Development of a Smart Classroom for Chinese Language Learning Using a Smartphone & Tablet*

Jianming Wu*1, Tsuneo KATO*1 and Da YANG*2

*1 KDDI R&D Laboratories Inc. 2-1-15 Ohara, Fujimino, Saitama Japan
*2 Faculty of Letters, Arts and Sciences, Waseda University, Toyama 1-24-1, Shinjuku Ward, Tokyo Japan

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We developed a PC-based Chinese language learning system Dig for LL (Language Laboratory) classroom in Waseda University, which achieved more effective learning than ever (Wu and Yang, 2003). Due to the increasing number of students, a more effective method using rich multimedia and not limited to the LL classroom is required. In this paper, we propose a mobile application suite for the smartphone & tablet to make a smart Chinese learning classroom a reality. This system features: 1) Communication functions for interactive lectures, 2) rich learning materials for smartphone & tablet, 3) a Chinese IME which requires Pinyin to be precisely specified and offers prompt advice on frequent patterns of spelling mistakes. The effectiveness is shown through an 8-week experiment in a traditional classroom.

Key words : Smart Classroom, Chinese Language Learning, Interactive, Rich Learning Contents, IME

1. INTRODUCTION

With the globalization of business, the number of students taking Chinese as a second foreign language is increasing in Japanese universities. However, learning Chinese is not easy due to its many different pronunciations from Japanese (Yang, 1996). In particular, as each Chinese character is assigned one of a specified “four tones” for the intonation of the syllable, it is crucial to pronounce the word with the correct tone, otherwise the meaning will be incorrect.

To date, the authors (Wu and Yang 2003) have developed an original Chinese learning system Dig (hereinafter referred to as “Dig”). We brought Dig into two Chinese learning classes in the Faculty of Letters, Arts and Sciences of Waseda University experimentally, and confirmed its effectiveness. Subsequently, we began conducting lectures in the LL and traditional classrooms combined for all 11 Chinese learning classes, using Dig in the LL classroom, correcting pronunciation, making conversation & practicing translation in the traditional classroom. In other words, we are promoting a hybrid Chinese learning lecture style.

In recent years, there has been a significant increase in the number of students learning Chinese. However, it is difficult to increase the number of LL classrooms to meet all students’ demands. In fact, about 100 students requesting the chance to take our Chinese learning lecture missed the chance by lottery in 2011.

Conversely, innovations in information technology have enabled rapid advances in mobile phones, whereupon smartphones & tablets with PC functions have emerged. In recent years, the spread of these smart devices means the digitization of educational materials has become a topical issue.

Therefore in this study, to put a smart Chinese learning classroom using smartphone & tablet into practice, we constructed an effective educational mobile system with rich multimedia for the traditional classroom. Specifically, this system features: ① Promotion of an interactive teacher–student lecture style to enhance the motivation of students in lectures; ② An easy development method for rich smartphone/tablet learning materials for learning effectiveness equivalent to Dig in the LL classroom; ③ To overcome the difficulty of Chinese pronunciation, provision of a Chinese IME which requires the “Pinyin” to be precisely specified and can prompt with advice on frequent patterns of spelling mistakes.

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In the following section, Chapter 2 explains research issues and related works and Chapter 3 describes the proposal, while evaluation of the system is included with consideration in Chapter 4.

2. RESEARCH ISSUES

2.1. Interactive Lectures

Usually, many lectures are given by projecting a PC onto a large screen in front of the classroom (Nonaka et al. 2009). To promote a sense of participation and the large-scale motivation of students, the interactive lecture style is considered effective. To use an interactive mechanism, considerable related research linked to a web-based training system (WBT) has been reported to date (Helic et al. 2003). Based on a client-server model, WBT allows students to access the web server from a web browser anytime and anywhere. However, WBT basically uses asynchronous communication technology, making it difficult to maintain real-time interaction for lectures between teachers and students. In contrast, (Maruno 2005) has proposed a "dialogue style lecture", which facilitates on-the-spot judgments by teachers based on real-time feedback from students. This method is expected to arouse students' interest and motivation for lectures, and deepen their thinking and understanding. For example, to report the status of a student to a teacher instantly, a learning system collecting notes from the digital pen used by the student via wireless communication has been developed (Miura et al. 2005). Using this system, the notes written by students are projected onto a large screen, and the teacher can hold the situation of the classroom in detail. However, the system is problematic in terms of convenience and cost.

