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EFFECTIVENESS OF MOBILE APPLICATION IN LEARNING MANDARIN TONES

Pawares Funoi[1*], Mingwei Huang[2], Changwei Niu[3]

[1]Chinese Department, School of Liberal Arts, Walailak University 222 Thasala, Nakhon Si Thammarat 80160, Thailand, Center of Excellence on Women and Social Security (CEWSS). Email: pawares.fu@gmail.com Orcid ID: https://orcid.org/0000-0001-7865-8548
[2]Chinese Department, School of Liberal Arts, Walailak University 222 Thasala, Nakhon Si Thammarat 80160, Thailand, Center of Geosocial and Cultural Research for Sustainable Development (GCSR). Orcid ID: https://orcid.org/0000-0001-8578-7284
[3]International Education School, Zhongnan University of Economics and Law Wuhan, China

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Corresponding Author: Pawares Funoi (pawares.fu@gmail.com)

ABSTRACT

This research investigates the efficacy of a mobile application in facilitating Mandarin tone acquisition among Thai university students. Twenty first-year Chinese majors, including seven-tone Southern Thai dialect speakers, engaged in pre-and post-assessments, including 120 Chinese characters (60 disyllabic words), resulting in 4,800 pronunciation samples. The data is analysed with a customised version of Praat Chinese software, including k-means clustering, t-tests, and one-way ANOVA to assess improvement. The results indicate substantial enhancements in tone pronunciation accuracy, especially among students with limited prior knowledge, with the most pronounced increase shown in Tone 2 and 3. The results underscore the educational potential of mobile-assisted language learning (MALL) in tone instruction and indicate the importance of incorporating tailored and data-driven approaches into Mandarin pronunciation education. However, the findings should be interpreted with caution due to the relatively small and homogeneous sample and the short intervention period. Future research with larger and more diverse cohorts and extended durations is recommended to further validate and generalise these results.

KEYWORDS: Mobile-Assisted Language Learning; Mandarin Chinese; Tone Acquisition; Pronunciation; Thai Learners; Educational Technology.

1. INTRODUCTION

In globalization, international communication is becoming increasingly common, and acquiring new languages is extremely important for promoting intercultural interactions and economic cooperation. One of the six official languages of the United Nations, the Chinese are becoming more important worldwide. Sun, Whatavibonsawat and Zhang (2020) argue that China significantly impacts international trade. Data from world ethnographic languages (Eberhard et al., 2024) show that around 1.1 billion people worldwide are interested in studying Chinese and positioning it as English's second most popular language.

Notwithstanding the increasing global interest in acquiring proficiency in Chinese, it continues to be a linguistically demanding language. Mandarin Chinese comprises four principal tones—high level, rising, low (dipping), and falling—alongside a neutral tone, predominantly linked to function words, whose pitch is affected by the preceding tone. According to the Chao tone numbers (1948), Mandarin tones are categorised as follows: Tone 1 (high level, 55), Tone 2 (rising, 35), Tone 3 (low dipping, 213), Tone 4 (falling, 51), and the neutral tone. These tones correlate to five relative pitch levels, forming the foundation of Mandarin's tonal system. Thai students, especially those who speak the seven-tone Southern Thai dialect, (Rose, 1997; Thompson, 1998) encounter a distinct barrier in understanding Mandarin tones due to the considerable disparities between the tonal systems of Southern Thai and Mandarin. This discrepancy frequently results in challenges when acquiring Mandarin tones. For Thai learners, particularly those specialising in Chinese, attaining precise tonal articulation is essential for efficient verbal communication and overall competency in the Chinese language (Kwanrean, 2001; Aroonawongsa et al., 2025).

