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國小組 物理科

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聲音的形狀－國小英語與國語發音教學的探討

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關鍵詞：聲波、KK 音標、注音符號

摘要：

本研究利用電腦程式，紀錄分析聲音在時間領域的形狀，探討英語音標和國語注音相似音的差異，並分析聲音在頻率領域的形狀，並瞭解受測學生和老師在英語句子和國語成語的差異，作為發音教學評估的指標。

壹、研究動機

聲音是日常生活中每天都要聽到的東西，從自然課中，我們知道聲音是一種波，透過空氣為介質來傳送，但聲音是看不見的，我們希望能夠看見聲音形狀，來幫助我們學習國語、英語的發音。

由於聲音在空氣中的傳播是屬於縱波，也就是波前進的方向與介質振動的方向平行，我們要利用聲波描述聲音：以振動的幅度（振幅）大或小，來代表音量；以振動的次數（頻率）多或少，人的聲音在 20-20000Hz，來代表音調的高低；以波的形狀（波形），代表音色。

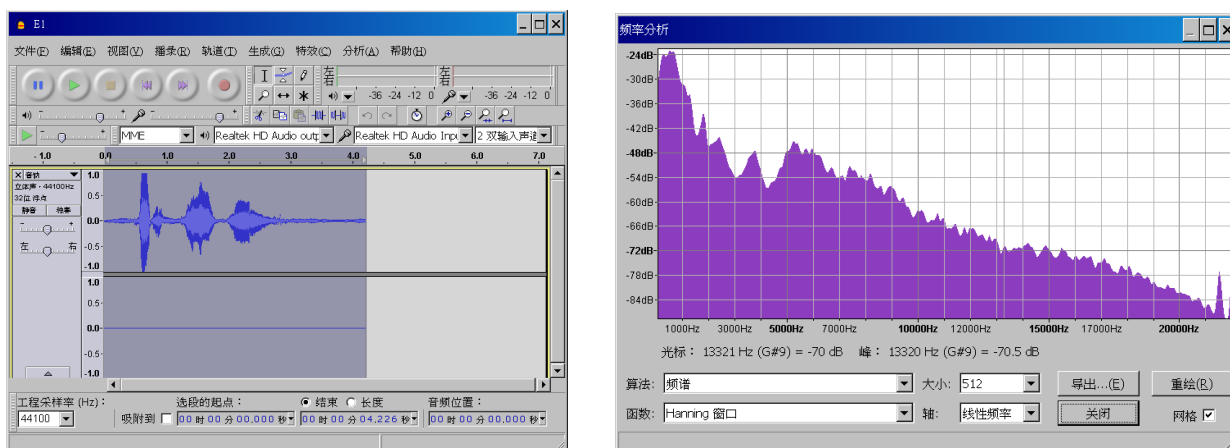
貳、研究目的

- 一、記錄英語 KK 音標發音的形狀，了解相似音在時間領域和頻率領域的差異。
- 二、紀錄英語句子發音的形狀，比較教師和學生的差異，用來修正錯誤的發音。
- 三、記錄國語注音符號發音的形狀，了解相似音在時間領域和頻率領域的差異。
- 四、記錄國語成語發音的形狀，比較教師和學生的差異，用來修正錯誤的發音。

參、研究設備及器材

- 一、個人電腦一部。
- 二、印表機一台。
- 三、麥克風及延長線一組，連結至電腦聲音輸入孔（粉紅色）。
- 四、喇叭一組。

五、錄音程式一套 (AudacityPortable)：將語音輸入選擇為麥克風，按下紅色錄製鍵即可錄製聲音，橫座標為時間，單位為秒，縱座標為聲音的振幅；選擇「視圖」、「放大」或按「Ctrl 1」可將橫坐標時間放大，得到更清楚的波形圖；選擇「分析」、「繪製頻譜圖」即可分析頻譜，橫座標為頻率，單位為 Hz，縱座標為聲音的能量，單位為分貝值 dB；按「導出」，即可將頻譜的數值儲存為.txt 檔。



六、螢幕截圖程式一套 (FastStone Capture v5.3)：可以擷取電腦螢幕上任何圖形。



七、KK 音標發音光碟 (康軒文化)：所有 KK 音標的正確發音，由外籍教師示範。

八、注音符號發音網站 (國語日報)：所有注音符號發音發音示範。



九、Matlab R2006b 程式一套：計算學生與老師頻譜數據差異的指標數值。



在頻率領域的比較，因為頻譜的數據是從 86Hz 到 21964Hz 中取 256 個頻率的

分貝值 dB，先以 Matlab 程式分別將老師與學生的頻譜數值檔 s1.txt 和 t1.txt 讀入，但因為學生和老師聲音大小不同，需先將兩者的能量調整至相同，再取兩者差的均方根(root mean square)作為評估指標 m，了解學生發音與老師發音的差距。以數學式表示如下：

$$m = \sqrt{\frac{\sum_{i=1}^{255} (S_i - T_i)^2}{255}} \quad \text{S: 學生} \quad \text{T: 老師}$$

Matlab 的程式碼如下：

```
clear all
close all
%讀取頻譜圖的數值開始
[a1,a2]=textread('s1.txt','%f%f','headerlines',1);
a=[a1,a2];
[b1,b2]=textread('t1.txt','%f%f','headerlines',1);
b=[b1,b2];
%讀取頻譜圖的數值結束
%調整頻譜的能量開始
c=0;
d=0;
for i=1:255
    c=c+10^(a(i,2)/10);
end
for i=1:255
    d=d+10^(b(i,2)/10);
end
n=10*log10(d/c);
a=a+n;
%調整頻譜的能量結束
%計算指標均方根開始
sum=0;
for i=1:255
    sum=(a(i,2)-b(i,2))^2+sum;
end
m=sqrt(sum/255);
計算指標均方根結束
```

肆、研究過程或方法

一、英語教學中，同學對於以下音標的發音常會混淆：

- (一) 母音：1. [æ]、[ɛ]、[e] 2. [ɑ]、[ʌ]、[ə] 3. [o]、[ɔ]
4. [i]、[ɪ] 5. [u]、[ʊ] 6. [ə]、[ɜ]
- (二) 子音：1. [b]、[p] 2. [d]、[t] 3. [z]、[s]、[ð]、[θ]
4. [g]、[k] 5. [v]、[f] 6. [ʒ]、[dʒ]、[ʃ]、[tʃ]
7. [m]、[n]、[ŋ] 8. [l]、[r]

(三) 先經由教學光碟中，外國老師的正確發音，使用 AudacityPortable 紀錄並分析聲音的形狀，在時間領域和頻率領域做比較，了解易混淆音有何差異。

(四) 挑選五位志願受測的學生說出以下的句子，紀錄並分析聲音的形狀，並和老師的發音在時間領域和頻率領域做比較。

1. What's your name? 2. Thank you very much. 3. Lock the door.
4. Good morning. 5. Five apples.

二、國語教學中，同學對於以下的發音的發法常會發法常會混淆：

- (一) 聲母：1. ㄅ、ㄆ 2. ㄇ、ㄏ
3. ㄐ、ㄌ 4. ㄑ、ㄎ

- (二) 韻母：1. ㄣ、ㄨ 2. ㄛ、ㄨ

(三) 先經由教學網站中老師的正確發音，紀錄並分析聲音的形狀，在時間領域和頻率領域做比較，了解易混淆音有何差異。

(四) 挑選五位志願受測的學生說出以下的句子，紀錄並分析聲音的形狀，並和老師的發音在時間領域和頻率領域做比較。

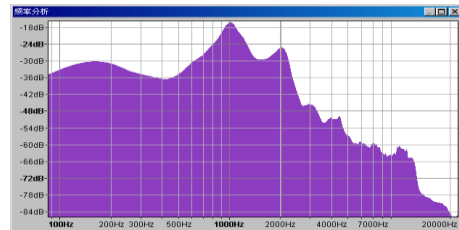
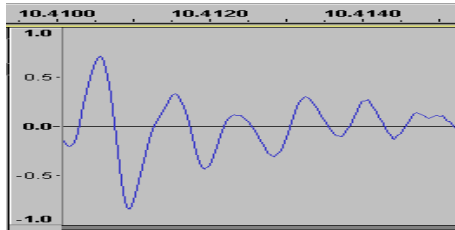
1. 平安喜樂。 2. 天氣悶熱 3. 老師您好
4. 癡人說夢。 5. 畫蛇添足。

伍、研究結果

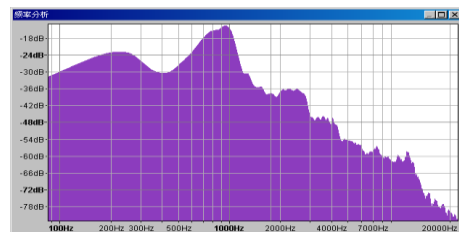
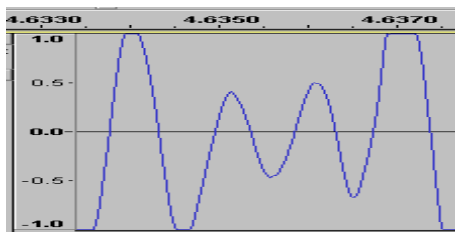
一、英語發音

(一) 母音

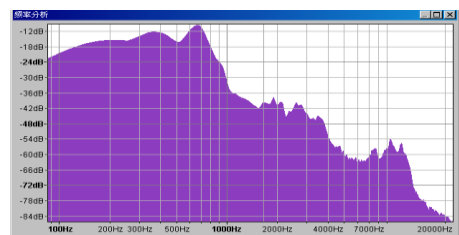
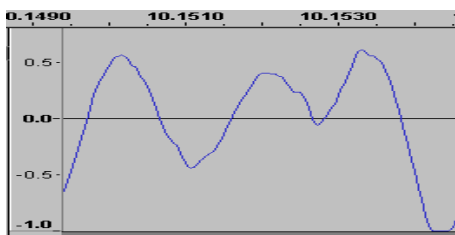
1. (1) [æ]



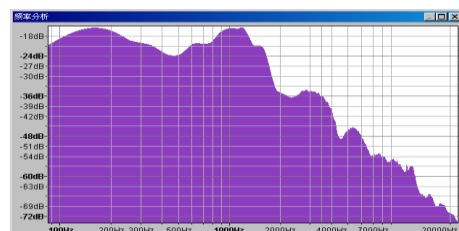
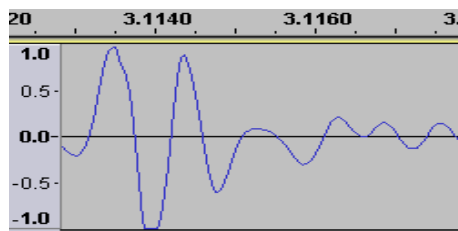
(2) [ɛ]



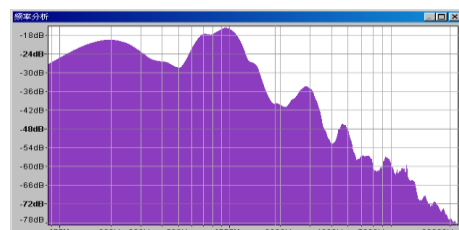
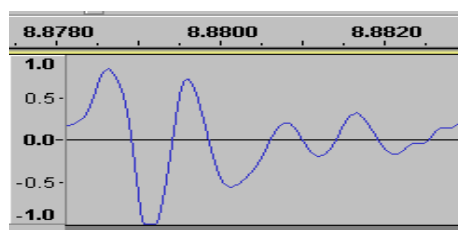
(3) [e]



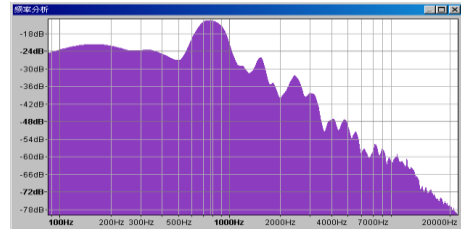
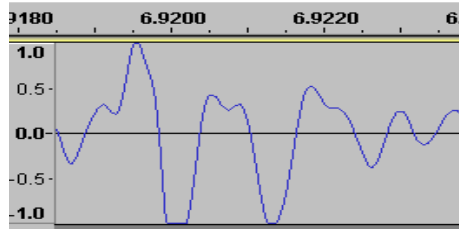
2. (1) [ɑ]



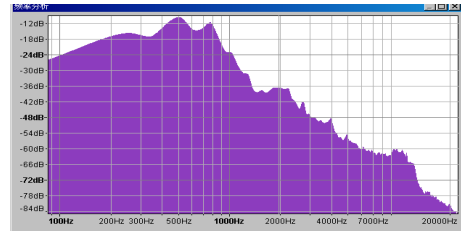
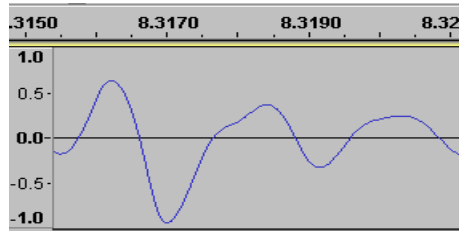
(2) [ʌ]



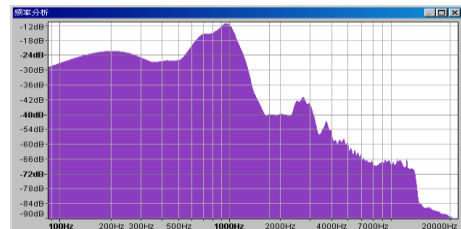
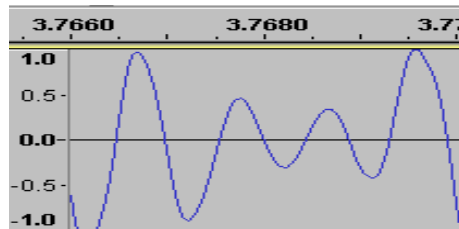
(3)[ə]



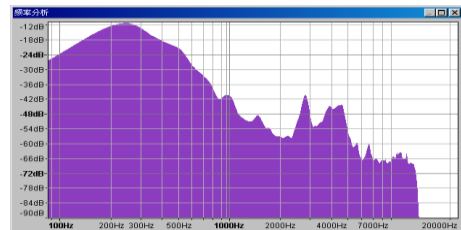
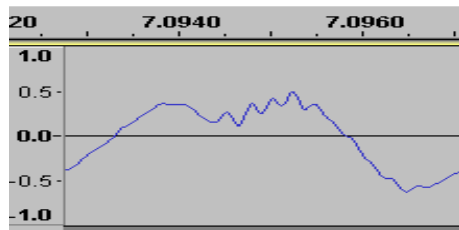
3. (1) [o]