In contrast, the prevalence of smartphones & tablets equipped with wireless communication modules mean the smart classroom has become practical. Compared to a PC, smartphones & tablets are lightweight, easily portable and convenient information devices. It is also easy to construct a ubiquitous mobile learning environment using the IEEE802.11 Wi-Fi standard (Nonaka et al. 2009). Two-way and low-latency communication can be established through the Wi-Fi connection between devices of teachers and students. For example, to increase the students' focus on learning, we use the fastest-finger-first to obtain an appropriate sense of competition. However, since mobile devices connected with the Wi-Fi AP use the same radio frequency, the transmission latency would soar with increasing simultaneous connections, and possibly bring a Wi-Fi network down. In addition, the need for a strong Wi-Fi signal for long-distance transfers, not only in the same classroom but also over different classrooms, would result in radio interference. Other problems are pointed out as follows: 1) The power consumption is high due to a radio polling for all the time; 2) The network setting takes time; 3) The power and space for the Wi-Fi AP need to be secured.

Conversely, Bluetooth is a low-latency and low power consumption wireless communication technology, which involves little radio interference by utilizing a frequency-hopping method. This makes it promising as a wireless means of connecting mobile devices between teacher and students (Miller et al. 2001). As Bluetooth devices can interconnect without an access point, teachers and students can move into any room or even outdoors, hence the Bluetooth is considered ideal for making the smart classroom a reality. However, Bluetooth was initially designed for single peer-to-peer connection usage. When using it for multiple parties, the maximum numbers of simultaneous connections must be extended, and a low-latency bulk-data transfer function incorporated.

2.2. The Production of PC-like Rich Multimedia Learning Materials

To improve learning effectiveness using a smartphone & tablet, the production of PC-like rich learning materials is essential. For example, it is effective to fully utilize video, audio and animation to present attractive lecture descriptions and exercises without feeling tired based on the individual study progress (Iribu, 2008).

However, as the specification of the smartphone & tablet (OS, resolution, etc.) varies widely compared to PCs, the production of such rich learning materials as mentioned above tends to be costly. In addition, the PC software assets for the LL classroom we have developed to date must be continually reused on the smartphone & tablet.

Therefore, a layered development method is essential to isolate the upper-layer for multiple platforms without modifying existing PC learning materials, and the lower-layer adapt multi-
platform according to different device specifications.

2.3. **Chinese IME to Address the Issue of Chinese Pronunciation Learning**

Each Chinese character has its own pronunciation. To pronounce the word, the Chinese government determined a Pinyin standard from 1958. In a Pinyin, the “initial consonant” corresponds to the Japanese consonant, while the “single/plural vowel” corresponds to the Japanese vowel (the combination of initial consonant and vowel is called a syllable). In addition, “Four Tones” are used to indicate the intonation of the syllable. The syllable is written in Roman letters, while “Four Tones” are written with 4 kinds of symbols representing the intonation as below (Besides “Four Tones”, “Light Voice” also exists, but since it is not essential to the topic of discussion, it is omitted from the following explanation).

- **Tone 1**: Flat pitch. Marked as “—”
- **Tone 2**: Low to high pitch. Marked as “/.”
- **Tone 3**: Lowering from treble and becoming treble again. Marked as “\.”
- **Tone 4**: From high to low pitch. Marked as “\/”

Pinyin is said to be the most difficult part of learning Chinese (Liu et al. 2009). In particular, although Japanese students using almost the same Chinese characters (kanji) will exploit their knowledge of grammar and notation from the Japanese language, the “syllable” and “Four Tones” for Pinyin are quite difficult and annoying for Japanese students.

In response, Wu and Yang (2003) conducted a hybrid lecture style as follows. First, for lectures held in an LL classroom, the teachers teach Pinyin of new words and grammar. Subsequently, after students understand the theory, they repeat key typing of the requested words while practicing listening exercises at natural speed. This is intended to form an auditory image (Li 2009) in the brain, allowing students to become aware of the exact pronunciation, including “Four Tones”, even at high speed. During the next stage, lectures are held in a traditional classroom, with teachers talking directly with students, making them read the textbook, correcting wrong pronunciation and strengthening their new knowledge. However, the general PC-based Chinese IME (Omron Pinyin, Microsoft Chinese IME, etc.) for the LL classroom can only enter Pinyin syllables without distinguishing “Four Tones.” Furthermore, these general input methods have simplified predictive capabilities for displaying word candidates, which supports inputting Chinese words in a sequence of the front part of the entire Pinyin. This means the students need not remember the precise Pinyin, meaning this function is not good for learning usage.

