appendix 6.

3.5.1 Findings

Overall, the lessons were quite successful in achieving our evaluation goals: testing the initial acceptance, learnability, and the usability and robustness of MOGCLASS interface (both teacher and student interfaces). Most of the feedback from students and teachers were positive. The response gathered from the student questionnaire results were clearly favorable, with all classes reporting that MOGCLASS was fun and generally easy to use. All teachers, observing and participating, liked the system very much. They especially appreciated the mute function as it makes managing large groups of

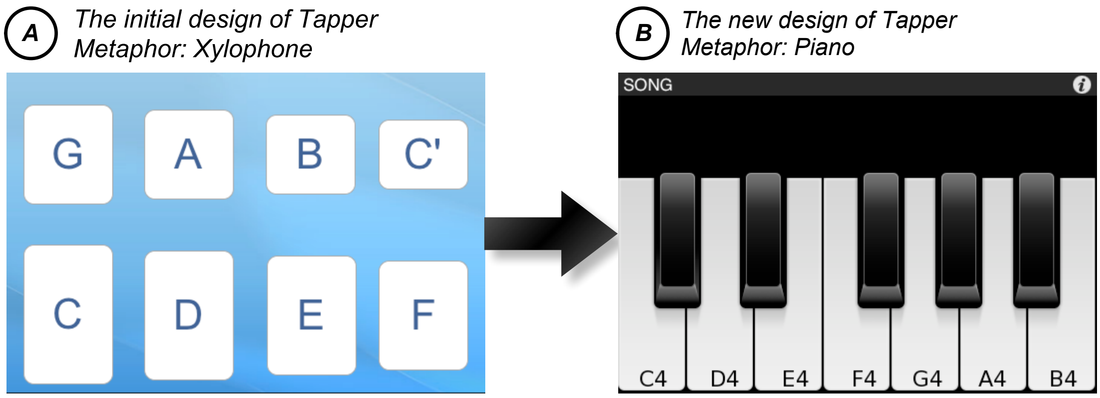


Figure 3.12: The change of the Tapper interface

students much easier.

The prototype received a few complaints, concerning limitations that are intrinsic to the mobile devices, such as limited display and processing resources.

3.5.1.1 Constructive Feedback from Students

Students with a background in piano complained about the split-level notes in the original Tapper interface in Figure 3.12 and the limited range (one octave). After discussions with music teachers, we adopted the piano as the metaphor for the Tapper; and users can go up and down 3 octaves by sliding their fingers on the top of the screen. Some students were also unhappy with the Hitter interface, as the gestures and the sounds produced were not synchronized enough. We solved this problem by improving the algorithm using machine learning approach [130].

We observed that some students had difficulty reading sheet music – their eyes alternated between the musical notation and the screen of their device, with each change requiring half a second or more for them to "find their place." This motivated us to develop scaffolding.

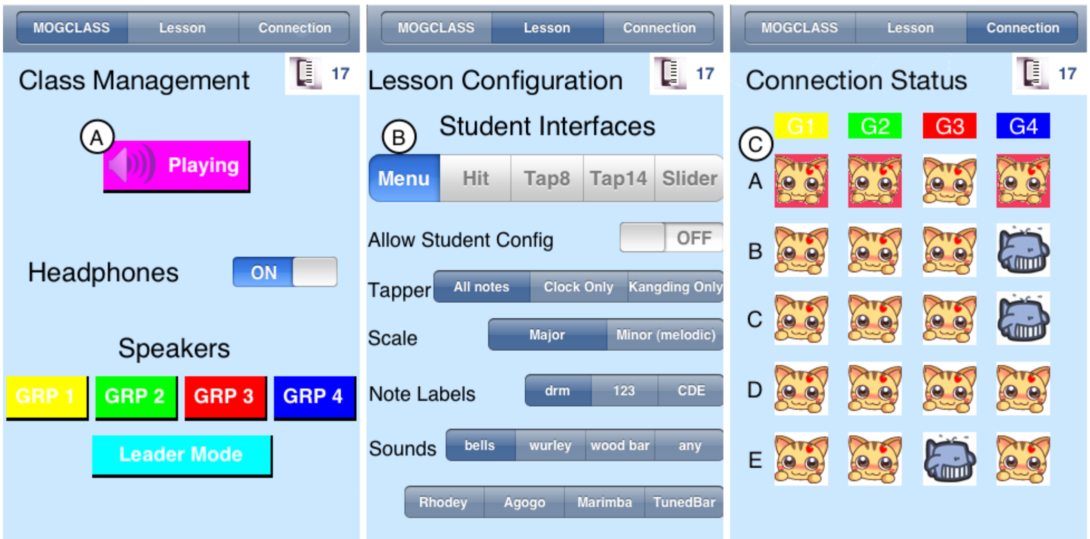


Figure 3.13: The three seperate displays in the original teacher interface design

3.5.1.2 Feedback from Teachers

In the teacher interface design of our initial prototype (Figure 3.13), the mute function (A) was not selective. It disabled all student devices, so when a group was performing the teacher could not selectively silence the rest of the class. The teacher also did not have the option for selecting sounds and interfaces (B) for a specific group of student devices because the devices of the entire class were configured at once.

In the prototype, we only allowed each student to practice with headphones on their own. After the evaluation, the teachers valued the headphone feature because it eliminated the cacophony during music practice. More importantly, the teachers' suggestions inspired us to design the *virtual sound space*.

Some students were overly absorbed in the devices during the evaluations, repeatedly activating the instrument control even after the teachers disabled them. One suggestion we received was to provide the teacher device a function that identifies these students and freezes all the controls and displays on their devices.

In addition, three reasons motivated us to streamline the initial teacher interface design (Figure 3.13): 1) the teacher has to switch among the three views to change the configurations of the student devices; 2) class-wide control is provided but there is no control on individual device; and 3) the Connection Status display does not show whether a student device is muted (in C of Figure 3.13, the cat and the whale represent the online and offline students, respectively. The red background means the student is pressing the buttons) and does not provide enough feedback on changes in the student interfaces (Hitter, Tapper, or Slider). Consequently, the separation of MOGCLASS functions into several separate displays increased teachers' cognitive load. We solved this problem by displaying all the functionalities in one screen.

3.6 Controlled User Study

The evaluation aimed to gather teachers' and students' initial reaction towards MOGCLASS, detect usability issues, and gather feedback for improvements. However, the lessons we conducted were insufficient for us to judge the system's educational value. It was also difficult to understand the advantages of teaching with MOGCLASS without comparing it with a traditional music class. Thus, we carried out a controlled user study to investigate the following research questions:

- Does MOGCLASS stimulate student interest and motivation and increase collaboration in music classes?
- Does MOGCLASS empower the teachers to organize and manage their classes more effectively?
- Can MOGCLASS easily be integrated into the current music curriculum in pri-

mary schools?

3.6.1 Participants

One music teacher and two classes (4A and 4B) consisting of 77 students in Primary 4 (Grade 4 in the US school system) participated in the study. The two classes were randomly chosen. Grade 4 was chosen because of their availability. Meanwhile, since there is a huge difference in musical expertise between grade 3 and 6 students, gauging the system for a medium grade 4 also helps us to extend the scenarios for both ends. Class 4A had 20 females and 19 males, while class 4B had 19 females and 19 males. Students in both classes were familiar with computers and mobile devices. Both classes were taught by the same music teacher, who was familiar with mobile devices but did not have any previous experience with MOGCLASS.

3.6.2 Research Hypotheses

We established the following research hypotheses, with the null in each case indicating no difference between the mean scores for class 4A and class 4B.

H1: *Perceived enjoyment will be higher in Class 4A compared to Class 4B.*

H2: *Perceived competence will be higher in Class 4A compared to Class 4B.*

H3: *Perceived autonomy will be higher in Class 4A compared to Class 4B.*

H4: *Perceived relatedness will be higher in Class 4A compared to Class 4B.*

Table 3.2: Questionnaire

#	Questions
Perceived Enjoyment	
Q1	I enjoyed the music lesson.
Perceived Competence	
Q2	I feel the instrument is easy to learn.
Q3	I can easily play music using the instrument.
Perceived Autonomy	
Q4	I would like to use the instrument frequently.
Q5	I would like to play more songs on this instrument.
Perceived Relatedness	
Q6	I enjoyed the music that our group performed in the class.
Q7	I am happy with my performance in our group.

3.6.3 Study Design and Procedure

The study adopts a between-subjects design in order to avoid asymmetrical transfer effects [86]. The only experimental factor (i.e., independent variable) is musical instrument with two levels (MOGCLASS and recorder). Class 4A used MOGCLASS while Class 4B used recorders. All other variables – the teacher, the classroom where the lessons were conducted, the lesson plans, and the duration of the lessons – were controlled so that both groups worked in the identical environments.

Prior to the study, we provided a 30-minute MOGCLASS training session for the teacher. Each class then went through a five-lesson program within 3 weeks. Details of the lesson program are in Chapter 3.6.3.3. A survey and a questionnaire were given at various stages of the lesson program.

3.6.3.1 Survey and Questionnaire

We used a survey and a questionnaire to measure the students' level of motivation and collaboration. The survey focused on general interest in music education. It was administrated before the first lesson and after the last lesson. The students ranked their interest in school's subjects (from 1 to 9, with higher numbers indicating more interest). The sample survey sheet is in Appendix 7.

The questionnaire (see Table 3.2) studied motivation in more details and was administered three times. The questions were based on Deci and Ryan's self-determination theory [95], which states three basic psychological factors contributing to intrinsic motivation:

- **Competence:** The feeling that one can reliably produce desired outcomes or avoid negative outcomes.
- **Autonomy:** The urge to engage in behavior on one's own initiative.
- **Relatedness:** The sense of being connected to a larger social experience, which is also a metric for student collaboration.

We created two questions on each category and included one question on "enjoyment". Each question was rated on a 7-point Likert scale, with higher numbers indicating stronger agreement with the given statement. The sample questionnaire sheet is in Appendix 8. Hence, the dependent variables in our study are the student general interest towards music subject and their motivation in learning music, and the random variables are the student scores to the questionnaire questions.

We also recorded and transcribed video from all classes to study and document the students' behaviors while using MOGCLASS. We conducted semi-structured interviews with the music teacher after each lesson, and the interview questionnaire is in Appendix 9. One group interview with four students from Class 4A was conducted to investigate their attitudes towards using MOGCLASS.

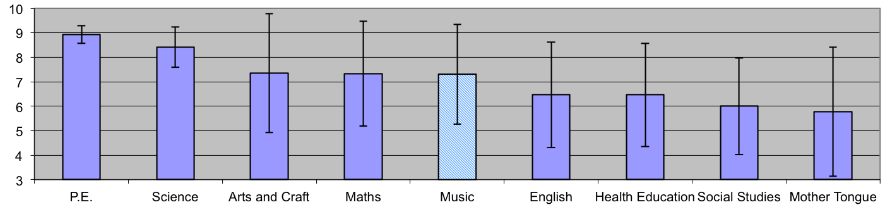
3.6.3.2 Classroom Setup

Due to budget constraints, we could only provide 21 iPod Touches for the study (one for the teacher and 20 for the students). Students in 4A shared the devices in pairs. Students in 4B brought their own recorders. We brought in additional equipment for data collection: an HD camera positioned at the back of the room to record the whole class, 2 JVC camcorders to film two selected groups, and a pair of Cardio condenser microphones connected to a MacBook to pick up sound. The only difference in the classroom setup is the two laptops and four speakers we installed to support MOGCLASS in Class 4A's lessons.

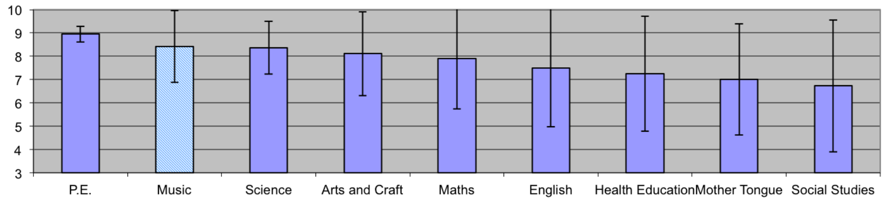
3.6.3.3 Lesson Program

The music teacher created five-lesson program before the study. The lessons were conducted in 3 weeks. Each lesson lasted for 30 minutes. The details of the lessons are as follows:

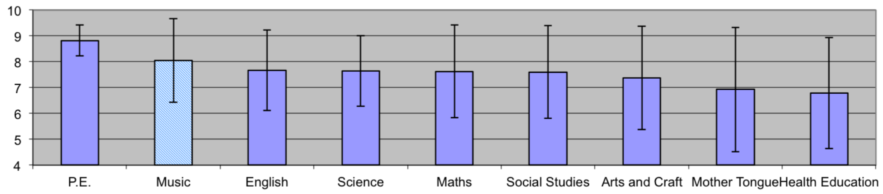
1. Introduction of the musical instruments by playing the notes G, A, and B. At the end of the lesson, students are to answer questions Q2 - Q5 in Table 3.2.
2. Learn how to play a simple song ("Mary had a little lamb") on the instruments. Students using MOGCLASS can use scaffolding.
3. Learn how to play a more advanced song ("Edelweiss") on the instruments. Students using MOGCLASS can use scaffolding. Students are to answer questions Q1 - Q7 at the end of the lesson.
4. Repeat the same song ("Edelweiss") with proper timing. Students using MOGCLASS will no longer use scaffolding. Students are to work in small groups where some play the song while others add their own percussion compositions.



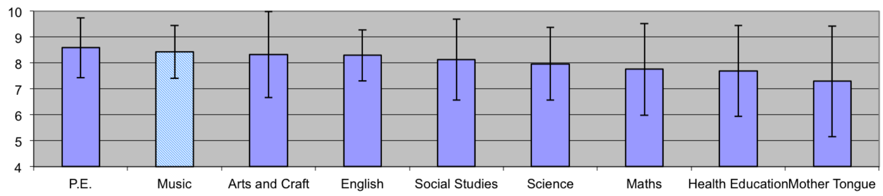
(a) Class 4A before the first lesson



(b) Class 4A after the last lesson



(c) Class 4B before the first lesson



(d) Class 4B after the last lesson

Figure 3.14: Survey results in Class 4A and 4B before and after the study

5. Evaluation: the teacher will grade the performance of the groups in terms of creativity, style and technical proficiency. Students are to answer questions Q1 - Q7 at the end of the lesson.

The detailed description of MOGCLASS and Recorder lesson plans are in Appendix 10 and 11, respectively.

3.6.4 Results and Analysis

3.6.4.1 Student Motivation, Interest, and Collaboration

When asked how interesting the subject of music is on a scale of 1 (least interesting) to 9 (most interesting), class 4A gave an initial rating of 7.31 and class 4B gave 8.05. After the five lessons, in which class 4A used MOGCLASS and class 4B only recorders, class 4A's rating increased significantly to 8.42 ($F(1, 33) = 9.862$, $p = 0.004$) (see Table 3.3). While class 4B's rating also edged up to 8.43, the increase was not significant ($F(1, 28) = 1.451$, $p = 0.238$). Figure 3.14 presents the complete survey results for all subjects. It shows that the initial rank of music among 9 subjects in class 4A has increased from 5 to 2 after using the MOGCLASS system. But for class 4B the rank of music among all subjects did not change at all. It demonstrates that the recorders just "maintained" rather than improved the students interest towards music. However, one may argue that although class 4A demonstrated MOGCLASS's effectiveness in promoting student interest, due to class 4B's higher initial rating it is insufficient to conclude that MOGCLASS is more effective than the recorders. Next we will take a close look at the questionnaire results to address this issue.

Since the students answered the questionnaire (in a 7-point Likert scale) three times, we analyzed the results via the repeated-measures ANOVA test using musical instrument as the between-subject factor (in Table 3.4 and Figure 3.15). Students using MOGCLASS had higher ratings on all the questions except for Q1, where no sig-

Table 3.3: Survey Results: General Interest (*$p < 0.05$; **$p < 0.01$)

Class	Before	After	F	p
4A	7.31	8.42	9.862	0.004**
4B	8.05	8.43	1.451	0.238

Table 3.4: Analysis of questionnaire results:
one-way ANOVA test. (* $p < 0.05$; ** $p < 0.01$)

#	C	Mean	Std. Error	$F(1, 61)$	p
Q1	4A	6.767	0.114	0.404	0.527
	4B	6.667	0.109		
Q2	4A	6.567	0.161	14.9	< 0.001**
	4B	5.707	0.154		
Q3	4A	6.611	0.205	17.236	< 0.001**
	4B	5.434	0.196		
Q4	4A	6.611	0.169	3.085	0.084
	4B	6.202	0.161		
Q5	4A	6.722	0.168	9.653	0.003**
	4B	6.000	0.160		
Q6	4A	6.383	0.192	7.926	0.007**
	4B	5.636	0.183		
Q7	4A	6.267	0.212	3.6	0.063
	4B	5.712	0.202		

nificant difference was found, indicating that, though both classes may have enjoyed the lesson equally, students preferred MOGCLASS in many aspects. MOGCLASS received significantly higher scores in Q2 and Q3, indicating that it was perceived as much easier to learn than the recorder. It also rated marginally higher in Q4 ($p < 0.1$) and significantly higher in Q5 ($p < 0.05$), indicating students had higher interest in using it and were likely to spend more time practicing it instead of recorders. The last two questions are related to the support of collaborative learning. MOGCLASS scored significantly higher than the recorder for Q6 ($p < 0.05$) and marginally higher for Q7 ($p < 0.1$), indicating it was more effective in facilitating and supporting group practices.

The questionnaire results support hypotheses **H2**, **H3**, and **H4**, showing MOGCLASS effectively enhanced perceived competence, autonomy, and relatedness, all of which factors needed to fuel intrinsic motivation.

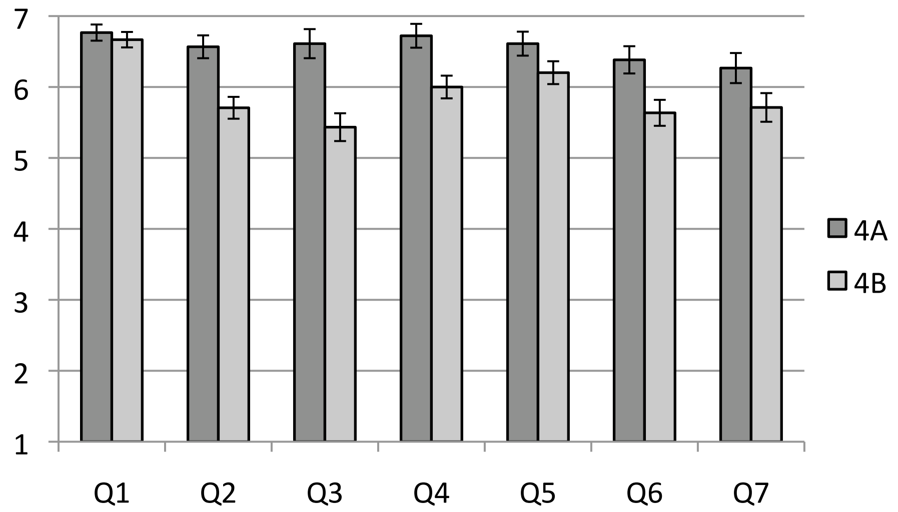


Figure 3.15: Graph of questionnaire results

Hypothesis **H1** is not supported by data, but since both classes reported such high values (up to a mean of 6.77 on a 7-point Likert scale), it is not surprising that there is little difference. Future studies on MOGCLASS might attempt to reduce the overall "enjoyment" numbers by asking students to choose between one enjoyable activity and attending music class (i.e., extra music classes vs. lunch break).

In addition to between-subject effects between MOGCLASS and recorder, we also tested within-subject effects across multiple lessons. We found no significant within-subject effects ($p > 0.05$), which means that both Class 4A and Class 4B maintained the same level of motivation throughout the five-lesson period.

3.6.4.2 Subjective Feedback

The field observation and interviews validated our questionnaire results. MOGCLASS lessons required much less intervention from the teacher during song practice. Most students were able to practice playing "Edelweiss" on their own using the scaffolding feature. As a result, some students fully mastered the playing of the music piece

Table 3.5: 3 categories of the student comments

Categories	Example comments
Positive	It is very fun. It very good I enjoy myself. Fantastic!!! It is good and Awesome! I like the class a lot!
Negative	Too noisy. I want to perform. It is very noisy. Our group's position of the instrument is not nice. It was quite hard
Neutral	Nothing. So so. Fun but noisy. (Contradictory)

(Edelweiss) through classroom practice without any teacher involvement. On the other hand, the level of assistance in the recorder class was much higher. The teacher made rounds helping various students, yet most of them still wanted more assistance. As a result, despite more individual attention from the teacher, none of the students learned to play Edelweiss.

We also collected students' comments from the questionnaires. Since the students of the 4th grade had limited vocabularies, we could easily transcribed their comments into 3 categories: (1) positive (2) negative (3) neutral. The example comments of 3 categories are in Table 3.5. 74 and 87 students, who are from class 4A and 4B respectively, have left their comments in the questionnaire. In class 4A, 64 out of 74 comments are positive (86.5%); 1 comment is negative (1.3%); and 9 comments are neutral (12.2%). In class 4B, 65 out of 87 comments are positive (74.7%); 16 comments are negative (18.4%); 6 comments are neutral (6.9%). We will quote some interesting comments below.

Many students strongly expressed the desire to have more MOGCLASS lessons in the future. They found MOGCLASS interesting and easy to use and liked that it made sounds of many musical instruments. They also “enjoyed the class”, felt “fortunate to be able to use an iPod Touch to learn music”, and “look forward to my next music class”. The students “highly recommend MOGCLASS to other schools”.

On the other hand, feedback from the recorder class was mixed. Although most students agreed playing with recorder was “interesting and fun”, “it is a little hard” and “noisy when practice in groups”. The students felt that they want “more different instruments to learn”. These comments confirmed that MOGCLASS is easier to use and has higher perceived competence from students.

