MOGCLASS: Evaluation of a Collaborative System of Mobile Devices for Classroom Music Education of Young Children

Yinsheng Zhou, Graham Percival, Xinxi Wang, Ye Wang, Shengdong Zhao
School of Computing (SoC), National University of Singapore, Singapore 117417
{yzhou86, wangxinx, wangye, zhaosd}@comp.nus.edu.sg, graham@percival-music.ca

ABSTRACT
Composition, listening, and performance are essential activities in classroom music education, yet conventional music classes impose unnecessary limitations on students' ability to develop these skills. Based on in-depth fieldwork and a user-centered design approach, we created MOGCLASS, a multimodal collaborative music environment that enhances students' musical experience and improves teachers' management of the classroom.

We conducted a two-round system evaluation to improve the prototype and evaluate the system: Improvements were 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 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.

ACM Classification Keywords
H.5.5 Information Interfaces and Presentation: (e.g., HCI): Multimedia Information Systems: Sound and Music Computing; K.3.1 Computing Milieux: Computers and Education; J.5 Computer Applications: Arts and Humanities—*Music*

General Terms
Design, Experimentation, Human Factors.

Author Keywords
Mobile devices, music, education, musical instruments, children, user-centered design.

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 the students have mastered the necessary technique to accomplish different tasks [20].

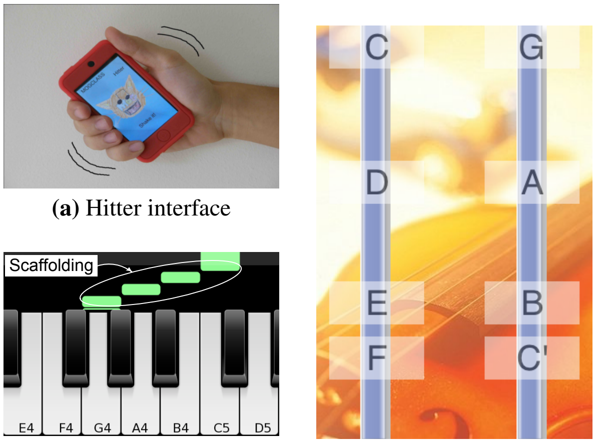
Conventional classroom music education constrains the development of students' musical skills [14]. Most instruments require years of practice to achieve competency, setting a technical demand which is too high for most students. The limited number of instruments available also restricts students' artistic expression. Furthermore, the chaos and noise produced by acoustic instruments during class-wide practice makes listening and self-analysis difficult. Teachers must spend a huge amount of time and effort keeping the class in order, which reduces the time for teaching technical instrumental skills or musical expression.

By carefully analyzing current practices in music education in classrooms, we designed MOGCLASS (Musical mObile Group for Classroom Learning And Study in Schools) [25], a collaborative system and multimodal music environment based on networked mobile devices. It supports students' music experience and assists teachers in managing the classroom. It enhances active listening, composition, and performance, which enables creative music making and engagement 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 playing a wide range of musical instruments through suitable 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 the teacher to assist students through "scaffolding", a set of visual hints that guide students through the piece of music.

To support peer collaboration during practice sessions, we designed *virtual sound spaces*, allowing students within a group hear each other's sounds via headphones, but do not hear sounds produced by other groups. Consequently, students can collaborate better without disturbing others. Their devices can also be switched to *public performance mode*, which plays sound over loudspeakers so that everybody in the classroom can hear.

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.
CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
Copyright 2011 ACM 978-1-4503-0267-8/11/05...$10.00.



(a) Hitter interface

(b) Tapper interface with scaffolding

(c) Slider interface

Figure 1: Student interfaces in MOGCLASS

A device that acts as a remote control for all students' devices facilitates the teacher's management of the classroom. It can automate tasks for different instructive and disciplinary purposes such as changing the sounds and interfaces of students' devices, grouping students, activating or deactivating students' 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), requirements and the 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. 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.

Our work makes the following contributions: 1) general design principles 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.

USAGE SCENARIO

To illustrate the various functionalities of our system, we 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 students' devices to show a piano-like interface (Figure 1b) by pressing a few buttons on her device. To help the students learn a musical piece, she provides extra visual cues by enabling scaffolding. A set of bars drop down from the top of the screen of all devices. The location and size of each bar indicates a note and the duration it should be played. Students can press the buttons 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 are allowed to do group improvisation. The teacher enables the headphones so that students within a group can hear each other's devices. She allows them choose any instrument, and turns off the visual cues. Students who choose percussion instruments produce sounds by shaking the device (Figure 1a). A few advanced students who choose to play the melody can make sounds such as an expressive glissando ("swooping in between" normal notes) using the interface in Figure 1c, which 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 the misbehaving students through her device, and she mutes their devices so that they cannot disrupt the class.