3. **THE PROPOSED SYSTEM**

3.1. **Overview of the Proposed System**

As this research is for the purpose of building a smart classroom for Chinese language learning using the smartphone & tablet, we have developed group software with the following three features: 1) An interactive learning system to retain interest, exert appropriate pressure on students and a sense of competition; 2) Rich and effective PC-like multimedia learning materials; 3) A Chinese IME requiring precisely-specified Pinyin and prompt advice on frequent patterns of spelling mistakes for effective self-learning. We mainly focus on solving the issues described in Chapter 2, and explain the details of the proposed system below.

First of all, to improve the collective motivation of students, we decided to implement an interactive learning system. By retaining the traditional one-to-many lecture style, this system allows interactive communication among individual students and teachers, and enables learning with moderate pressure and a sense of competition. More specifically, two-way interactive functions are implemented. Learning materials on the teacher-device are delivered to student-devices, consisting of descriptions of lectures, exercises and fastest-finger-first, while at the same time, students’ answers are collected from the beginning of the lecture.

Subsequently, we ensure a method of easily converting the rich PC version learning material (descriptions of lectures and exercises) for the LL classroom to smartphones & tablets, which applies an isolation scheme for the display and I/O layers. The display layer uses the same learning materials for PC, including rich multimedia, lecture descriptions and exercises. Conversely, the I/O layer is customized with functions such as exercises database connection and a record function of learning history according to each smartphone & tablet specification.

In addition, to address the issue of learning “Pinyin”, a Chinese IME is provided for effective self-learning by ensuring precise and correct input
of "Pinyin." This IME requires students to specify precisely matching Pinyin (syllable + "Four Tones") before converting them to Chinese characters. Furthermore, it will give advice on frequent patterns of spelling mistakes to avoid users making habitual errors unaware (ensuring they clearly understand the problems), based on a pattern dictionary of mistakes.

The technical elements used to realize the proposed system will be discussed in the following section.

3.2. Interactive Lecture System

The usage image of the interactive lecture system is shown in Figures 1 and 2. When the teacher and students enter the classroom, the students’ tablets automatically connect to the teacher’s notebook PC via Bluetooth, downloading the materials for the lecture description that day. Thereafter, as the lecture progresses, the teacher can specify the content transferring to devices of students. For example, the start command of the description PPT slide, video of a conversation scene, and various exercises may be broadcast to all the students (Figure 1). Furthermore, while in a traditional class, only one student could be questioned face to face, our fast finger first function can swiftly ascertain the status of all students in a short time. As shown in Figure 2, when the teacher switches to the fastest-finger-first mode, both the quiz zone and the list of student devices are shown on the teacher device. When the teacher selects the quiz, it will be displayed on the student devices. The result of each student is sent to the teacher device when he/she has determined the choice. The collective result can be confirmed by everyone using a projector displaying on a large screen at the front, with moderate pressure and a sense of competition, which makes the students enjoy this game-style learning.

3.2.1. Automatic Configuration of Network Between Teacher and Students via Bluetooth

To implement a two-way interactive lecture platform, we adopt Bluetooth technology due to its low-latency, low-energy consumption and fewer radio interference features as described in Section 2.1.

Bluetooth communication consists of the ‘master’ device for control and the ‘slave’ devices for being controlled. In the specification, a ‘master’ device connecting with seven ‘slave’ devices can construct a picnet, within which each device can be either a ‘master’ or ‘slave’, while a device requests connection with another device it acts as the role of ‘master’, and the other device accepting the requests adopts the role of ‘slave’. Although Bluetooth allows connections with up to seven devices, each ‘slave’ can only be controlled by a single ‘master’.

Due to the problem of power consumption and security considerations, the student device cannot remain in ‘slave’ mode when on standby. In fact, when a student device requests connection with the teacher device it automatically occupies the role of ‘master’. However, the problem is that only a single student device can connect to the teacher device.

Therefore, in the proposed system, we modified the Bluetooth RFCOMM HCI (Host Controller Interface) layer to change the role before establishing connection when a student device requests connection with the teacher device, keeping the teacher device as a ‘master’, which can be connected with up to seven ‘slaves’ (student devices).