Video footage showed how students collaborated during group practice in a MOGCLASS lesson. Like any other music lesson, each student was preoccupied with a certain idea, wanted to do other things, or cause mayhem. However, as the music teacher reported, the major difference was that the din of music practice, which can be overwhelming in a normal class, was gone. Except for occasional conversations among students, the noise level in Class 4A was negligible compared to the cacophony in Class 4B.

3.6.4.3 Classroom Management

Because MOGCLASS is a new system, it is expected that the teacher will take a while to learn and use its features. In the first lesson, the teacher did not use his device frequently. He still gave verbal orders to silence students instead of pressing the mute button on his device. As the study progressed, he became more familiar with the system and used the device more frequently. For example, before a group made a public performance, he would first put everybody else’s devices on mute.

Managing the classroom using MOGCLASS also increased the teacher's competence in managing student activities. Since the statuses of student devices are displayed in his device's interface, he could easily identify misbehaving students. This is especially helpful in a large class. The teacher liked the function that allows group practices using headphones because it was quieter. He also approved of the system's ability to simulate different musical instruments. It eliminated the need to buy new instruments as he can simply install new software applications.

Children are curious and active by nature. During the study, some students were overly absorbed in testing the instruments, continuing to play with them even when they were asked to place them on the floor. After one session with Class 4B, the teacher had to stop and explain to the class that he would not proceed with the lesson unless everyone listened. In Class 4A, the teacher simply disabled all the student devices before giving verbal instructions. The group interview revealed that while one student found the classroom management functions of the teacher device (particularly the mute function) restricted freedom, other students understood that they were necessary to keep order in the class.

3.6.4.4 Integration into the Music Curriculum

After using MOGCLASS for five lessons, the teacher is confident that it can be integrated into the current music curriculum at the primary level. MOGCLASS fulfills the objective specified in the General Music Programme for students to "sing and play melodic and rhythmic instruments individually and in groups." [12].

MOGCLASS's basic configuration, which was used in this study, has melodic elements (Tapper and Slider) as well as a percussion element (Hitter). It enabled students to play music using the sounds of many melodic instruments or through the striking actions of percussive instruments. It also provides an almost infinite expansion capability, requiring the devices only to be updated to receive new musical instrument sounds and functionalities. As the teacher commented in the interview, MOGCLASS can be used for a variety of music lessons because of the options to play many musical instruments and its classroom management functionalities. He thinks it has a huge potential as a tool for music lessons involving singing if a voice recording function can be added.

However, group music making is one of the most important objectives of classroom music education that traditional music technology has failed to address [94]. This is also specified within the first objective of the 2008 General Music Programme Syllabus [12].

MOGCLASS is easy to deploy, requiring only five minutes for two students to set up and clean up. After a short training period, a typical music teacher was able to use the system smoothly. Once during the study, the students encountered some problems in the system (e.g., they could not log in) that the teacher was nevertheless able to solve without technical assistance. After the evaluation, the school purchased the system for long-term use. With a tight budget, schools often find it a challenge to obtain the necessary hardware and software. But with the ubiquity of mobile devices, the teacher looks forward to a day when everyone can bring their own mobile devices and use them to learn music.

By developing the music experience through three activities (listening, performance, and composition), MOGCLASS effectively motivates students to study music and helps teachers manage the classroom. The survey and questionnaire results, field observation, and interviews from the controlled study showed that MOGCLASS rated higher in questions regarding the three basic psychological factors described in the theory of intrinsic motivation. The study also showed that MOGCLASS is effective in reducing teacher workload in classroom management. There is a huge potential in deploying this system of networked mobile devices to enhance classroom music education.

3.7 Limitations

The physical actions of the Tapper and Slider interfaces bear little resemblance to the actions in playing an acoustic instrument. However, these interfaces still capture the essential interactivity of music performance: physical actions produce sounds, and sounds are analyzed to plan future actions. The development of this "action-sound-action" feedback loop is a crucial part of music education. Future work will compare MOGCLASS-trained and recorder-trained students' ability to learn a third musical instrument.

Unlike acoustic musical instruments, the playing time of an iPod Touch is constrained by its battery life. The 2^{nd}-generation iPod Touch can last 2.5 hours with the Wi-Fi in constant use. If a teacher wants to conduct a longer lesson or use the devices throughout several sessions, we would need to install a charging facility or prepare backup batteries or devices.

Although the interface of the teacher device is easy to use, the limited size of the screen poses a challenge when many students are involved. The current interface was designed for up to 20 student devices; more students would result in a cluttered display. One possible solution is to use a tablet computer such as the iPad, which can display more student information and control functions on the screen.

Our study evaluated the progress of the students in the MOGCLASS class throughout the five-lesson program. In the future, we could work with the school to study the improvement on students' musical skills that can be attributed to the use of MOGCLASS over semesters.

3.8 Summary

We developed MOGCLASS based on careful considerations of music education needs in school. First of all, the interfaces of the teacher and student devices were designed to facilitate learning in a creative environment via the diversity of interactions and synthesized sounds and the minimized technical demands. Secondly, MOGCLASS allows students to learn in a collaborative setting while exploring music in groups or as individuals, a separation of performance and practice supported by *virtual sound space* and distributed mobile system synchronization. Finally, MOGCLASS provides not only an active and motivating learning environment for children but also an effective e-learning tool for the teacher to manage classes. In sum, MOGCLASS enhanced classroom music education from the perspectives of learners and instructors.

Our iterative design evaluation and controlled user study have shown that MOGCLASS has achieved our goals. It was so enthusiastically received by our participants (students, teachers, and music education experts) that our proposed system and approach may prompt educators to rethink current practices so that music education can be an active engaging experience.

This study will be helpful for designers and researchers who are interested in studying interactive classroom technologies. The success of this project makes us believe that MOGCLASS can be applied not only to music education but also to music therapy. We have adapted MOGCLASS as an assistive technology for children with physical disabilities (e.g., muscular dystrophy) to decrease their isolation, improve their social skills, and boost their self-confidence and self-esteem (see Chapter 5). We will continue to explore broader applications for MOGCLASS in our future work.

3. CLASSROOM MUSIC EDUCATION OF YOUNG CHILDREN

Chapter 4

Auditory Training for Children with Cochlear Implants

4.1 Introduction

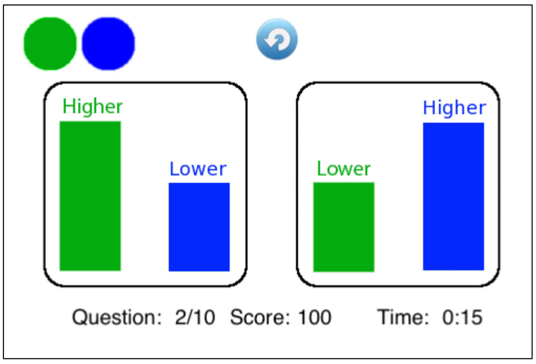
Music plays an important role in people's lives. The vast majority of people enjoy music with unaided ears, but millions of people have partially or profoundly impaired hearing. How can they experience music? One approach is to sense the tactile vibrations; the highly acclaimed percussionist Evelyn Glennie "feels" music with different parts of her body [46]. Another approach is through amplifying vibrations with mechanical devices; Beethoven was an early adopter of such technology [33]. Nowadays, cochlear implants (CI) have taken the place of the ear horns of the nineteenth century. By surgically implanting an electronic device in the cochlea, people with profoundly impaired hearing can (re)enter the world of sound.

Although CI can adequately support spoken communication, it is far from ideal when encoding and transmitting music [69]. The rich spectrum of musical sounds is not well preserved by feature extraction devices; intelligible speech only requires a very narrow frequency bandwidth. CI recipients generally have poorer perception and identification of melodic patterns [54] and musical timbre [31] than normal hearing people.

Post implantation, auditory habilitation is required to boost recipients' adaption for the devices. It must address the perception and production of both speech and music [13]. As such, musical auditory habilitation complements the standard speech programs [104]. It has been shown to not only help recipients better recognize melody [44] and identify timbre [43] but also motivate them in their habilitation process and improve their self-esteem [13]. However, musical habilitation is plagued by the lack of appropriate teaching resources, professional training, and administrative support [97].

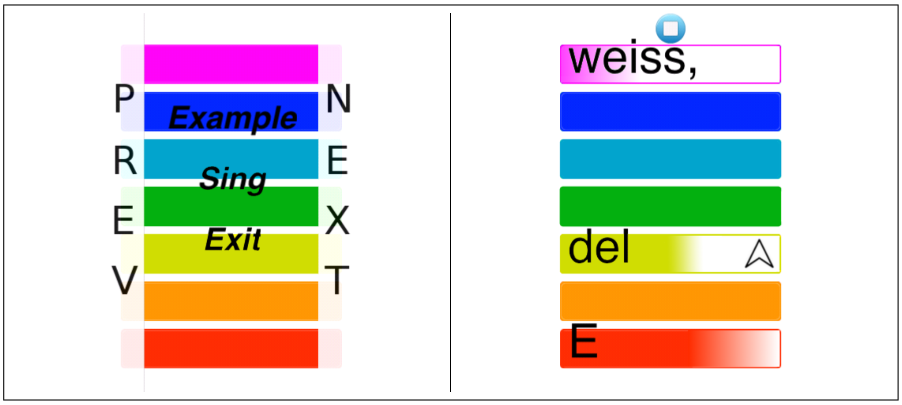
We must also note that compared with adults, many of whom have previously experienced sounds before the onset of deafness, almost all children with CI are pre-lingually deaf before forming memories of music or even language. These children are not exposed to sound until their implantation, while post-lingually deafened adults with CI have in their mind the sound experience established prior to their deafness. As such, the training methods for children with CI should be specifically designed [45]. Delay in their language development may affect their cognitive and behavioral development [85, 89], which will further inform the choice of vocabulary and material for those children. Therefore, when designing MOGAT, the unique characteristics of children with CI must be considered when selecting objectives, content, and particular stimuli.

A pilot study is conducted to understand the children's deficiency in terms of pitch and rhythm perception/pitch production in contrast to normal hearing peers. Based on those findings, we designed and developed MObile Games with Auditory Train-



(a) *Higher Lower*

(b) *Vocal Matcher*



(c) *Ladder Singer*

Figure 4.1: The game interfaces in MOGAT

ing (MOGAT) using off-the-shelf mobile devices to provide a fun, intuitive, and cost-effective way to enhance musical habilitation for children with CI.

MOGAT contains three structured music games focusing on pitch-based habilitation. *Higher Lower* (Figure 4.1a) targets interval perception; *Vocal Matcher* (Figure 4.1b) focuses on single-pitch production with appropriate voice control; *Ladder Singer* (Figure 4.1c) combines pitch, breath, and lyrics in an intuitive user interface to guide users in singing songs. Using an effective singing analysis algorithm, MOGAT transcribes the user's pitch and provides real-time feedback to help them make adjustments. With optimized computation load, MOGAT can be built into low-cost mobile devices to provide a cost-effective way for children's habilitation.

In addition, since all recorded audio and other data can be uploaded, synchronized, stored, and managed in our server, MOGAT realizes a cloud computing service that allows music teachers and therapists to support the habilitation of a large number of children simultaneously. Furthermore, MOGAT provides a web interface to visualize the progress of individual children over days, weeks, and months, and teachers are able to pinpoint children's singing problems and send comments or encouragements to their children (i.e., to remotely provide appropriate teaching resources, professional training, and administrative support that is lacking in the musical habilitation).

This work's main contributions can be summarized as:

- MOGAT is the first integrated solution to support musical (rather than general audio) habilitation for children with cochlear implants.
- An analysis of the user's pitch and rhythm perception and intonation accuracy that guides the system design, which caters specifically to their musical needs and cognitive abilities.
- We conducted systematic and in-depth user evaluation to test the effectiveness of MOGAT in enhancing musical habilitation for children with CI.

4.2 Audio Analysis

4.2.1 Automatic Note Annotation

Automatic note annotation produces a list of notes onsets and pitch curves from audio.

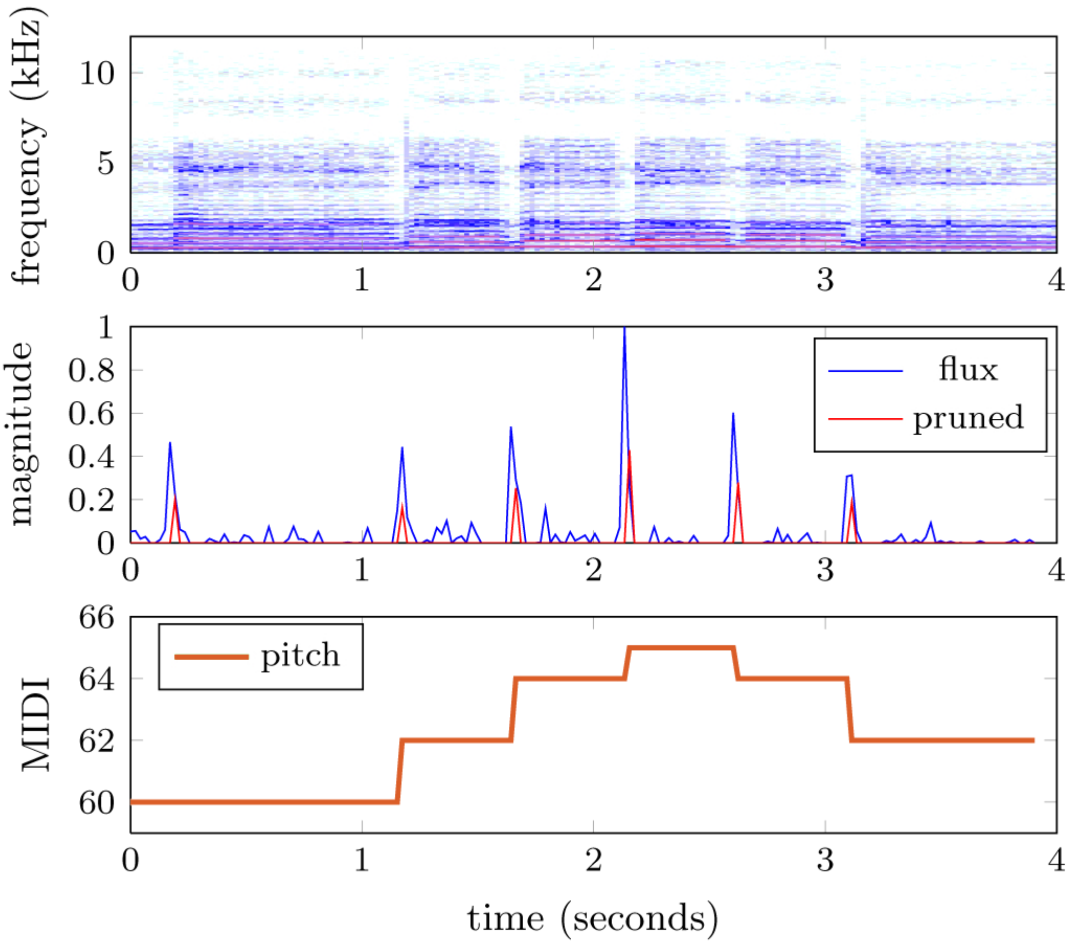


Figure 4.2: Note segmentation result on a singer's recording. The top plot is a spectrogram; the lower plot is the normalized and adjusted spectral flux; and the bottom plot is the extracted pitch contour.

4.2.1.1 Note Segmentation

Since users will be singing the hard consonant "La" (see Section 4.3.1.1), notes onsets are easily identified in a spectrogram (Figure 4.2). Our input audio is a monophonic signal at 24 kHz. We take the short-term Fourier transform (STFT) with a hamming window, using a window size of 512 and a FFT length of 512. The detection function is constructed using the half-wave rectified spectral flux,

$$SF(k) = \sum_{i=0}^{n-1} H(s(k,i) - s(k-1,i)) \tag{4.1}$$

where $s(k,i)$ is the magnitude of the i^{th} frequency bin in the k^{th} frame, and $H(x) = (x + |x|)/2$ is a half-wave rectifier assigning zeros for its negative arguments. The rectification emphasizes onsets rather than offsets. The spectral flux was first normalized to $[0,1]$ by subtracting the minimum and dividing the maximum absolute difference. Then, a low-pass filter was applied to remove jitter and noise. Finally, a high-pass FIR filter adaptive threshold was subtracted from the normalized spectral flux to create a "pruned" flux before peak-picking.

$$SF_{pruned}(k) = \alpha + \frac{\beta}{H} \textstyle\sum_{i=k-H/2}^{k+H/2} SF(i) \tag{4.2}$$

We empirically determine the moving window size $H = 10$ and let $\alpha = 0.03$ and $\beta = 1.2$. After post-processing and thresholding the detection function, peak-picking is used to identify the local maxima in the adjusted spectral flux above the defined threshold.

4.2.1.2 Pitch Estimation

We used the YIN algorithm to estimate pitch [27]. In order to find the periodicity (indicated by $\widetilde{\tau}$, i.e., the number of samples in the period) of a discrete time-domain signal s, we begin by calculating the squared difference function $d(\tau)$ for a desired range of lag values:

$$d(\tau) = \sum_{n=0}^{N-1} (s(n) - s(n+\tau))^2 \tag{4.3}$$

We then use a cumulative mean normalized difference function to determine the aperiodicity of the audio frame:

$$d'(\tau) = \begin{cases} 1, & \tau = 0 \\ d(\tau)/[(1/\tau)\sum_{j=1}^{\tau} d(j)], & \text{otherwise} \end{cases} \tag{4.4}$$

Next, we search for the smallest value of τ that minimizes $d'(\tau)$ below a given absolute threshold $\kappa = 0.10$. If no such value is found, we instead search for the global minimum of $d'(\tau)$. Once we find the lag value $\widehat{\tau}$ from last step, we interpolate $d'(\tau)$ at $\widehat{\tau}$ and its immediate neighbors with a second order polynomial. The length of the period $\widetilde{\tau}$ corresponds to the minimum of the polynomial in the range of $(\widehat{\tau} - 1, \widehat{\tau} + 1)$, and the pitch is estimated as the sampling rate divided by $\widetilde{\tau}$. Since consonant and silence frames have relatively high aperiodicity, we omit values of $d'(\tau) > 0.15$ (value set experimentally). We then convert the pitch (in Hz) to a MIDI pitch value.

Within each note segment, we adopt the median as the pitch value for all frames. After note segmentation and pitch estimation, the output of automatic note annotation is the note sequence $\mathbf{O} = o_1, o_2, ..., o_t$, which will be the input for the singing evaluator in the following section.

4.2.2 Singing Evaluator

In this study, "intonation accuracy" refers to the similarity between subject's pitch contour and the reference one. In order to find the optimal matching path between pitch contours $\mathbf{A} = \{a_1, a_2, ..., a_N\}$ (the reference from sheet music) and $\mathbf{B} = \{b_1, b_2, ..., b_M\}$ (the detected values from Section 4.2.1), we adopt the classic note-level Dynamic Time Warping (DTW) method. A singer may shift the pitch up or down ("transposition" in musical terms) by a constant interval to fit his/her vocal range. To detect transposition, we enumerate 12 semitones in a octave and shift the subject's pitch contour from one octave down to one octave up to find the minimum matching cost. The absolute differences between two pitch contours then are averaged across all the notes in reference sequence $\mathbf{A}$ (4.5).

$$\begin{aligned} C_{DTW}(\mathbf{A}, \mathbf{B}) \quad &= \tfrac{1}{N} \min\nolimits_{i \in [-12,12] \bigcap \mathbb{Z}} \{Dist(\{a_1, a_2, ..., a_N\}, \\ &\qquad \{b_1 + i, b_2 + i, ..., b_M + i\})\} \end{aligned} \tag{4.5}$$

where

$$Dist(\{a_1, a_2, ..., a_N\}, \{b_1, b_2, ..., b_M\}) = D_{N,M} \tag{4.6}$$

$$D_{i,j} = d(a_i, b_j) + \min(D_{i-1,j-1}, D_{i-1,j}, D_{i,j-1}) \tag{4.7}$$

$$d(a_i, b_j) = |a_i - b_j| \tag{4.8}$$

where $d(a_i, b_j)$ is the absolute difference between note a_i and b_j. $D_{i,j}$ is the minimum cumulative absolute difference up to a_i and b_j. $Dist(\mathbf{A}, \mathbf{B})$ is the absolute difference between two pitch contours $\mathbf{A}$ and $\mathbf{B}$, note by note.

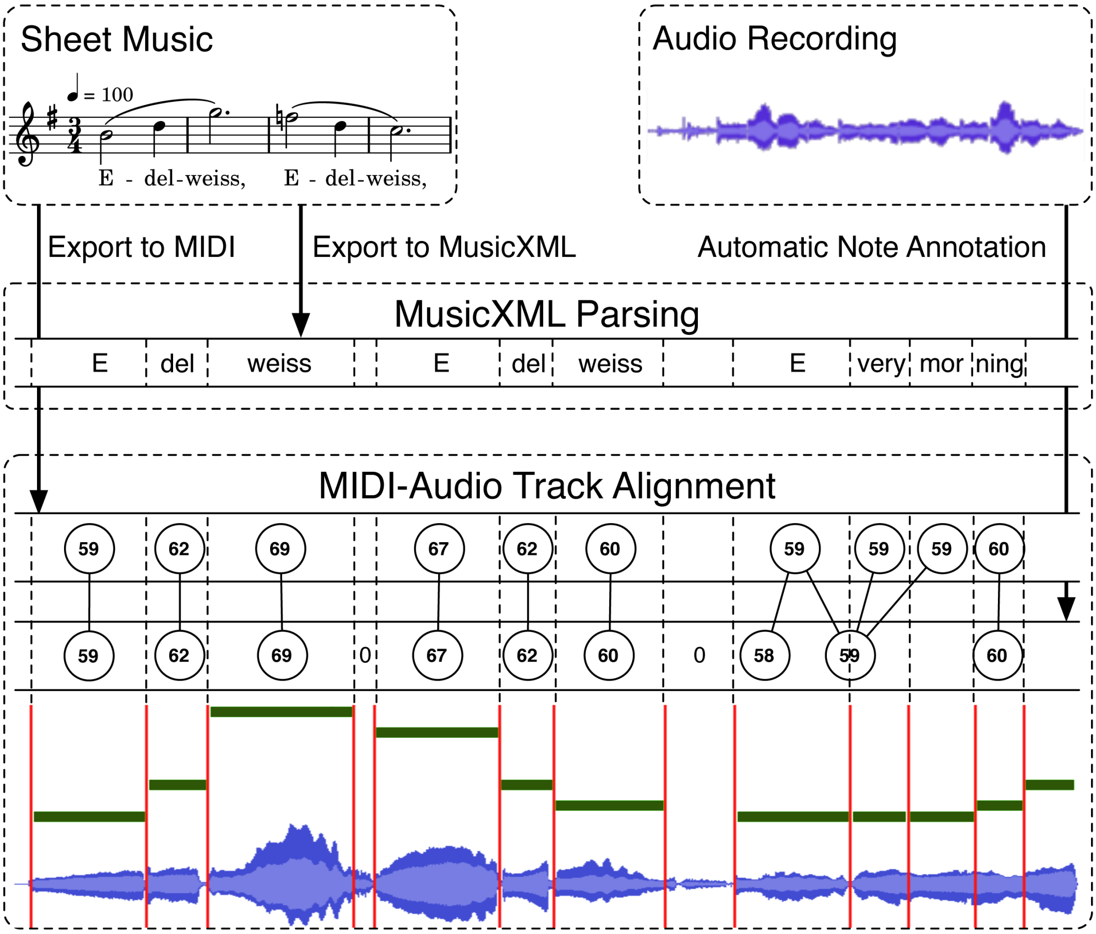


Figure 4.3: Alignment of recorded audio with the reference MIDI and MusicXML files. There are three rows of information for alignment from top to bottom: lyrics, MIDI pitch sequence, and audio track annotation. A "pitch" of 0 indicates breath noise or silence.