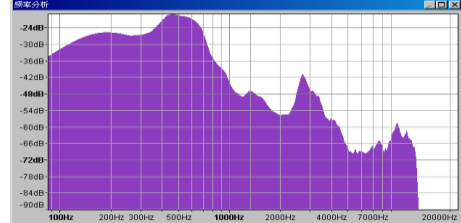
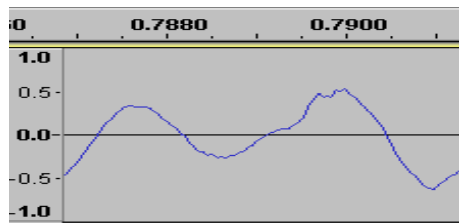
(2)[ɔ]



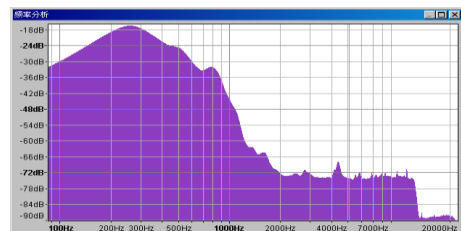
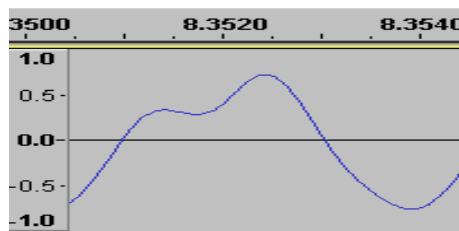
4. (1) [i]



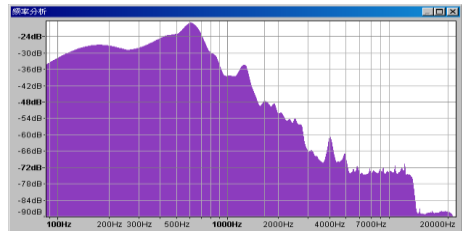
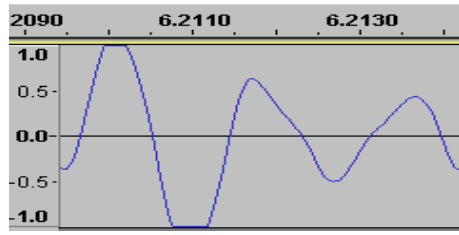
(2) [I]



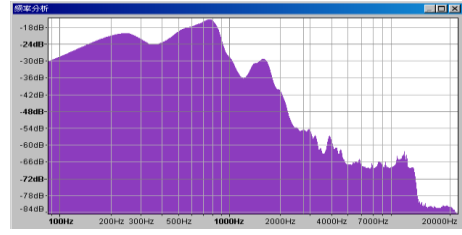
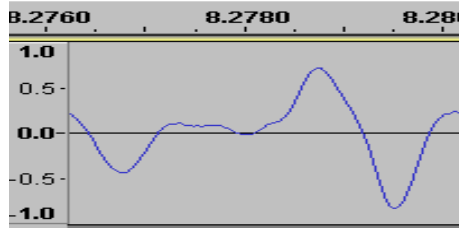
5. (1) [u]



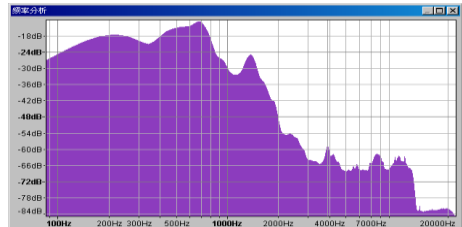
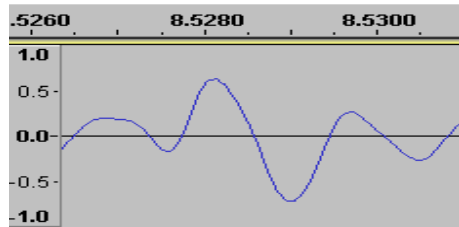
(2) [ʊ]



6. (1) [ə]

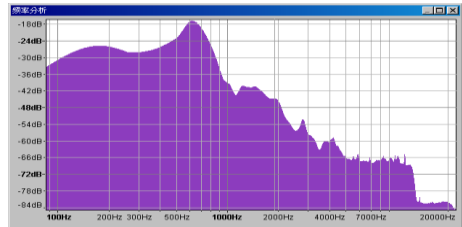
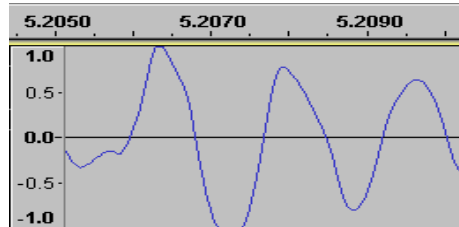


(2) [ɜ]

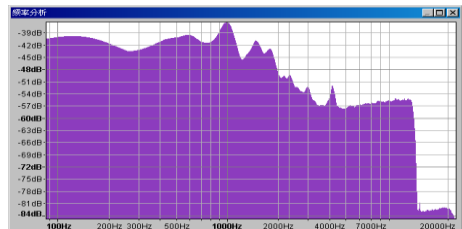
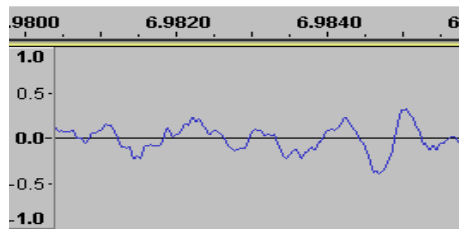


(二) 子音

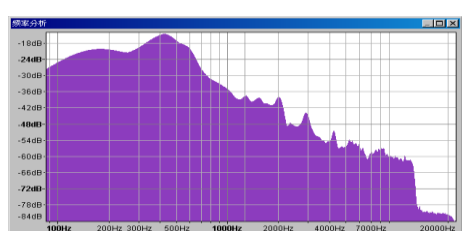
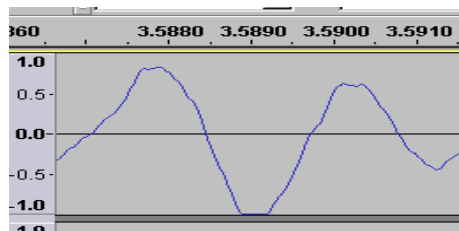
1. (1) [b]



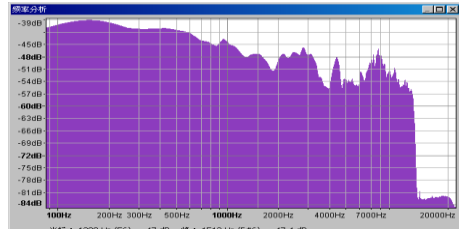
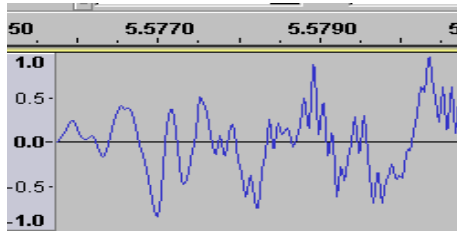
(2) [p]



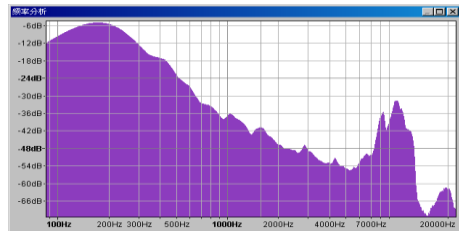
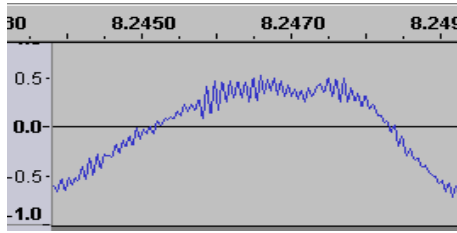
2. (1) [d]



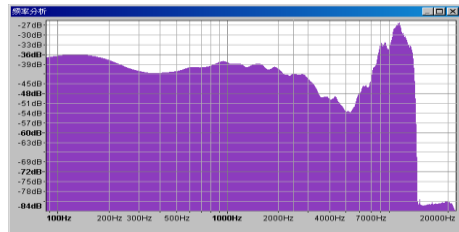
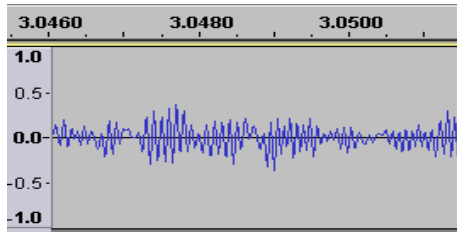
(2) [t]



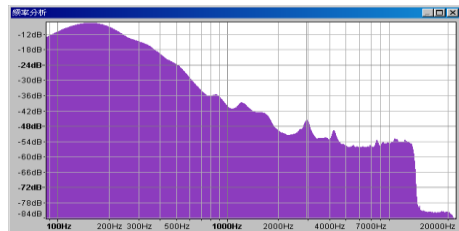
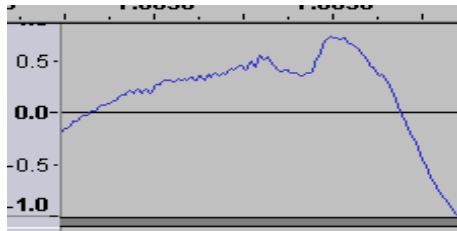
3. (1) [z]



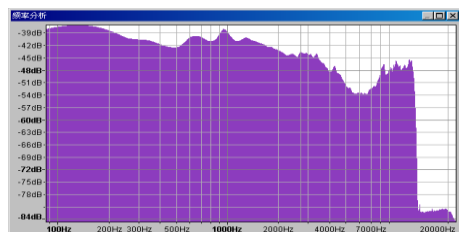
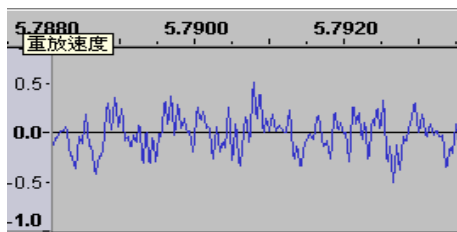
(2) [s]



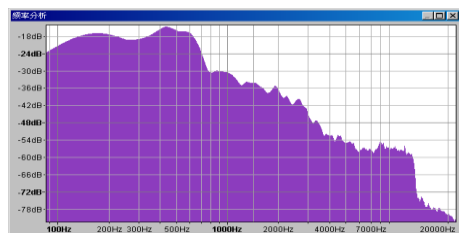
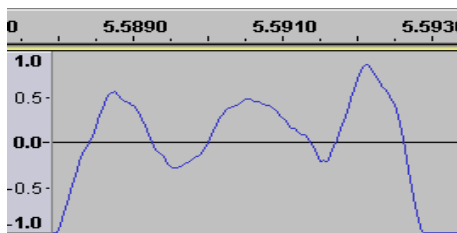
(3) [ð]



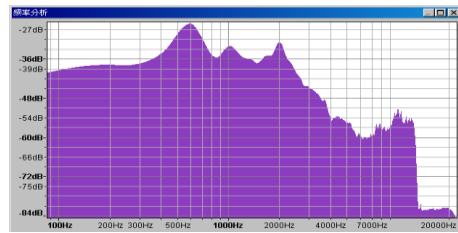
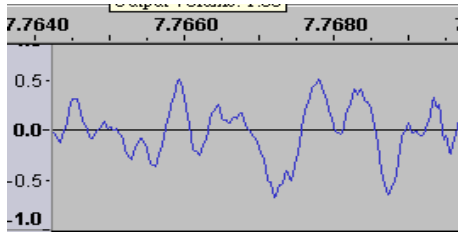
(4) [θ]



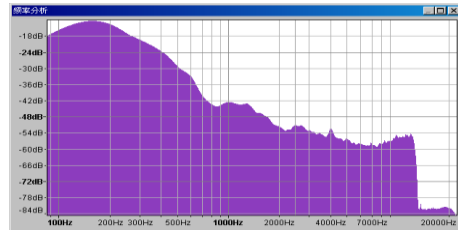
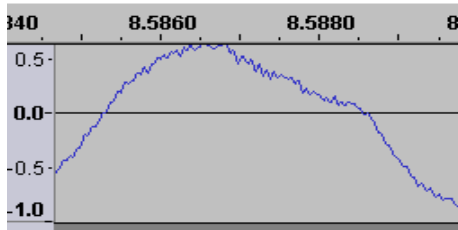
4. (1) [g]



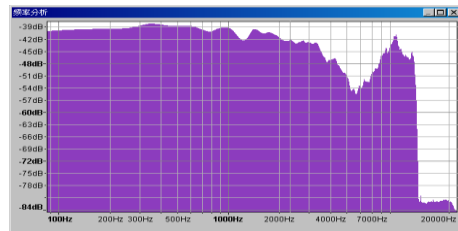
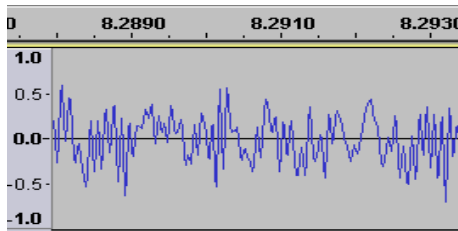
(2) [k]



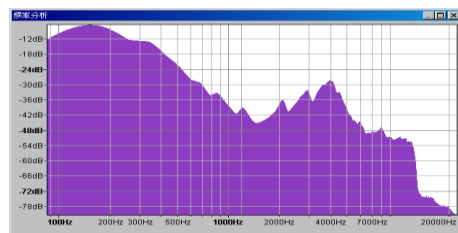
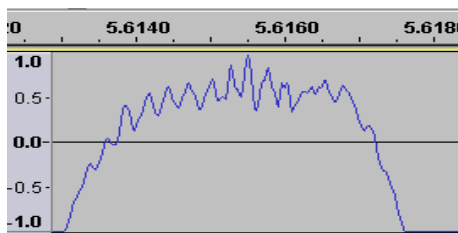
5. (1) [v]