Thai students have numerous challenges in mastering Mandarin tones that warrant thorough examination and resolution. In contrast to conventional classroom instruction, the prevalence of mobile devices provides enhanced opportunities for learning Mandarin tones (Gangaiamaran & Pasupathi, 2017; Kang et al., 2018; Wu & Satjaharuthai, 2019). Mobile phones, indispensable instruments in contemporary society, exhibit a significant student penetration rate (Phromsiri & Areesantichai, 2018). Utilising mobile applications to aid students in mastering Mandarin tones is an efficient approach. Consequently, assessing the efficacy of this pedagogical approach and students' perceptions is essential for refining instruction and augmenting the educational experience. Comprehending students' perceptions and efficacy in utilising mobile applications for learning Mandarin tones offers significant insights for academics and educators, enhancing pedagogical approaches and optimising educational resources.

This research examines the efficacy of the mobile application *Tone Detector* in facilitating the acquisition of Mandarin tones among first-year Chinese major students at Walailak University in Thailand.

The research inquiries are as follows:

1. Can the mobile application substantially enhance the precision of Mandarin tone pronunciation for Thai students?
2. Are there notable disparities in the efficacy of utilising the mobile application for learning Mandarin tones across students from diverse backgrounds?

The researchers conduct empirical investigations to examine students' proficiency in tone detection before and after utilising the mobile application. The efficacy of the mobile application is assessed by quantifying pupils' tonal precision and fluency. Simultaneously, researchers perform interviews to ascertain students' perceptions regarding the mobile application's usability, its effectiveness in facilitating learning, its influence on learning motivation, and their likelihood of recommending it to others. The study investigates the influence of students' linguistic backgrounds and technological proficiency on the efficacy and perceptions of mobile applications designed to facilitate the acquisition of Mandarin tones. This study identifies student groups more adept at utilising mobile applications for tone learning and establishes a foundation for individualised training.

Current studies indicate that mobile-assisted Chinese language acquisition is viable and beneficial. Lai et al. (2021) assert that mobile technology presents significant potential for language acquisition among university students. Similarly, Zhou's comprehensive review (2019) of studies conducted between 2007 and 2019 highlights the positive impact of mobile phones on Chinese language learning, particularly in vocabulary acquisition and skills enhancement. Building on these insights, Chai et al. (2016) demonstrate the practicality of seamless language learning, further validating their approach through the Mobile-Assisted Seamless Chinese Learning Questionnaire (MSCLQ).

These findings indicate that mobile-assisted

Chinese learning enhances classroom instruction, facilitating students' comprehension and mastery of the material and elevating their proficiency in the Chinese language. Rungruang and Mu (2017) administered a Mandarin tone assessment to 14 Thai university students, revealing superior performance in Tone 1 and Tone 4 but encountering challenges with Tone 2 and Tone 3. Zhang and Liu (2020) perform an acoustic analysis of Mandarin tones produced by Thai learners, revealing that the students encounter difficulties with pitch register, tone shapes, and length. Importantly, studies such as Chen et al. (2019) demonstrate that mobile applications for tone training, incorporating real-time feedback and acoustic modelling, significantly enhance learners' accuracy in tone production, especially for challenging tones like Tone 2 and Tone 3. It underscores the role of mobile-assisted learning in addressing specific phonetic challenges learners face.

These studies indicate that Thai students exhibit biases in acquiring Mandarin tones, primarily attributable to the parallels and discrepancies between Chinese and Thai tones regarding tone kinds and values. Prior research predominantly emphasises problem identification and elucidation, with less discourse on specific solutions. Jureynolds and Ying (2021) assert that conventional face-to-face pedagogical approaches are inadequate in keeping pace with advancements in internet technology. The proliferation of mobile applications for learning Chinese influences conventional face-to-face teaching methods, and foreign language learners are increasingly inclined to utilise mobile applications to enhance their education. Teeranon (2020) administered a Thai tone perception assessment to 40 Chinese learners of Thai and discovered that the Thai Tone Application mobile app positively influences these learners.