4.2.3 Audio Alignment to MIDI and Lyrics

The meta-data in the game of *Ladder Singer* consists of the pitches, onsets, lyrics, and sample audio. The sample audio was recorded from one of our female teachers' singing, while other data was extracted directly from the sheet music. For score editing, first we got the music sheet data from Noteflight [9], a crowdsourcing website for creating and sharing music online. We then associated each note with its corresponding syllable in a word in lyrics using the website. After editing, the notes and lyrics were exported into MIDI and MusicXML files, respectively. To control the animation synchronously with audio playback, we need to align the MIDI with the audio track.

Alignment is performed with the algorithm in Section 4.2.1 to detect breath and silence events before aligning notes with the score (Figure 4.3). The alignment is done by finding the minimum cumulative cost in DTW (see Section 4.2.2). There are sometimes ambiguous note boundaries among some consecutive notes with the same pitch, which are occasionally detected as one long note. In order to separate them for further manual adjustment, we automatically separate the long note into a number of matched notes in proportion to their lengths in the MIDI file. After alignment, we modify the "Note On" and the "Note Off" events for each note in MIDI files to its matched note onset and offset in the audio track. Experiments show that over 90% notes are aligned accurately and the rest are positioned at the approximate positions which are then adjusted manually. As a result, our alignment method significantly reduces the time and effort required for annotation.

4.3 MOGAT Design

In order to understand the disadvantages of children with CI and to further analyze their musical needs, we performed a pilot study to compare the music abilities of children with CI and normal hearing (NH) children. This led to several design objectives that informed the design of three games and our web service for teachers.

4.3.1 Pilot Study

All children in the study (see Table 4.1) were from Canossian school and its affiliated school for the hearing impaired. The study was approved by the school principal and

Table 4.1: Subjects in pilot survey

Grade	Age	CI children	NH children
Primary 2	7 - 9	9	9
Primary 1	6 - 8	8	8
Kindergarten	5 - 7	13	13

carried out during their normal school time.

4.3.1.1 Procedure

For our assignment protocol, we adopted their regular music assessment exercises, which were built into our iPad application beforehand to easily and quickly collect their answers and recordings. The app contains three modules testing users' abilities in pitch perception (10 questions), rhythm perception (10 questions), and intonation accuracy (11 questions). In the three modules, piano sound is used for audio playback as the music educators mainly use the piano to teach music to children with CI.

In the pitch perception module, subjects first hear two notes played by a piano sound and then they are asked to identify if they are the same or different by choosing one of two buttons displayed on the touch screen. The maximum interval between two notes is a fifth.

In the rhythm perception module, subjects first hear a two-bar rhythmic phrase synthesized by a piano sound and then they need to tap on the touch screen to reproduce all the note onsets. The app records the time stamps of user tappings and saves them into a log file.

The singing module is relatively more complicated than the other two. During the example demonstration, the app plays a synthesized two-bar melodic phrase using a piano sound. Immediately after the melody finishes playing, the app displays countdown ("3, 2, 1, Go") label on the screen, and subjects are then to sing "La" for each note without hearing the synthesized piano sound. Recording stops automatically once the animation finishes. Subjects are always shown the visual animation of the note sequence in a piano roll format during demonstration and recording, where the visual note sequence moves from right to the left piano keyboard, indicating the active note being played at this moment.

4.3.1.2 Research Hypotheses

We established the following research hypotheses, with the null in each case indicating no difference between children with CI and NH children.

H1: *The results of pitch perception would be worse for children with CI than NH children*

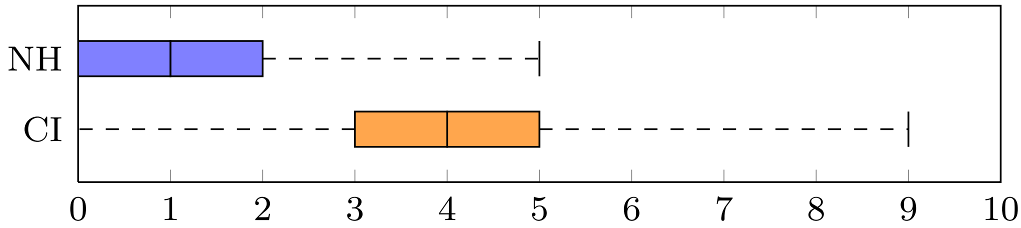
H2: *The results of rhythm perception would be worse for children with CI than NH children*

H3: *The results of intonation accuracy would be worse for children with CI than NH children*

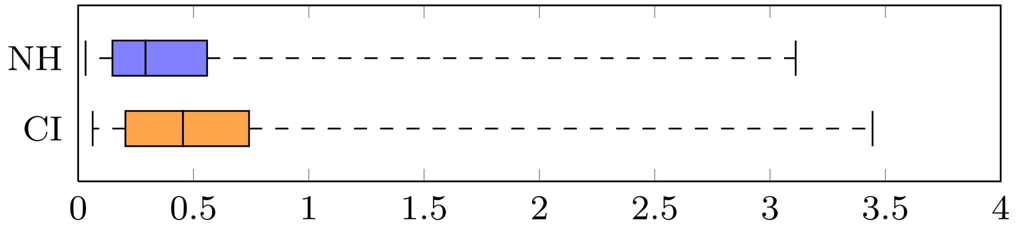
4.3.1.3 Analysis

We first underwent the normality test for each data set and found that only the pitch perception data set from NH children follows the normal distribution. Therefore, we used Kruskal-Wallis H test for comparing the means of the data sets from NH and CI children, which does not assume normality in the data. Results and the detailed data analysis are presented in Figure 4.4 and Table 4.2, respectively.

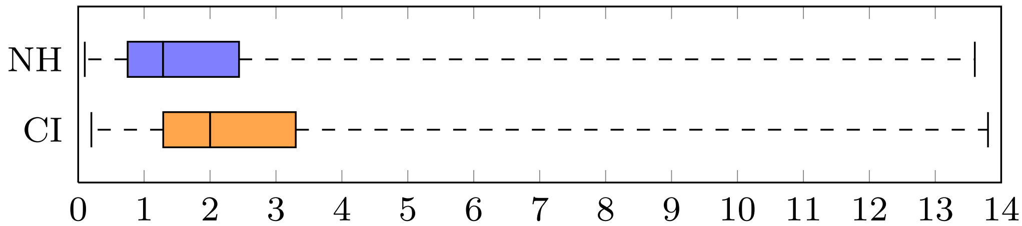
Pitch perception: This test presented children with a choice of two pitch intervals.



(a) pitch perception (number of mistakes)



(b) rhythm deviation (seconds)



(c) singing note mean deviation (semitones)

Figure 4.4: Three metrics used for evaluating music perception and singing ability in the two subject groups. Each box plot shows the lower limit, lower quartile, median, upper quartile, and the upper limit of the data. Lower numbers indicate fewer mistakes.

Children with CI chose the incorrect option a significantly higher number of times than NH children with $p < 0.01$. The effect size based on the value of Cohen's d [24] is 1.55. On average, children with CI made almost 3 more errors than NH children. As each question has only two options, random guessing should result in a score of 5/10.

Rhythm perception: We define our rhythm perception metric as the mean absolute deviation between user taps and reference sequence after aligning the first de-

Table 4.2: Data analysis from the pilot study

	Pitch Perception		Rhythm Perception		Pitch Production	
Subjects	NH	CI	NH	CI	NH	CI
Min	0	0	0.0322	0.0631	0.1	0.2
1st Quartile	0	3	0.1487	0.2047	0.75	1.2929
Median	1	4	0.2918	0.4541	1.2857	2
3rd Quartile	2	5	0.5591	0.74	2.44	3.3
Max	5	9	3.1112	3.4445	13.6	13.8
Mean	0.9643	3.8571	0.4358	0.6358	1.9958	2.675
Std Dev	1.1701	2.1553	0.4448	0.6232	2.0079	2.1522

tected onset to the first reference onset. Although there is a statistically significant different ($p < 0.05$) in rhythm deviation among the NH and CI children. The effect size based on the value of Cohen's d is 0.37. Since the effect size is small and the finding from previous research [31, 69] suggests that the rhythm perception of children with CI is a minor issue compared to their pitch-related skills, we did not follow this up. But we will investigate this problem as our future work (see Chapter 6.4).

Intonation accuracy: We used the mean note deviation calculated by the singing evaluator in Section 4.2.2 to represent intonation accuracy. Children with CI demonstrated significantly larger mean note deviation than NH children with $p < 0.01$. The effect size based on the value of Cohen's d is 0.33. The results show that on average NH children's singing voices had 0.68 semitone (68 cents) less deviation from the correct pitch contour than children with CI. Our data also revealed large individual variability in both NH children and children with CI.

4.3.2 Design Objectives

Based on our pilot study, we established four objectives:

- Improve children's pitch perception skills by determining the relative pitch difference.
- Improve children's pitch production skills with appropriate use of voice and breath support in singing.
- The interfaces should be easy and intuitive to use, and the games should be fun and interesting to play.
- Supply a remote centralized administration allowing teachers to easily monitor and personalize child habilitation.

The emphasis on pitch perception and production arises from the deficiencies found in the pilot study. Our music therapist required that the system support breath control in singing by testing children's ability to sustain the correct pitch for a certain duration.

On the basis of our pilot study and design objectives, we created three games for children and a web service for teachers.

4.3.3 Game Design

Children with CI are a special user group, in terms of not only their hearing disabilities but also their cognitive ability. In order to achieve an intuitive design, we organized a multidiscipline research team and adopted the relevant design methodology in HCI (e.g., iterative design, and user-centered design). We actively involved all stakeholders, including music teachers, music therapists, CI children, and the school principal, in the design process.

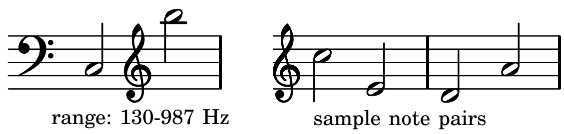


Figure 4.5: Range of *Higher Lower*, and minimum difference between the pairs of notes used for CI children.

4.3.3.1 Higher Lower (pitch perception)

The game begins by playing two notes. The child then indicates whether the first note is higher than the second, or vice versa (Figure 4.1a). The total range of the pitches is shown in Figure 4.5, while the minimum difference between two pitches can be altered according to the user's ability. Users can replay the sound by pressing a button on the interface. Incentives such as a game score and fireworks are provided in the game.

In our user evaluation, we followed the advice of the children's music educator and chose 7 semitones as the minimum difference between two notes. To a skilled musician this may appear to be a rather easy game, but test results show that some children with CI find this quite challenging.

4.3.3.2 Vocal Matcher (singing individual pitches)

In this game, users listen to a note, and then they sing the pitch and sustain it for 1 second until the note bar is filled up (Figure 4.1b). In order for a user to practice the pitches matching his/her vocal pitch range, the game will first search for the user's pitch range by testing both the lowest and the highest pitch values that the user can sing. When the pitch range is found, the program will log the data into the device, and will randomly select notes from this range for playing in the future. We provide automatic note checking for the produced pitch against the reference. When users are singing the correct pitch, its note bar will gradually fill up until they sustain that pitch

Figure 4.6: Karaoke Revolution in Playstation 3

for the note duration; when users are singing the wrong pitch, on the right of the note bar appears an arrow to indicate whether users should increase or decrease their pitch. Users can replay or skip the sound if they deem it too difficult to sing.

Following the advice of the children's music teacher, any pitch within 3 semitones of the correct one will be accepted. We also provide score and fireworks within the game as the incentives.

4.3.3.3 Ladder Singer (singing a melody)

To design this game, we began by studying the common features of existing Karaoke games (e.g., KaraokeParty [60], Karaoke Revolution [90], and Glee Karaoke [102]). In a Karaoke game, a singer sings along with on-screen guidance using a microphone and receives a score based on pitch, timing, and rhythm. We found that most of them display one row of pitch contour and another row of lyrics in parallel, with animation highlighting the relevant portion in time with the playback of audio track. Figure 4.6

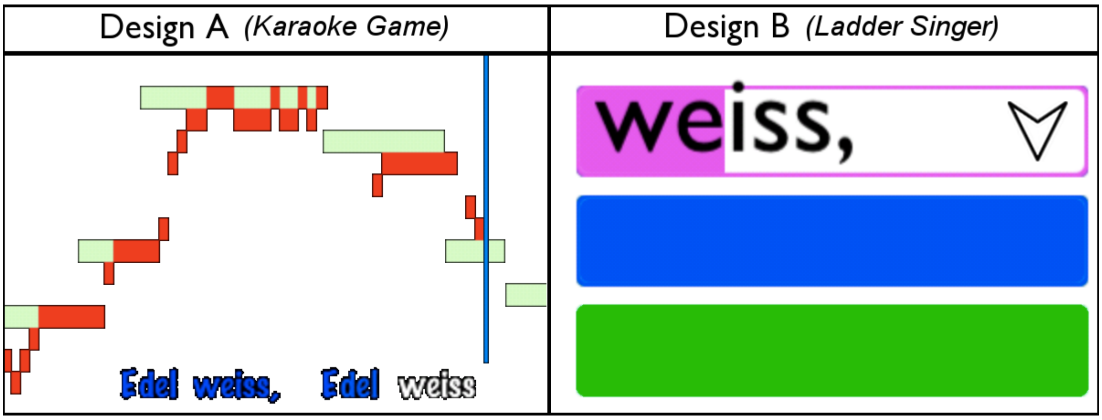


Figure 4.7: The comparison of two game designs. In Design A, the reference MIDI is in green; the users' pitch contour is in red. In Design B, the downward/upward arrow on the right means that users' pitch is higher/lower than the reference and they should lower/increase their pitch.

presents a Karaoke video game called Karaoke Revolution. In order to investigate the usability of this kind of games in our scenario, we implemented a Karaoke game incorporating the basic mechanism of Karaoke games on mobile devices shown in Design A of Figure 4.7. However, feedback from special educators and users suggested the following 2 problems:

1. **Pitch correction:** Design A uses a vertical bar to indicate the current singing progress, under which the user's pitch is displayed. However, it does not check the correctness of the detected pitch, and thus the user has to rely on the relative positions of their past pitch contour compared with the reference to do pitch adjustment. This incurs additional cognitive burden during the game play.

2. **Lyrics reading:** Compounding problem 1, lyrics are difficult to read as a user's visual field is already overloaded with information from reading pitch feedback, especially when lyrics are merely displayed like subtitles at the bottom of the screen while the pitch contour occupies the most screen space.

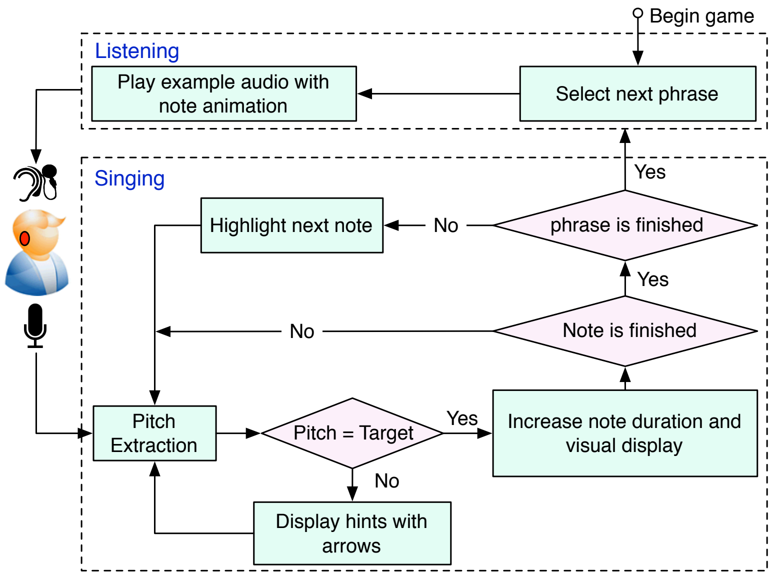


Figure 4.8: Internal game-state of *Ladder Singer*

These are not serious problems for adults and children with normal hearing, as they likely have the lyrics of these well-known songs memorized and are good at pitch detection and singing. However, our target group is younger children with CI, so a different design is necessary.

Design B in Figure 4.7 shows the interface design of *Ladder Singer*. We used a "color ladder", a simple metaphor used in their math textbooks, where notes from the lowest to the highest are "rung" on the ladder from the bottom to the top of the screen. In order to guide the user to sing each note, we first empty its corresponding note bar. To solve problem 1, automatic note checking as in *Vocal Matcher* is provided to help users to adjust their pitch. The game first detects users' pitch using algorithm in Chapter 4.2.1 and then compares it with the reference stored in a MIDI file in the mobile device. If the pitch matches the reference correctly, the note bar would keep being filled up for the duration of the note. Otherwise, it would display an arrow on the right to tell users the correct direction to move their pitch. To solve problem 2, we display the word inside its corresponding note bar. This way, all the necessary information - note, duration, lyrics, and hints for correction - are seamlessly integrated into the narrow space of a note bar. Furthermore, we break down the whole song into phrases so that children can learn the song phrase by phrase. As a result, it is easier for them to concentrate on both lyrics and note information simultaneously. Figure 4.8 shows the internal game state of *Ladder Singer*. There are two stages in the game: listening and singing. Users begin the game by selecting a musical phrase to listen to with note animation. During singing, the game checks the correctness of the user's singing pitch and provides feedback. Meanwhile, it will automatically proceed to the next note when users finish the current one, and return to the listening stage when they finish the phrase. We will validate the usability of Design B compared with Design A in Section 4.5.6.

4.3.4 Cloud Computing Service

In order to help the music teachers communicate with children with CI, we built a cloud computing service with the following main features (see Figure 4.9):

A. Individual progress tracking: Teachers can view a graphical visualization of a child's scores over a daily, weekly, or monthly period. They can listen to the singing recorded in the games to take note of any problem.

B. Enabling reciprocal interaction: Teachers can examine the children's singing, give overall rating, and post comments. The rating displayed is the collective average rating across all teachers. The social media interaction made available by the website allows children and teachers to communicate effectively with each other.

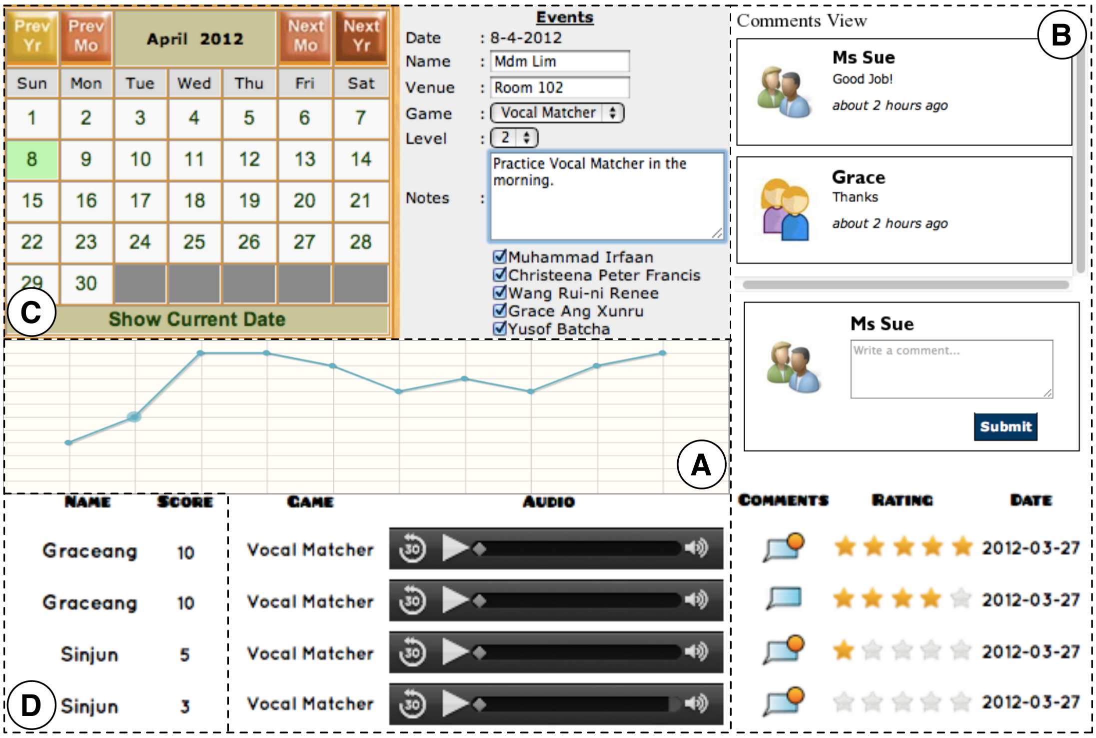


Figure 4.9: A montage of teacher view

C. Events planning: Teachers can plan children's habilitation in an event calendar, through which they can set/set up the time, location, game, and difficulty for a child to play according to his/her preference.