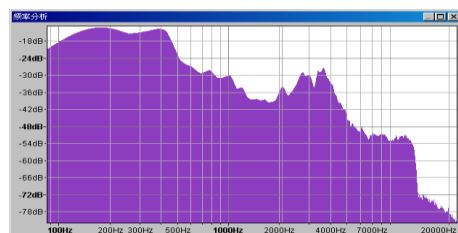
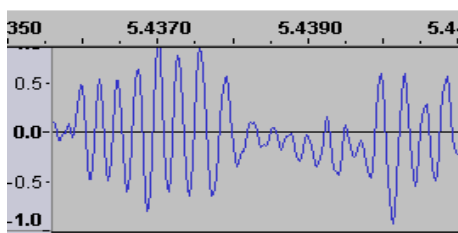
(2) [f]



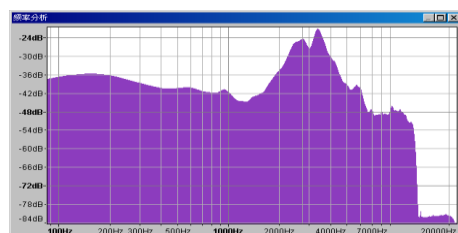
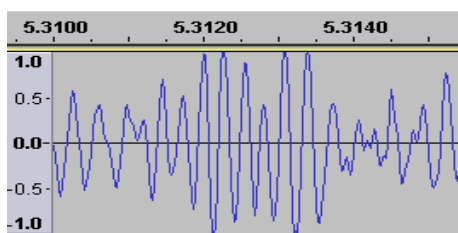
6. (1) [ʒ]



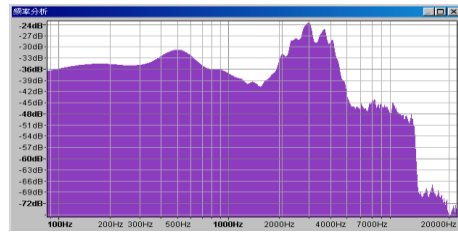
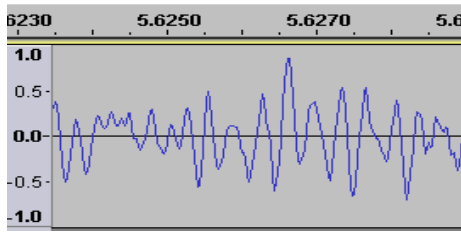
(2) [dʒ]



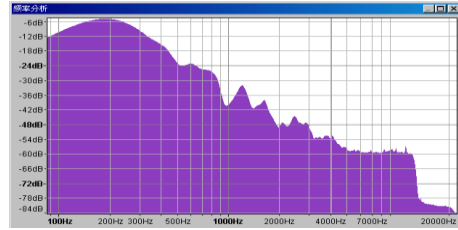
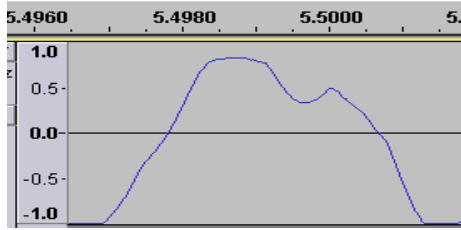
(3) [ʃ]



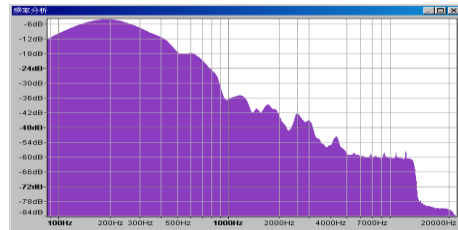
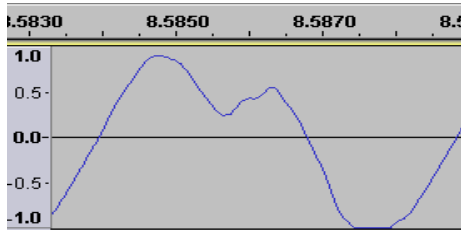
(4) [tʃ]



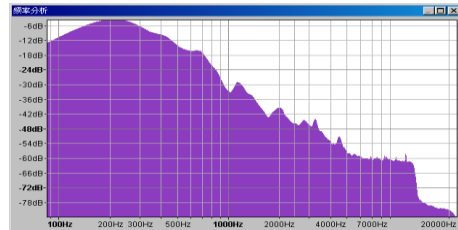
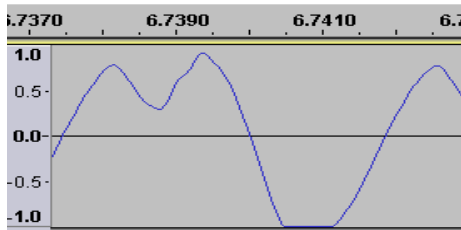
7. (1) [m]



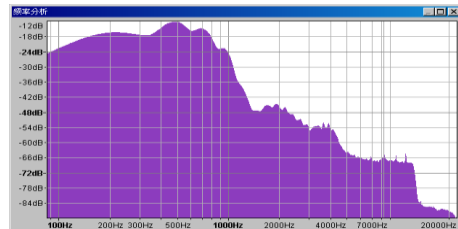
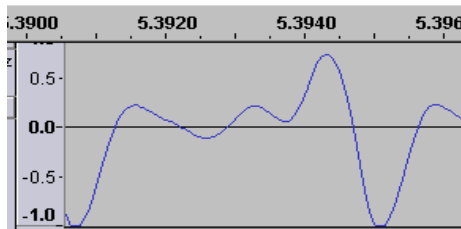
(2) [n]



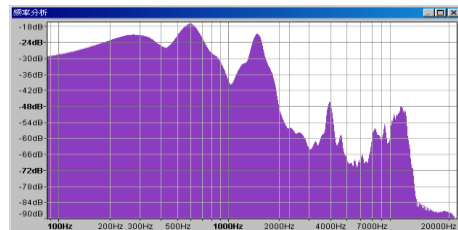
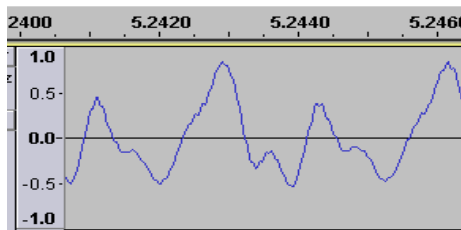
(3) [ŋ]



8. (1) [l]



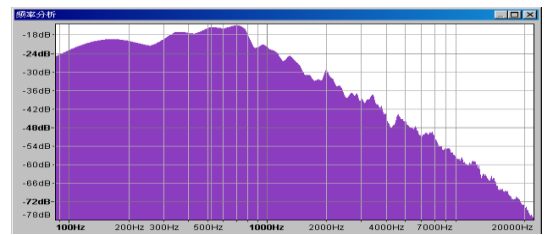
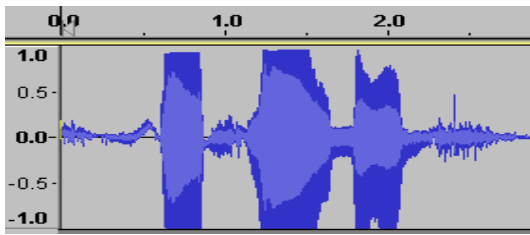
(2) [r]



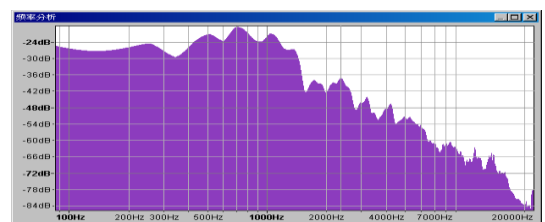
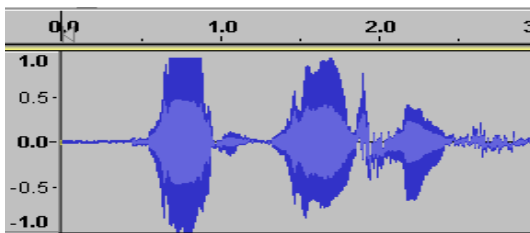
(三) 英文句子

1. What's your name?

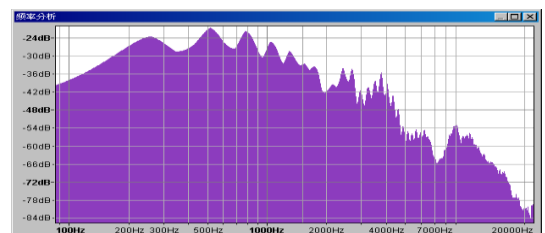
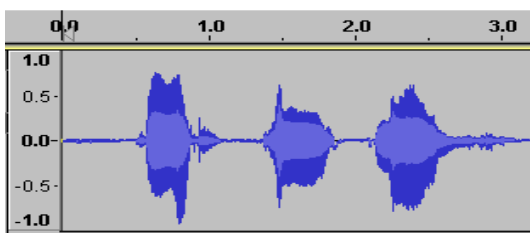
(1) 學生甲



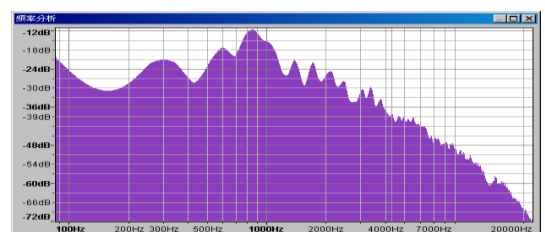
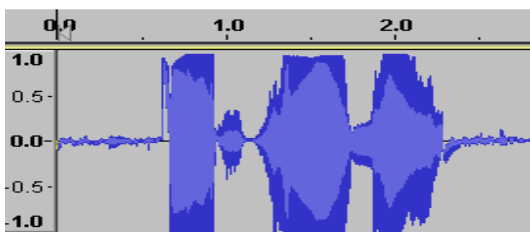
(2) 學生乙



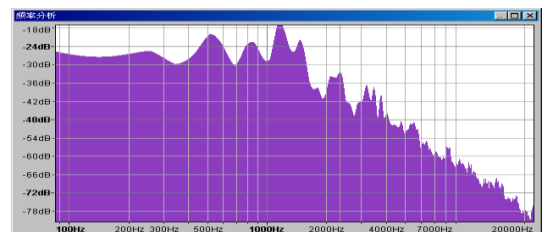
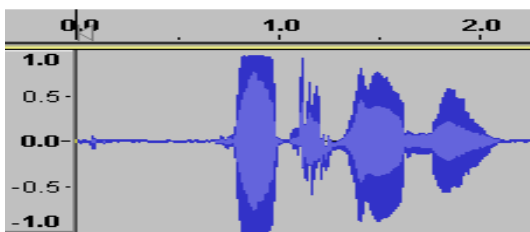
(3) 學生丙



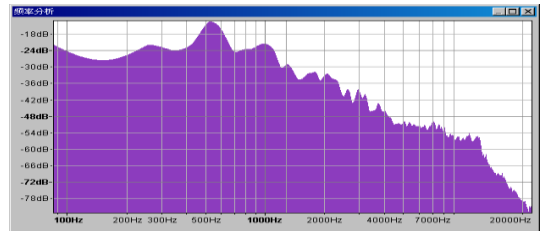
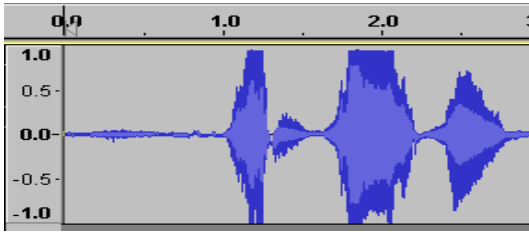
(4) 學生丁



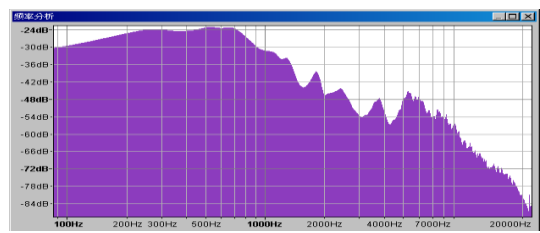
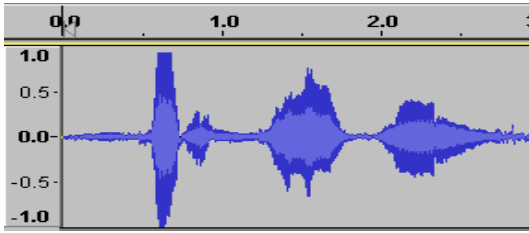
(5) 學生戊



(6) 學生己

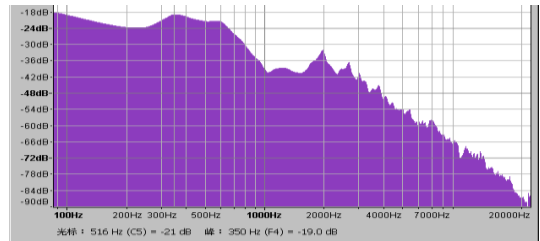
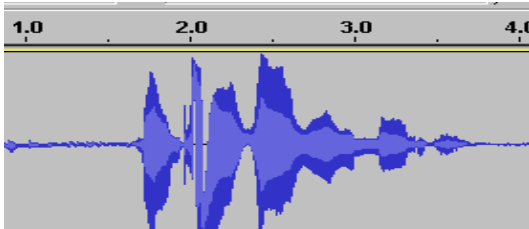


(7) 教師

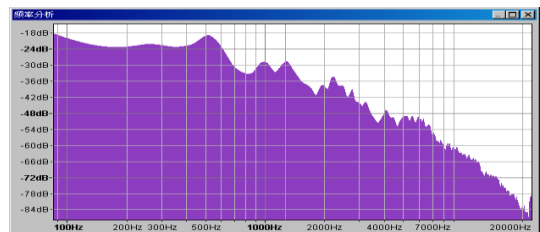
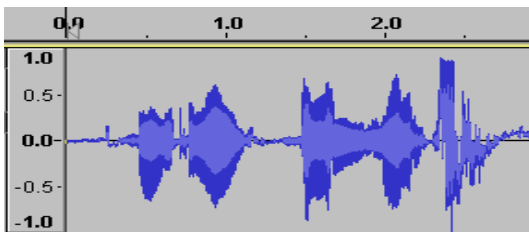