RELATED WORK

Technology in music education has been growing rapidly over the last few decades. Programs such as GNU Solfege [2] and Practica-Musica [4] can be used for ear training and teaching music theory, while systems like i-Maestro [15] and the Digital Violin Tutor [23] provide interactive self-learning environments for studying how to play an instrument. Many schools teach composition using notation software [16], which allows students to hear their scores without the need for live musicians, while programs like Hyperscore [3] allow students to create music without any knowledge of music theory. 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.

One solution is to create non-standard physical interfaces to act as controllers for synthesizers (e.g., Toy Symphony [10]). However, customized hardware limits the potential for widespread adaptation by schools. We adapted current mobile interfaces, especially since these devices are increasingly powerful and ubiquitous. One example of this approach is MoPhO [21], a new repertoire-based ensemble using mobile phones as primary musical instruments. Other projects have focused on accelerometers within commercial mobile phones [6, 7] or the Wii remote [22], using gesture recognition as input methods for musical instrument applications. Nevertheless, very few attempts to translate this approach so that it can be applied in large classrooms.

A few systems have been developed to support non-music classroom education. KidPad [8] developed a shared 2D

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

drawing tool for storytelling. Livenotes[11] created a shared white board system using wireless communication and tablet PCs to support real-time communication within small groups of students during lectures. Mischief [13] is 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. Systems for special needs have also been developed. One example is vSked [9], an interactive and collaborative visual scheduling system that supports classroom activities for children with autism and eases teachers' workload.

DESIGN METHOD

We followed the *classroom-centered design* suggested by Loh [12]. This approach is aimed at "inquiry-oriented" education, which is a good fit for the current music curriculum in local primary schools [1]. 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, observing five classroom sessions in Grades 3-6 and interviewing four music teachers. 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.

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 to learn and develop the physical skills required to play them.[2] Students must learn those skills in conjunction with music theory, collaboration, and composition. Since none of the objectives of the music subject [1] is instrument technical skills, we could simplify the physical skills required to make music so that students would be able to spend more mental effort on the other three activities.

[2]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.

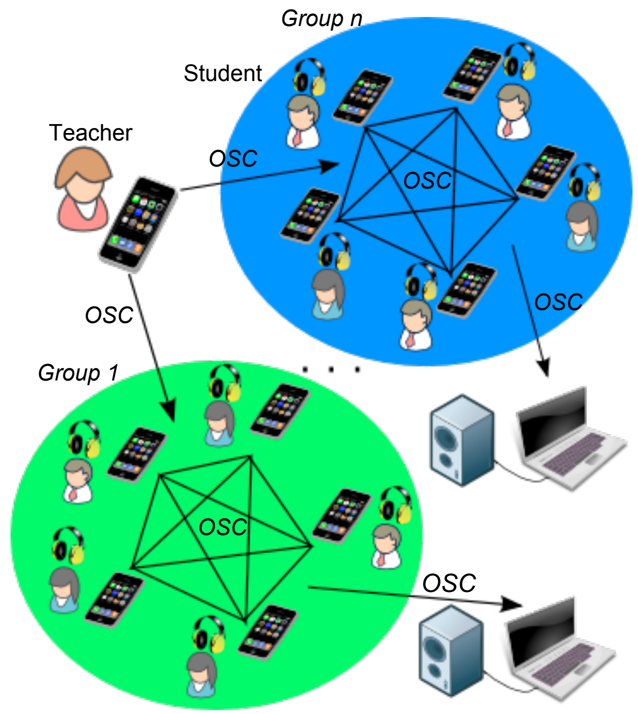


Figure 2: System diagram

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 [5], without giving students the ability to play and experiment with the instruments themselves.

C. Individual and group activities: There are frequent switches 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 hopes technology can be used to solve the problem.

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 time giving warnings or punishments to noisy students.

Design Principles

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 support a wide range of functions and simulate sounds of 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 speakers when performing. The wireless network allows students to be interconnected, supporting collaborative music making.

D. Facilitate teacher's task. Some activities can be automated: the teacher can carry out different classroom activities such as 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.