D. Leader board: Children and teachers can check the score leader board within one day, a week, and a month, adding a measure of competition to motivate practice.

4.4 Implementation

4.4.1 Games

The games were developed using Objective-C in iOS SDK. We adopted the cocos2d [23] framework for the graphics and animation rendering. The score layout layer,

Table 4.3: Performance comparison of *Vocal Matcher* between AQS and AU in our app on an iPod Touch (2^{nd}-generation).

	YIN		YIN FFT	
	AQS	AU	AQS	AU
CPU Usage (%)	28.49	53.47	27.57	37.06
Latency (ms)	0.021	0.624	N/A	0.022

which parses MIDI and lyrics files for scheduling the note animation and displaying lyrics respectively, was implemented using the C++ library libjdkmidi [6]. In order to permit widespread deployment, we targeted the older 2^{nd}-generation iPod Touches to reduce the devices' cost for children's parents. As a result, we had to take the limited computational power of the devices into consideration. We compared the computational cost and latency of two audio frameworks, Audio Unit (AU) and Audio Queue Services (AQS) in the CoreAudio framework. AU allows highest level of control and simultaneous audio I/O with low latency, and other high-level audio frameworks including AQS are built upon it.

To investigate the performance and latency of AQS and AU in our application, we implemented both in our application and performed the same tasks (i.e., pitch estimation and audio recording) in their callback functions. The pitch estimation algorithm is based on autocorrelation-based YIN algorithm ($O(n^2)$). The sample rate was 24000 Hz, and we used three buffers of 1024 samples ($\approx$ 43ms). We measured the average CPU usage of the application and the average latency of callback functions using Activity Monitor of instruments in Xcode 4 (Table 4.3).

In the experiment, we found that AQS had less CPU usage and latency. The reason is that although AU is the lowest level of audio framework, its render callbacks have a very strict performance requirement: Since the render callback lives on a real-time priority thread on which subsequent render calls arrive asynchronously, the current render callback must finish its computation before the next render call arrives. Otherwise, the program gets a gap in the sound [1]. For this reason, we must not perform a time-consuming task such as autocorrelation-based YIN algorithm ($O(n^2)$) or access the file system in the body of a render callback function in AU. Rather, AQS uses the buffer queue whose callback function gets called whenever its audio buffers come in. It allows computing with less strict time constraints so that we can synchronously perform an accurate but time-consuming algorithm as well as writing audio buffers to the file system. In order to handle both audio recording and real-time audio processing simultaneously, AQS is used in conjunction with Audio File Services that writes audio buffers into recording files.

In the callback function of AQS, we defined a fixed threshold to exclude frames of silence or irrelevant background noise and to preserve those representing potential singing voice. The volume was calculated by getting the decibel value from the root mean square of the audio signal within the frame. We empirically chose 30 dB as the threshold. We implemented spectral domain YIN algorithm [18] ($O(n \log(n))$) with vDSP framework to detect pitch for any frames, which were not deemed to be silence, to fully optimize the computational cost in the render callback (see Table 4.3).

4.4.2 Cloud Service

The back-end of the web service used PHP server to handle HTTP requests and MySQL for the database. For front-end, we use HTML5, JavaScript, CSS3, and jQuery, a commonly used JavaScript framework. Furthermore, the web service adopts the RESTful architecture. The metadata (including scores, user ids, and recordings in games) are automatically sent to the web server via JSON and are then parsed and stored into our database. This allows minimal end user actions, which makes for a seamless data transmission process and a better user experience.

4.5 User Evaluation

4.5.1 Participants

15 children with CI were selected at random from Canossian School (ages 6 to 10) for the hearing impaired. Their average hearing age after implantation is 4 years and 10 months. The evaluation approved by the school principal was carried out during normal school hours.

4.5.2 Apparatus

MOGAT was installed on 15 2^{nd}-generation iPod Touches. As they do not have built-in microphones, we plugged an audio adapter containing a microphone into each iPod Touch to enable its audio input. To provide better sound quality than the iPod Touch speakers, we connected children's cochlear devices directly with the audio adapters via children's own personal audio cables.

4.5.3 Procedure

The three games were evaluated in the order of *Higher Lower* (*HL*), *Vocal Matcher* (*VM*) and *Ladder Singer* (*LS*). Children were asked to play each game once everyday for two weeks under supervision. To evaluate the effectiveness of MOGAT in enhancing the children's musical habilitation, we measured their scores in the three games for two weeks. The experimental factor (i.e., independent variable) is the week with two levels (first week vs. second week). Chapter 4.5.4 describes the measures in 3 games. The experiment design is as follows:

15 subjects ×

3 games (*HL*, *VM*, and *LS*) ×

5 blocks per week (1 block per day) ×

2 weeks

= 450 tests in total

During our study, variables such as training materials (i.e., sound stimuli), training difficulties, and training duration (30 mins/per day) were controlled throughout two weeks.

The second test was to evaluate their experience during the games by asking them to complete a user questionnaire (see Chapter 4.5.5).

In order to understand whether *LS* is more useful for learning singing than Karaoke, we conducted a usability evaluation by comparing *LS* with the Karaoke Game that we implemented (see Chapter 4.5.6).

Finally, we asked the teachers to use our web service and then complete a questionnaire about the web service (see Chapter 4.5.7).

During the evaluation, we sought to answer the following three questions:

1. *Can MOGAT improve children's pitch perception and production abilities?*

2. *Do children find MOGAT intuitive and fun to use? Can MOGAT motivate them to practice?*

3. *Can MOGAT enhance a teacher's ability to organize and manage children's habilitation?*

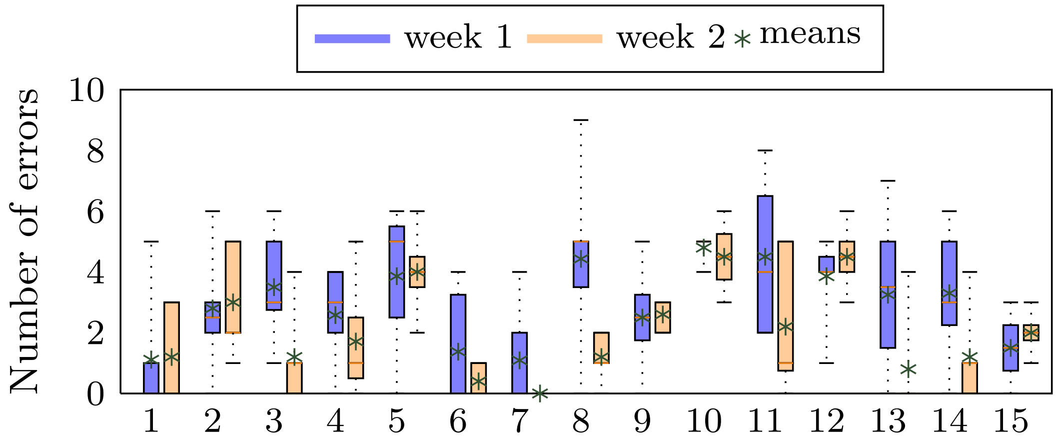
4.5.4 User Performance Evaluation

Higher Lower (*HL*): To match the initial pilot study, we tracked the number of incorrect answers to measure children's pitch perception skills.

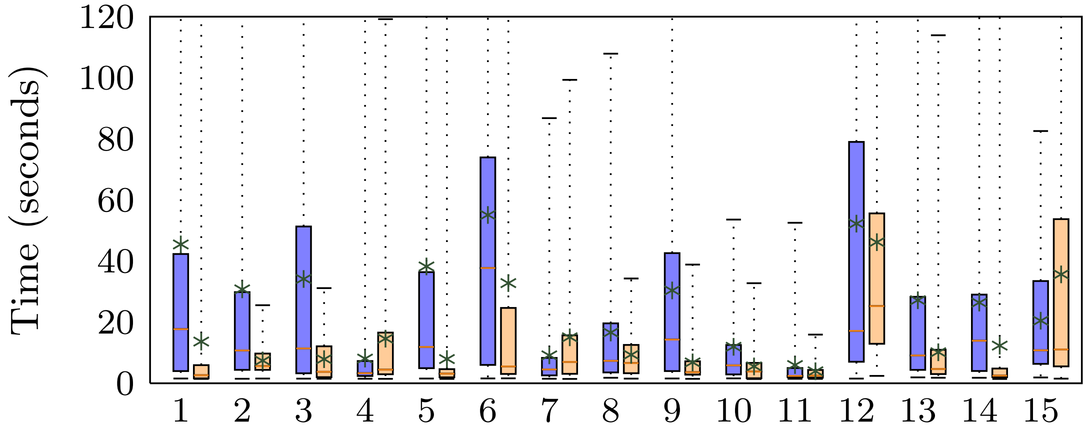
Vocal Matcher (*VM*): Since children must sing a pitch for 1 full second before the game moves on to the next one, the total time a child spends on each exercise should indicate how quickly they can reach the correct pitch. Intonation skill is therefore inversely proportional to time. We excluded those recordings with extremely long duration (≥ 120 seconds) from when children were not familiar with the interface.

Ladder Singer (*LS*): A music phrase links many individual notes. We consider the total time a child spends on completing all the notes within the phrase to measure their pitch production skills in singing Edelweiss.

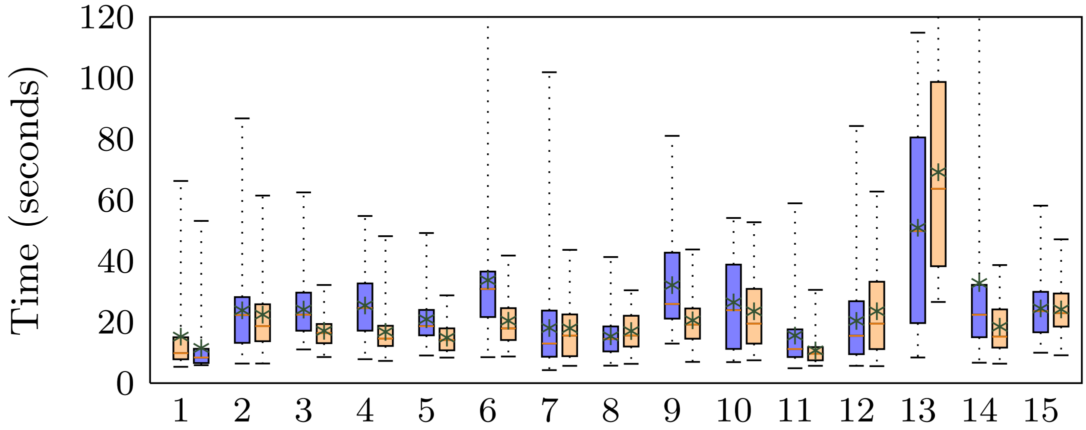
Figure 4.10 shows the children's individual scores in the first and the second weeks. Since the data significantly deviate from a normal distribution, we used Kruskal-Wallis H test to compare the means from two weeks, which was a weekly based test adopted by the existing studies [40, 126]. Table 4.4 shows the results. Furthermore, we collected all the scores from 15 children, calculated the average score for each week and compared their means using Kruskal-Wallis H test as the data did not follow a normal distribution. The mean error in *HL* decreased significantly from 2.82 to 1.98 ($p < 0.05$). The mean time for completing single pitch in *VM* decreased significantly from 25.99s to 13.86s ($p < 0.01$). The mean time for completing single phrase in *LS* decreased significantly from 24.33s to 18.97s ($p < 0.01$). Furthermore, only one child (S13) who did significantly worse for *LS* in the 2nd week than in the 1st week, while none of the other children who did worse in the 2nd week showed statistically signif-



(a) Scores for *Higher Lower* (student number)



(b) Scores for *Vocal Matcher* (student number)



(c) Scores for *Ladder Singer* (student number)

Figure 4.10: Evolution of children' scores during the user evaluation: Children's scores in the first week are compared to those in the second week for all three games. Lower numbers indicate fewer mistakes, i.e., higher proficiency.

Table 4.4: The Kruskal-Wallis H test results on comparing each child's score means in the first week and his/hers in the second week (*$p < 0.05$,**$p < 0.01$). The scores are printed in boldface when there is improvement in their second-week scores compared to their first-week scores.

Users	*Higher Lower*		*Vocal Matcher*		*Ladder Singer*	
	The mean of each user's scores					
	1st week	2nd week	1st week	2nd week	1st week	2nd week
S1	1.11	1.2	**45.44**	**13.65** **	**15.23**	**11.51**
S2	2.8	3	**30.74**	**7.41** **	**23.86**	**22.44**
S3	**3.5**	**1.2** *	**34.13**	**7.89** **	**24.11**	**17.13** **
S4	**2.58**	**1.71**	8.08	14.60	**25.45**	**16.79** *
S5	3.86	4	**38.24**	**7.93** **	**20.94**	**14.9** **
S6	**1.38**	**0.4**	**55.09**	**32.79** *	**33.72**	**20.44** **
S7	**1.09**	**0**	9.14	15.05	**18.07**	**17.99**
S8	**4.43**	**1.2** *	**16.61**	**9.34**	15.35	17.07
S9	2.5	2.6	**30.39**	**6.83** **	**32.11**	**20.58** **
S10	**4.8**	**4.5**	**11.93**	**5.51** **	**26.45**	**23.55**
S11	**4.5**	**2.2**	**5.97**	**3.94**	**15.58**	**10.72**
S12	3.86	4.5	**52.26**	**46.18**	20.39	23.56
S13	**3.25**	**0.8**	**27.18**	**10.15** **	50.92	69.12 *
S14	**3.3**	**1.2**	**26.41**	**12.32** **	**32.79**	**18.49**
S15	1.5	2	20.47	35.65	**24.49**	**24.15**

icant regression. But since S13 has showed the improvement in both *HL* and *VM*, it is possible that he lost the interest in *LS* or he needed more time in learning an entire melody in *LS* than the other two games. Based on the results and feedback from the other students, the second possibility is more reasonable. The improvement among subjects was also highly variable. For *HL*, 9 out of 15 children improved, and 2 out of the 9 (S3 and S8) showed statistically significant improvement ($p < 0.05$). For *VM*, 12 out of 15 children improved, and 9 out of the 12 (S1, S2, S3, S5, S6, S9, S10, S13, and S14) showed statistically significant improvement ($p < 0.05$). For *LS*, 12 out of 15 children improved, and 5 out of the 12 (S3, S4, S5, S6, and S9) showed statistically significant improvement ($p < 0.05$). In sum, 5 out of 15 children (S3, S6, S10, S11, and S14) improved in all three categories and one (S3) had significant improvement across the board.

The reason that 6/15 students did worse in *HL* might be that only one score is not enough to motivate students in playing the games. So more praises or incentives should be provided. For example, we should give them some bonuses and praises (e.g., “5 Combo! you are doing great!”) if the student scores consecutively, or provide some encouraging words (e.g., “Hurry up! You can do it”) if their score is below a certain value. The incentives can be in the form of their familiar concepts such as fruits or candies. In our study, only one student did worse in *LS* showed significant degradation, so generally MOGAT achieved our expected results. Although the duration of study is relatively short (we expect to have 1-month test for each game in the future work), there was one student (S3) who consistently improved across all 3 games. We found that this student played the game very seriously, so his improvement was attributed to his dedication in training his music skills. Another example is S7 who improved her music skills significantly based on the school principal’s description: “This child also improved her speaking ability much faster although she was late implanted at the age of 9. Before then, she was wearing hearing aid device. More surprisingly, her parents are both deaf. Can you believe that? But she talked very frequently to her cousin who helped her a lot in establishing her verbal communication ability.”. Basically the principal felt it reasonable that the child did well in these games for training her music skills and reflected that the reason was largely due to her superior intelligence.

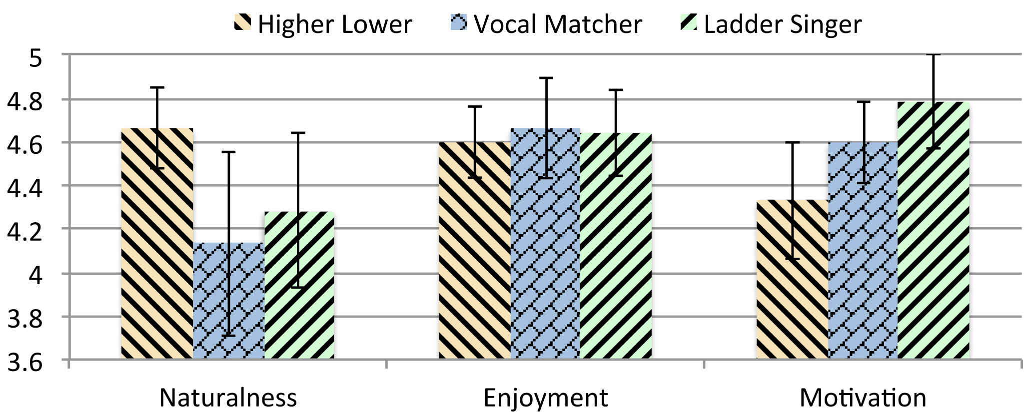


Figure 4.11: Results of user experience

4.5.5 User Experience

Our user experience evaluation is based on the following three criteria: *naturalness*, *enjoyment*, and *motivation*. At the end of the first week, the children were asked to rate questions using a five-point Likert scale. The questionnaire is in Appendix 12.

- *I feel the game is easy to play.*
- *I enjoyed playing this game.*
- *I would play this game for fun if I had it.*

Figure 4.11 shows the results averaged over all the children. In terms of *naturalness*, *HL* is the most intuitive one to play with. *VM* is a simplified version of *LS* and thus has a practice and carryover effect on *LS*. Therefore, although *LS* is relatively hard to play with, the naturalness score of *LS* was slightly higher than *VM*. The children enjoyed playing three games to a similar extent and expressed strong motivation to play them for fun in the future (all ratings are over 4.3 out of 5), especially *LS* (4.8 out of 5).

4.5.6 Ladder Singer vs. Karaoke Game

First of all, we implemented a typical Karaoke Game in mobile phone according to the description in Section 4.3.3.3. Figure 4.12 shows the interface of the implemented Karaoke game. Then we organized a comparison study between Karaoke Game and *LS*.

During the process, we randomly chose the order of two games to control for the practice and carryover effects. After each game, users rated the games using three additional factors (*pitch correction, lyrics reading, training effect*) as below in addition to the criteria of user experience. We used the questionnaire in Appendix 13.

- *I can correct my pitch based on the feedback from the game.*
- *I can follow the lyrics during singing.*
- *The game can help me with learning this song.*

Figure 4.13 shows the results averaged across 15 users. *LS* was ranked higher than Karaoke Game in all aspects. During the experiment, we observed that most of their pitch contours displayed in Karaoke Game were quite flat, which illustrates that they could not easily correct their pitch according to the reference. However, *LS* requires

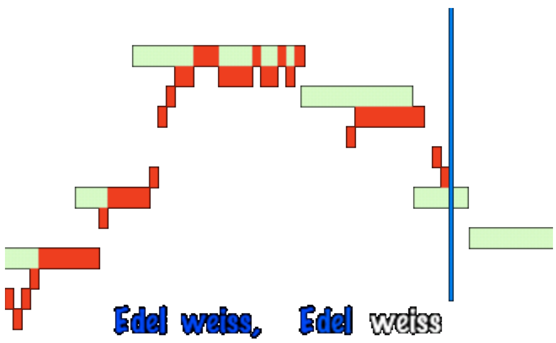


Figure 4.12: The interface of the implemented Karaoke Game

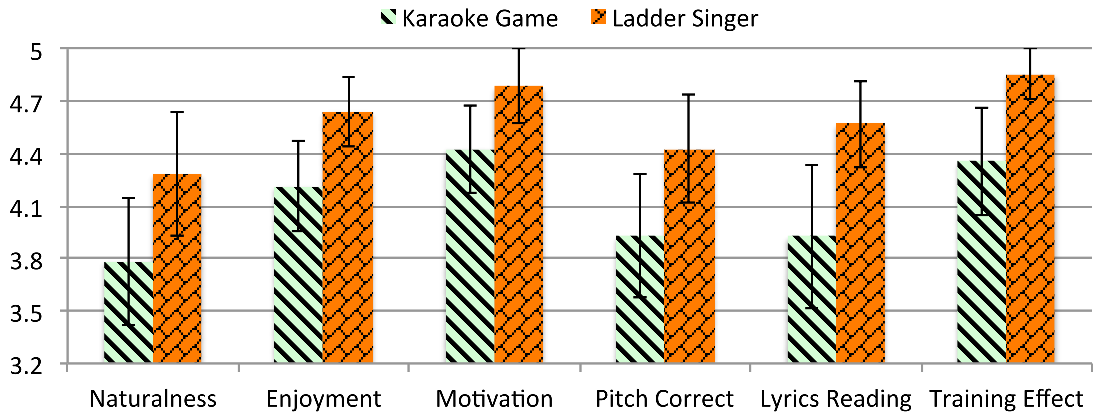


Figure 4.13: Karaoke Game v.s. *Ladder Singer*

each note to be performed correctly before moving on to the next note, thus prompting pitch correction without fail.

4.5.7 Web Service Evaluation

Our purpose is to evaluate whether our cloud-based web service can enhance special teachers in supporting the children' musical habilitation. We recruited two special musical educators in this study. First, they received instructions demonstrating the interface and features of the website. Then they were asked to use the interfaces and website without our help. Finally, teachers answered a questionnaire related to the usability of the web service. The detailed evaluation procedure and the questionnaire are in Appendix 14.