2. Thank you very much.

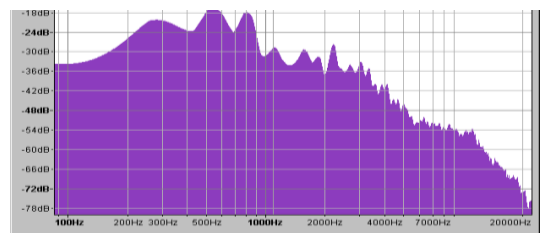
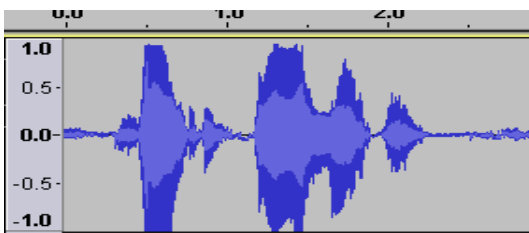
(1) 學生甲



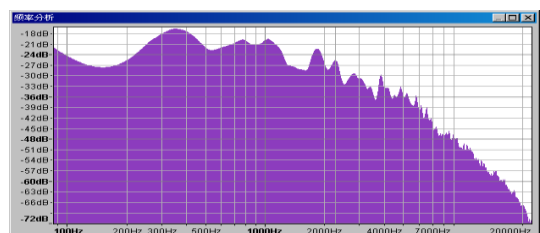
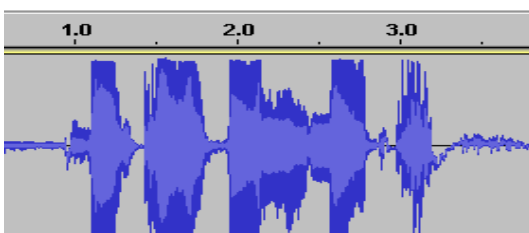
(2) 學生乙



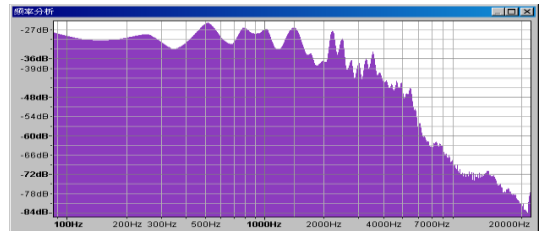
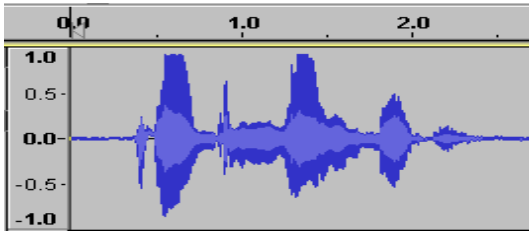
(3) 學生丙



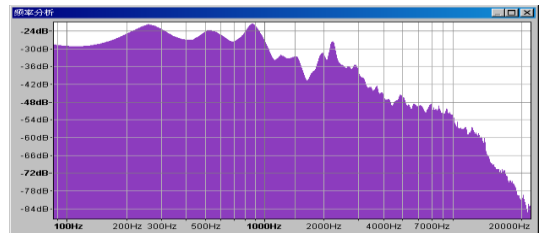
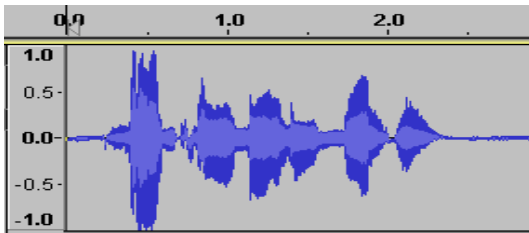
(4) 學生丁



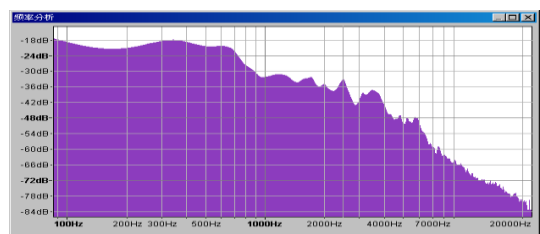
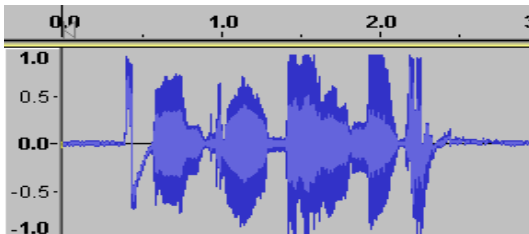
(5) 學生戊



(6) 學生己

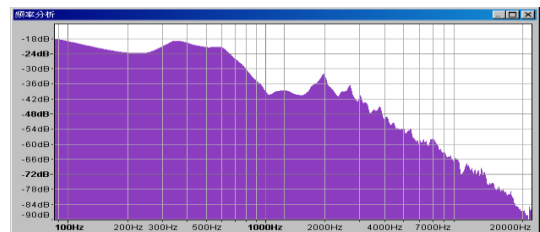
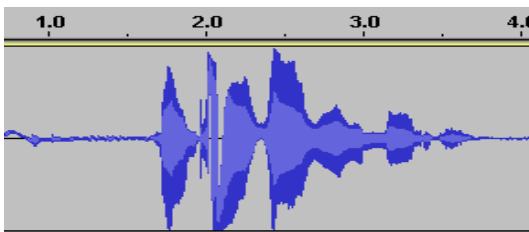


(7) 教師

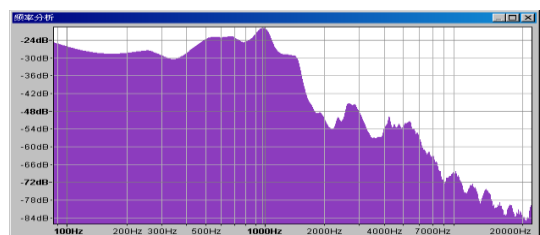
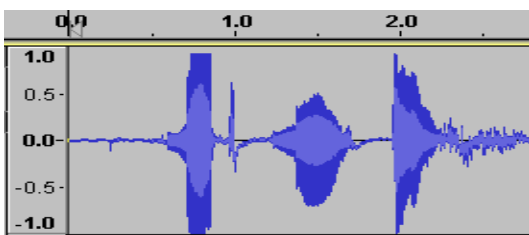


3. Lock the door.

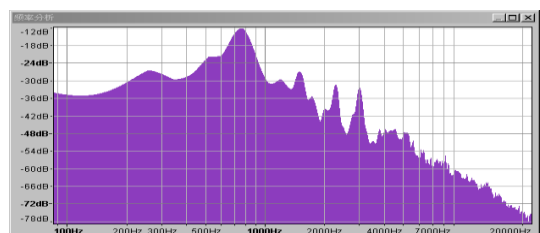
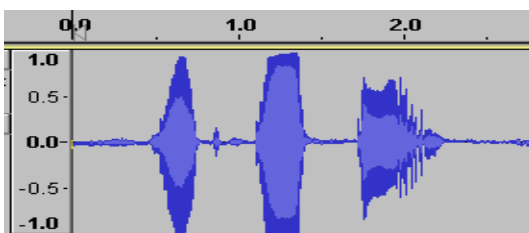
(1) 學生甲



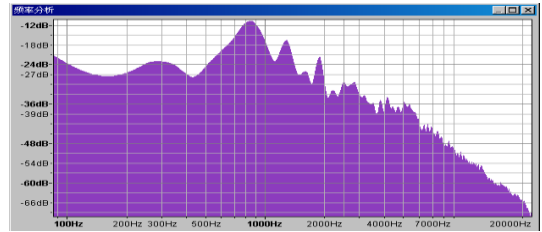
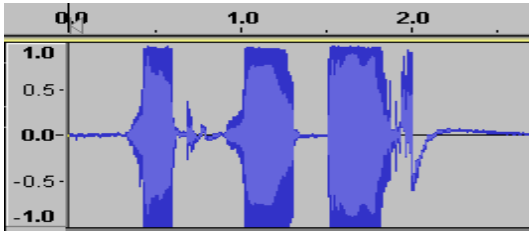
(2) 學生乙



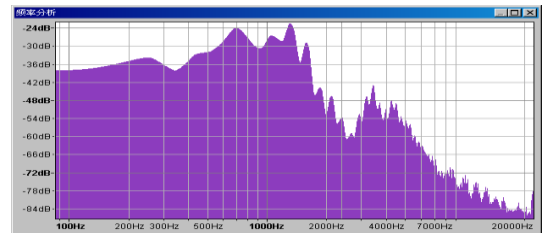
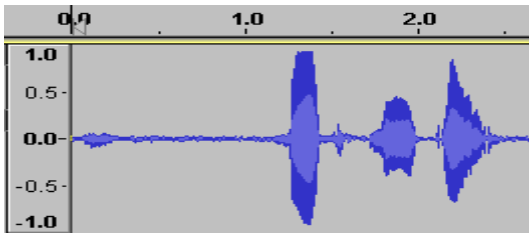
(3) 學生丙



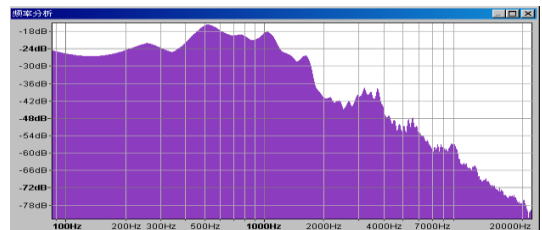
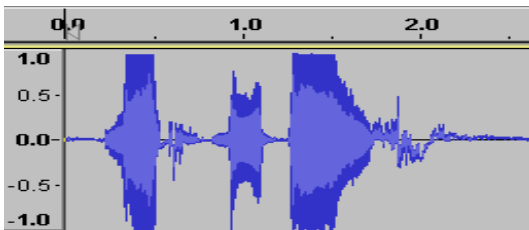
(4) 學生丁



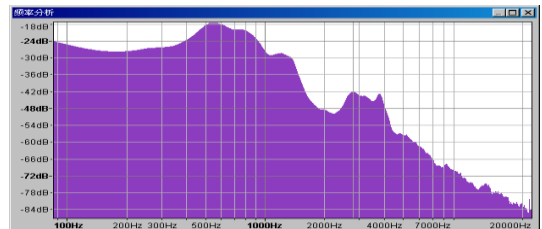
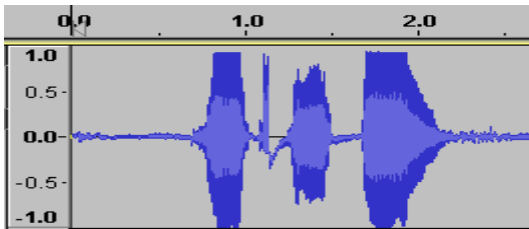
(5) 學生戊



(6) 學生己

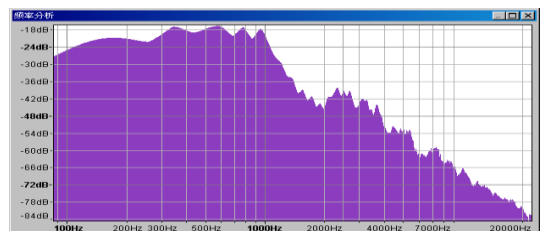
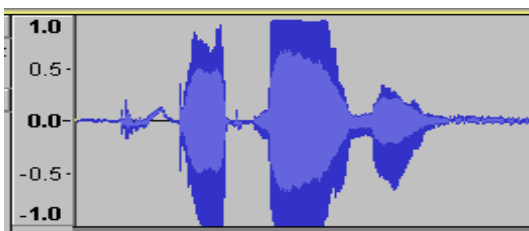


(7) 教師

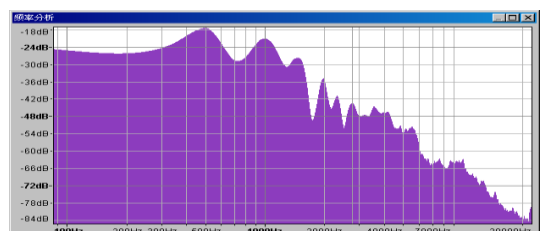
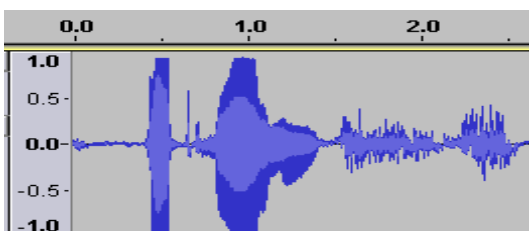


4. Good morning.

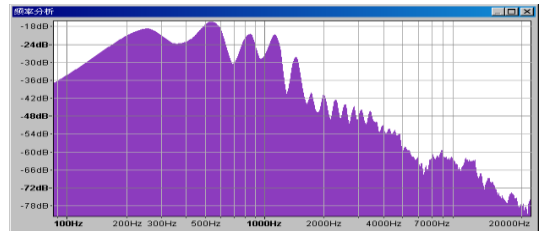
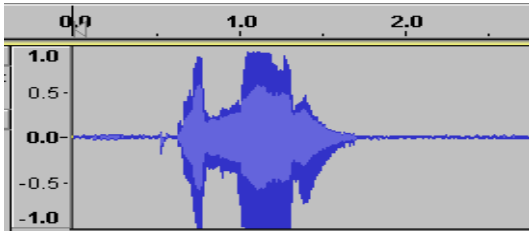
(1) 學生甲



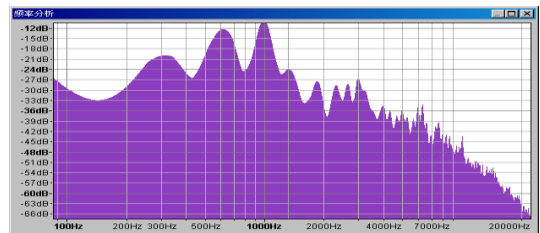
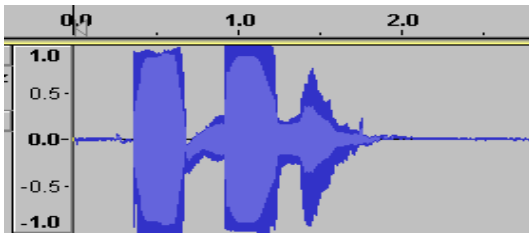
(2) 學生乙