Conversely, as the maximum number of

Fig. 1. Interactive Lecture Style

Fig. 2. Fastest finger First
connections is seven, using multiple receivers for the teacher device should solve the problem of limitation. However, a general Bluetooth driver stack does not support controlling multiple Bluetooth receivers. Therefore, we expanded the system for managing multiple USB prober processes, each of which is respectively activated to associate with a Bluetooth receiver as a USB device and connects with up to seven mobile devices concurrently. By assigning identified IDs and collaborating with each process, the USB prober makes multiple receivers work together as a single unit, meaning the maximum number of connections can easily be expanded to multiples of seven by increasing the number of Bluetooth receivers. As shown in Figure 3, a PC equipped with 50 Bluetooth receivers supports the simultaneous connection of up to 350 student devices.

3.2.2. Low Latency and Bulk-data transferability Between Teacher and Student Devices

Traditionally, it is easy to communicate with each Bluetooth device using the specific Bluetooth profile. However, many profile interpreters are developed together with the hardware (BLUETOOTH SIG 2004). For example, as a typical mobile phone Bluetooth profile, the Basic Image Profile (BIP) provides a standard to transfer image files (Scheibe et al. 2006). Another sample involves using a Hands Free Profile (HFP) for hands free calls, although there is no flexible interaction mechanism for a wide range of applications such as control commands, text messaging, and video data transmission.

Therefore, we developed an extensible flexible method for low latency and bulk-data-transfer communication based on the Serial Port Profile (SPP).

The SPP is a profile through the Bluetooth RFCOMM layer, which makes it possible to define extensive functions by emulating serial cable connections to transfer RAW data. As an SPP packet is limited to several KB, a data division / concatenation method was designed to transfer unlimited bulk data on any data format by multiple packets in the proposed system. We extend the SPP Packet to comprise the UID (Unique ID), the operation type, sequence number and raw data body, which can be interpreted into system actions of various sizes, such as control commands, text messaging, and video data transmission.

When a teacher device conducts the data transfer to a student device, it first obtains the Unique ID (UID) of the communications target and divides the data exceeding a single SPP packet size into multiple SPP packets. Subsequently, the student device receives and concatenates the packets according to the sequence number to interpret into system actions and data. By repeating this process, any bulk-data can be transferred. Furthermore, to reduce the application development burden, we provide an API that allows the extended SPP packets mentioned above to be transmitted and received, encapsulating complex wireless communication processing so that make it possible to create and extend various apps easily for developers.

3.3. Rich Learning Materials for Smartphones & Tablets

In consideration of the rich expression, reuse of the PC software assets and multiple deployment of mobile platforms, we have adopted a widespread and high flexibility Android-based Flash, and utilize a layered development method isolating the presentation and I/O layers in the proposed system.

As Flash is more powerful for creating intelligible presentations in rich animation than text and photos, it has been widely used in most of our PC-based learning materials in the LL classroom to date. In particular, unlike bitmap the vector elements used by Flash make it possible to retain the display quality even after scaling, making it ideal for creating self-adaptive contents to adapt to various resolutions of Android mobile devices.

However, due to the security policy problem, it is impossible to access the database and files inside Android mobile devices via Flash, which lack the necessary record functions for learning history, such as the material usage time, learning
progress, and exercise results.

In contrast, in our proposed system, the presentation layer uses the Flash contents as before, while we extend the flexible data exchange module between the Flash and Android native layer with file access permission, using HTML5 and JavaScript in the I/O layer. Figure 4 shows the architecture of rich learning materials in this proposed system. In the presentation layer on top we use the same Flash binary file as for the PC, whereas the HTML5+JavaScript in the I/O layer can read/write the binding parameters of Flash for learning progress, etc. Consequently, the I/O layer becomes an integrated data-exchange interface to transfer the data between the Flash presentation layer and the native Android layer on the bottom.

Therefore, in the proposed system, the PC version Chinese Flash content for the LL classroom developed previously can be quite easily ported to other new platforms. The developer only needs to change the font size and the button layout, which are adapted for use in various different Android mobile devices.

We have ported all Flash contents for the LL classroom produced to date to the new mobile platform. The contents are summarized in the following types: 1) Description of lectures on vocabulary, grammar and text, which utilize multimedia elements such as sound, slides, video, and animation. 2) Exercises comprising word practice blocks, sentence pattern practice blocks and application practice blocks, each of which has seven sections with Chinese character selection, Pinyin selection, Pinyin input, sentence pattern selection, array substitution selection, sentence pattern input and array substitution input.

Figure 5 shows the “array substitution selection” for dragging and dropping randomly assigned words into the correct sentence order, on devices with different resolutions (top: 800x480, below: 1024x600). Figure 6 shows the “sentence pattern selection”, recording the learning progress and listing the results as answers marked right or wrong.