Overall, the participants responded that MOGAT web service was fairly easy to use, all giving it a 4 on a scale of 1 (extremely difficult to use) to 5 (extremely easy to use). Participants also expressed satisfaction and willingness to use the website to support children's habilitation. However, they requested that we improve the documentation for more advanced features, such as setting up an event. They asked us to describe the ratings in more details on the website so that different teachers can keep the rating criteria consistent with each other. Furthermore, one educator wished to track the children's performance by hours so that she could know when the best time would be to carry out activities involving MOGAT. The website should thus be able to offer statistics of game scores for each and every hour during the day. Also, they requested event planning and score ranking in order to facilitate class-wide activity organization and interclass competition. Meanwhile, teachers are cognizant of the potential of the web service to support other subjects.

4.6 Discussion

While most children benefited from MOGAT-enhanced auditory training, individual variability in the amount of improvement remained large. Many factors may affect the outcomes. For example, training materials (i.e., sound stimuli), training difficulties, and training duration. Although these variables were controlled in our user evaluation, we have yet to fully understand how they affect individual performance. It could help us to design the most suitable individualized training protocols.

We would like to mention that teaching hearing-impaired children to sing, something children with normal hearing do, can enhance their confidence and self-esteem. Moreover, singing can help them improve their speech intelligibility. It is almost impossible for hearing-impaired children to achieve the same skills by merely playing any other video games.

It is important to emphasize that throughout the project we aim to train the user's relative pitch production ability rather than their absolute pitch ability, because each child has his/her own vocal range. The singing evaluator was thus developed to transpose the pitch to fit their vocal range.

The limitation of the work is that the audio-MIDI alignment algorithm is not ideal and requires manual adjustment. Nevertheless, a statistical model can solve this problem. First, the DTW-based algorithm can help to build the training dataset, ridding the need for human annotation. We can then train a Hidden Markov Model (HMM) on the dataset to do the alignment. It will become our future work.

4.7 Summary

We have presented the design, development, and deployment of MOGAT, the first integrated training system to supplement the music habilitation of pre-lingually deaf children. In our pilot study, we found that, compared with children with normal hearing, children with CI are significantly worse in their pitch perception and production skills. Based on the 4 design objectives derived from the pilot study, three mobile musical games were designed specifically for their musical needs and tailored to cognitive abilities. In order to maximize the limited teaching resources, we developed a cloud-based web application to connect special music teachers with children with CI to provide them with administrative and teaching support. A comprehensive user evaluation has demonstrated the effectiveness and efficiency of MOGAT in enhancing children's musical habilitation as well as the teaching experience of music educators.

Chapter 5

Group Music Therapy for Individuals with Muscular Dystrophy: A Pilot Study

5.1 Introduction

According to the National Institute of Neurological Disorders and Stroke (NINDS), Muscular Dystrophies (MD) refers to "a group of more than 30 genetic diseases characterized by progressive weakness and degeneration of the skeletal muscles that control movement" [79]. MD is characterized also by muscle "wasting and contractures, that are usually progressive and sometimes life threatening" [100]. The age of onset, rate of progression, and pattern of inheritance varies, depending on the specific disease, the distribution, and extent of muscle weakness [79]. The most common is Duchenne Muscular Dystrophy, which "affects all voluntary muscles, and the heart and breathing muscles" [101]. Other types of MD include: Becker MD, Facioscapulohumeral

MD and Myotonic MD. Presently no specific treatment can stop or reverse any form of MD, though research is ongoing to "understand MD and to develop techniques to diagnose, treat, prevent, and ultimately cure the disorder" [79].

The incidence for MD varies, as some forms are more common than others. Its most common forms in children, Duchenne and Becker MD, alone affect approximately 1 in every 3,500 to 5,000 boys or between 400 and 600 live male births each year in the United States [78]. Duchenne MD primarily affects boys, although girls and women who carry the defective gene may show some symptoms. No published statistics are available for Singapore's MD incidence, but extrapolation calculation based on U.S., U.K., Canada, and Australian statistics [48, 49] suggested 6-8 per year.

5.2 Experiments

5.2.1 Research Hypotheses

The following research hypotheses were established for the purpose of this study:

H1: *Subjects have greater perception of enjoyment in group music therapy sessions using MOGCLASS.*

H2: *Subjects have greater perception of success in group music therapy sessions using MOGCLASS.*

H3: *Subjects have higher motivation level in group music therapy sessions using MOGCLASS.*

5.2.2 Subjects

We used convenience sampling to recruit a total of 7 subjects. They attended regular music therapy group at a non-profit community organization for individuals with MD and progressive muscle weakness. The subjects were aged 14 to 29 years and wheelchair-bound. Upon getting approval from the organization's management committee (as there was no ethics committee that could grant study approval for non-hospital/university-based subjects), all subjects and their parents or guardians (as applicable) were informed about the study protocol and were given the opportunity to ask questions. All the subjects' parents and the investigators have signed the consent forms in Appendix 15. Participation in the study was voluntary and subjects were assured that they were able to withdraw from the study at any time, with no consequences.

5.2.3 Study Design

The current study was a within-subject design study comparing the conditions of acoustic musical instruments and MOGCLASS. The study factors include a two-level instrument and a three-level session. The study comprised three sessions using acoustic musical instruments, followed by three sessions using MOGCLASS. All other variables such as therapists, MOGCLASS developer, room where sessions were conducted, and session plans and duration were controlled throughout the study. A board-certified music therapist implemented the six-session program.

7 subjects ×

2 instruments (MOGCLASS and traditional musical instruments) ×

3 sessions

= 42 tests in total

5.2.4 Design Rationale

The above design was chosen due to two reasons. First, fewer subjects are needed in a within-subjects since each subject is tested on all levels of a factor. Due to the small MD population in Singapore, the recruiting and scheduling of the subjects was really hard. There is an advantage in organizing the within-subjects study as fewer subjects were involved. Another advantage is that there is less variance due to *participant disposition* (since there are fewer subjects). A subject who is predisposed to be meticulous (or reckless!) will likely exhibit such behavior consistently across all conditions. This is beneficial because the variability in measurements is more likely due to differences among conditions than to the behavioural differences between subjects. We thus chose to use within-subjects design in order to minimize the differences within the individuals and to examine the variability within the instrument factor in more details.

5.2.5 Questionnaire Design

Two survey forms were created for the purpose of this study. Form A (see Appendix 16) focused on the subject's background so as to have a better understanding of their exposure to technology and musical training (we are not allowed to disclose the results of Form A due to the privacy issue). The second questionnaire, Form B, was created to evaluate the subject's perception of success, motivation, and enjoyment in both study conditions during music therapy group sessions. The items on the questionnaire were created by modifying some questions from the questionnaire in Kwang Suk Yoon's work [128]. We adopted a 7-point Likert scale, which labelled response from "strong disagree" to "strongly agree" with numbers one through seven. Subjects circled a number in response to each statement.

All subjects were required to complete Form A and B. Form A was administered prior to the study, and Form B was at the end of each session. One of the investigators who did not conduct the session clarified any questions during this process, so as to minimize contamination of the data.

5.2.6 Acoustic Musical Instruments and MOGCLASS Setup

We used various acoustic musical instruments during the sessions: For example, tambourines with skin head, small djembe (drum from Western part of Africa), ocean drum, chimes on stand, cymbal on stand, cabasa, multi-tone drum, wrist bells, small and regular shakers/maracas, handbells, agogo bell, and triangle. Most of the instruments were played using mallets.

MOGCLASS consists of a set of networked mobile devices as music controllers, laptops as servers to synthesize sound, and loud speakers to overcome the problem of insufficient volume of the speakers within mobile devices. The hand-held component for the user weighs 115 grams (4.1 oz). The interfaces of MOGCLASS include Hitter, Tapper, and Slider. The Hitter interface mimics the drums to support body percussion; the Tapper simulates xylophones or mallet instruments; the Slider represents violins. The design of the user interface in MOGCLASS originates from the music curriculum of local primary schools. However, in order to support MD clients, we redesigned the interface to suit their specific characteristics. For example, we adjusted the sensitivity of the Hitter interface to match the subjects' weaker hand strength. In addition, the number of buttons in the Tapper interface was changed from twelve small buttons to one big button covering the whole screen. Subjects could easily trigger the button

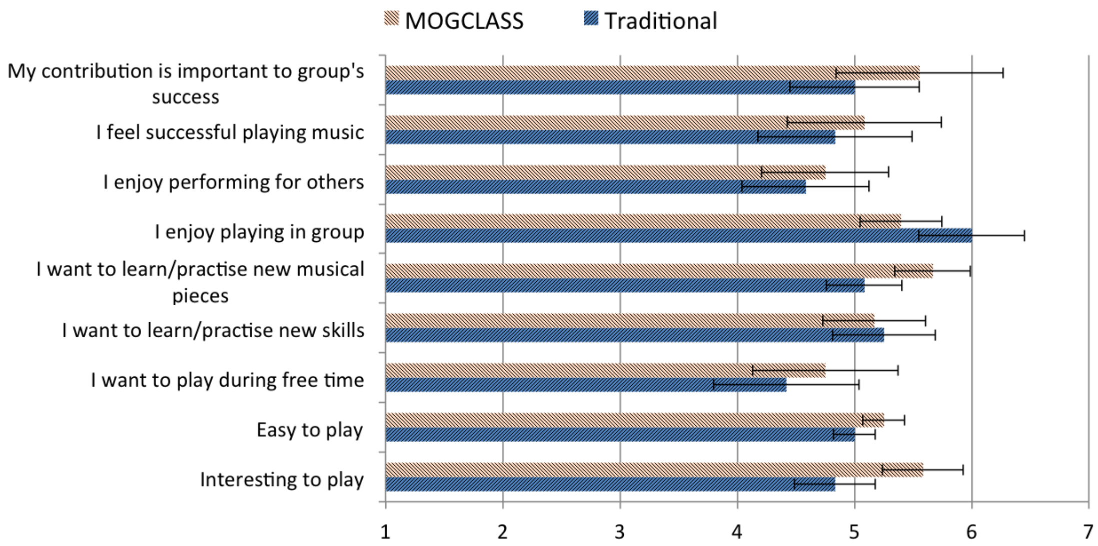


Figure 5.1: Data from Form B. The x-axis is the 7-point Likert scale from "strongly disagree" (1) to "strongly agree" (7).

by touching anywhere on the screen. The MOGCLASS system consisted of percussion (e.g., bass drum, snare drum, high hat, crash cymbal, cowbell, cabasa, and other sounds) and pitch-based sounds (e.g., marimba and other sounds).

5.2.7 Session Plan

Each session, lasting thirty minutes, involved a familiar routine that included breathing exercises, physical warm-up exercises (involving movements from head to toe), a rhythm band activity, and either a structured percussion exercise or a melodic activity.

5.2.8 Results

Only four subjects attended all six sessions. Three missed at least one session due to medical appointments or extenuating circumstances, and their data were not included in the analysis. Subjects who attended all sessions ($n = 4$) had the diagnosis of

Table 5.1: Analysis of second Form B results: one-way ANOVA test. (Methods 1 and 2 are traditional music instruments and MOGCLASS respectively)

Statements on Form B		METHOD	MEAN	Std. Error	F(1,6)	P
1. Interesting to play		1	4.833	0.345	2.359	0.175
		2	5.583	0.345		
2. Easy to play		1	5.000	0.177	1.000	0.356
		2	5.250	0.177		
3. Like to play during free time	Motivation	1	4.417	0.622	0.144	0.718
		2	4.750	0.622		
4. Want to play to learn/practice new skills		1	5.250	0.440	0.018	0.898
		2	5.167	0.440		
5. Want to play to learn/practice new musical pieces		1	5.083	0.325	1.615	0.251
		2	5.667	0.325		
6. Enjoy playing in the group	Enjoyment	1	6.000	0.450	1.111	0.332
		2	5.400	0.349		
7. Enjoy performing for others		1	4.583	0.542	0.047	0.835
		2	4.750	0.542		
8. Feel successful playing in the group	Perceived Success	1	4.833	0.659	0.072	0.797
		2	5.083	0.659		
9. Feel personal contribution is important to the group's success		1	5.000	0.553	0.378	0.561
		2	5.556	0.714		

Duchenne MD. We analyzed the collected data using the repeated-measures ANOVA test. The between-subject factor was the instrument (traditional musical instrument vs. MOGCLASS). Table 5.1 and Figure 5.1 summarize the results of Form B.

Based on the results, it is not definitive that MOGCLASS led to a higher level of perceived enjoyment (**H1**). The use of MOGCLASS garnered higher levels of success reported by subjects, though not significantly higher (**H2**). Finally, the use of MOGCLASS did not consistently lead to higher levels of motivation (**H3**).

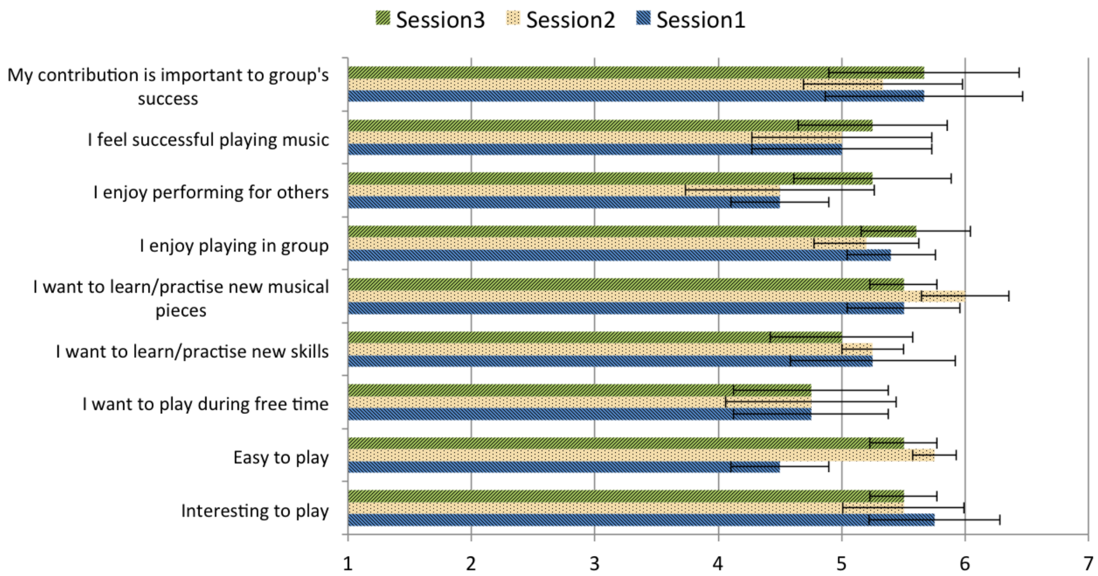


Figure 5.2: Data of session-to-session comparison for traditional instruments condition. The x-axis is the 7-point Likert scale from "strongly disagree" (1) to "strongly agree" (7).

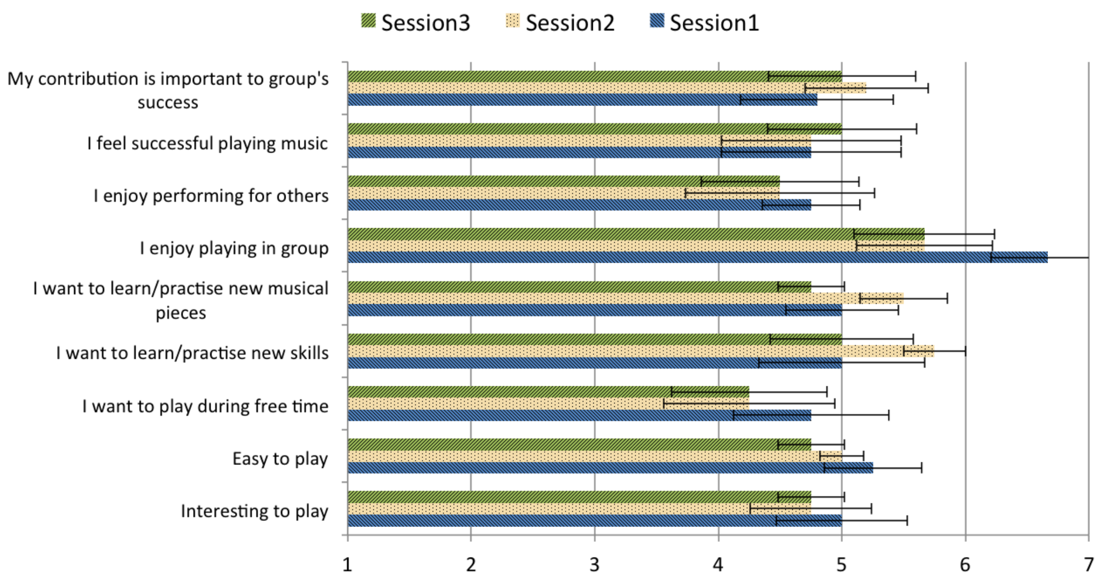


Figure 5.3: Data of session-to-session comparison for MOGCLASS condition. The x-axis is the 7-point Likert scale from "strongly disagree" (1) to "strongly agree" (7).

The ratings were also compared from session to session in the traditional instruments and MOGCLASS conditions respectively (Figures 5.2 and 5.3) for trends. It was noted that for the traditional instrument condition, statements relating to the ease, interest factor, ratings decreased over the sessions consecutively, while statements related to perceived success elicited increased ratings over the sessions. Data were also compared from session to session in the MOGCLASS condition. It was noted that mean responses to statements 2 and 5 for the 2nd MOGCLASS session were higher compared to the 1st MOGCLASS session, though not significantly so.

5.3 Discussion

For seven out of nine questions, MOGCLASS rated higher than traditional instruments, though the difference was not statistically significant. Specific findings follow: subjects found MOGCLASS more interesting (5.583 vs. 4.833) and easier to play (5.25 vs. 5.00). Subjects also liked to play it during their free time more than traditional instruments (4.75 vs. 4.42), and they were more eager to learn or practice new musical pieces using MOGCLASS (5.67 vs. 5.08). They also enjoyed performing music for others using MOGCLASS more (4.83 vs. 4.75) and perceived more success using MOGCLASS than traditional musical instruments (5.08 vs. 4.83). Finally, they felt that their contribution to the group was important using MOGCLASS compared to traditional instruments (5.56 vs. 5.00). The higher ratings for MOGCLASS may be due to the relative ease with which sounds were made, as the mobile device's sensitivity was adapted to match the subject's physical ability. Hence, with a light shake or touch, the subjects were able to make loud sounds (as volume was also set by the designer). Subjects also asked for more MOGCLASS sessions after study was completed, demonstrating continued interest.

For questions four and six (wanting to learn or practice new skills and enjoyment of playing in the group respectively), subjects rated traditional musical instruments higher than MOGCLASS. A few possible reasons include: skill required to make a sound with MOGCLASS was limited to tapping on the screen or shaking the device - which, though simple, could be experienced as being boring and unrealistic. Subjects commented that while traditional instruments produce different sounds when played a different way, such as with a different angle or impact of contact, MOGCLASS sounded always the same no matter how it was shook or tapped on. This created a one-dimensional sound that discerning users may notice and hence derive less enjoyment. Also, traditional musical instruments provide instantaneous auditory and vibro-tactile feedback, while MOGCLASS produced the only auditory feedback from the same loud speaker. As there was a slight delay in the sound, it made it more difficult for subjects to locate their own sound(s). Finally, subjects also commented that MOGCLASS was heavy, which taxed their already weak muscular strength. Also, subjects may have been more worried not to drop MOGCLASS and hence concentrated more on not losing grip on it, therefore reporting a lower level of enjoyment.

Lastly, data were also compared from session to session in the traditional instrument condition to detect trends. The marked improvement for statement #2 shows that MOGCLASS was easier to play after being adapted to their physical abilities.

It is also worth noting that the general ratings of perceived enjoyment, motivation, and success for both conditions were high - subjects agreed that they enjoyed making music in the group, felt successful, and were motivated to learn or practice new skills using musical instruments/MOGCLASS. This demonstrates that the subjects were enjoying group music therapy sessions. Enjoyment of making music in the group scored the highest for the traditional musical instrument condition. Playing musical instruments as a way to maintain hand strength and range of motion is motivating and enjoyable particularly in the group setting. This lends support to the long-held belief that music therapy (in this case, group music therapy sessions) is appropriate and enjoyable for clients with MD.

5.4 Summary

There is a great need for music therapy research with MD clients, with particular emphasis on the use of assistant technology. This study, while attempting to fill a significant void, faced a number of limitations. The sample size was relatively small. A bigger-scale study would give a clearer indication of the preferences of clients with MD. In order to extend our m-learning system to this special user group, adaptation of both software and hardware is a must. For example, in the first MOGCLASS session, the devices were not yet fine-tuned to match the subject's ability, hence the MOGCLASS condition was not held constant. After we fine-tuned the user interface to match their abilities, their scores of easiness and collaboration increased. In contrast, traditional instruments did not require any fine-tuning. As such, subjects tended to choose traditional instruments with which they had experienced prior success. However, MOGCLASS was a new experience for them, and the device was identical - it was impossible to make hardware adaptations (e.g., so that they had a more secure grip) given existing time and resource constraints. Perhaps future improvements can reduce the device weight from the present 115 grams, add some sound variations according to the way it was shaken or tapped, and further shorten the time lag between movement and auditory output. In addition, subjects could use individual earpieces to locate their own sounds with ease.

5. GROUP MUSIC THERAPY WITH INDIVIDUALS WITH MUSCULAR DYSTROPHY

Chapter 6

Conclusions and Future Work

6.1 Summary

In this dissertation, we have proposed 2 research questions with respect to 3 types of user groups: grade school students with normal hearing, children with cochlear implants, and individuals with muscular dystrophy. In order to address these research questions and gather user feedback, we have visited 5 local primary schools, including one with the hearing impaired, 2 hospitals, and 1 association for muscular dystrophy in Singapore. Meanwhile, we have interacted, interviewed, and worked with over 260 students and 10 educators. We conducted research studies to provide pragmatic paradigms for researchers in designing, implementing, and evaluating educational and assistive systems in the future. To summarize our work:

- **MOGCLASS: a collaborative system and multimodal music environment based on networked mobile devices and its study in real classroom settings.** It describes a novel and useful system and guidelines for designers of collaborative systems for classroom music education. Moreover, it presents practitioners with a clear method for iterative design and system evaluations.