While the current study predominantly examines Chinese learners utilising mobile applications to facilitate the acquisition of Thai tones, there is a paucity of studies about Thai students employing mobile applications to assist in mastering Mandarin tones. This study assesses the efficacy of mobile applications in Mandarin tone acquisition for Thai students via empirical research, offering novel insights and direction for future pedagogical practices and investigations.

In conclusion, empirical research indicates that mobile applications utilised by Chinese major students in southern Thailand facilitate the acquisition of Mandarin tones. This study seeks to enhance research in this domain and offer reference material for instructing Thai students in Mandarin tones.

2. METHODS AND MATERIALS

2.1. Participants

This study included twenty first-year students majoring in Chinese at the School of Liberal Arts, Walailak University, Thailand, comprising 20 females, all hailing from southern Thailand. All participants satisfy the following criteria: they exhibit varied difficulty in acquiring Mandarin tones, are dedicated to complete the testing procedure as mandated, and possess individualised learning requirements. Participants for this study are recruited based on these criteria.

2.2. Tools

This study uses a mobile application named *Tone Detector*. This program features sophisticated speech recognition and analysis technologies, enabling real-time detection and feedback on Mandarin tone pronunciation. Its functionalities encompass recording, immediate feedback, historical records, and tailored learning recommendations.

2.3. Data Collection Process

Pronunciation Data—Pre- and post-assessments are administered to students 1266isualiza the *Tone Detector* app to assess their tonal proficiency before and after 30 days of intervention period. The 30-day intervention period was intentionally selected to align with prior research on Mandarin phonological acquisition, which indicates that a one-month duration is typically adequate to observe statistically significant improvements in tone production accuracy (Wu, 2022). Moreover, a 30-day schedule is logistically feasible and pedagogically optimal within the limitations of students' academic timetables, thereby 1266isualizat the practicality of implementation and the validity of the results. The data is segmented and analysed with the Praat Chinese modified version (3.6), created by Paul Boersma and David Weenink in 2020 and adapted for Chinese by Xianming Bei and Ning Xiang in the same year. The precision of the pronunciation data is predominantly evaluated by an auditory assessment conducted by a national-level expert in Mandarin Chinese. The listening assessment broadly examines the test outcomes. When errors are present in both pre-and post-tests, Praat software is employed for analysis and 1266isualization to confirm that certain subjects exhibit improved pronunciation accuracy following the test, thereby illustrating the application's efficacy.

2.4. Data Analysis

2.4.1. Pronunciation Data Analysis

Pre- and post-tests administered to 20 students, encompassing 120 Chinese characters (60 disyllabic words), yielded 4,800 samples.

The listening assessment broadly examines the test outcomes. Furthermore, Praat analysis and graphing are utilised to illustrate that, in instances where errors are present in both pre-and post-tests, the mobile application aids sure participants in achieving closer proximity to accurate pronunciation post-tests, hence substantiating its efficacy.

The precision of the pronunciation data is mainly evaluated by auditory assessment by a nationally recognised Mandarin examiner.

The researchers' auditory evaluations are employed to analyse speech data incompatible with software-based analysis.

2.5. Specific Data Analysis

1. Overall And Individual Accuracy Rates

1.1. Overall Accuracy Rate

- Overall pre-test accuracy rate is as in formula (1):

$$\text{Overall pre} - \text{test accuracy rate} = \frac{\sum_{i=1}^{120}\sum_{j=1}^{20}1(X_{ij}=1)}{120\times 20} \quad (1)$$

Where: 120 is the number of Chinese characters, 20 is the number of subjects, X_{ij} is the pronunciation result of the i character by the j subject in the pre-test. Result: $1(X_{ij} = 1)$ indicates correct pronunciation, counted as 1, incorrect as 0.

- Overall post-test accuracy rate is as in formula (2):

$$\text{Overall post} - \text{test accuracy rate} = \frac{\sum_{i=1}^{120}\sum_{j=1}^{20}1(Y_{ij}=1)}{120\times 20} \quad (2)$$

Where: Y_{ij} is the pronunciation result of the i character by the j subject in the post-test, the rest is the same as above.