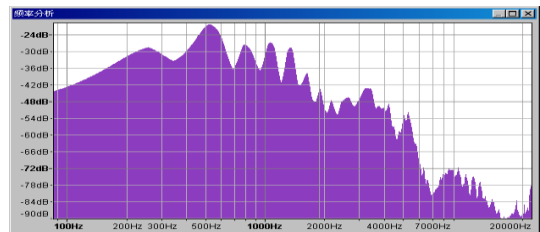
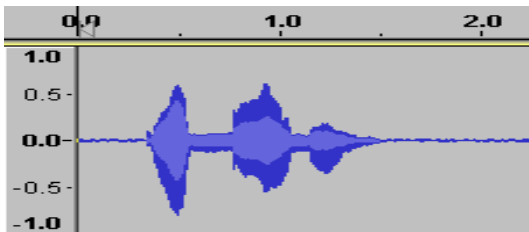
(3) 學生丙



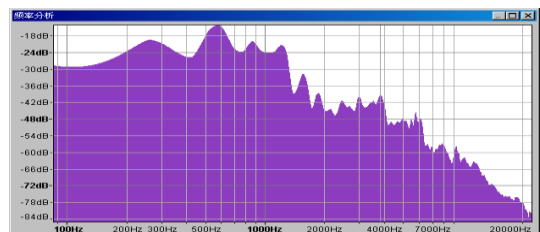
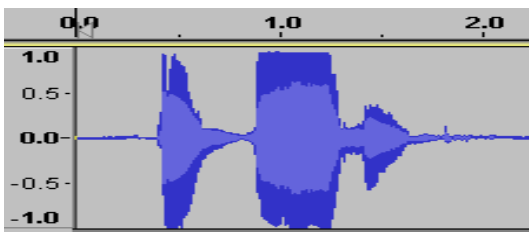
(4) 學生丁



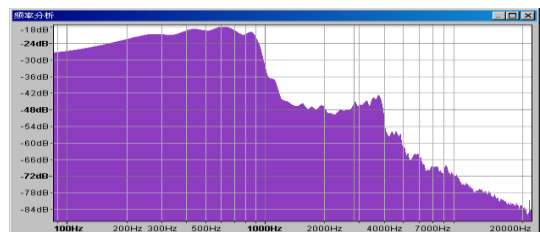
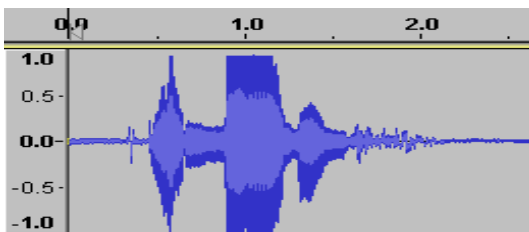
(5) 學生戊



(6) 學生己

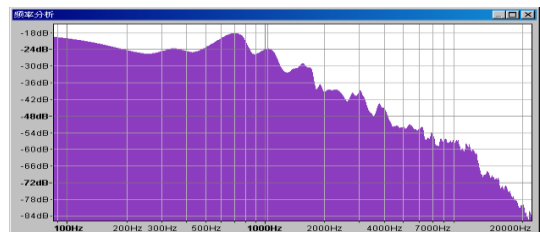
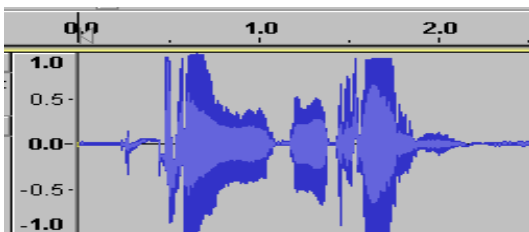


(7) 教師

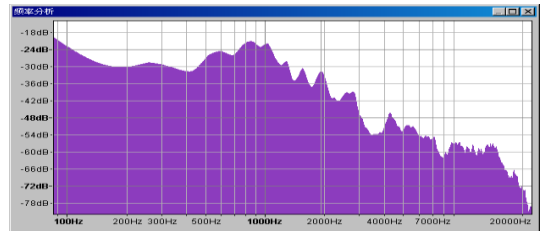
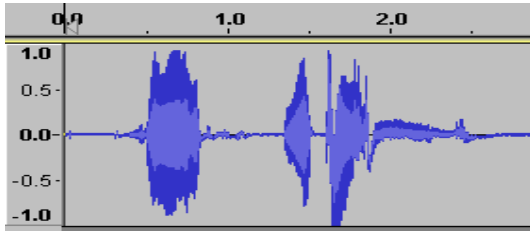


5. Five apples

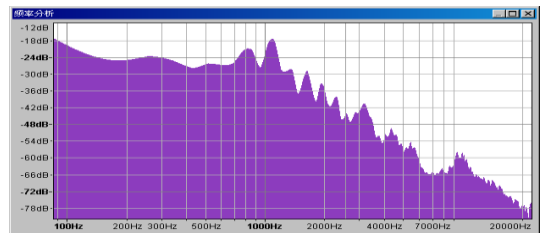
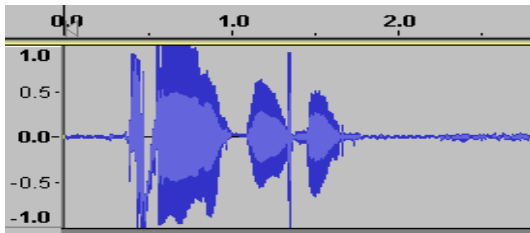
(1) 學生甲



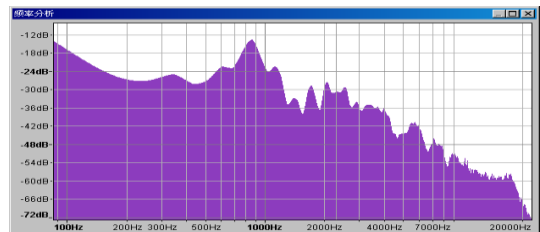
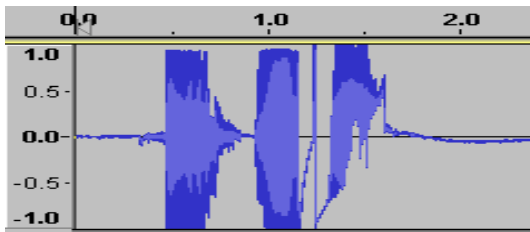
(2) 學生乙



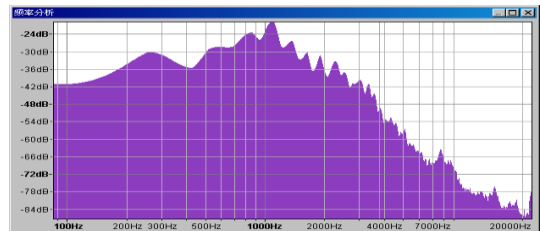
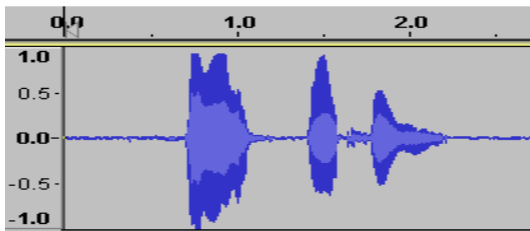
(3) 學生丙



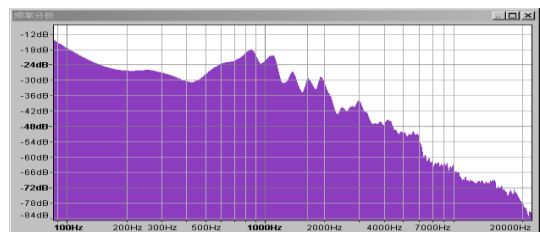
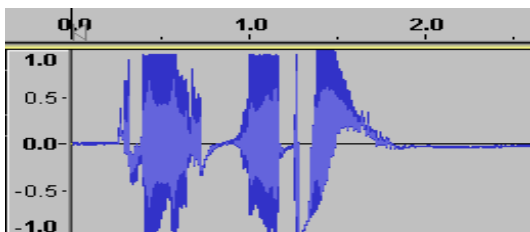
(4) 學生丁



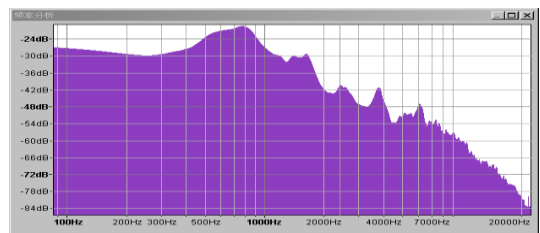
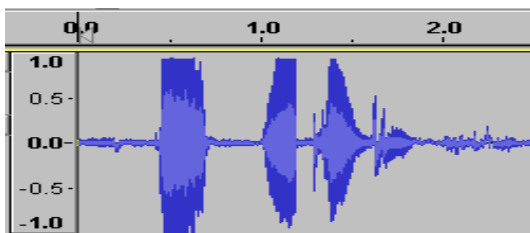
(5) 學生戊



(6) 學生己



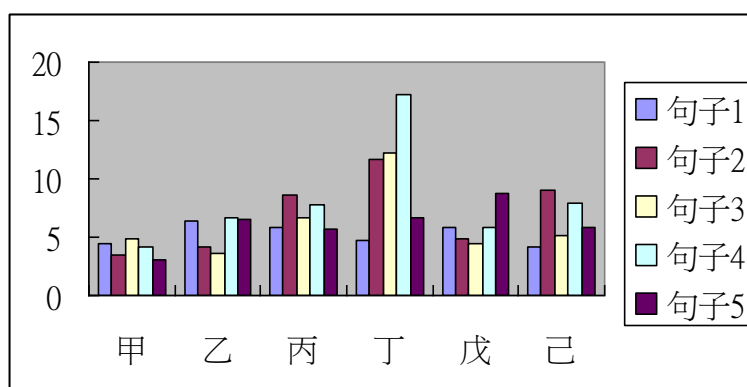
(7) 教師



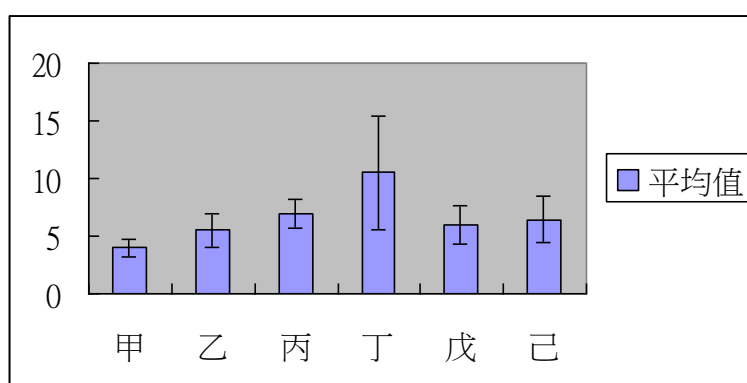
6. 學生與教師頻譜圖數值差的均方根 (root mean square) 表

英文句子	學生甲	學生乙	學生丙	學生丁	學生戊	學生己	平均值	標準差
句子 1	4.4754	6.4159	5.8246	4.7655	5.7730	4.2208	5.2458	0.8783
句子 2	3.4347	4.1932	8.6741	11.6619	4.8760	9.0254	6.9776	3.2783
句子 3	4.8791	3.6757	6.6552	12.2129	4.4099	5.0930	6.1543	3.1272
句子 4	4.1037	6.7352	7.7368	17.1822	5.8527	7.9682	8.2631	4.5904
句子 5	2.9926	6.5635	5.7320	6.7137	8.7660	5.8093	6.0962	1.8748
平均值	3.9771	5.5167	6.9245	10.5072	5.9355	6.42334		
標準差	0.7651	1.4603	1.1267	4.9030	1.6952	2.0097		

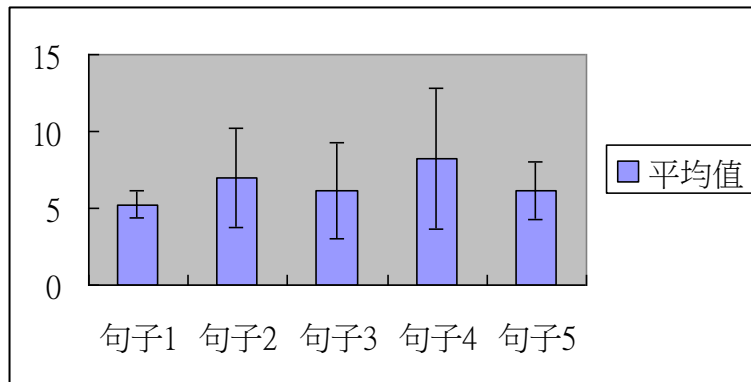
7. 學生與教師頻譜圖數值差的均方根 (root mean square) 圖



8. 六位學生的五個英語句子指標 m 的平均值與標準差圖



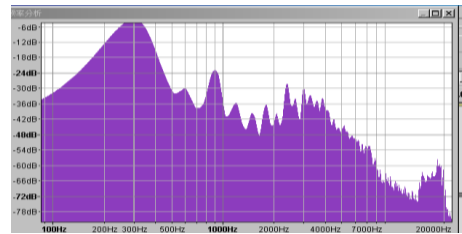
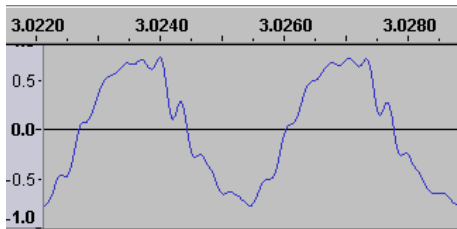
9. 五個英語句子的六位學生指標 m 的平均值與標準差圖