- **MOGAT: mobile games with auditory training for children with cochlear implants and its study.** It describes the design, implementation, and evaluation of cloud-based mobile games with auditory training for children with cochlear implants. It can serve as a blueprint for effective mobile-based rehabilitative systems in the future.
- **Using MOGCLASS in group music therapy with individuals with muscular dystrophy: a pilot study.** It investigates the effectiveness and usability of the technology intervention during group music therapy with individuals with muscular dystrophy. It shows that assistive technology has moderate potential in music therapy research for muscular dystrophy clients, and it also offers insights into designing healthcare related systems.

6.2 The Solutions to Research Questions

Here we will provide our solutions to the research questions.

P1: How should an m-learning system be designed to enhance music education in the classroom for normal children?

S1: The system design of this kind should be focused on the following 3 aspects: student motivation, classroom collaboration, and teacher management. First of all, motivation is an essential factor in learning any subjects, especially music. The m-learning systems for music education should provide students enough motivation by lowering the technical entry level and supporting all kinds of music interactions/movements (e.g., shaking, sliding, and tapping) and instrumental sounds (i.e., rhythmic and melodic instruments). For example, the MOGCLASS system provides various musical interfaces, interactions, and synthesized sounds on mobile devices and lowers the instrument technical demand, making it readily accessible for children to play and experiment with various music genres.

Moreover, the m-learning systems should embrace the collaborative learning throughout the learning process, which should utilize network technology such as *virtual sound space*, bonjour, and mobile distributed system synchronization. *Virtual sound space* is a collaborative interaction that enables students to practice music with other group members "silently", as the sound is heard only by members of the group. With *virtual sound space*, the system improves student-student (n-to-n) collaboration. As in our user study, this feature effectively solved the cacophony problem during student practice.

From the management point of view, systems should enhance productivity and efficiency for the instructors at large. The systems should improve the teacher-student (1-to-n) collaboration/communication by adopting the master-slave architecture. For example, we created a mobile p2p networked architecture in the MOGCLASS system that can be easily configured and deployed. Teachers can readily monitor student status from their mobile devices and manage student learning process at their fingertip (e.g., mute/unmute devices, enable *virtual sound space*, and initiate scaffolding simultaneously on all student devices).

P2: How should an m-learning system be designed to be accessible to individuals with disabilities (e.g., children with cochlear implants and individuals with muscular dystrophy), targeting for their special needs?

S2: Firstly, the design of such m-learning systems should take into account their disadvantages in their physical and cognitive abilities. For children with cochlear implants, we studied their disadvantages by quantitatively assessing their music skills compared with normal hearing children (i.e., what they are lacking in terms of music perception and singing ability compared with their normal hearing peers). The quantitative music assessment also turns into the a set of design objectives that guide our system implementation.

Secondly, the m-learning systems should strike a balance between their intellectual/physical ability and the variety of control parameters or the device sensitivity. For example, a method for differentiating the relationships of two tones is too simple for children with CI, while a method for singing single pitch according to the visual feedback is more suitable for them to achieve reasonable performance gain. Another example is the individuals with MD. Since those people have weak muscular strength, we made the Hitter interface in MOGCLASS easier to be triggered by increasing its sensitivity. Meanwhile, due to their weakness in precisely pointing at the small buttons, we limited the number of the buttons on the Tapper interface to one and made it as large as the whole touch screen. In sum, adaptive interface is the key, which should allow users to control the devices with the minimal difficulty initially and with increased controllability if they have made progress.

Furthermore, the design of such m-learning systems should cater to both learners and instructors, making it easy for instructors to support a large number of learners locally and remotely. For instance, MOGAT incorporates both mobile games and web service, which allows the synchronization between the student devices and the teacher web service and enables teachers to monitor and support student performance in both the short- and long-term period. With such features, the music therapists are able to provide professional training and administrative support to a group of children with CI simultaneously.

6.3 Contributions

The contributions made in this research fall into three categories: a) MOGCLASS/-MOGAT methodology, b) empirical results, c) design recommendations.

6.3.1 MOGCLASS/MOGAT methodology

Contributions 1-4 summarize the MOGCLASS/MOGAT methodology.

Contribution 1: Development of a method for rapid sliding up or down (glissando) the music scale and a slightly tremulous effect (vibrato) as on a violin using a multi-touch screen, whilst provide rectangle note regions to help the amateur to identify the frequency on the simulated violin string.

The intent of the Slider interface design is to simulate the violin on the mobile device with a multi-touch screen using glissando and vibrato movements and to permit a smooth and natural transition from a novice to an expert in playing this interface.

Contribution 2: Development of a method (scaffolding) for visualizing the music scores to reinforce the user's cognitive mapping between the music notes to play and the locations of the keys on the touch screen, whilst provide a way to synchronize the aforementioned visualization on multiple devices.

The scaffolding system translates the music sheet to the real-time visual guidance along with the musical interface, which allows the users to easily locate the next key to play on the touch screen and to reinforce the memory of the note-key mapping. In order to facilitate the class-wide practice, the MOGCLASS system can launch the scaffolding systems on multiple student devices simultaneously from the teacher interface.

Contribution 3: Development of a collaborative interaction method (virtual sound space) that enables users to perform music on mobile devices in a group using headphones, as their sounds are shared among the group members through wireless network.

Apart from mobile virtual musical instruments, the MOGCLASS system also emphasizes the role of collaborative learning throughout the entire m-learning process. By sharing the musical messages and simultaneously synthesizing the peer's sounds on one's devices, *virtual sound space* allows students to practice performance with their group members via headphones. This feature effectively solved the cacophony problem during student practice.

Contribution 4: Development of a method (Ladder Singer) for visualizing the music scores to reinforce the user's cognitive mapping between 4 elements that the user needs to perform (i.e., (1) the music note to sing; (2) the syllable to pronounce, (3) the duration to sustain the note; and (4) the direction to adjust the pitch) and the visual feedback on the touch screen, whilst provide a two-stage asynchronous way to learn singing a melody (first listen and then sing A cappella).

Ladder Singer provides an intuitive metaphor (i.e., color ladder) to represent all the music notes in a song. This color ladder, when combined with visual feedback such as syllable, duration, and the direction for adjusting pitch, helps users to correct their pitch and identify the lyrics during singing. Furthermore, the two-stage asynchronous way of *Ladder Singer* allows the users to focus on listening to and imitating the example respectively.

6.3.2 Empirical results

Contributions 5-6 summarize the major empirical results.

Contribution 5: Demonstration, through experimental results, that the motivation and interest toward music subject and the collaboration in students using MOGCLASS method were generally more than those using traditional musical instruments.

When compared with recorders in controlled user study, MOGCLASS was more effective in enhancing students' motivation and interest toward music subject from the analysis of the survey and questionnaire results. Through transcripts of subjective comments and class observation, MOGCLASS is also more efficient in facilitating students' collaboration and teachers' classroom management.

Contribution 6: Demonstration, through experimental results, that learning in pitch perception and reproduction can be achieved in children with cochlear implants after using MOGAT for two weeks.

The week-by-week performance evaluation in MOGAT shows that overall children with CI have achieved significant improvement in pitch perception and reproduction skills though there is a large individual variation. Subjective feedback and observation show that some students' consistent improvement might be attributed to either their dedication in the training program or superior intelligence.

6.3.3 Design recommendations

Contributions 7-8 summarize the major design recommendations.

Contribution 7: Derivation of a design recommendation for the singing pedagogical systems on mobile devices to use a two-stage asynchronous way (i.e., listening to the example music followed by singing A cappella) and to provide regions with a minimal size that display note duration, hints for adjusting pitch, and syllables.

Empirical results from this research implies that it is beneficial to use the method in *Ladder Singer* for singing pedagogical systems. During the experiments, subjects rated *Ladder Singer* higher than Karaoke Game in terms of pitch correction, lyrics reading, and training effect. The comparison between *Ladder Singer* and Karaoke Game shows that *Ladder Singer* is more intuitive, useful, and motivating for children with cochlear implants to practice singing than Karaoke Game.

Contribution 8: Derivation of an educational recommendation for music educators to use the MOGCLASS/MOGAT method as an alternative way to enhance classroom music education for primary school children.

We found, by examining the syllabus and interacting with the teachers, that MOGCLASS, combined with voicing technique in MOGAT, supports stage 1 and 2 in music syllabus [12] for primary school students: i.e., singing and/or playing a variety of tuned and untuned percussion instruments and string instruments individually or in a mixed ensemble. Teachers' comments from the controlled user study also indicated that primary schools could adopt MOGCLASS/MOGAT as an alternative way to enhance a variety of music lessons including instrument and singing lessons.

6.4 Future Work

This work has shown great potential of our collaborative m-learning systems in multimedia, education, and healthcare. Future work includes the improvement of current work as well as the audacious innovation in this research direction. In the MOGCLASS project, we use earpieces and *virtual sound space* to separate each student's sound from the others' during their instrumental practice. However, if the class involves singing, students can only practice by singing out loud and cause the cacophony problem to recur. This problem arose when we were evaluating MOGAT for children with cochlear implants in the classroom. We had to let individual student sing in a single room. One possible solution is to first teach students the rules of singing during class, and afterwards students can practice at home. The device can record their singing and then send the recordings to the server via the Internet, which allows their teachers to assess them on desktops. To achieve that, we could integrate the cloud-based web service in MOGAT into MOGCLASS for normal children in the future.

In the work of MOGAT, we did not follow up with the rhythm perception skills in children with cochlear implants according to the small effect size and literature review. But we could investigate why the delays in rhythm perception are more for children with CI. The delay can be introduced by the implant device (e.g., the sound processor or the signal transmission in circuits). Another possible explanation could be that these children do not enjoy music inherently and/or are less exposed to music than NH children, and hence they have not learnt the rhythms that NH children have naturally learnt. We could do more study to investigate these possibilities and come up with a suitable game to improve their rhythm perception skills.

One limitation of the work is the limited amount of musical offerings in two systems. To solve it, we can build an online database consisting of MIDI control data aligned with singing/instrument recordings by the means of crowdsourcing. Actually MOGAT is one of the first few music projects utilizing crowdsourcing website Noteflight [9] to generate the music sheet content. The scaffolding module in our systems, when combined with this database, will help users perform a wide range of instrumental and vocal melodies. The database should include as many songs as possible from the music curriculum, organized based on instrument types (including vocal) and difficulty levels. Students could download songs from the server to their local devices by browsing the song library.

Nowadays the biggest trend of computing is the intersection of mobile, social, cloud, and big data [129]. Our systems, assuming that they are successfully deployed in more schools and that students use them everyday, will generate a huge amount of educational data. When it comes to the domain of big data, a lot of research questions would arise, from data input, storage to analytic models, machine learning, and data visualization. The systems can provide data analytic modules to generate reports or statistics on students' past performance, and it can also predict their future performance by using analytic models and machine learning. We believe that it will provide a holistic way for teaching and learning not only music but also other subjects.

Finally, more work can be done to extend the paradigms and applications of our m-learning systems to other scenarios. For example, since singing can help people learn languages, MOGAT can be redesigned to help students learn a second language. Learning a new language will become fun and motivating, and eventually the public will benefit from this work. Currently these m-learning systems also plays a role in the design and development of the Sing2Speak project [121] in the Sound and Music Computing Lab. The Sing2Speak project aims to utilize singing evaluation technique (especially lyrics evaluation) to help the patients with aphasia to rehabilitate their speech abilities.

6.5 Final Remarks

Prior to this work, we already know that m-learning can be used for learning languages [63, 112], history [25], biology [96, 123], and work-related information [42]. However, so far no software tool met the infrastructure, interaction, and algorithmic needs of educators and researchers who want to apply m-learning to music education. In this sense, our work is novel and filled the gap between m-learning and music education. This work, which is based on three case studies, scientifically shows that it is feasible for children, including both normal and the disabled children, to use their mobile phones to learn music in the future. It is entirely reasonable as the number of students who use tablets and mobile phones keeps increasing.

Another broader contribution of this work is that m-learning has the ability to promote arts in education program, which recognizes the importance of arts learning both within schools (in non-arts and arts classroom) and beyond school walls in the community. Arts integrated learning is a new way of learning, which aims to improve learning through the arts, transfer learning in and through the arts to other disciplines, and discover and create understanding of human behaviour, thinking, potential, and learning through arts. Facilitated by our systems, students did improve their learning process via various forms of involvement in music experience. As such, our systems reemphasize the values of arts in education, i.e., the process and experiential learning as well as creation of art object or performance oriented learning.

Furthermore, our systems help to promote the movement of "music learning anywhere and anytime". With the mobility of m-learning, students are able to learn music anywhere and anytime, which nevertheless may not include learning singing at public. We would like to point out that the reason why it is unlikely for humans to learn singing at public is largely due to the psychological problem rather than the technical problems (such as noise reduction). Imagine that a guy sitting beside you on the bus suddenly starts to sing a song with his mobile phone. You will probably think he is psycho. Furthermore, most people have Glossophobia or speech anxiety, the fear of public speaking or singing. Therefore, due to these psychological problems it will be hard to ask people to learn singing anywhere and anytime.

During the evaluation, the biases and novelty effects for children need to be taken into consideration: On the one hand, we controlled all the other factors same (e.g., the classroom setup, the teacher, and the lesson program) except the independent variable (e.g., musical instruments). On the other hand, the design of the user interfaces (UI) was only focused on the essential parts (i.e., system functions and user interactions) without any extra art or graphic design. This helped users to concentrate on the testing features and ensured that we could get high quality data from users.

Last but not the least, we certainly acknowledge the efforts and the rigour in honing the musical proficiency. Therefore, our systems are by no means to replace the musicianship that is established by traditional musical instruments but rather to provide a ladder to the music "wonderland" by lowering the technical entry level. In this sense, the systems are meant to be more of a motivation tool to get children into music making and thinking about music rather than a step-by-step guide to professionalism. After all, music should be interesting to children.

References

[1] Audio unit hosting guide for iOS. http://developer.apple.com/library/ios/.

[2] Bonjour. http://en.wikipedia.org/wiki/Bonjour_(software).

[3] Gnu solfege. http://www.solfege.org/.

[4] Hyperscore. http://www.hyperscore.com/.

[5] Leisuresonic - cosmovox. http://leisuresonic.com/cosmovox/index.html.

[6] libjdkmidi. http://opensource.jdkoftinoff.com/jdks/docs/libjdkmidi/.

[7] Mobile music workshop. http://www.mobilemusicworkshop.org.

[8] New interfaces for musical expression. http://www.nime.org.

[9] Noteflight. http://www.noteflight.com/.

[10] Practica musica. http://www.ars-nova.com/aboutpm5/index.html.

[11] Youtube. `http://www.youtube.com`.

[12] *2008 Syllabus, General Music Programme*. Ministry of Education, 2008. [Online; accessed 24-Feb-2009].

[13] S. Abdi, M.H. Khalessi, M. Khorsandi, and B. Gholami. Introducing music as a means of habilitation for children with cochlear implants. *International Journal of Pediatric Otorhinolaryngology*, **59**, 2001.

[14] Mohamed Ally. *Mobile Learning Transforming the Delivery of Education and Training*. AU PRESS, 2009.

[15] William I. Bauer. Mobile learning and music: Get your iOS on! In *Ohio Music Education Association Conference*, 2012.

[16] Helen Bonny. Music and healing. *Music Therapy*, **6A**[1]:3–12, 1986.

[17] Richard Boulanger. *The Csound book: perspectives in software synthesis, sound design, signal processing, and programming*. MIT Press, Cambridge, MA, USA, 2000.

[18] Paul Brossier. *Automatic Annotation of Musical Audio for Interactive Applications*. PhD thesis, Queen Mary University of London, UK, August 2006.

[19] Peter A. Busby, Stuart A. G. Roberts, Yit C. Tong, and Graeme M. Clark. Results of speech perception and speech production training for three prelingually deaf patients using a multiple-electrode cochlear implant. *British Journal of Audiology*, **25**[5]:291–302, 1991.

[20] Joel Chadabe. *Electric Sound: The Past and Promise of Electronic Music*. Prentice-Hall, Upper Saddle River, New Jersey, 1997.

[21] Chih-Chung Chang and Chih-Jen Lin. *LIBSVM: a library for support vector machines*, 2001. Software available at `http://www.csie.ntu.edu.tw/~cjlin/libsvm`.

[22] Eun-Seok Choi, Won-Chul Bang, Sung-Jung Cho, Jing Yang, Dong-Yoon Kim, and Sang-Ryong Kim. Beatbox music phone: gesture-based interactive mobile phone using a tri-axis accelerometer. In *IEEE International Conference on Industrial Technology*, Hong Kong, 2005.

[23] Cocos2D. `http://www.cocos2d-iphone.org/`.

[24] Jacob Cohen. *Statistical Power Analysis for the Behavioral Sciences (2nd Edition)*. Routledge Academic, 2 edition, January 1988.

[25] Maria F. Costabile, Antonella De Angeli, Rosa Lanzilotti, Carmelo Ardito, Paolo Buono, and Thomas Pederson. Explore! possibilities and challenges of mobile learning. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Florence, Italy, 2008.

[26] Pam W PW Dawson and Graeme Clark. Changes in synthetic and natural vowel perception after specific training for congenitally deafened patients using a multichannel cochlear implant. *Ear and Hearing*, **18**:488–501, 1997.

[27] Alain De Cheveigne and Hideki Kawahara. Yin, a fundamental frequency estimator for speech and music. *Journal of the Acoustical Society of America*, 2002.

[28] Sara de Freitas and Steve Jarvis. A framework for developing serious games to meet learner needs. Orlando, Florida, USA, 2006.

[29] Amnon Dekel and Gilly Dekel. Mogmi: Mobile gesture music instrument. In *5th International Mobile Music Workshop*, Vienna, Austria, 2008.

[30] Paul Doornbusch. Computer sound synthesis in 1951: The music of csirac. *Computer Music Journal*, **28**[1]:10–25, March 2004.

[31] Ward R. Drennan and Jay T. Rubinstein. Music perception in cochlear implant users and its relationship with psychophysical capabilities. *Journal of Rehabilitation Research & Development*, **45**[5], 2008.

[32] Allison Druin, Jason Stewart, David Proft, Ben Bederson, and Jim Hollan. Kidpad: a design collaboration between children, technologists, and educators. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Atlanta, Georgia, USA, 1997.

[33] George Thomas Ealy. Of ear trumpets and a resonance plate: Early hearing aids and beethoven's hearing perception. *19th-Century Music*, **17**[3]:pp. 262–273, 1994.

[34] Lizbeth Escobedo, David H. Nguyen, LouAnne Boyd, Sen Hirano, Alejandro Rangel, Daniel Garcia-Rosas, Monica Tentori, and Gillian Hayes. Mosoco: a mobile assistive tool to support children with autism practicing social skills in real-life situations. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Austin, Texas, USA, 2012.

[35] Georg Essl and Michael Rohs. Shamus - a sensor-based integrated mobile phone instrument. In *International Computer Music Conference*, Copenhagen, Denmark, 2007.

[36] Korson Herman F. Music therapy for children hospitalized with muscular dystrophy. *Music in therapy*, 1968.

[37] Laura Ferrari, Anna Rita Addessi, and François Pachet. New technologies for new music education: The continuator in a classroom setting. In *International Conference on Music Perception & Cognition*, Bologna, Italy, 2006.

[38] John Finney and Pamela Burnard. *Music education and digital technology*. Continuum, London, 2007.

[39] Voices: A World Forum for Music Therapy Web site. Would you like to write your own song? page. `http://www.voices.no/mainissues/mi40007000239.php`.

[40] Qian-Jie Fu, John Galvin, Xiaosong Wang, and Geraldine Nogaki. Moderate auditory training can improve speech performance of adult cochlear implant patients. *Acoustical Society of America*, 2005.

[41] Qian-Jie Fu and John J Galvin III. Computer-assisted speech training for cochlear implant patients: Feasibility, outcomes, and future directions. *Seminar in Hearing*, 2007.

[42] Diane Gayeski. *Learning Unplugged: Using Mobile Technologies for Organizational Training and Performance Improvement*. American Management Association, 2002.

[43] Kate Gfeller, Shelley Witt, Mary Adamek, Maureen Mehr, Jenny Rogers, Julie Stordahl, and Shelly Ringgenberg. Effects of training on timbre recognition and

appraisal by postlingually deafened cochlear implant recipients. *Journal of the American Academy of Audiology*, **13**[3]:132–145, 2002.

[44] Kate Gfeller, Shelley Witt, Julie Stordahl, Maureen Mehr, and George Woodworth. The effects of training on melody recognition and appraisal by adult cochlear implant recipients. *Journal of the Academy of Rehabilitative Audiology*, **33**:115–138, 2000.

[45] Kate Gfeller, Shelley A Witt, Kyung-Hyun Kim, Mary Adamek, and Don Coffman. Preliminary report of a computerized music training program for adult cochlear implant recipients. *Journal of the Academy of Rehabilitative Audiology*, **32**:11–27, 1999.

[46] Evelyn Glennie. Hearing essay, 1993. `http://www.evelyn.co.uk/Resources/Essays/Hearing%20Essay.pdf`.

[47] Anne Goodsell, Michelle Maher, Vincent Tinto, Barbara Leigh Smith, and Jean MacGregor. *Collaborative Learning: A Sourcebook for Higher Education*. National Center on Postsecondary Teaching, Learning, and Assessment, University Park, PA., 1992.

[48] Inc Web site Health Grades. Statistics by country for muscular dystrophy page. `http://www.cureresearch.com/m/musdys/stats-country.htm`.

[49] Inc Web site Health Grades. Statistics by country for muscular dystrophy page. `http://www.wrongdiagnosis.com/m/musdys/stats-country.htm`.

[50] Sen H. Hirano, Michael T. Yeganyan, Gabriela Marcu, David H. Nguyen, Lou A. Boyd, and Gillian R. Hayes. vsked: evaluation of a system to support classroom activities for children with autism. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Atlanta, Georgia, USA, 2010.

[51] Wai-Chung Ho. Students' experiences with and preferences for using information technology in music learning in shanghai's secondary schools. *British Journal of Educational Technology*, **38**[4]:699–714, July 2007.