1.2. Individual Accuracy Rate: Calculate The Pre- and Post-Test Accuracy Rates for Each Subject.

Calculation Formula for Individual Subject's Pre- and Post-test Accuracy Rates

- Pre-test Accuracy Rate for Each Subject is as in formula (3):

$$\text{Pre} - \text{test Accuracy Rate for Subject } j = \frac{\sum_{i=1}^{120}1(X_{ij}=1)}{120} \quad (3)$$

Where: 120 is the number of Chinese characters, X_{ij} is the pronunciation result of the i character by the j subject in the pre-test. $1(X_{ij}=1)$ indicates correct pronunciation, counted as 1, incorrect as 0.

- Post-test Accuracy Rate for Each Subject is as in formula (4):

$$\text{Pos}t - \text{test Accuracy Rate for Subject } j = \frac{\sum_{i=1}^{120}1(Y_{ij}=1)}{120} \quad (4)$$

Where: Y_{ij} is the pronunciation result of the i character by the j subject in the post-test, the rest is the same as above.

2. Clustering Analysis

Determine the optimal K value using the elbow method, i.e., calculate the SSE (Sum of Squared Errors) for different K values and choose the K value at the elbow position as the optimal K value. Use the K-means clustering algorithm to classify the 20 subjects based on their pre-test accuracy rates.

1) K-value Clustering Algorithm is as in formula (5):

K Means (*n_clusters* = 3, *random_state* = 0). *fit*(pre_test_accuracy) (5)

2) Calculate the average pre- and post-test accuracy rate and difference for each cluster

- Cluster average pre-test accuracy rate is as in formula (6):

$$\text{Cluster Average Pre} - \text{test Accuracy} = \frac{\sum_{j\epsilon Cluster} Pre - test\ Accuracy_j}{|\text{Cluster}|} \quad (6)$$

- Cluster average post-test accuracy rate is as in formula (7):

$$\text{Cluster Average Post} - \text{test Accuracy} = \frac{\sum_{j\epsilon Cluster} Post - test\ Accuracy_j}{|\text{Cluster}|} \quad (7)$$

- Cluster average accuracy difference is as in formula (8):

$$\text{Cluster Average Accuracy Difference} = (\text{Cluster Average Post} - \text{test Accuracy}) - (\text{Cluster Average Pre} - \text{test Accuracy}) \quad (8)$$

3. Statistical Tests

3.1 Paired-Samples T-Test

Use a paired-samples t-test to compare the differences in pronunciation accuracy for each subject before and after using the mobile application.

3.2 One-Way ANOVA

Use One-Way ANOVA to compare whether there are significant differences in pronunciation improvement effects among different groups of subjects.

4. Praat Analysis

For subjects with incorrect speech data in both pre- and post-tests, Praat analysis is used to verify that some post-test results are closer to the correct reference after practicing with the mobile application, thereby demonstrating its effectiveness. For this purpose, 120 speech samples from a female Chinese volunteer teacher[1] who achieved a second-level A grade in the Putonghua Shuiping Ceshi (PSC), the official Standard Mandarin proficiency test in China, are used as the standard to compare differences in students' speech tones before and after the test. Pitch contour graphs and pitch measurement data are recorded, and Praat is utilised for statistical analysis of pitch data and for plotting tone T-value graphs to analyse tonal accuracy.

Through these analytical methods, the impact of the tone detection mobile application on Thai students' Mandarin tone learning can be systematically evaluated. This approach quantifies students' progress in pronunciation accuracy and explores differences in the software's effectiveness among students with varying backgrounds.