THE MOGCLASS SYSTEM

This section 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 [25]. The system diagram is in Figure 2.

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 [19], so we developed three users interfaces (hitter, tapper, and slider; Figure 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 multi-touch display; tapper is played using discrete buttons, while the vertical position of a finger on the slider plays its note.

To help teachers monitor students' status and manage their

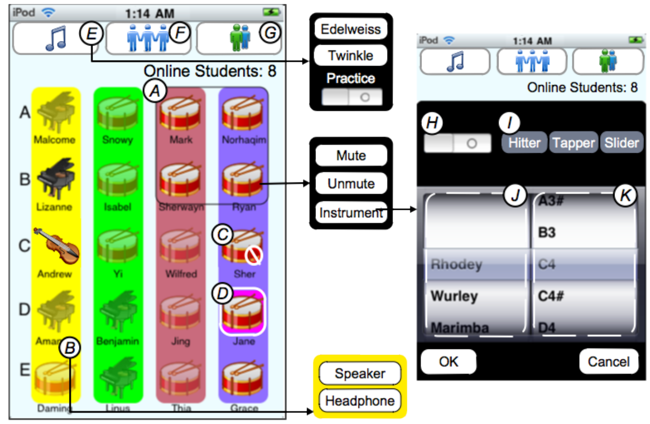


Figure 3: The workflow of the teacher's interface: the student icon represents hitter (drum), tapper (piano), slider (violin) that the student is using. Icons for students who are online are highlighted while the ones for those who are offline are semi-transparent. The students' names are displayed under each icon.

interfaces simultaneously, we designed an interface that integrates the teacher's functions in single display (Figure 3). Selecting individual students is done by dragging the finger to select students' icons (A) on the touchscreen, 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's device (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).

Virtual Sound Space and Public Performances

In the *virtual sound space* (Figure 4), the students' devices are grouped according to how the teacher sets them. Each device sends all its user actions to other devices in the group, allowing the sounds to be synthesized in each device. In *public performance mode*, the group's loudspeakers will be enabled so that the group can perform their composition to all the students.

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 [20]. The basic idea is similar to karaoke: students perform preset songs based on the visual hints. When the class is performing music together, all student devices are synchronized. The entire performance is started from the teacher's device.

Figure 4: Students working with MOGCLASS in a ***virtual sound space*** **under the teacher's direction.**

Table 1: Classroom session details. A: Bell pulling (hitter); B: Mechanical bells (hitter); C: Kangdi Qing Ge (Tapper); D: Frere Jaques (Tapper); E: Kangdi Qing Ge (Slider)

Grade	Time (min)	Lesson programs	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.

ITERATIVE DESIGN EVALUATION

We conducted four evaluations to test the usability of the initial prototype.

We tested our system on two groups of students in an actual classroom environment: Group 1 consisted of students aged 8 to 9 years (from two classes: C-3A, which has 44 students and C-3B, which has 42). This group was selected because they were at a key stage of music development where they can benefit from this type of technological enhancement. Group 2 consisted of students aged 11 to 12 years from one class C-6, which has 18 students). They represented the higher end of our target users, with better musical and analytical skills. These allowed us to collect more feedback for improving the system. All classes were roughly balanced in gender with 80% of them having some experience with mobile devices.

The first two sessions were carried out with class C-3A, the third session with C-6, and the final session with C-3B. A total of 104 students and 3 teachers participated in our evaluations.

To avoid excessively training the teachers on MOGCLASS's incomplete versions, the first three lessons were taught by one of the authors, who is also an experienced music teacher. The regular music teachers observed and gave comments after the lessons. The final evaluation was taught by a primary school teacher who was not previously exposed to MOGCLASS. This was done to test whether the system could be used effectively by a music teacher with no technical background.

Working closely with the teachers, we created lessons to evaluate the effectiveness of our system (see Table 1). These lessons aim to test with a variety of music from different cultures, instruments, and varying degree of difficulties. Lessons A, B, E represented a basic introduction to each music-making interface. Lesson C and D allowed students to play more challenging music which requires more coordination among different groups of students.

During each session, student feedback was collected via direct observation, video recordings, and questionnaires. We also conducted semi-structured interviews with the observing teachers.

Findings

Overall, the sessions were very successful in achieving our evaluation goals: testing the initial acceptance, learn-ability, and usability of MOGCLASS interface (both teacher and student interfaces), and to test the robustness of the system. Most of the feedback from students' and teachers' were positive. The response gathered from the students' 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. Managing large groups of young students is typically a difficult task, but the mute function helped significantly. The teachers highly approved of this feature.