[52] James A. Hoffmann. Computer-aided collaborative music instruction. *Harvard Educational Review*, **61**[3]:270–278, August 1991.

[53] D. Hoppe, Makiko Sadakata, and Peter Desain. Development of real-time visual feedback assistance in singing training: a review. *Journal of Computer Assisted Learning*, 2006.

[54] John J Galvin III, Qian-Jie Fu, and Robert V. Shannon. Melodic contour identification and music perception by cochlear implant users. *The Neuroscience and Music III - Disorders and Plasticity*, 2009.

[55] Kevin Jennings. Toy symphony: An international music technology project for children. *Music Education International*, pages 3–21, 2003.

[56] Faith L. Johnson. Integrating technology. *Music Therapy Perspectives*, **13**[2]:7–8, 1995.

[57] Faith L. Johnson. Integrating technology. *Music Therapy Perspectives*, **14**[2], 1996.

[58] Faith L. Johnson. Integrating technology. *Music Therapy Perspectives*, **15**[1]:9–10, 1997.

[59] Matthew Kam, Jingtao Wang, Alastair Iles, Eric Tse, Jane Chiu, Daniel Glaser, Orna Tarshish, and John Canny. Livenotes: a system for cooperative and augmented note-taking in lectures. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Oregon, US, 2005.

[60] KaraokeParty. Karaokeparty. `http://www.karaokeparty.com/`.

[61] Roy Kennedy and Yitteck Angel Kua-Walker. Movement, singing, and instrument playing strategies for a child with myotonic dystrophy. *Music Therapy Perspectives*, **24**[1]:39–51, 2006.

[62] Robert Krout. Music therapy with multi-handicapped students: individualizing treatment within a group setting. *Journal of Music Therapy*, **24**[1]:2–13, 1987.

[63] Anuj Kumar, Pooja Reddy, Anuj Tewari, Rajat Agrawal, and Matthew Kam. Improving literacy in developing countries using speech recognition-supported games on mobile devices. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Austin, Texas, USA, 2012.

[64] Anuj Kumar, Anuj Tewari, Geeta Shroff, Deepti Chittamuru, Matthew Kam, and John Canny. An exploratory study of unsupervised mobile learning in rural india. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Atlanta, Georgia, USA, 2010.

[65] Ben Loh, Josh Radinsky, Eric Russell, Louis M. Gomez, Brian J. Reiser, and Daniel C. Edelson. The progress portfolio: designing reflective tools for a class-

room context. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Los Angeles, California, USA, 1998.

[66] David W. Luce. Collaborative Learning in Music Education: A Review of the Literature. *Update: Applications of Research in Music Education*, **19**[2]:20–25, January 2001.

[67] Wendy Magee and Karen Burland. Using electronic music technologies in music therapy: Opportunities, limitations and clinical indicators. *British Journal of Music Therapy*, **22**[1]:3–15, 2008.

[68] Oscar Mayor, Jordi Bonada, and Alex Loscos. The singing tutor: Expression categorization and segmentation of the singing voice. In *121st AES Convention*, San Francisco, California, USA, 2006.

[69] Hugh J. McDermott. Music perception with cochlear implants: A review. *Trends In Amplification*, **8**, 2004.

[70] Neema Moraveji, Taemie Kim, James Ge, Udai S. Pawar, Kathleen Mulcahy, and Kori Inkpen. Mischief: supporting remote teaching in developing regions. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Florence, Italy, 2008.

[71] James L. Mursell. The challenge to music education. *Music Educators Journal*, **36**[5]:20–22, 1950.

[72] Joseph Charles Nagler. *A qualitative study of children in crisis: Interventions through music therapy and digital music technology*. Doctoral dissertation, New York University, New York, 1993.

[73] Joseph Charles Nagler and Mathew H.M. Lee. Music therapy using computer music technology. *Rehabilitation, music, and human wellbeing*, pages 226–241, 1989.

[74] Laura Naismith, Peter Lonsdale, Giasemi Vavoula, and Mike Sharples. Literature review in mobile technologies and learning. *Futurelab Series*, 2004.

[75] Jaana Näsänen, Antti Oulasvirta, and Asko Lehmuskallio. Mobile media in the social fabric of a kindergarten. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Boston, MA, USA, 2009.

[76] Kia Ng and Paolo Nesi. i-maestro framework and interactive multimedia tools for technology-enhanced learning and teaching for music. In *International Conference on Automated solutions for Cross Media Content and Multi-channel Distribution*, Florence, Italy, 2008.

[77] Ministry of Education Web site. Speeches: Speech by dr. aline wong page. `http://moe.gov.sg/media/speeches/2001/sp28032001.htm`.

[78] National Institute of Neurological Disorders and Stroke Web site. Muscular dystrophy: Hope through research page. `http://www.ninds.nih.gov/disorders/md/detail_md.htm`.

[79] National Institute of Neurological Disorders and Stroke Web site. Muscular dystrophy information page. `http://www.ninds.nih.gov/disorders/md/md.htm`.

[80] Claire O'Malley, Giasemi N. Vavoula, J.P. Glew, Josie Taylor, Mike Sharples,

and Paul Lefrere. Guidelines for learning/teaching/tutoring in a mobile environment. In *MOBIlearn*, October 2003.

[81] Chika Oshima, Kazushi Nishimoto, and Masami Suzuki. Family ensemble: a collaborative musical edutainment system for children and parents. In *ACM Multimedia*, New York, NY, USA, 2004.

[82] Joseph A. Paradiso and Neil Gershenfeld. Musical applications of electric field sensing. *Computer Music Journal*, **21**:69–89, 1997.

[83] Graham Percival, Ye Wang, and George Tzanetakis. Effective use of multimedia for computer-assisted musical instrument tutoring. In *International workshop on educational multimedia and multimedia education*, Augsburg, Bavaria, Germany, 2007.

[84] Jacqueline Schmidt Peters. *Music therapy: An introduction. 2nd ed.* Springfield, IL: Charles C Thomas Publisher Ltd, 2000.

[85] Candida C. Peterson. Theory-of-mind development in oral deaf children with cochlear implants or conventional hearing aids. *Journal of Child Psychology and Psychiatry*, 2004.

[86] E. C. Poulton and P. R. Freeman. Unwanted asymmetrical transfer effects with balanced experimental designs. *Psychological Bulletin*, **66**[1]:1–8, 1966.

[87] Impack Productions. Voice tutor. `http://voicetutorapp.com/`.

[88] Miller Puckette. Combining Event and Signal Processing in the MAX Graphical Programming Environment. *Computer Music Journal*, **15**[3]:68–77, 1991.

[89] Alexandra L. Quittner, Pamela Leibach, and Kristen Marciel. The impact of cochlear implants on young deaf children: new methods to assess cognitive and behavioral development. *Arch Otolaryngol Head Neck Surg*, 2004.

[90] Karaoke Revolution. Karaoke revolution. `http://www.konami.com/games/karaoke-revolution/`.

[91] Krout Robert. Integrating technology. *Music Therapy Perspectives*, **10**[1]:8–9, 1992.

[92] Krout Robert. Integrating technology. *Music Therapy Perspectives*, **13**[1]:5–6, 1995.

[93] Margaret D Roblyer. *Integrating Educational Technology into Teaching*. Pearson Prentice Hall Publications, 2006.

[94] Alex Ruthmann. The composers' workshop: An approach to composing in the classroom–the way writing teachers approach composition can illuminate how we teach composing. *Music Educators Journal*, **93**[4]:38+, March 2007.

[95] Richard M. Ryan and Edward L. Deci. *The Handbook of Self-Determination Research*. University of Rochester Press, 2007.

[96] Kimiko Ryokai, Lora Oehlberg, Michael Manoochehri, and Alice Agogino. Greenhat: exploring the natural environment through experts' perspectives. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Vancouver, British Columbia, Canada, 2011.

[97] Hagedorn Victoria S. Musical learning for hearing impaired children. *Research perspective in music education*, 1992.

[98] Anthony Saggese, Jr. *Bringing music technology to music therapy: Using MAX/MSP as a therapeutic agent*. Final master's project [dissertation], New York University, New York, 2003. http://www.theanthill.com/.

[99] Ian Simon, Dan Morris, and Sumit Basu. Mysong: automatic accompaniment generation for vocal melodies. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Florence, Italy, 2008.

[100] Muscular Dystrophy Association Web site. About muscular dystrophy page. http://www.mdas.org.sg/index.php?option=com_content&view=article&id=8&Itemid=10.

[101] Muscular Dystrophy Association Web site. Duchenne muscular dystrophy page. http://www.mda.org/disease/dmd.html.

[102] Smule. Glee karaoke. http://itunes.apple.com/sg/app/glee-karaoke/id360736774?mt=8.

[103] Elliot Soloway, Mark Guzdial, and Kenneth E. Hay. Learner-centered design: the challenge for hci in the 21st century. *interactions*, **1**[2]:36–48, April 1994.

[104] Donna L. Sorkin and Nancy Caleffe-Schenck. Cochlear implant rehabilitation. Online, June 2008. http://www.cochlear.com/files/assets/ci_rehab_not_just_for_kids.pdf.

[105] Shmuel Spitzer. Computers and music therapy: An integrated approach: Four case studies. *Music Therapy Perspectives*, **7**:51–54, 1989.

[106] Danae Stanton, Victor Bayon, Helen Neale, Ahmed Ghali, Steve Benford, Sue Cobb, Rob Ingram, Claire O'Malley, John Wilson, and Tony Pridmore. Class-

room collaboration in the design of tangible interfaces for storytelling. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Seattle, Washington, USA, 2001.

[107] Keith Swanwick and Cecilia C. Franca. Composing, performing and audience-listening as indicators of musical understanding. *British Journal of Music Education*, **16**[01]:5–19, 1999.

[108] Robert Sweetow and Catherine V Palmer. Efficacy of individual auditory training in adults: A systematic review of the evidence. *Journal of the American Academy of Audiology*, **16**[7]:494–504, June 2005.

[109] Atau Tanaka. Musical performance practice on sensor-based instruments. *Trends in Gestural Control of Music*, pages 389–406, 2000.

[110] TigerSpeech Technology. Sound express auditory training. `http://www.tigerspeech.com/tst_soundex.html`.

[111] Michael H Thaut. Music therapy for children with physical disabilities. In William B Davis, Michael H Thaut, and Kate E Gfeller, editors, *An introduction to music therapy: Theory and practice*. Boston, MA: McGraw-Hill, 1999.

[112] Feng Tian, Fei Lv, Jingtao Wang, Hongan Wang, Wencan Luo, Matthew Kam, Vidya Setlur, Guozhong Dai, and John Canny. Let's play chinese characters: mobile learning approaches via culturally inspired group games. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Atlanta, Georgia, USA, 2010.

[113] Emily A. Tobey, Ann E. Geers, Chris Brenner, Dianne Altuna, and Gretchen

Gabbert. Factors associated with development of speech production skills in children implanted by age five. *Ear and Hearing*, **24**:36S–45S, February 2003.

[114] Toy Symphony Music toys. `http://www.toysymphony.net/`.

[115] Theta Music Trainer. `http://trainer.thetamusic.com/`.

[116] John Traxler. Defining mobile learning. In *IADIS International Conference Mobile Learning*, Qawra, Malta, 2005.

[117] Peter Vorderer Ute Ritterfeld, Michael Cody. *Serious Games: Mechanisms and Effects*. Routledge, 2009.

[118] Ge Wang. Designing smule's iphone ocarina. In *Proceedings of the International Conference on New Interfaces for Musical Expression*, Pittsburgh, USA, 2009.

[119] Ge Wang, Georg Essl, and Henri Penttinen. Do mobile phones dream of electric orchestras? In *International Computer Music Conference*, Belfast, Northern Ireland, 2008.

[120] Ge Wang, Dan Trueman, Scott Smallwood, and Perry R. Cook. The laptop orchestra as classroom. *Computer Music Journal*, **32**[1]:26–37, 2008.

[121] Ye Wang. When music, information technology, and medicine meet. In *Proceedings of the second international ACM workshop on Music information retrieval with user-centered and multimodal strategies*, International ACM Workshop on Music Information Retrieval with User-Centered and Multimodal Strategies, Nara, Japan, 2012.

[122] Peter R. Webster. Computer-based technology and music teaching and learning: 2000 – 2005. In *International Handbook of Research in Arts Education*, **16** of *Springer International Handbook of Information Technology in Primary and Secondary Education*, pages 1311–1330, 2007.

[123] Sean M. White, Dominic Marino, and Steven Feiner. Designing a mobile user interface for automated species identification. In *ACM SIGCHI Human Factors in Computer Systems Conference*, San Jose, California, USA, 2007.

[124] Elaine L. Wong, Wilson Y. F. Yuen, and Clifford S. T. Choy. Designing wii controller - a powerful musical instrument in an interactive music performance system. In *International Conference on Mobile Computing and Multimedia*, Linz, Austria, 2008.

[125] Mike Wozniewski, Nicolas Bouillot, Zack Settel, and Jeremy R. Cooperstock. Large-scale mobile audio environments for collaborative musical interaction. In *New Interfaces for Musical Expression*, Genoa, Italy, 2008.

[126] Jiunn-Liang Wu, Hui-Mei Yang, Yi-Hui Lin, and Qian-Jie Fu. Effects of computer-assisted speech training on mandarin-speaking hearing-impaired children. *Audiology and Neurotology*, **12**, 2007.

[127] Jun Yin, Ye Wang, and David Hsu. Digital Violin Tutor: an Integrated System for Beginning Violin Learners. In *ACM Multimedia*, Singapore, 2005.

[128] Kwang Suk Yoon. Exploring children's motivation for instrumental music. In *The biennial meeting of the Society for Research in Child Development*, Washington, D.C., USA, 1997.

[129] Liang-Jie Zhang. Editorial: Big services era: Global trends of cloud computing and big data. *IEEE Transactions on Services Computing*, **5**[4]:467–468, 2012.

[130] Yinsheng Zhou, Graham Percival, Xinxi Wang, Ye Wang, and Shengdong Zhao. MOGCLASS: a collaborative system of mobile devices forclassroom music education. In *ACM Multimedia*, Florence, Italy, 2010.

[131] Yinsheng Zhou, Graham Percival, Xinxi Wang, Ye Wang, and Shengdong Zhao. MOGCLASS: evaluation of a collaborative system of mobile devices for classroom music education of young children. In *ACM SIGCHI Human Factors in Computer Systems Conference*, Vancouver, British Columbia, Canada, 2011.

REFERENCES

Appendix

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Appendix 1

Research Consent Form: MOGCLASS

I hereby consent to participate in a research study conducted by Dr. Wang and his students for a research project in School of Computing, National University of Singapore.

I agree to participate in this study the purpose of which is to investigate the usability of MOGCLASS and its pedagogical values.

I understand that

- The procedures to be used are interviews and questionnaires.
- I will receive no compensation for my participation.
- I am free to withdraw before or any time during the study without the need to give any explanation.
- This interview may be audio (or video) recorded
- All materials and results will be kept confidential, and, in particular, that my name and any identifying or identified information will not be associated with the data.

Participant

Name (Please print) ____

Signature________________Place and Date_________________________

Investigator(s)

Name (Please print)____

Signature________________Place and Date_________________________

Appendix 2: MOGCLASS Interview Protocol for Field Study

Introduction and Background Phrase

We are studying how MOGCLASS, which is a mobile and networked interactive system, can facilitate music education. First of all, we will show you a demo of MOGCLASS. Immediately after the demo, we will arrange an interview to discuss with you about the system usability and its pedagogical values in music education. Be assured that all the information you will give in this interview will remain strictly confidential and will only be used for the purposes of this research.

Video-record the interview if they agree. Otherwise, take audio recording or notes.

Participants:

The whole sessions should only have one principal interviewer: Dr. Wang or Yinsheng Zhou.

Other interviewers: Dr. Zhao Shengdong (if he has time), Xinxi, Andy.

Warm-up Phrase

Ask the interviewees some basic questions, for example:

1. How many years of teaching experience do you have in music education?
2. What kind of IT technology do you use for music class? For example, name some related software, hardware.
3. How often do you use IT technology for a music class?
4. What are teachers' and students' typical tasks during a music lesson?
5. What are the challenges of current music education?

Main body Phrase

Elicit their requirements on the system.

1. What features do you want if we introduce mobile devices into music education curriculum?
2. What is your expectation of the system if we want it to enhance students' performance and collaboration skills?

Then we can introduce the features of MOGCLASS to them.

In MOGCLASS, basically we can offer the following features:

– Theoretically, students can change among unlimited kinds of music sounds.
– Teachers can control students' interfaces for classroom management including their instruments sound and interfaces, muting and unmuting their speakers and headphones, monitoring students' connection status.
– Music hints on iPod touch can facilitate their music performance without memorizing the notes all the time during the lesson. Eventually we can hide

the music hints on the iPod touch and let them watch the music notation on the large display while playing together. We hypothesize that this feature can help them learn music notation.
– Students can use earpieces to practice "silently" in different groups without disturbing others.

1. Could you give us your comments on these features of our system?

2. Do you like to use the teacher interface for classroom management, which features do you like most: the classroom management view to mute and unmute the speakers or students' headphones, the lesson plan view to change students' instrument sounds or interface, the connection status view to check students' status during the lesson.

3. Do you think this system can help students learn the fundamental music skills such as performance and collaboration?

4. How to quantitatively show students' performance and collaboration skills for evaluation?

5. What is your suggestion about evaluation of system in the classroom?

6. What other useful features should we add to the system?

Wrap-up or Closure Phrase

Thank you for your constructive suggestions to our project. Signal the end of interview. Summarize the interview.

Appendix 3: MOGCLASS Interview Questionnaire for Field Study

This questionnaire is conducted by Dr. Wang and his students for a research project called MOGCLASS in School of Computing, National University of Singapore.

1. What is your gender?

□Female □Male

2. How old are you?

□Under 25 □25-29 □30-39 □40-49 □50+

3. What is your employment status as a teacher?

Part-time employment is where the contracted hours of work represent less than 90 per cent of the normal or statutory number of hours of work for a full-time employee over a complete school year. Please consider your employment status for all of your teaching jobs combined.

□Full-time

□Part-time (50-90% of full-time hours)

□Part-time (less than 50% of full-time hours)

4. How long have you been working as a music teacher?

□This is my first year □1-2 years □3-5 years □6-10 years □11-15 years □16-20 years □More than 20 years

5. What kind of IT technology do you use for music class? Name some related software, hardware.

6. How often do you use IT technology for a music class?

7. What activities do you engage students in terms of performing, listening and creating in the music classroom and which of these components do you feel technology can play a part in enhancing students' musical exploration and learning?

8. What are the challenges of current music education?

Appendix 4: The 1st Student Questionnaire in Iterative Design Evaluation

1. Gender: ☐ Male ☐ Female

2. Age: ________

3. Have you studied music outside of school? ☐ Yes ☐ No
   If so, how many years?
   ☐ less than 1 ☐ 1-3 ☐ 3-5 ☐ 5-7 ☐ 7 more

4. Do you use any mobile devices? ☐ Yes ☐ No
   If so, which of the following mobile devices do you use? (More than one choice allowed)
   ☐ mobile phone ☐ PDA ☐ handheld computer ☐ iPod ☐ MP3/MP4 ☐ PSP ☐ Nintendo DS ☐Others: ________

5. Please rank in order your three favorite music instruments:

   A. ________________

   B. ________________

   C. ________________

6. From overall experience of using iPod as music instruments, what do you think of it?

Question A: **Is iPod touch difficult to use?**

☐ Strongly disagree ☐Disagree ☐ Ok ☐ Agree ☐ Strongly agree

Question B: **Is iPod touch fun to use?**

☐ Strongly disagree ☐Disagree ☐ Ok ☐ Agree ☐ Strongly agree

Question C: **To what extent do you like “*rope pulling*”?**

☐ To a great extent ☐ To some extent ☐ Very little ☐ Not at all

Question D: **To what extent do you like “*mechanical bells*”?**

☐ To a great extent ☐ To some extent ☐ Very little ☐ Not at all

---

1. I am comfortable with playing Kangding Love Song with the iPod.

Strongly disagree___ Disagree___ Ok___ Agree___ Strongly agree___

2. I enjoyed practicing music on the iPod by myself more than with my group.

Strongly disagree___ Disagree___ Ok___ Agree___ Strongly agree___

3. I enjoyed listening to the sounds with speakers more than with headphones.

Strongly disagree___ Disagree___ Ok___ Agree___ Strongly agree___

4. Which instrument do you like best?

Wood bars___ Mandolin___ Wurley___ Plucked___ Rhodey___

5. Do you experience any problems in playing with the iPod? If you do, please list them below.

____

____

6. Comments

____

____

Thank you ☺

Appendix 5: The 2nd Student Questionnaire in Iterative Design Evaluation

1. Gender: ☐ Male ☐ Female

2. Age: ________

3. Have you studied music outside of school? ☐ Yes ☐ No

If so, how many years?

☐ less than 1 ☐ 1-3 ☐ 3-5 ☐ 5-7 ☐ 7 more

4. Do you use any mobile devices? ☐ Yes ☐ No

If so, which of the following mobile devices do you use? (More than one choice allowed)

☐ mobile phone ☐ PDA ☐ handheld computer ☐ iPod

☐ MP3/MP4 ☐ PSP ☐ Nintendo DS ?Others: ________

5. Which interface do you like best?

☐ Hitter ☐ Tapper ☐ Slider

6. Try to describe the way you felt when your feelings were most intense.

Answers range from (1) Not at all true to (9) Definitely true.