3. RESULTS

3.1. Overall Accuracy Analysis

The study reveals substantial changes in individuals' pronunciation accuracy before and after implementing tone detection. The pre-test accuracy rate is 60.29%, while the post-test accuracy rate is 68.29%. The findings indicate that after using the program, the respondents' overall pronunciation accuracy rate improved by around eight percentage points, demonstrating the application's substantial impact on enhancing Mandarin tone pronunciation.

3.2. Individual Accuracy Changes

The pre- and post-test outcomes analysis (see Table 1) indicates a general enhancement in pronunciation accuracy, but advancement differed among the 20 participants. S1, S4, S12, and S18 exhibited the most significant improvements (+17.5%), underscoring the intervention's efficacy in minimising mistakes. S5, S7, S8, S10, and S15 exhibited moderate improvements (+7.5% to +15.84%), whereas S2, S13, and S20 showed small gains (+1.66% to +1.67%). S11 exhibited no alteration, whereas S6 encountered a decrease of (-3.33%), indicating possible difficulties. High performers, such as S14, S16, and S19, saw marginal improvements, presumably attributable to a ceiling effect.

Table 1: The Pre-Post Pronunciation Accuracy and Error Changes for Different Subjects.

Subject	Pre-test Accuracy Rate (%)	Pre-test Error Rate (%)	Post-test Accuracy Rate (%)	Post-test Error Rate (%)	Improvement (%)
1	60.83	39.17	78.33	21.67	+17.5
2	62.50	37.50	64.17	35.83	+1.67
3	76.67	23.33	80.83	19.17	+4.16
4	61.67	38.33	78.33	21.67	+16.66
5	51.67	48.33	63.33	36.67	+11.66
6	68.33	31.67	65.00	35.00	-3.33
7	36.67	63.33	44.17	55.83	+7.5
8	40.00	60.00	52.50	47.50	+12.5
9	65.00	35.00	74.17	25.83	+9.17
10	42.50	57.50	54.17	45.83	+11.67
11	66.67	33.33	66.67	33.33	0
12	56.67	43.33	74.17	25.83	+17.5
13	59.17	40.83	60.83	39.17	+1.66
14	75.83	24.17	80.00	20.00	+4.17
15	35.83	64.17	51.67	48.33	+15.84
16	80.00	20.00	85.00	15.00	+5
17	50.00	50.00	56.67	43.33	+6.67
18	50.83	49.17	68.33	31.67	+17.5

[1] Miss Jiali Li, a master's degree holder, was a volunteer Chinese teacher at Walailak University in Thailand from 2022 to 2024.

19	89.17	10.83	90.00	10.00	+0.83
20	75.83	24.17	77.50	22.50	+1.67

Source. Own Research.

3.3. Clustering Analysis

Based on the elbow method graph, we can see that when the number of clusters K is 3, the curve starts to flatten, indicating that K=3 is a reasonable choice (see Figure 1). The optimal number of clusters was determined to be 3 through the elbow method, and the K-means clustering method is used to divide the subjects into three clusters (see Figure 2). Cluster 0 (good foundation group), with the highest initial accuracy (79.50%), shows the most minor improvement (+3.17%), likely due to a ceiling effect. Cluster 1 (poor foundation group), with the lowest initial accuracy (43.93%), achieves the most significant improvement (+11.90%), highlighting the intervention's effectiveness in addressing weaknesses. Cluster 2 (medium foundation group), starting at 62.60% accuracy, shows moderate improvement (+7.60%). Overall, the intervention proves most impactful for participants with lower proficiency levels, while high-performing subjects experience steady but limited progress (see Table 3).