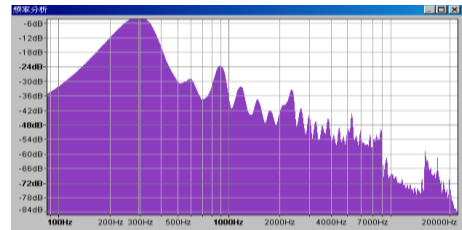
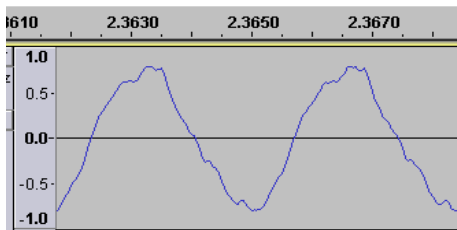
二、國語教學

(一) 聲母

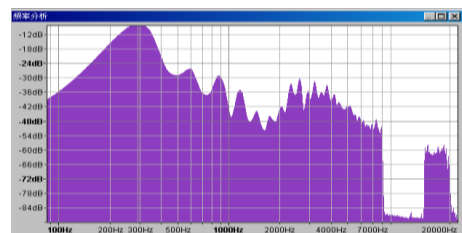
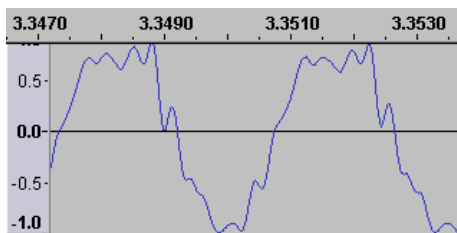
1. (1) ㄅ



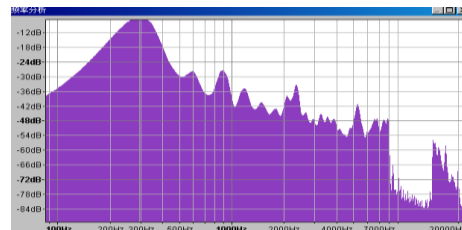
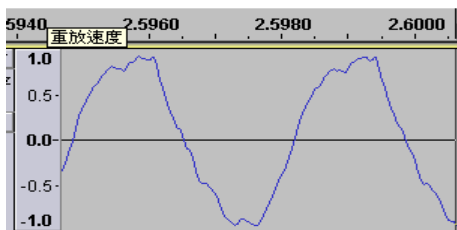
(2) ㄆ



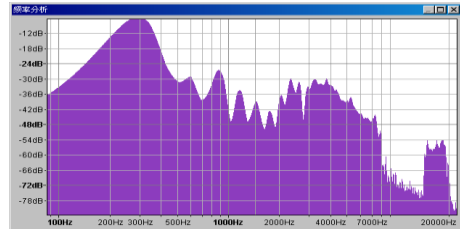
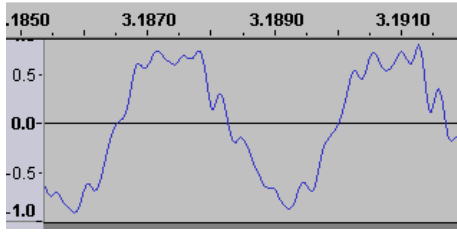
2. (1) ㄆ



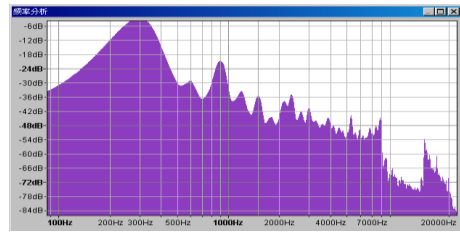
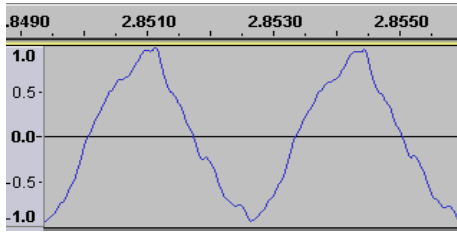
(2) ㄆ



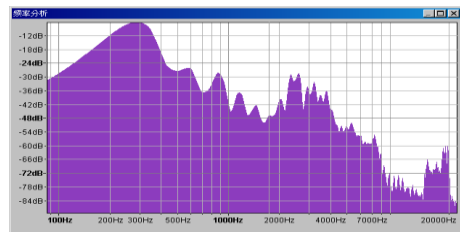
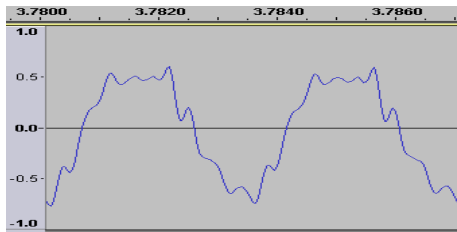
3. (1) 戸



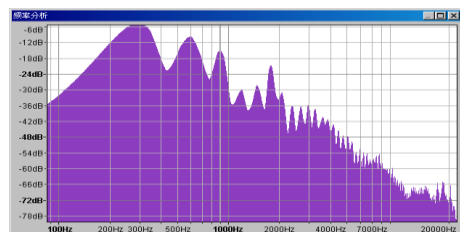
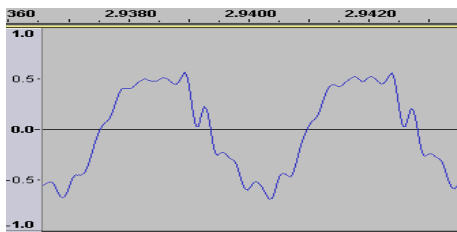
(2) ム



4. (1) 𪛗

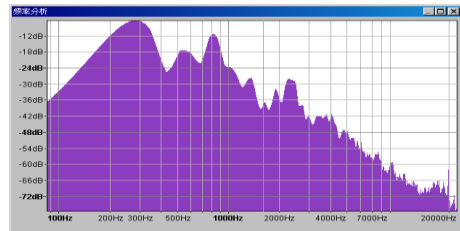
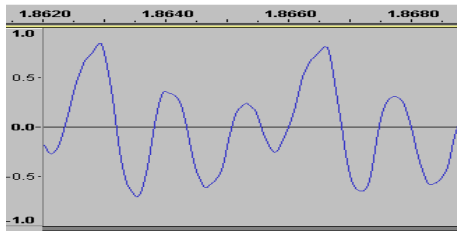


(2) 𪛘

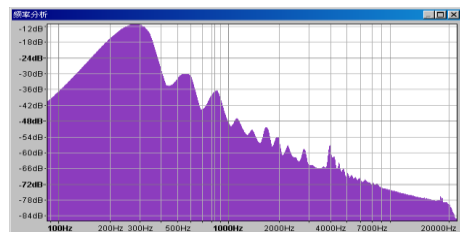
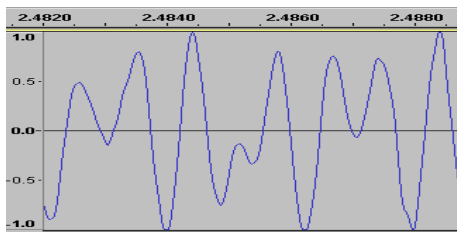


(二) 韻母

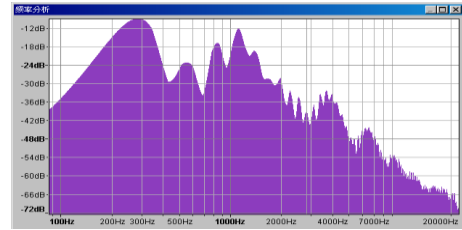
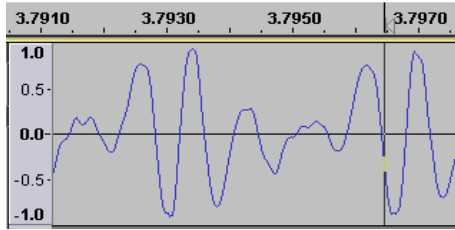
1. (1) ㄛ



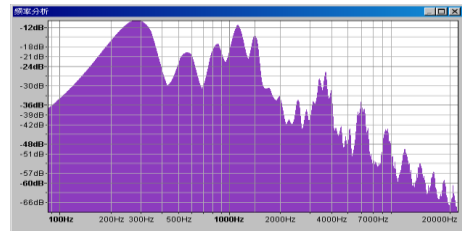
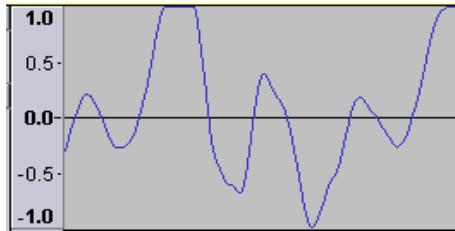
(2) ㄛ



2. (1) 弓



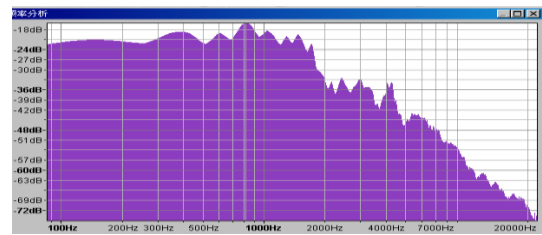
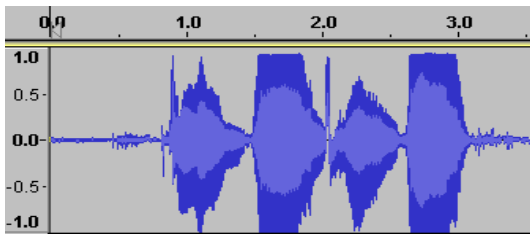
(2) 尤



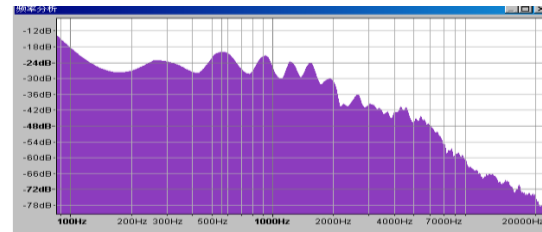
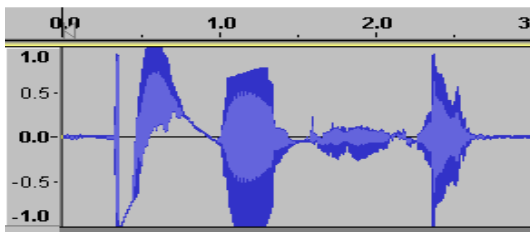
(三) 國語句子

1. 平安喜樂。

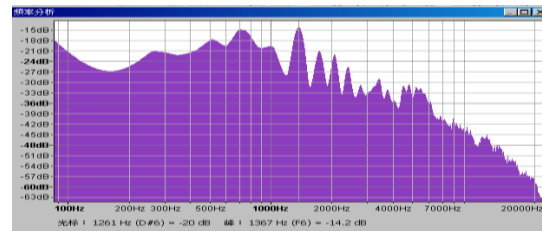
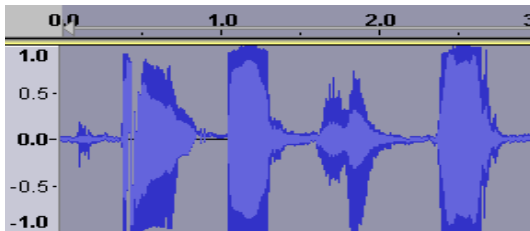
(1) 學生甲



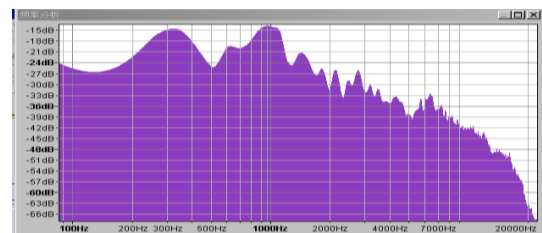
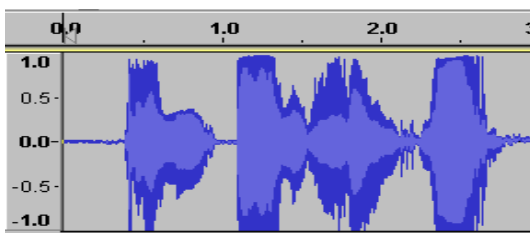
(2) 學生乙



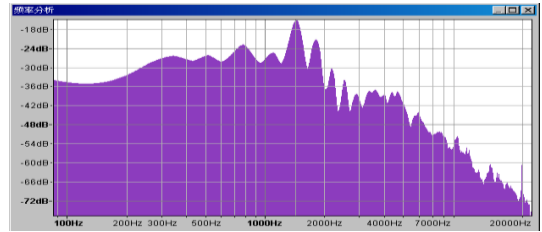
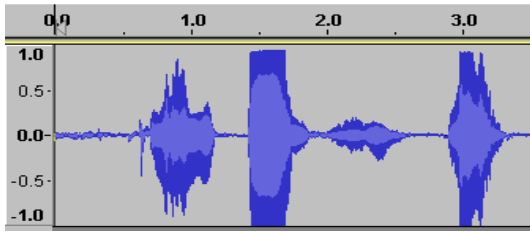
(3) 學生丙



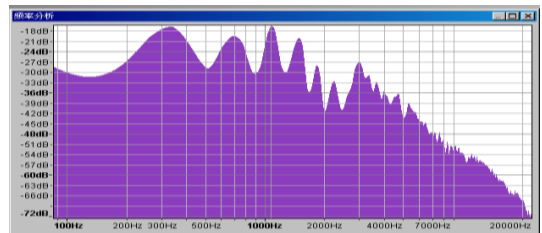
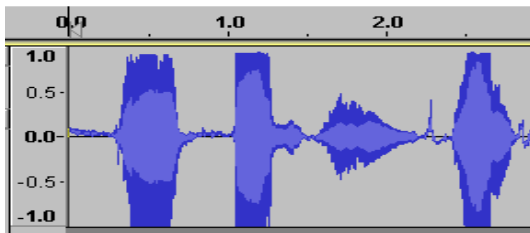
(4) 學生丁



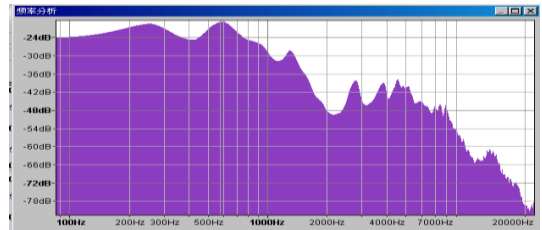
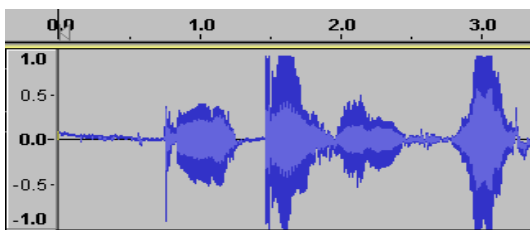
(5) 學生戊