	Not at all true				ok				Definitely True
1) iPod touch is difficult to use.	1	2	3	4	5	6	7	8	9
2) iPod touch is fun to use.	1	2	3	4	5	6	7	8	9
3) I am comfortable with playing Kangding Love Song with the iPod.	1	2	3	4	5	6	7	8	9

4) I am comfortable with playing Clock Chime with the iPod.	1	2	3	4	5	6	7	8	9
5) I enjoyed practicing music on the iPod by myself more than with my group.	1	2	3	4	5	6	7	8	9
6) I enjoyed listening to the sounds with speakers more than with headphones.	1	2	3	4	5	6	7	8	9

7. Do you experience any problems in playing with the iPod? If you do, please list them below.

____

____

____

8. Comments.

____

____

____

Thank you :)

Appendix 6: Teacher Questionnaire in Iterative Design Evaluation

1. Gender ☐ Male ☐ Female

2. Age: ________

3. How long have you been teaching music in school?

4. When did you start learning music?

5. How often do you use your personal computer?

6. What are the three most challenging problems in music education you can think of?

   1) ______________________________

   why?

   ____

   ____

   2) ______________________________

   why?

   ____

   ____

   3) ______________________________

   why?

   ____

   ____

7. What kinds of computer technologies do you use in music education?

8. How do you use them, could you give us some examples?

9. Do you have any suggestions on Graham's teaching today?

10. Do you think the current NuMOG is helpful for your teaching?

11. What can we improve NuMOG to help you teach?

    Please give us some suggestions.

Appendix 7: Pre Post Study Survey On Student Interests on 9 School Subjects

Student ID: ____

1. How much do you enjoy learning these subjects (choose one number and circle it)?

Arts and Craft	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
English	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Health Education	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Maths	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Mother Tongue	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Music	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
P.E.	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Science	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)
Social Studies	(I really don't like it)	1	2	3	4	5	6	7	8	9	(I really like it)

Appendix 8: The Student Questionnaire in Controlled User Study

1. Student ID: ______________________________

2. I enjoyed the music lesson.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

3. I would like to use the instrument frequently.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

4. I feel the instrument is easy to learn.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

5. I can easily play music using the instrument.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

6. I would like to play more songs on this instrument.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

7. I enjoyed the music that our group performed in the class.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

8. I am happy with my performance in our group.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree

9. Comments about the music class.

   ____

   ____

Appendix 9: Teachers Interview Questions in Controlled User Study

1. Do you use any mobile devices?

   ☐Yes ☐No

   If so, what type of mobile devices do you use?

   ☐Smartphone with touch screen (e.g., iPhone/iPod Touch) ☐PDA ☐handphone without touch screen ☐MP3/MP4 ☐PSP or Nintendo DS ☐Others: _____________
2. Overall, I am satisfied with how easy it is to use this system.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree
3. I can effectively do classroom management using the system.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree
4. I think that I would like to use this system frequently.

   Strongly disagree 1 2 3 4 5 6 7 Strongly agree
5. Does MOGCLASS fit into the music curriculum? Why and why not?
6. Please compare the MOGCLASS lesson with recorder lesson in terms of students' discipline, motivation, creativity and technique fluency.
7. Please grade students' group performance in terms of creativity, style, and technical proficiency.
8. Comments about the system.

Appendix 10: MOGCLASS Lesson Plan in Controlled User Study

Lesson 1	
Target level(s):	Primary 4
Topic:	Music learning with iPod
Objectives:	1. Operate and navigate within the application used in this project. 2. Create and improvise music
Learning Outcomes:	At the end of the lesson, students should be able to 1. Play Mary had a Little Lamb 2. Play the notes G, A and B using the iPod application.
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**
1	**Lesson Introduction:** Teacher to tune in the pupils, explaining and introducing the pupils to the device and the purpose of this project.	5 min
2	**Lesson Development:** Teacher teaches the various functions and trains the pupils in navigating through the application. The teacher then teaches the pupils to play 3 simple notes G, A and B on the iPod.	15 min
3	**Lesson Closure** Teacher teaches a simple song; Mary had a little Lamb on the iPod to reinforce the 3 notes taught.	5 min

4	**Lesson Extension (Optional):** Teacher questioning: How are the notes arranged in the application?	

Additional Resources:

iPod installed with the music learning software.

Lesson 2	
Target level(s):	Primary 4
Topic:	Music learning with iPod
Objectives:	1. Operate and navigate within the application used in this project. 2. Create and improvise music
Learning Outcomes:	At the end of the lesson, students should be able to 1. Demonstrate how the notes are arranged in the application 2. Play the C major scale (Doh-Doh) on the iPod
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**
1	**Lesson Introduction:** Teacher to tune in the pupils, explaining and introducing the pupils to the device and the purpose of this project. - How to handle the device - How to access the application - Dos and Don'ts	5 min
2	**Lesson Development:** Teacher teaches the various functions and trains the pupils in navigating through the application. The teacher then teaches the pupils to play 3 simple notes G, A and B on the iPod.	15 min

3	**Lesson Closure** Teacher teaches a simple song; Mary had a little Lamb on the iPod to reinforce the 3 notes taught.	5 min
4	**Lesson Extension (Optional):** Teacher to teach the song “Twinkle Twinkle” to the class if they have no difficulties playing “Mary had a Little Lamb”	5 min
Additional Resources: iPod installed with the music learning software.		

Lesson 3	
Target level(s):	Primary 4
Topic:	Music Learning with iPod
Objectives:	O1 – Sing and play melodic and rhythmic instruments individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts
Learning Outcomes:	At the end of the lesson, students should be able to 1. Sing the song Edelweiss 2. Play the song Edelweiss 3. State that the song Edelweiss is in 3/4 time
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**

1	**Lesson Introduction:** Teacher to screen a video clip on the song "Edelweiss" from the Sound of Music. Then, the teacher demonstrates the playing of the song with the iPod device.	5 min
2	**Lesson Development:** Teacher teaches the song Edelweiss to the class, phrase by phrase. Pupils take turns with their partner to learn the song on the iPod device. Then, the class plays the song together as reinforcement. Teacher to question the class what time the song is in.	15 min
3	**Lesson Closure** Teacher revises the song Edelweiss.	5 min
4	**Lesson Extension (Optional):** Teacher might wish to 'unlock' the 'hitter' feature and encourage the pupils to explore the various sounds that can be used to accompany the song.	5 min
Additional Resources: 1. Sheet music of Edelweiss		

Lesson 4	
Target level(s):	Primary 4
Topic:	Music Learning with iPod
Objectives:	O1 – Sing and play melodic and rhythmic instruments

	individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts
Learning Outcomes:	At the end of the lesson, students should be able to 1. Play the song Edelweiss in good timing with own composed accompaniment 2. Compose a simple ¾ accompaniment with the percussion feature on the iPod.
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**
1	**Lesson Introduction:** Teacher to recap and revise the song 'Edelweiss' with the class	5 min
2	**Lesson Development:** Teacher leads the class in recalling that the song is in ¾ time and demonstrates how to create a simple accompaniment with the iPod striker interface. Teacher then splits the class up into groups according to the colour of the iPod and assigns them the task of creating a suitable accompaniment for 'Edelweiss'.	15 min
3	**Lesson Closure** Teacher selects one or two groups that has completed to give the class a demonstration. Pupils may give comments on the demonstration.	5 min

4	**Lesson Extension (Optional):**	
Additional Resources:		

<u>**Lesson 5: Evaluation**</u>

This lesson would be the evaluation lesson, where the teacher will assess the performance of the groups with reference to selected rubrics in order to grade the performance in terms of creativity, style and technical proficiency.

Appendix 11: Recorder Lesson Plan in Controlled User Study

Recorder Lesson 1	
Target level(s):	Primary 4
Topic:	Recorder
Objectives:	O1 – Sing and play melodic and rhythmic instruments individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts O5 – Discern and understand music from various cultures and of various genres O6 – Understand the role of music in daily living
Learning Outcomes:	At the end of the lesson, students should be able to 1. Play the recorder with proper posture and technique. 2. Play the notes G, A and B on the recorder.
Lesson Duration:	1 period (30 minutes)

Part	Lesson Activities	Duration
1	**Lesson Introduction:** Teacher to tune in the pupils in by showing a variety of recorders and then screening a video of a professional recorder quartet.	5 min
2	**Lesson Development:** Teacher teaches the correct posture and basic blowing techniques of the recorder. Teacher teaches the notes G, A, and B on the recorder	15 min

3	**Lesson Closure** Teacher teaches a simple song; Mary had a little Lamb on the recorder to reinforce the 3 notes taught.	5 min
4	**Lesson Extension (Optional):**	
Additional Resources: 1. Sopranino, Soprano, Alto and Tenor recorders 2. Youtube clip of SIRENA Recorder Quartet		

Recorder Lesson 2	
Target level(s):	Primary 4
Topic:	Recorder
Objectives:	O1 – Sing and play melodic and rhythmic instruments individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts O5 – Discern and understand music from various cultures and of various genres O6 – Understand the role of music in daily living
Learning Outcomes:	At the end of the lesson, students should be able to 1. Play the recorder with proper posture and technique. 2. Play the notes E, F, C and D on the recorder.
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**

1	**Lesson Introduction:** Teacher to revise the notes B, A and G taught last lesson on the recorder. Teacher revises the song Mary Had a Little Lamb and picks individual pupils to perform as an assessment of learning.	5 min
2	**Lesson Development:** Teacher teaches the notes E, F, C, D on the recorder	15 min
3	**Lesson Closure** Teacher revises all the notes E, F, G, A, B, C and D on the recorder.	5 min
4	**Lesson Extension (Optional):** Teacher screens a short clip of Edelweiss from the sound of music and tells them they will be learning the song during the next lesson	5 min

Additional Resources:

1. Edelweiss video clip
2. Edelweiss music sheet

Recorder Lesson 3	
Target level(s):	Primary 4
Topic:	Recorder
Objectives:	O1 – Sing and play melodic and rhythmic instruments individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts

	O5 – Discern and understand music from various cultures and of various genres O6 – Understand the role of music in daily living
Learning Outcomes:	At the end of the lesson, students should be able to 4. Sing the song Edelweiss 5. Play the song Edelweiss 6. State that the song Edelweiss is in 3/4 time
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**
1	**Lesson Introduction:** Teacher to hand out music sheets to pupils and teach the song Edelweiss.	5 min
2	**Lesson Development:** Teacher teaches the song Edelweiss on the recorder. Teacher to question the class what time (triple/duple) the song is in.	15 min
3	**Lesson Closure** Teacher revises the song Edelweiss.	5 min
4	**Lesson Extension (Optional):**	

Additional Resources:

1. Sheet music of Edelweiss

Recorder Lesson 4	
Target level(s):	Primary 4
Topic:	Recorder
Objectives:	O1 – Sing and play melodic and rhythmic instruments individually and in groups O2 – Create and improvise music O3 – Describe and evaluate music through listening O4 – Develop understanding of music elements / concepts O5 – Discern and understand music from various cultures and of various genres O6 – Understand the role of music in daily living
Learning Outcomes:	At the end of the lesson, students should be able to 1. Play the song Edelweiss in good time and technique 2. Compose simple accompaniment patterns on un-pitched percussion instruments for the song Edelweiss.
Lesson Duration:	1 period (30 minutes)

Part	**Lesson Activities**	**Duration**
1	**Lesson Introduction:** Teacher revises the song Edelweiss on the recorder.	5 min
2	**Lesson Development:** Teacher shows the class that they can make the song more interesting by adding in percussion accompaniments. The teacher then demonstrates a simple percussion accompaniment for the song. Teacher breaks the class up into groups and asks the groups to compose their own accompaniment patterns.	15 min
3	**Lesson Closure** Teacher tells the class that there will be an evaluation session. The pupils will play the song Edelweiss and accompany them	5 min

	with their own created accompaniment patterns.	

Lesson 5: Evaluation

This lesson would be the evaluation lesson, where the teacher will assess the performance of the groups with reference to selected rubrics in order to grade the performance in terms of creativity, style and technical proficiency.

Appendix 12: User Experience Questionnaire for MOGAT

Student Name: ______________________________

1. I feel the game is easy to play.

Strongly disagree	1	2	3	4	5	Strongly agree

2. I enjoyed playing this game.

Strongly disagree	1	2	3	4	5	Strongly agree

3. I would play this game for fun if I had it.

Strongly disagree	1	2	3	4	5	Strongly agree

4. Comments about the Higher Lower/Vocal Matcher/Ladder Singer game.

____

____

Appendix 13: Questionnaire for the Evaluation of Karaoke vs. Ladder Singer

Student Name: ______________________________

1. I feel the game is easy to play.

Strongly disagree 1 2 3 4 5 Strongly agree

2. I enjoyed playing this game.

Strongly disagree 1 2 3 4 5 Strongly agree

3. I would play this game for fun if I had it.

Strongly disagree 1 2 3 4 5 Strongly agree

4. I can correct my pitch based on the feedback from the game.

Strongly disagree 1 2 3 4 5 Strongly agree

5. I can follow the lyrics during singing.

Strongly disagree 1 2 3 4 5 Strongly agree

6. The game can help me with learning this song.

Strongly disagree 1 2 3 4 5 Strongly agree

7. Comments about the game.

____

____

Appendix 14: Questionnaire for the Evaluation of the Web Service for MOGAT

Website Tour

MOGAT website is built to support students' game based auditory habilitation by providing an online service for teachers to monitor students' progress, give subjective feedback, and schedule individual program. We invite you to help us to evaluate the website. Please follow the instructions as follows.

I. Login

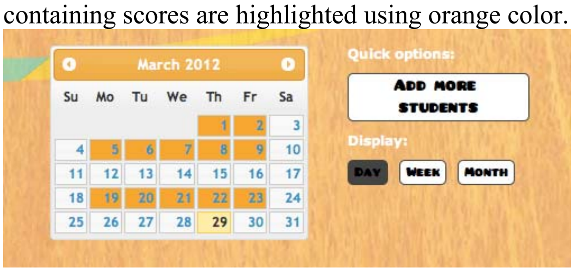
1. Head to http://m3r.comp.nus.edu.sg/mdst/

2. Login is done using the top login form.

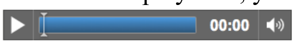
User name: **testuser** password: **testuser**

II. Teacher View

1. Upon login, click on the calendar for the scores of the games for that day. The date entries containing scores are highlighted using orange color. (The scores are in March and Feb)



2. If there was a playback, you can listen to the playback for the score.



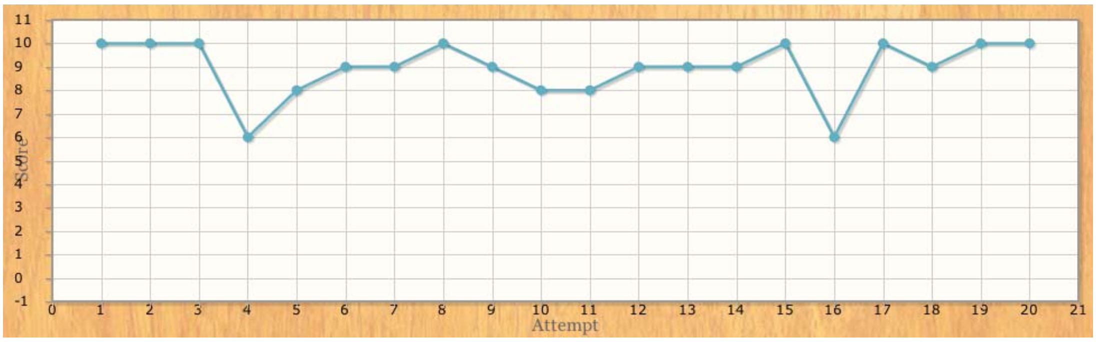
3. You can change to time period blocks to view scores in days, week spans or month spans. These buttons are 

4. You can also give ratings for a students scores by clicking on the stars for that score's row.

5. Leave a comment for the score to possibly help the students identify their weaknesses. The comment button is . Please Click it and leave some comments in the dialog box. Once you leave comments, the icon will be modified to notify you that there are comments.

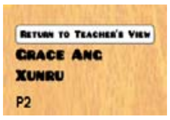
6. Clicking on a student's name in the scoreboard redirects you the student's view.

7. In the students view, you can see a graphical representation of the students' scores for the day, week or month as below.

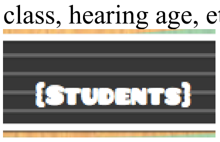


Click week 

and select a date in a week in the calendar to show the score plot in that week.

8. Click "Return to the teachers' view" 

9. You can click on "Students" tab on the navigation bar to check all students' status including their class, hearing age, etc.



10. Click the "Events" on the navigation bar.

11. You can also schedule students' events in the "Events" view. Click the specific date, and then edit the event information like name, venue, game, level, notes, and the students involving in the events.

Navigate the website for about 10mins …

Please answer the following questions:

Just underline the number like below

Strongly disagree 1 2 3 <u>4</u> 5 Strongly agree

1. Overall, the website is easy to use.

Strongly disagree 1 2 3 4 5 Strongly agree

2. I can easily use the website to check students' singing and game progress.

Strongly disagree 1 2 3 4 5 Strongly agree

3. I can easily use the website to give students ratings and comments.

Strongly disagree 1 2 3 4 5 Strongly agree

4. I can easily use the website to set up students' events.

Strongly disagree 1 2 3 4 5 Strongly agree

5. The website can effectively assist me to support a group of children with their musical habilitation.

Strongly disagree 1 2 3 4 5 Strongly agree

6. I will be likely to use the website to support and manage students in the future

Strongly disagree 1 2 3 4 5 Strongly agree

7. Overall, I am satisfied with this website.

Strongly disagree 1 2 3 4 5 Strongly agree

8. What do you like about the website?

____

9. What do you think we can improve the website?

____

Appendix 15: Consent Form for MOGCLASS MDAS

You/Your child are/is invited to be in a research study, “Using the MOGCLASS in group Music Therapy with individuals with Muscular Dystrophy: A pilot study” concerning the use of assistive technology in enhancing feeling of success, motivation and enjoyment during group music therapy session. You/Your child were/was considered for the possible participation because of your/his/her attendance at Muscular Dystrophy Association (Singapore) (MDAS). It is asked that you read this form and ask any questions you may have before agreeing to give permission (to have your child) to be included in the study.

This study is being conducted by:

1. Ms. Ng Wang Feng, MMT, MT-BC, music therapist at MDAS
2. Dr. Patsy Tan, PhD, MT-BC, NMT, MICU-MT, music therapist at SGH
3. Mr. Zhou Yinsheng, PhD candidate at NUS Computer Science Department
4. Dr. Wang Ye, PhD, Assistant Professor at NUS Computer Science Department

Background Information: There are many studies about the use of technology in music therapy literature (Nagler & Lee, 1989; Spitzer, 1989), however very little has been conducted on muscular dystrophy clients. It is obvious that the successful participation of individuals with severe physical limitations would require the therapist to make some adaptation so that they may participate successfully in the music therapy interventions. Elliot (1982), as cited in Peters (2000), has also written about how to select musical instruments for individuals with physical limitations. Traditional musical instruments often need to be adapted to make for successful participation in the music-making by clients (Peters, 2000). However, certain instruments would be difficult for a client with very weak muscular control and strength to manipulate, such as the tone chimes or claves. This is where technology can come in, e.g. by making available a wide variety of sounds to the MD client, using his/her existing physical functioning ability.

Procedures: If you give permission, music therapist, Ms. Ng Wang Feng will approach you/your child during his/her music therapy session to ask if he/she wishes to participate in the activities. The study consists of a total of six thirty-minute sessions spreading across six weeks. During the first three weeks, you/your child will be having music therapy session using acoustic instruments of your/his/her choice. For the final 3 weeks, you/your child will be attending music therapy sessions using MOGCLASS programmed with instrumental sounds of your/his/her choice.

Each session will begin with a familiar breathing exercise and a physical warm-up exercise programme involving movements from head to toe, to live music accompaniment. Then, you/your child will be given the opportunity to choose instruments (or instrument sounds – using MOGCLASS) for a structured percussion exercise, which also gives you/him/her space to come up with your/his/her own rhythms or sounds with opportunities for solo turn-taking. Finally, you/your child and other group members will work on a new song suggested by one of the participants in the group earlier – by putting instrumental/percussion parts to it. The therapist will facilitate and ask for suggestions from the group. At the end of each session, you/your child will be given a short questionnaire on perception of success, enjoyment and motivation to complete. The questionnaire should take no more than 10 minutes to complete. If you/your child require(s) assistance in filling up the questionnaire due to muscle weakness, assistance will be provided.

Particular attention will be paid to the overall well-being of the participant. Any activities that cause agitation or discomfort to you/your child will be immediately stopped.

Risks and Benefits of Being in the Study: There are no known risks in the activities used. There are also no direct benefits for being in the study.

Confidentiality: The records of this study will be kept private in a password-protected computer. In any sort of report that might be published, no information will be included that would make it possible to identify a subject. No names will be used as all subjects will be number coded. Records will only be viewed by researchers and manager at MDAS.

Voluntary Nature of the Study: Your decision whether or not to give permission for the researcher to ask you/your child to participate in this study will not affect your current or future relations with Muscular Dystrophy Association (Singapore), Singapore General Hospital and National University of Singapore. If you give your consent now, you are free to withdraw at anytime without affecting those relationships.

Contacts and Questions:

For questions related to music therapy session contact Ms. Ng Wang Feng at wanfen@gmail.com.

For questions related to MOGCLASS technology contact Mr. Zhou Yinsheng at yzhou86@comp.nus.edu.sg

You will be given a copy of this form to keep for your records.

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to allow the researcher to approach me/my child for the study.

Signature:________________________________ Date: _____________________

Relationship to child (if applicable): _______________________

Signature of Investigator(s) ____________________ Date: ____________________

Signature of Investigator(s) ____________________ Date: ____________________

Signature of Investigator(s) ____________________ Date: ____________________

Signature of Investigator(s) ____________________ Date: ____________________

Appendix 16: Form A for MOGCLASS MDAS

1. Student name: ______________________________

2. Age: ______________________________

3. Gender: ☐Male ☐Female

4. Have you studied music outside of school? ☐Yes ☐No

   If so, how many years?

   ☐Less than 1 ☐1-2 ☐3-4 ☐5 or more

5. Do you use computers? ☐Yes ☐No

6. Do you use any mobile devices? (Check any that apply, or leave them blank)

   ☐Smartphone with touch screen (e.g., iPhone/iPod Touch) ☐MP3/MP4

   ☐Handphone without touch screen ☐PSP or Nintendo DS

   ☐Others: _____________