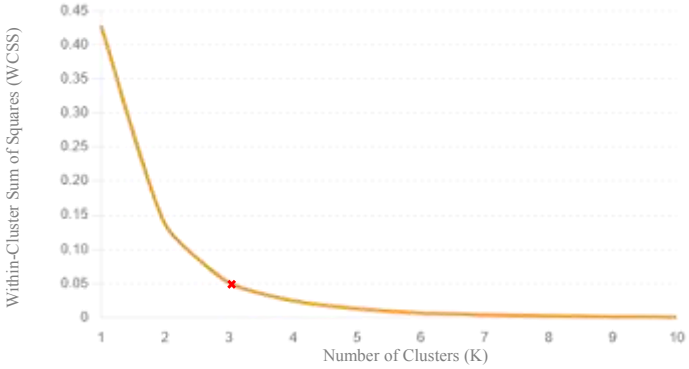

Figure 1: The Optimal Number of Clusters (K) In K-Means Clustering.
Source. Own Research.

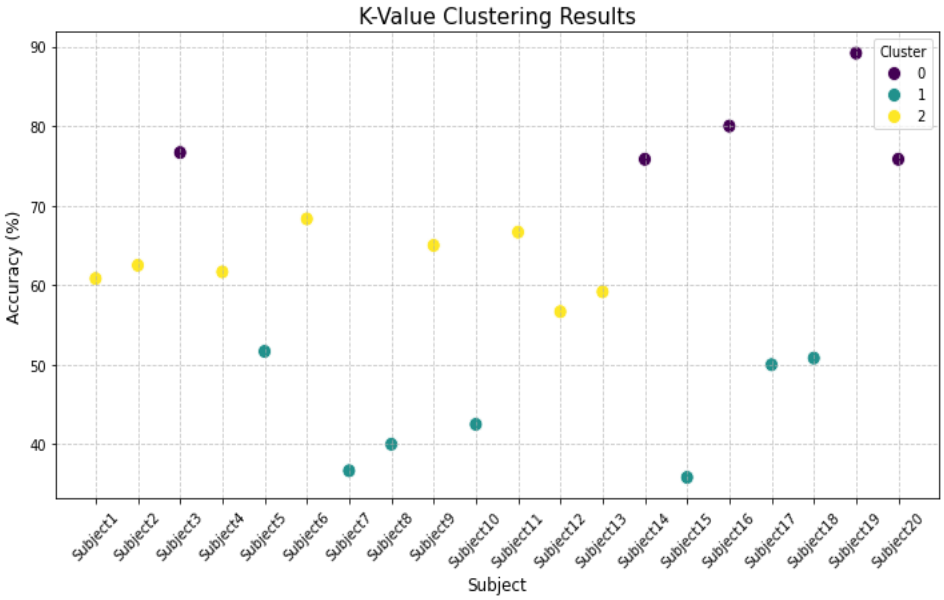

Figure 2: The K-Value Clustering Results of Each Subject's Pre-Test Accuracy Rate.
Source. Own Research.

Table 3: The Accuracy Changes for Different Clusters.

Cluster	Pre-test Accuracy Rate (%)	Post-test Accuracy Rate (%)	Accuracy Difference (%)
Good Foundation (0)	79.50	82.67	+3.17
Poor Foundation (1)	43.93	55.83	+11.90

Medium Foundation (2)	62.60	70.21	+7.60

Source. Own Research.

3.4. Statistical Tests

The paired-sample t-test results (see Table 4) show varied effects of the intervention. S1, 4, 5, 8, 9, 10, 12, 15, and 18 demonstrated significant improvements ($p \leq 0.05$), with S1, 4, 12, and 15 showing the most substantial results (p-values ≤ 0.001). Meanwhile, S2, 3, 6, 7, 13, 14, 16, 17, 19, and 20 exhibit no significant changes ($p \geq 0.05$), and S11 displays no improvement ($p = 1.000$). S6 experiences a non-significant decline ($t = -0.729$, $p = 0.468$). Moreover, the analysis of variance (ANOVA) results indicated significant disparities in pronunciation development among several subject groups (F-value = 2.341, P-value = 0.00088). It indicates that these results are not accidental.

Table 4: Paired-Samples T-Test Results.