(6) 學生己

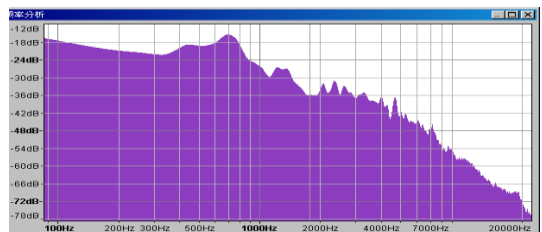
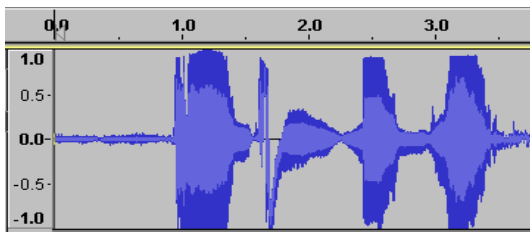


(7) 教師

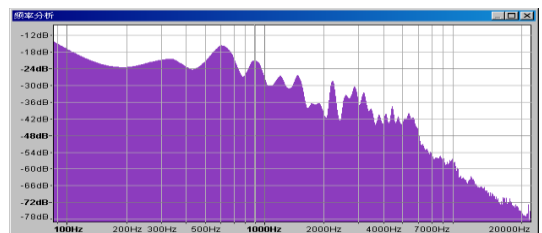
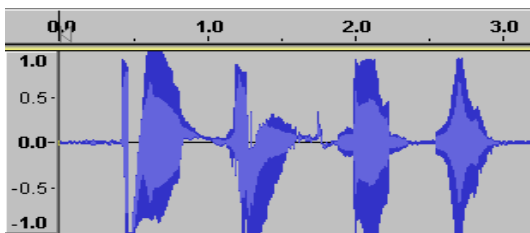


2. 天氣悶熱。

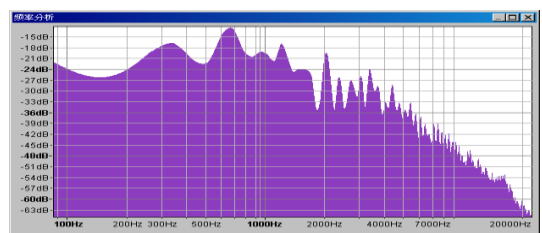
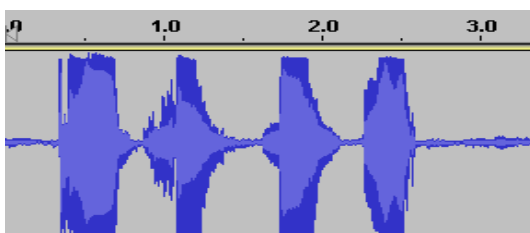
(1) 學生甲



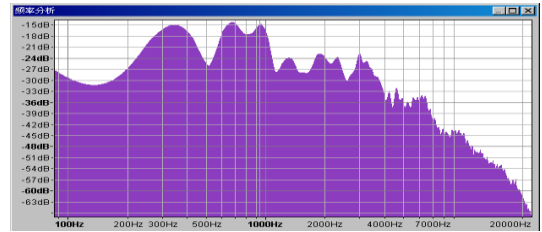
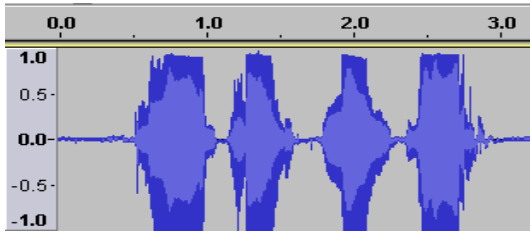
(2) 學生乙



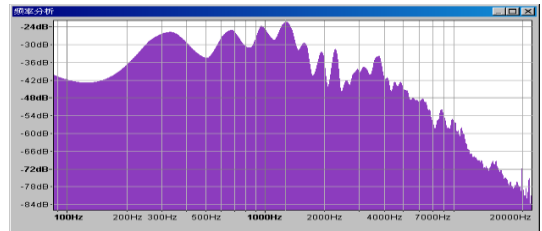
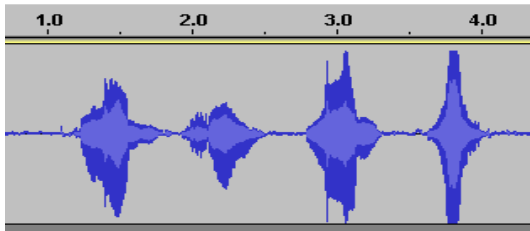
(3) 學生丙



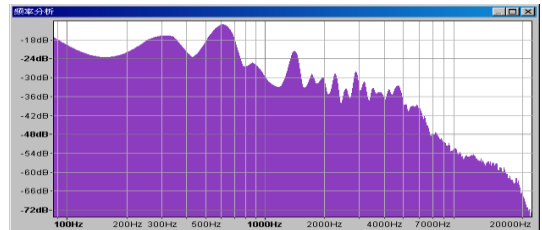
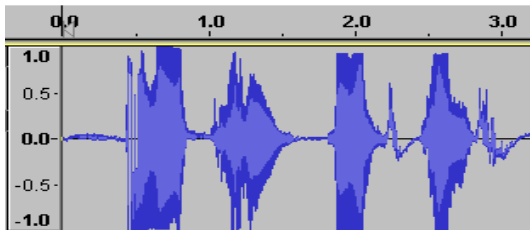
(4) 學生丁



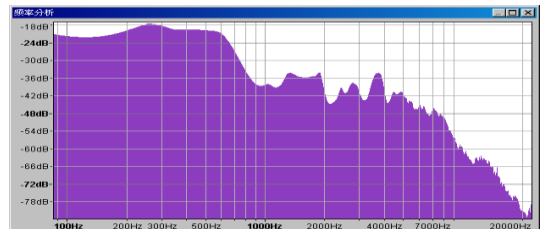
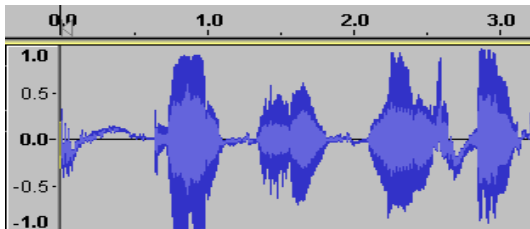
(5) 學生戊



(6) 學生己

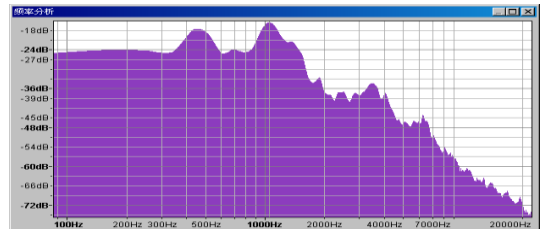
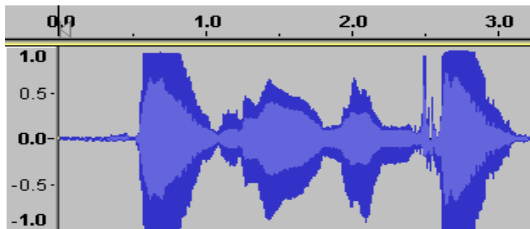


(7) 教師

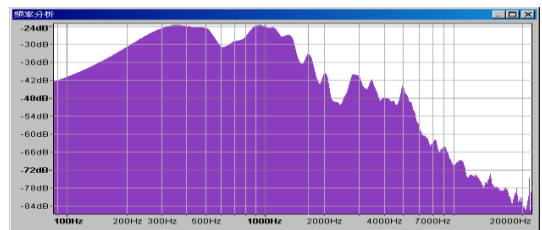
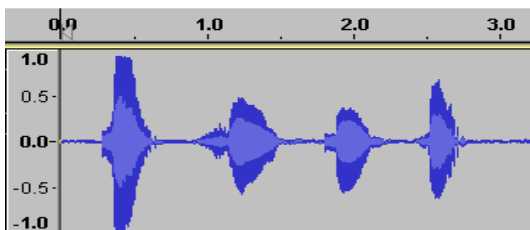


3. 老師您好。

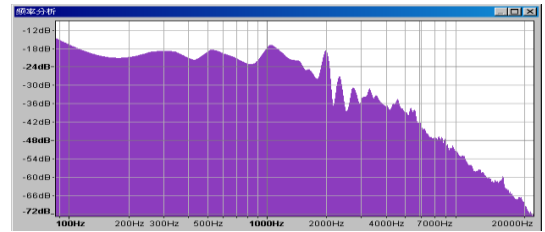
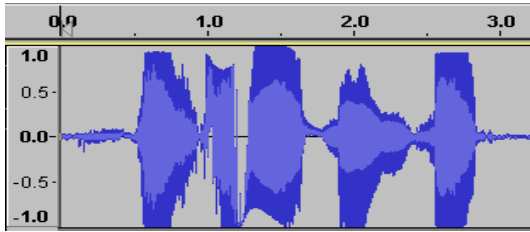
(1) 學生甲



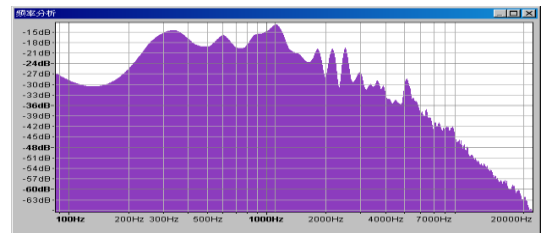
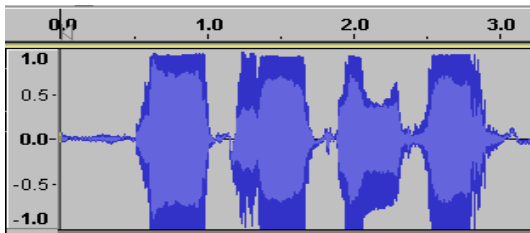
(2) 學生乙



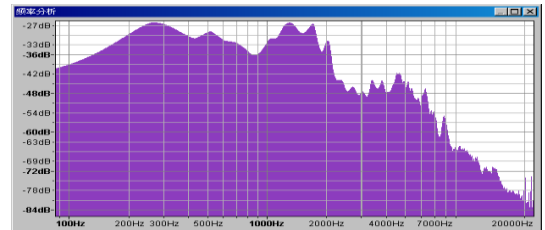
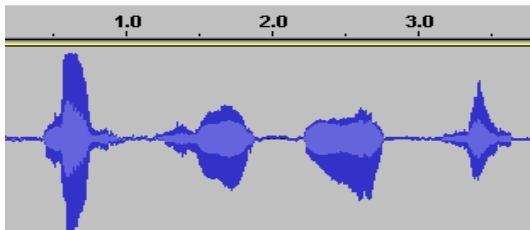
(3) 學生丙



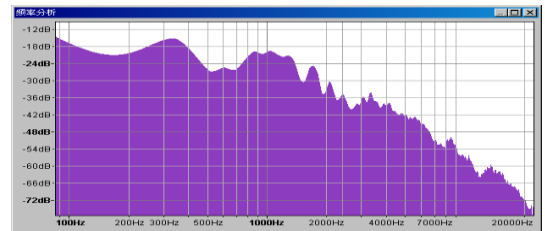
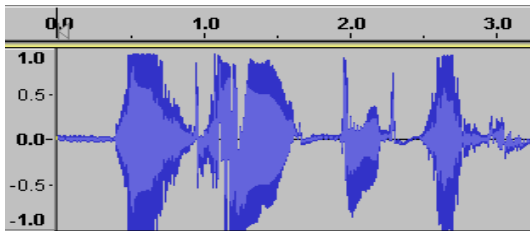
(4) 學生丁



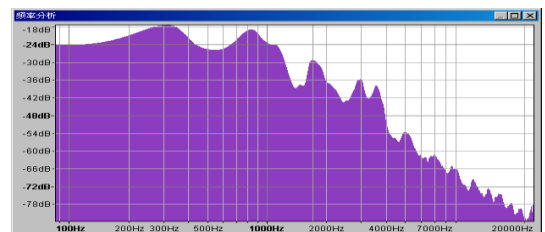
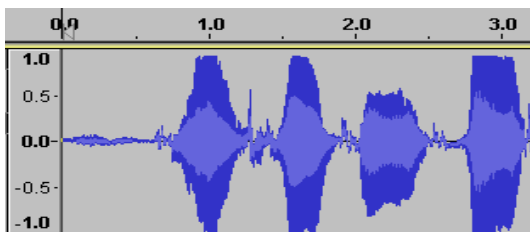
(5) 學生戊



(6) 學生己

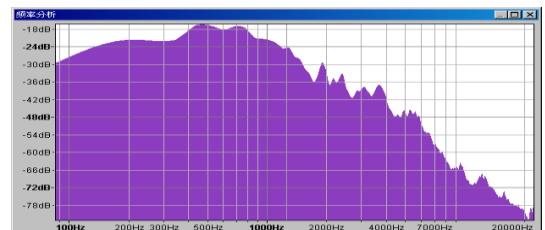
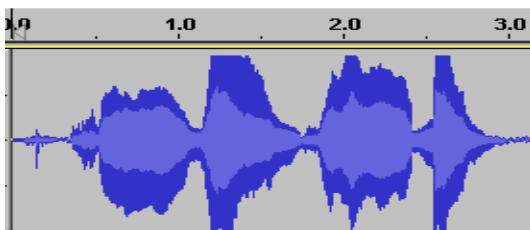