3.4. A Chinese IME Requires Input by Specifying the precise Pinyin and prompt advice on patterns of frequent spelling mistakes

We propose an input method converting to Chinese characters only when the syllable (consisting of Roman letters) and the “Four Tones” match completely.

However, there is concern that some difficult Pinyin may result in frequent spelling mistakes, which may confuse students. In addition, not only do students want to input the practice text determined as part of self-learning, they also want to engage in communication practice such as e-mail or chat as training to express free ideas and thoughts in their heads. To enhance students’ motivation and learning effectiveness through such learning opportunities, an IME method that repeats the input process to automatically fix spelling mistakes and avoid new mistakes is required. Therefore, the proposed system was implemented with a prompt advice function to
ensure students are aware of their more frequent spelling mistakes. Not only does this allow students to be reminded of the correct “Four Tones” when inputting the Chinese characters, they can be indicated with advice to strengthen the newly-learned Pinyin.

3.4.1. Converting to Chinese Characters Only When the Syllable and “Four Tones” match completely

Figure 7 shows an example of inputting a Chinese character 「黄」(huang 2), explaining in detail about the procedure of converting the Chinese characters only when the syllables and “Four Tones” match exactly.

According to the national standard of Chinese syllable collections as determined by the People’s Republic of China, the Chinese pronunciation constitutes the “ initial consonant + vowel + Four Tones.” There are 21 initial consonants, 7 single vowels and 37 plural vowels. In total, the most commonly used 6763 Chinese characters have 413 syllables. Even the same syllable may come with a range of “Four Tones.” When inputting 「黄」, the keys [h] [u] [a] [n] [g] [Tone 2] are pressed in sequence, whereupon the candidate Chinese characters with the syllable “huang” and “Tone 2” are listed. The student can then touch the screen to select the target from the candidates and input the Chinese characters.

3.4.2. Prompt Advice on Spelling Mistakes

As for the spelling mistake indication function, which uses a spelling mistake pattern dictionary to detect patterns of frequent mistakes, this will be described in the flowchart in Figure 8.

First, the input key code is split one by one to check whether it is “Four Tones.” If not, the key code is inserted into the buffer, whereupon the sequence reverts to the “input key analysis process” to await the next input. If it is, all the alphabet key code in the buffer is extracted and the word dictionary is searched to confirm whether the corresponding word exists. If the search for the word is positive, the student chooses a candidate for input. If the search is unsuccessful, advice on revising the Pinyin is retrieved by searching the spelling mistake pattern dictionary, whereupon the result is displayed on the indication bar. The student can then select the indication to replace his/her wrong input and search the word dictionary to confirm whether the corresponding word existed. Next, if the appropriate word comes up in the dictionary this time, the student can choose the candidate Chinese character to be input. If the result is still not found, the Levenshtein Distance (LD: 2010 Rane and Wei) is calculated to search the word dictionary again for a similar Pinyin displayed on the indication bar. Finally the student chooses the candidate for complete the input. Accordingly, the input process is continually repeated until students have completed all the Chinese character input.

Here, LD distance is used to indicate the character string distance. This method determines a calculated LD value, which involves checking two compared character strings and counting how many times the character should be inserted/removed/replaced to make them exactly...
the same thing. In other words, assuming the source to be \( s \) and the target \( t \), the LD is the sum of the processing count required for deletion/insertion/substitution to convert \( s \) to \( t \).

For example, \( LD(s, t) \) is notated as the LD value between \( s \) and \( t \), \( LD(\text{"test"}, \text{"tent"}) = 1 \), \( LD(\text{"test"}, \text{"past"}) = 2 \), LD value of exactly the same character string is 0. The indicated candidates are sorted so that the lowest values are at the top of the indication bar. As the input string will be compared with all syllables in the dictionary by the LD value, the user intention is thus estimated and the most similar Pinyin to the word can be prompted to the user.

3.4.3. Word Dictionary and Spelling Mistake Pattern Dictionary

The format of the word and spelling dictionaries, and the indication method using them is described below in detail.

The word dictionary is stored with the Pinyin coded for the words. Since the four tones is adjacent to the syllable at the tail, when students press the “Four Tones” key, it is searched for as a precise match from the word dictionary.

Conversely, in the spelling mistake pattern dictionary, the correct Pinyin, associated mistake pattern and an explanatory text is stored.