Subject	T-value	P-value	Interpretation
1	4.000572	0.000110	Significant
2	0.498432	0.619100	Non-significant
3	1.215083	0.226740	Non-significant
4	3.484660	0.000691	Significant
5	2.311847	0.022506	Significant
6	-0.728869	0.467514	Non-significant
7	1.529749	0.128733	Non-significant
8	2.451551	0.015677	Significant
9	2.335858	0.021172	Significant
10	2.194317	0.030155	Significant
11	0.000000	1.000000	Non-significant
12	4.000572	0.000110	Significant
13	0.445718	0.656611	Non-significant
14	0.927939	0.355317	Non-significant
15	3.711243	0.000315	Significant
16	1.507941	0.134220	Non-significant
17	1.268112	0.207233	Non-significant
18	3.039883	0.002911	Significant
19	0.445718	0.656611	Non-significant
20	0.445718	0.656611	Non-significant

Source. Own Research.

3.5. Mandarin Tone Analysis Results

The analysis of pronunciation accuracy changes for the four tones plus a neutral tone is as Table 5. The most significant improvements occur with Tone 2 and Tone 3, reflecting their initial difficulty for Thai learners. Neutral tone improvement is minimal, suggesting a need for targeted instructional strategies.

Table 5: Pronunciation Accuracy Changes for the Tones.

Tone	Pre-test Accuracy (%)	Post-test Accuracy (%)	Improvement (%)
Tone 1 (High)	74.07	77.59	+3.52
Tone 2 (Rising)	53.71	64.84	+11.13
Tone 3 (Low)	51.46	65.83	+14.37
Tone 4 (Falling)	82.69	88.65	+5.96
Neutral Tone	15.42	17.08	+1.66

Source. Own Research.

4. DISCUSSION

4.1. Improvement In Pronunciation Accuracy

The research results demonstrate that using the *Tone Detector* application significantly improves the Mandarin tone pronunciation accuracy of Thai students, particularly those with weaker foundations. The overall accuracy rate increases from 60.29% to 68.29%, highlighting the application's effectiveness in correcting pronunciation errors and reinforcing correct pronunciation. When comparing the improvement rates among the three groups—those with poor, medium, and good foundations—it is evident that subjects with poor foundations benefit the most, achieving an 11.90 percentage point increase in accuracy. This study suggests that the application is particularly beneficial for beginners or learners with weaker pronunciation foundations, providing targeted support where it is most needed.

4.2. Influence Of Individual Differences

The study indicates substantial disparities in learning outcomes across several disciplines following the utilization of the program. Individuals with inadequate foundations (Cluster 1) exhibit the most significant enhancement, succeed by those with moderate foundations (Cluster 2) and those with strong foundations (Cluster 0). This suggests that individual differences significantly influence learning results, necessitating personalised help and direction in education. These disparities may be attributed to factors including the subjects' cognitive capacities, learning dispositions, adaptability to the application, and motivational levels for learning.

Students with strong foundations (Cluster 0) exhibit a high accuracy rate of 79.50% before the exam. However, they improve by 3.17 percentage points after utilising the application, demonstrating that even those with proficient pronunciation can benefit. Students with moderate foundations (Cluster 2) exhibit an improvement of 7.60 percentage points, indicating that individuals with intermediate competency might substantially enhance their pronunciation accuracy following the utilization of the application.

The researchers employ Praat software for analysis for certain participants whose accuracy remained relatively unchanged (e.g., S16), along with their erroneous pre- and post-test outcomes. The results indicate that their post-test outcomes are comparatively nearer to the accurate reference values.

Figure 3 illustrates that the red curve denotes the reference pronunciation for character number 8, the green curve signifies the pre-test pronunciation of character number 8 by S16, and the blue curve indicates the post-test pronunciation of character number 8 by S16. Praat presents the following analysis: Character number 8 signifies Tone 2 with a standard Mandarin pronunciation pitch of 35. The real pitch for the female teacher is 445 or approximately 535, with a minor deviation, which is typical. The pre-test pronunciation pitch for S16 is 11, whereas the post-test pitch is 544. Despite the inaccuracies in this subject's pre- and post-test findings, there is a discernible enhancement in both pitch elevation and tonal contour.