The prototype received a few complaints, which were caused by limitations intrinsic to mobile devices such as limited display and processing resources.

Feedback from Students

Students with a background in piano complained about the split-level notes in the original tapper interface [24] and the limited range (one octave). After discussions with music teachers, we adopted the piano for the metaphor of 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 synchronizing of the gesture and the sound produced is not accurate enough. We solved this problem by improving the algorithm using machine learning approach [25].

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.

Feedback from Teachers

In the teacher interface design of our initial prototype (Figure 5), the mute function (A) was not selective. It disabled all students' devices, so the teacher could not use it to silence the rest of the class when a group was performing. 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, teachers valued the headphone feature because it eliminated the chaos during music practice. Furthermore, teachers' suggestions inspired us to design the *virtual sound space* that students can do group practice without disrupting the rest of the class if their devices were shared with the group through headphones.

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.

The separate displays in the original interface of the teacher's device (Figure 5) should be streamlined. There are three main reasons we want to change the old teacher interface design: 1) the teacher has to switch among the three views to change the configurations of the students' 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's device is muted (in C of Figure 5, 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 students' 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.

CONTROLLED USER STUDY

The evaluations aimed to gather teachers' and students' initial reaction towards MOGCLASS, discover usability issues, and gather feedback for improvements. However, the lessons we conducted are insufficient for us to judge the system's educational value. It is 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 further and answer the following research questions:

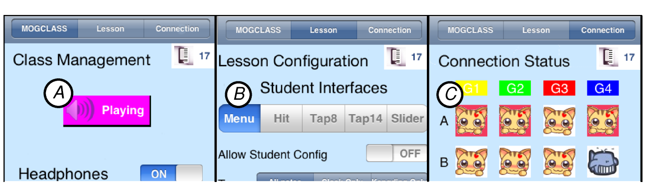


Figure 5: A partial view of the three seperate displays in the original teacher interface design

- Does MOGCLASS increase students' interest and motivation, and improve collaboration in music classes?
- Does MOGCLASS enhance the teacher's ability to organize and manage the class?
- Can MOGCLASS easily be integrated into the primary schools' current music curriculum?

Participants

Two classes (4A and 4B) consisting of 77 students in Primary 4 (Grade 4 in the US school system) and one music teacher participated in the study. The two classes were randomly chosen. 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. He was familiar with mobile devices, but did not have any previous experience with MOGCLASS.

Study Design and Procedure

The study adopts a between-subjects design. There is one independent variable (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 identical environments.

Prior to the study, we spent 30 minutes in the lab training the music teacher on the use of MOGCLASS. A survey and questionnaire were given at various stages of the lesson program.

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 at the end of the lesson.
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 the 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.

5. Evaluation: the teacher will assess and 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.

Classroom Setup

Due to budget constraints, we only had 21 iPod Touches for use in 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 lesson.

Survey and Questionnaire

We used a survey and a questionnaire to evaluate 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 questionnaire (see Table 2) studied motivation in more detail, and was administered three times. The questions were based on Deci and Ryan's self-determination theory [18], which states three basic psychological factors contributing to self-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 factor, 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.

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 had one group interview with four students from Class 4A regarding their attitudes towards using MOGCLASS.

Research Hypotheses

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

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

Table 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.

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.*

Results and Analysis

Students' Motivation, Interest, and Collaboration

In the survey, which presents a scale of 1 to 9 (1 being the least interesting, 9 being the most interesting), both classes perceived music as an interesting subject. Class 4A (MOGCLASS) with an initial rating of 7.31 and Class 4B (recorder) with an initial rating of 8.05. After the five lessons, Class 4A's rating increased significantly from 7.31 to 8.42 ($F(1,33) = 9.862$, $p = 0.004$) (see Table 3). For Class 4B, although the average rating also increased from 8.05 to 8.43, it was not significant ($F(1,28) = 1.451$, $p = 0.238$). The significant increase in the regard for music as an interesting subject demonstrates that MOGCLASS is effective in promoting students' interest. However, due to the higher initial rating of Class 4B, it is insufficient to conclude that MOGCLASS is more effective than recorders in increasing students' interest.