Many forms of Chinese pronunciation do not exist in Japanese or other foreign languages. In particular, special syllables such as [front nasals and back nasals] and [retroflex] are difficult and confusing for foreigners to audibly distinguish. Conversely, based on results of Chinese lectures and examinations to date, we have collected many patterns of spelling mistakes having occurred frequently during Pinyin learning steps, and the mistakes have been indicated by matching students input sequences with the data collected. Accordingly, during the input exercises, the student is made clearly aware of habitual mistakes, which is acknowledged as an effective strategy of learning Chinese pronunciation. In other words, this is considered an effective method by repeating the indication process, promoting users to learn the correct Pinyin independently and positively.

The following 3 mistake pattern samples are considered the most difficult barriers for Japanese students:

1. font nasals “an, en, in”, and back nasals “ang, eng, ing, ong”

For example, the syllable of the word “沉静” is hard to distinguish from the following 4 kinds of combinations:

- Chenjing
- Chenjin
- Chengu
- Chengjing.

(2) lingual pronunciation: alveolar consonants (z, c, s), and retroflex consonants (zh, ch, sh, r)

The absence of lingual pronunciation in Japanese language makes it a major challenge for Japanese students to distinguish them.

(3) vowel “u.”

si, zi are influenced by the pronunciation in the Japanese language, meaning many Japanese students consider si and zi to be the same as su and zu.

Figure 9 shows the input example of “思考”, for which the correct Pinyin is “s1 kao3.” If the student inputs the wrong Pinyin of “s1 kao3”, patterns of spelling mistakes are searched for in the spelling mistake pattern dictionary for a record matching the keyword “s1 kao3.” If the conditional record is fulfilled, the result “s1” is shown as advice on the indication bar.

Thus, in terms of the most difficult problem of Pinyin for Chinese language learning, the student is repeatedly made aware of the mistake pattern. If he/she pays attention to the key typing, he/she can avoid making fresh mistakes, strengthen his/her knowledge of Pinyin and improve his/her native Chinese language ability. Figure 10 shows students studying exercises using IME in the proposed system.

Therefore, compared with the traditional LL classroom, by implementing the 3 new featured functions: interactive lecture style, rich learning materials for mobile devices and a Chinese IME to learn precise Pinyin, education can be provided more economically and effectively in traditional classrooms.

4. EVALUATION

To verify the effectiveness of the proposed system, we started a trial from the fall semester in 2011, which lasted 8 weeks. A total of 14 students participated in the trial by registering for the “Basic Chinese” lecture, from the Department of Letters, Department of Culture and Ideas, Department of Education, Department of Politics and Economics of Waseda University. We conducted a subjective evaluation on the 3 new features of the proposed system. In specific terms, this involved quantitative evaluation of the communication performance of the interactive...
lecture system, evaluation of the usability of rich learning materials for smartphones & tablets, and evaluation of the usability of Chinese IME with a Chinese character conversion function by specifying precise Pinyin and a prompt advice function for frequent spelling mistake patterns.

4.1. Interactive Lecture System with Tablet

The application on the student device was developed on the Android 2.2 Tablet “SMT-9100i”, while that on the teacher device was developed on a Windows notebook PC. Both the wireless communication modules were based on Bluetooth versions 2.1+EDR. As an evaluation task, the teacher device sent the control command and several kinds of learning materials to the student device.

To evaluate the communication performance, we conducted physical measurement of 14 concurrent connections, comparing Bluetooth 2.1 + EDR with Wi-Fi IEEE 802.11b.

Table 1 shows the response time of the control command for PPT slide synchronization of learning materials.

The average response time of Bluetooth was 65.4 ms for 14 connections. In general, with a response time of within 70~200 ms, the system can support real-time action games enjoying quicker interaction (Network Analysis, accessed 20 October, 20111020). In our system, learning materials such as fastest-finger-first, which require low latency interaction, are also satisfied. Conversely, with an increasing number of connections, the latency of Wi-Fi increases dramatically.

Table 2 shows the bulk data transfer speed of Bluetooth. The transfer speed of a 10 MB data file between teacher and student devices is measured, compared with Wi-Fi IEEE 802.11b. In both cases, the speed is lower than the theoretical value, while the bulk data transfer speed of Bluetooth is 1/3 of that using Wi-Fi. However, learning materials for our lecture can be downloaded by Bluetooth within 5 minutes, which we considered an affordable time cost.