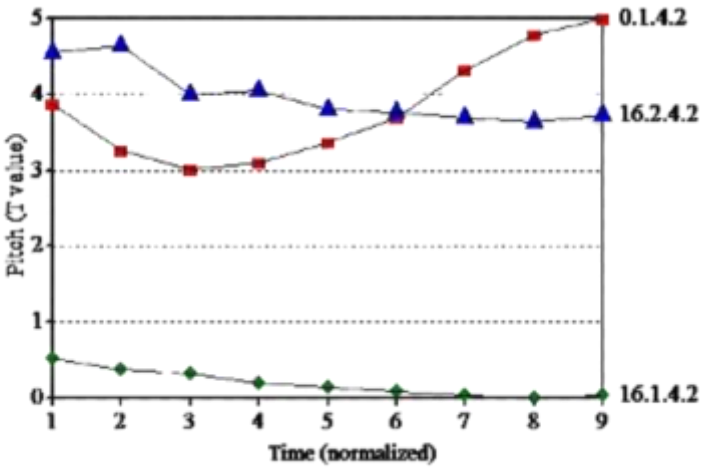

Figure 3: ***Comparison of the Mandarin Second Tone Pitch Between S16 And the Chinese Teacher Volunteer.***
Source. Own Research

4.3. Improvement In Tone Pronunciation

Table 5 indicates that the treatment yields varying effects on pronunciation enhancement for each tone, with the most pronounced gains observed in Tone 2 and Tone 3, which increased by 11.13 and 14.37 percentage points, respectively. This study may be due to the increased difficulty of these tones for Thai pupils, and the application's repetitive practice and immediate feedback facilitate improved mastery of these tones. The enhancement in neutral tone is minimal, at 1.66 percentage points, signifying that greater emphasis must be placed on instructing the neutral tone in speech training. This study advocates for specialised training in pedagogy, emphasising the nuances of various tones and the distinct challenges students face.

5. CONCLUSION

This study analyses the pronunciation data of twenty Thai students, encompassing speakers of a seven-tone Southern Thai dialect, before and after employing, resulting in the following conclusions:

1. **Overall Effectiveness:** Students, especially those with weaker basic skills, significantly

improve their Mandarin tone pronunciation accuracy through this application. Including individuals from a seven-tone Southern Thai dialect highlights the tool's broader applicability compared to studies restricted to speakers of Standard Thai, a five-tone language. It underscores the unique problems and opportunities learners with more intricate tonal backgrounds pose.

2. **Individual Variations:** Notable discrepancies in learning results within disciplines after the application's implementation underscore the necessity of addressing individual differences in the promotion and execution of this application. Customised learning assistance and individualised supervision are essential, especially for students with diverse learning abilities and core knowledge, to enhance educational outcomes successfully.
3. **Tone Enhancement:** The application shows various effects on learning tones, with notable gains in the second and third tones. This discovery indicates that tones vary in complexity, requiring focused training on increasingly difficult tones during education.

The findings offer empirical support for the effectiveness of mobile applications in aiding Mandarin tone acquisition, especially among learners from various tonal linguistic backgrounds. They provide essential insights for enhancing and marketing these applications. Nevertheless, this study is constrained by its relatively small and homogeneous sample (n=20, all female students from the same institution) and by the short intervention period (30 days). Future research should therefore employ larger and more diverse cohorts and extend the intervention duration to validate and generalise these findings. Moreover, investigating long-term impacts, designing personalised techniques for learners from intricate tonal systems, and integrating additional educational tools and resources may cultivate a holistic learning system, further augmenting the efficacy of Mandarin tone acquisition.

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