Since the students answered the questionnaire three times, we analyzed the results using the repeated-measures ANOVA test with the musical instrument as the between-subject factor (in Table 4 and Figure 6). Students using MOGCLASS had higher ratings on most of the questions except for Q1, where no significant difference was found. This indicates both classes enjoyed the five music lessons equally. However, since students using MOGCLASS initially had lower interest in the music (7.31 vs. 8.05), gaining comparable interest after the lessons seems to indicate greater improvement. For the other questions, MOGCLASS received signif-

Table 3: Survey Results: General Interest

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

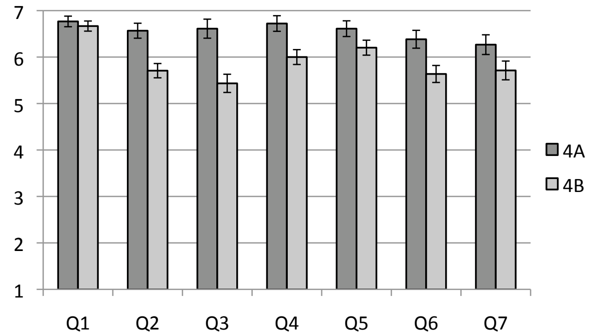


Figure 6: Graph of questionnaire results

icantly 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**, proving MOGCLASS covered the components of self-intrinsic motivation. The survey shows that MOGCLASS increased Class 4A's interest in music education to the level of Class 4B. Thus, MOGCLASS has a significant effect on motivation.

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 for each class across multiple lessons. We found no significant difference for 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.

The field observation and interviews validated our questionnaire results. Teacher's assistance during song practice was much less in MOGCLASS lessons. Most students were able to practice playing "Edelweiss" on their own using the "scaffolding" feature without much involvement of teacher. As a result, some students fully mastered the playing of the music piece (Edelweiss) through classroom practice alone. On the other hand, the level of assistance in the recorder class was much higher. The teacher frequently approached students, but they still expressed the need for more assistance. As a result, none of the students learned to play Edelweiss during class even with more help from the teacher.

Table 4: Analysis of questionnaire results: one-way ANOVA test. (*$p < 0.1$; **$p < 0.05$)

#	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		

Many students strongly expressed the desire to have more MOGCLASS lessons in the future. They found MOGCLASS interesting and very easy to use, and liked that it made sounds of many musical instruments. They also "enjoyed the class", and 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 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. It was a scene from any other music lesson, where each student was preoccupied with a certain idea, or wanted to do other things or cause mayhem. However, the music teacher reported that the major difference was 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 inconsequential compared to the cacophony in Class 4B.

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 students' activities.

Since the status of students' 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 since 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 will not proceed with the lesson unless everyone listens. In Class 4A, the teacher simply disabled all the students' devices before giving verbal instructions. The group interview revealed that while one student found the classroom management functions of the teacher's device (particularly the mute function) restricted freedom, other students understand that they were necessary to keep order in the class.

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." [1].

MOGCLASS's basic configuration, which was used in this study, has melodic elements (tapper and slider) and a percussion element (hitter). It allowed students to play almost all elements of classroom music making needs in terms of many common musical instrument sounds and the basic striking action of the percussion. It also provides an almost infinite expansion capability, requiring the devices only to be updated to receive new musical instrument sound 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 that involve no instruments (e.g., singing) if a voice recording function can be added.

However, one of the most important objectives of classroom music education that traditional music technology fails to provide for is music making in groups [17]. This is also specified within the first objective of the 2008 General Music Programme Syllabus [1].

MOGCLASS is easy to deploy, requiring only five minutes for two students to set up and clean up the whole system in classroom. 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 and continued to use it on a long-term basis. The potential challenge for schools with a tight budget is to find the means to obtain the necessary hardware and software. But with the ubiquity of mobile devices, the teacher foresees 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 is effective in motivating students to study music and helping 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 self-intrinsic motivation in music education. The study also showed that MOGCLASS is effective in reducing teachers' workload in managing the classroom. There is a huge potential in deploying this system of networked mobile devices to enhance classroom music education.

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 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's 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.

CONCLUSION AND FUTURE WORK

Based on careful considerations of music education needs in schools we developed MOGCLASS. The interfaces of the teacher's and students' devices were designed to facilitate learning in a creative environment. It allows students to learn in a collaborative setting while exploring music in groups or as individuals. It can play sounds from a wide range of musical instruments and lowers the physical skills and time required to become proficient in playing music. MOGCLASS was developed to provide an active and motivating learning environment for children, while providing the teacher with an effective tool to manage classes.