Table 3 shows the battery lifetime when the student device receives a control command every 30 seconds, with the screen constantly ON. The statistic of Wi-Fi is listed as a comparison. The battery lifetime using Bluetooth was about 1.31 times that using Wi-Fi.

4.2. A Subjective Evaluation of Rich Learning Materials for Smartphones & Tablets

At the end of the 8-week trial, we conducted a questionnaire of all 14 students having used the proposed system. The students were given an evaluation with a 5-level rating of 5 questions, and also asked to freely write comments and feedback on usage. The results are shown below.

1) Item 1 [Did you engage in the interactive lecture system?] got an average of 4.6 points. Generally speaking, continuously enjoying and advancing in foreign language learning is relatively difficult. However, the use of the fastest-finger-first system in the traditional classroom got the following comment “Despite pressure, I was motivated to engage in the contest.” As for the response time, we received the comment that “As the results showing whether answers were right / wrong were immediately shown on the large screen in the fastest-finger-first system, the response time was good.” Meanwhile, teachers have also demanded a function namely “I want a function to mark important explanations on my screen, as well as showing them on the student device at the same time.”

2) Item 2 [Did you feel using the learning
system was convenient? [got an average point rating of 4.3. We got the comment "It is convenient that my tablet is automatically connected to the teacher notebook PC as soon as I switch the tablet ON," "The good point is that I can use it anywhere, anytime, and adjust the study time based on my own pace", etc.

3) Item 3 [Did you feel rich lecture materials making full use of multimedia were effective?] got an average point rating of 4.1. We got the comment "I felt funny at language learning with rich multimedia", "The tablet is easier to use than a PC, as it supports intuitive touch for learning operations", "I am impressed that on the tablet we can also enjoy easy understanding of contents", etc.

4) Item 4 [Did you feel it was easy to use the exercises with rich interaction?] got an average point rating of 3.8. Although the Flash contents were originally developed based on a PC and assuming the use of a computer keyboard, there is also no problem operating with the touch panel interface of the 7-inch SMT-9100i either. However, some users gave opinions such as "I want a feedback response such as vibration to know when the button has been pressed on screen." Furthermore, other users complained that "Selection buttons were quite small and difficult to press."

5) Item 5 ["Do you think it is a good system overall?"] got an average point rating of 4.2. This was a satisfactory result for the comprehensive evaluation. There were also comments such as "I want to continue studying with the next middle-level lecture. Have you implemented it?"

Conversely, with a function of displaying the results of learning such as fastest-finger-first on the teacher device in real time, we made the teacher and his/her assistants in charge of the lecture write comments after use. According to the comment "As we are able to understand the real-time learning status of all students and determine their weaknesses, we can tackle the latter on the spot", the effectiveness was confirmed. In addition, the unplanned function of student management was evaluated with the comment that "We didn’t expect to take the attendance data of students at the same time, but ultimately we found this function really reduced effort and time on work to confirm attendance compared to before", and the request "We would like a function to upload student personal history data to the Waseda student management center server, which could be implemented in the near future."

In addition, we also ensure developers who have transplanted the PC learning materials for the LL classroom into smartphone & tablet write comments and feedback. These including positive evaluations, namely "Simply by adjusting the button size and font size, the Flash contents developed to date can be transferred swiftly and easily." In addition, the diversity of Android devices triggered the demand that "It would be better if there were a guideline concerning the layout adjustment parameter value in detail for each device."

Based on the questionnaire results above, the effectiveness of the interactive lecture system and rich learning materials are considered confirmed by students. Conversely, the reusability of the PC version of learning materials for LL classrooms was also confirmed by developers. At the same time, functional evolution and further ease of use is demanded for the user interface of the touch panel.

### 4.3. A Subjective Evaluation of the Chinese IME that converts Chinese Characters by Specifying the Correct Pinyin exactly and Prompt Patterns of frequent spelling mistakes

To continuously observe the usage of Chinese IME by students, logs of the usage date and time, words that could be entered correctly at one time

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<th>Table 2. Data Transfer Speed (Kbps)</th>
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and the word input by modifying or indications were recorded on the SD card of student devices.

(1) Changes in the percentage of correct answers

Figure 11 showed the change in the ratio of correctly input characters, based on the log data statistics. With learning progress, the percentage of correct answers improved more than 10% in 12 students except for 2 (Students 3 and 5). According to interviews with the students, we confirmed that they studied continuously and that their learning time rose with the increased learning. In addition, regardless of the progress of the lecture, 3 students used the system at their own pace, even outside class. Conversely, as for the opinion of students citing less than 10% improvement, they said they felt motion sickness when operating the tablet on the train, and also found the touch panel operation difficult. The reduced percentage of correct answers is considered due to reduced motivation.

(2) Examination Score

As for the evaluation result of the import effect of the proposed system, Figure 12 showed the results of examinations when the 8-week class was over. From the left, the “experimental class” of 14 students who used the proposed system and the “traditional class” conducted in the lecture LL classroom with 47 students, were shown the compared sequential results of the conversational ability and comprehensive ability tests. The experimental conditions included an interactive lecture description, the fastest—fingertip—first method, tablet version Dig exercises and IME with exactly matching convert/indication functions for the “experimental class”, while the “traditional class” used the projector projection for the lecture description, PC version Dig exercises, and the Microsoft IME.

In the conversational ability test for the “experimental class”, the teacher specified the question of Pinyin pronunciation from the notebook PC to the tablets of students and evaluated in sequence based on the student answers (Figure 13). Meanwhile, as for the “traditional class”, the teacher distributed the Pinyin pronunciation question in paper—based form and then evaluated in sequence based on the student answers. Consequently, the average points of the “experimental class” were 84.23, more than 10 higher than the average score of 74.15 in the “traditional class.” The result of the T-test with two samples assuming equal variances was \( t(df = 59) = 2.394, p = 0.020 \). Based on the result of a significance level \(< 5\%\), we confirmed the significant statistical difference. In addition, when reading Chinese characters without Pinyin pronunciation notation, the “experimental class” was closer to native than that of the “traditional class.”

In the comprehensive ability test, including a listening comprehension and reading comprehension, we used the examination functions of Dig for the LL classroom. Consequently, the average point rating of the “experimental class” was 78.29, and the average point rating of the “conventional method class” was 76.02. The result of the T-test with two samples assuming equal variance was \( t(df = 59) = 0.897 \) and \( p = 0.373 \). Although no significant statistical difference was observed due to a level of significance \( \geq 5\% \), the average point rating of the “experimental class” was 2.27 higher. We found that although the experiment team were unfamiliar and unused to the system of PC version Dig exercises in the LL classroom, the result was still better. As a factor, we estimated that increasing of learning time and learning opportunity by taking the tablet home, and an IME capable of promoting the correct usage of Pinyin compared to the “traditional class” may be factors. Furthermore, to verify the learning effectiveness of each factor, the evaluation experiment must be performed with more students, and the learning conditions defined in more detail in future.

As well as discussing in Section 4.2, at the end of all lectures, we have the 14 students who used the IME for a questionnaire, freely writing comments and feedback on its usage. The results are shown below.

1) Item 1 “Did you master Pinyin well?” got an average point rating of 4.3. We received the comment that “although Pinyin is difficult, now I can properly focus on Four Tones and syllables via this proposed system” from 12 of the 14 students, meaning the most difficult part was effectively improved as intended. However, this dictionary had only about 30,000 words, hence there was also feedback stating “I want more vocabulary.”

2) Item 2 “Did you improve other language abilities (reading, listening, etc.) besides Pinyin?” got an average point rating of 3.7 and the comment “I think that because many of the exercises revolve around Pinyin, we can somehow connect other abilities to memory.”
5. SUMMARY

To realize a smart classroom for Chinese language learning, we developed a platform available on smartphones & tablets with rich multimedia and at low cost. It includes the following 3 features. 1) It is possible to allow an interactive lecture between teacher and students, which increases the motivation for the class of students. 2) It paves the way for providing rich learning materials to reuse traditional PC multimedia contents. 3) For the most difficult part of learning "Pinyin", we have developed a Chinese IME involving conversion of Chinese character by specifying the correct Pinyin exactly and prompting with advice on patterns of frequent spelling mistakes.

From the evaluation experiment, the effectiveness of the features of our proposed system: low-latency / numerous simultaneous connections and power-saving/ large-capacity communication network configuration, economical and rich learning contents, and the strengthened learning of particularly difficult Pinyin have been verified. An overall improvement in conversational ability was also confirmed.

In future, by running the system in practice, we should reinforce the results of the experiments described in the previous section by obtaining study data for more students and further analysis. In addition, we made a plan to advance and facilitate the user interface, evolve the interactive functions, and the implementation applied to the iPhone / iPad.

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Network Analysis Homepage : ping.
Development of a Smart Classroom for Chinese Language Learning Using a Smartphone & Tablet