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 rethinking 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 are currently working to adapt 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. We will continue to explore broader applications for MOGCLASS in our future work.

ACKNOWLEDGMENTS

We thank Ms. Chua Yu Gek from Henry Park Primary School, Mr. Weili Gan from Pasir Ris Primary School and their classes for assistance and participation in the user studies. Special thanks to Dr. Lum Chee Hoo for his kindly support and discussion, and Dillion Tan, Yang Zhao, Xiaoming Chen, Zhonghua Li for their support in system implementation. The work was supported by Singaporean Ministry of Education grant R-252-000-341-112.

REFERENCES

1. *2008 Syllabus, General Music Programme*. Ministry of Education, Singapore. [Online; accessed 24-Feb-2009].
2. Gnu solfege. `http://www.solfege.org/`.
3. Hyperscore. `http://www.hyperscore.com/`.
4. Practica musica. `http://www.ars-nova.com/aboutpm5/index.html`.
5. Youtube. `http://www.youtube.com`.
6. E.-S. Choi, W.-C. Bang, S.-J. Cho, J. Yang, D.-Y. Kim, and S.-R. Kim. Beatbox music phone: gesture-based interactive mobile phone using a tri-axis accelerometer. In *ICIT '05*.
7. A. Dekel and G. Dekel. Mogmi: Mobile gesture music instrument. In *5th International Mobile Music Workshop*, 2008.
8. A. Druin, J. Stewart, D. Proft, B. Bederson, and J. Hollan. Kidpad: a design collaboration between children, technologists, and educators. In *CHI '97*.
9. S. H. Hirano, M. T. Yeganyan, G. Marcu, D. H. Nguyen, L. A. Boyd, and G. R. Hayes. vsked: evaluation of a system to support classroom activities for children with autism. In *CHI '10*.
10. K. Jennings. Toy symphony: An international music technology project for children. *Music Education International*, (2):3–21, 2003.
11. M. Kam, J. Wang, A. Iles, E. Tse, J. Chiu, D. Glaser, O. Tarshish, and J. Canny. Livenotes: a system for cooperative and augmented note-taking in lectures. In *CHI '05*.
12. B. Loh, J. Radinsky, E. Russell, L. M. Gomez, B. J. Reiser, and D. C. Edelson. The progress portfolio: designing reflective tools for a classroom context. In *CHI '98*.
13. N. Moraveji, T. Kim, J. Ge, U. S. Pawar, K. Mulcahy, and K. Inkpen. Mischief: supporting remote teaching in developing regions. In *CHI '08*.
14. J. L. Mursell. The challenge to music education. *Music Educators Journal*, 36(5):20–22, 1950.
15. K. Ng and P. Nesi. i-maestro framework and interactive multimedia tools for technology-enhanced learning and teaching for music. In *AXMEDIS '08*.
16. M. D. Roblyer. *Integrating Educational Technology into Teaching*. Pearson Prentice Hall Publications, 2006.
17. A. 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.
18. R. M. Ryan and E. L. Deci. *The Handbook of Self-Determination Research*. University of Rochester Press, 2007.
19. D. Stanton, V. Bayon, H. Neale, A. Ghali, S. Benford, S. Cobb, R. Ingram, C. O'Malley, J. Wilson, and T. Pridmore. Classroom collaboration in the design of tangible interfaces for storytelling. In *CHI '01*.
20. K. Swanwick and C. C. Franca. Composing, performing and audience-listening as indicators of musical understanding. *British Journal of Music Education*, 16(01):5–19, 1999.
21. G. Wang, G. Essl, and H. Penttinen. Do mobile phones dream of electric orchestras? In *ICMC '08*.
22. E. L. Wong, W. Y. F. Yuen, and C. S. T. Choy. Designing wii controller - a powerful musical instrument in an interactive music performance system. In *MoMM2008*.
23. J. Yin, Y. Wang, and D. Hsu. Digital Violin Tutor: an Integrated System for Beginning Violin Learners. In *ACM MM '05*.
24. Y. Zhou, Z. Li, D. Tan, G. Percival, and Y. Wang. Mogfun: musical mobile group for fun. In *ACM Multimedia '09*.
25. Y. Zhou, G. Percival, X. Wang, Y. Wang, and S. Zhao. Mogclass: a collaborative system of mobile devices forclassroom music education. In *ACM Multimedia '10*.