(7) 教師

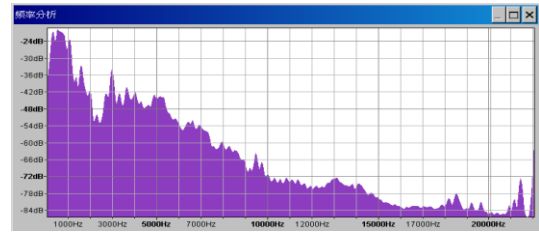
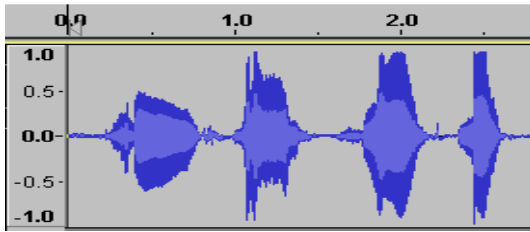


4. 癡人說夢。

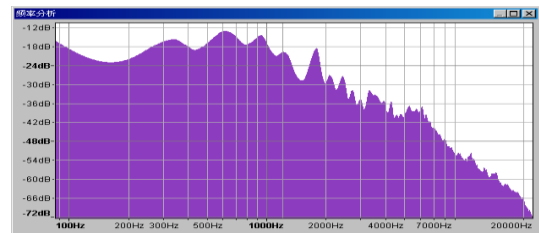
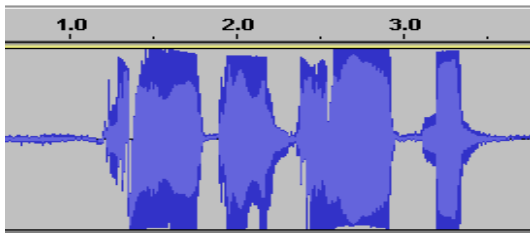
(1) 學生甲



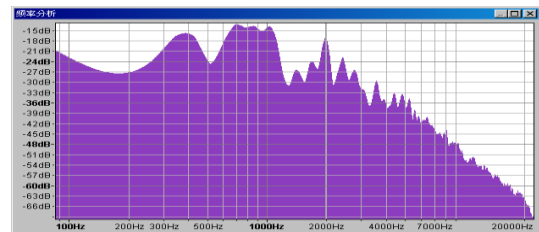
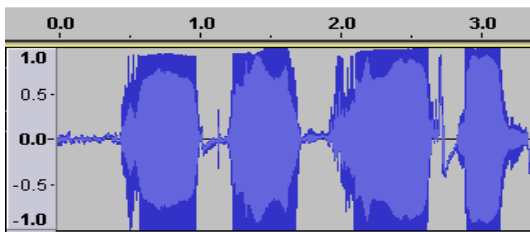
(2) 學生乙



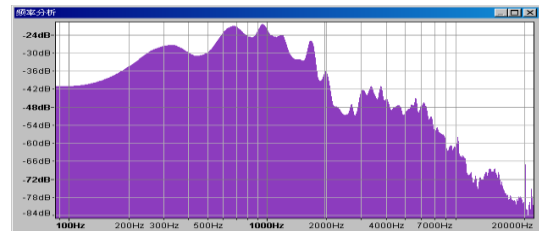
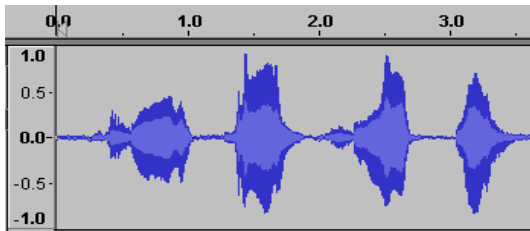
(3) 學生丙



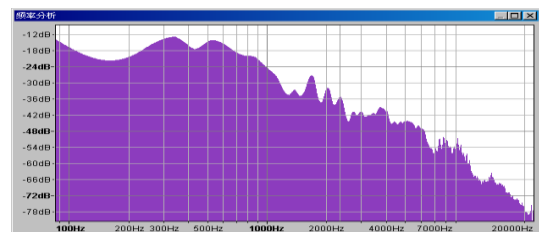
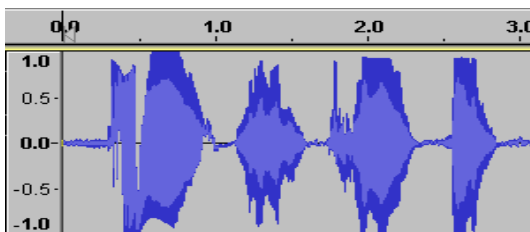
(4) 學生丁



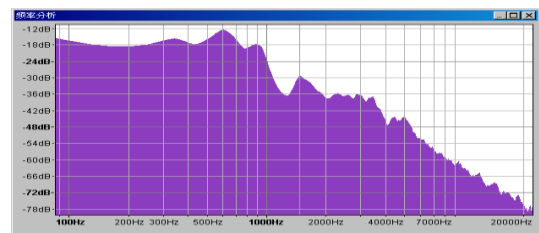
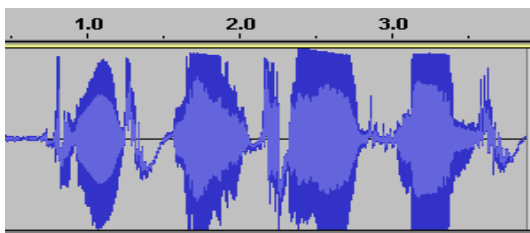
(5) 學生戊



(6) 學生己

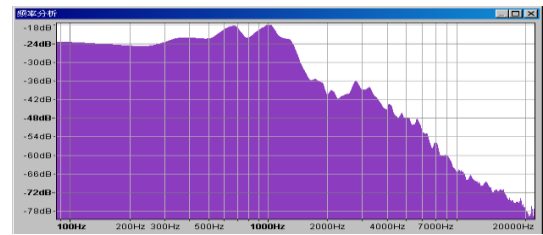
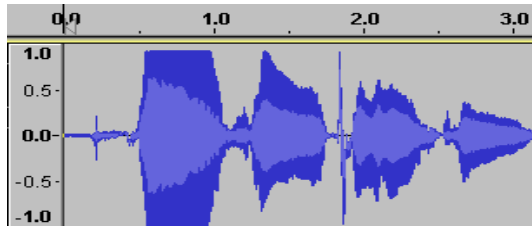


(7) 教師

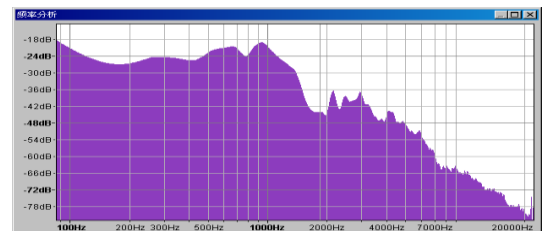
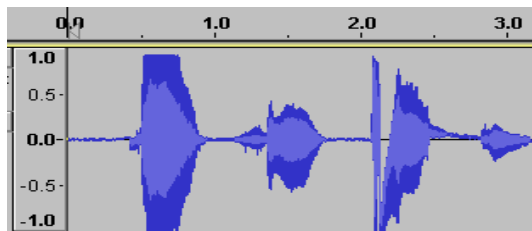


5. 畫蛇添足。

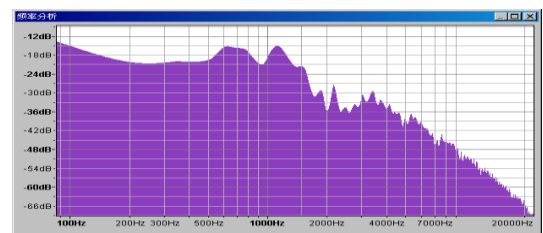
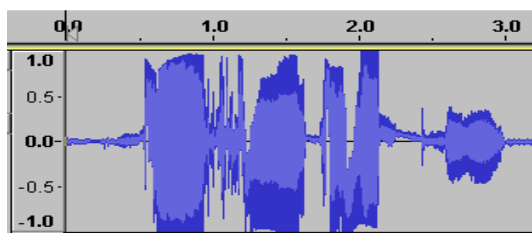
(1) 學生甲



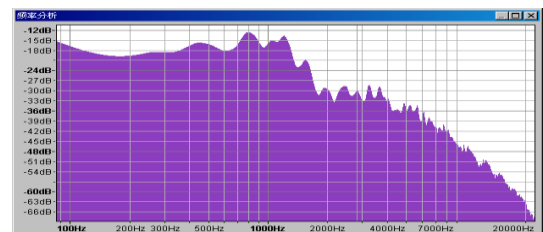
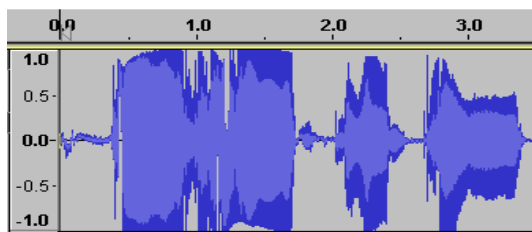
(2) 學生乙



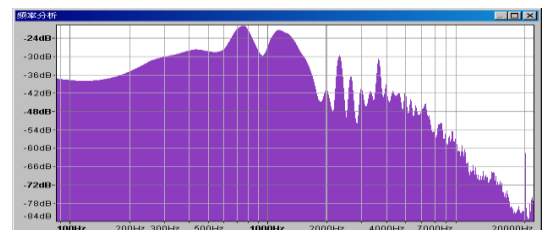
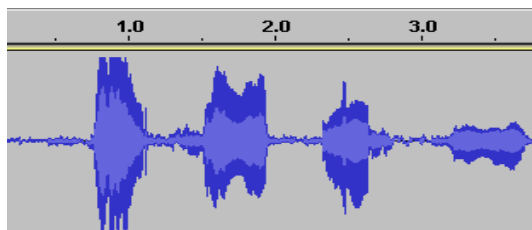
(3) 學生丙



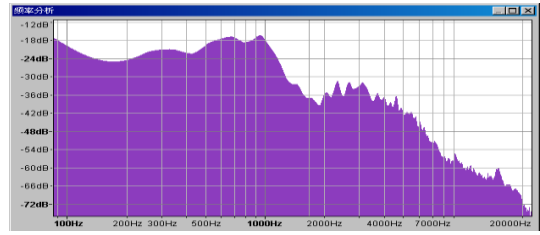
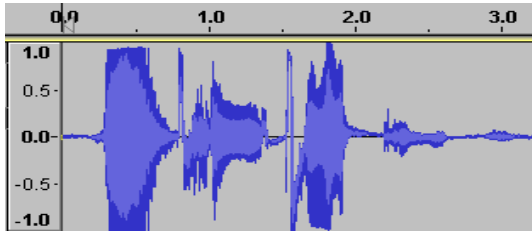
(4) 學生丁



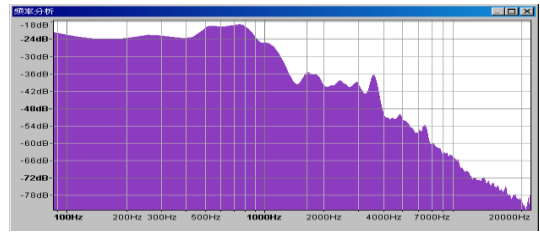
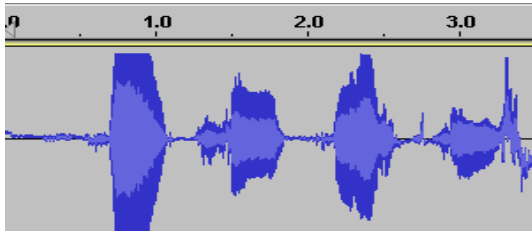
(5) 學生戊



(6) 學生己



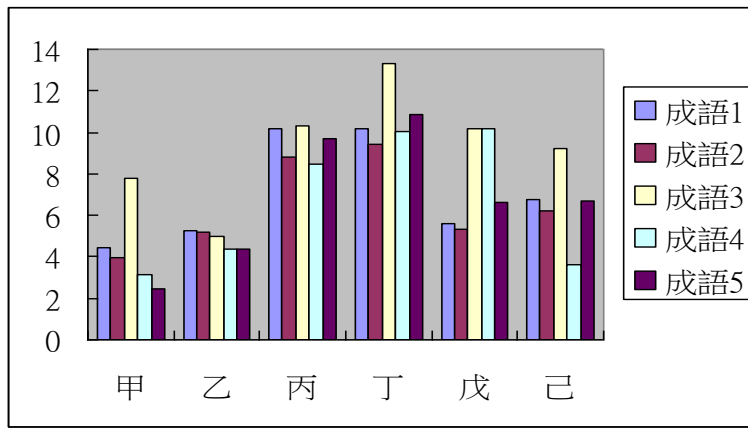
(7) 教師



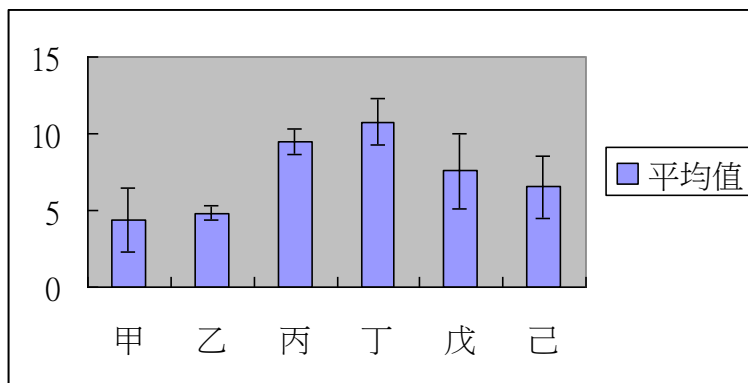
6. 學生與教師頻譜圖數值差的均方根 (root mean square) 表

成語	學生甲	學生乙	學生丙	學生丁	學生戊	學生己	平均值	標準差
1. 平安喜樂	4.4584	5.2912	10.1776	10.1500	5.5928	6.7623	7.0721	2.5062
2. 天氣悶熱	3.9916	5.1646	8.8159	9.4526	5.3022	6.2425	6.4949	2.1752
3. 老師您好	7.7652	4.9840	10.2989	13.3104	10.1891	9.2110	9.2935	2.7879
4. 癡人說夢	3.1309	4.3507	8.4562	10.0097	10.1891	3.6319	6.6281	3.2818
5. 畫蛇添足	2.4756	4.3507	9.7294	10.8423	6.6456	6.7135	6.7926	3.1513
平均值	4.3642	4.8282	9.4956	10.7530	7.5838	6.5122		
標準差	2.0495	0.4494	0.8227	1.5129	2.4303	1.9847		

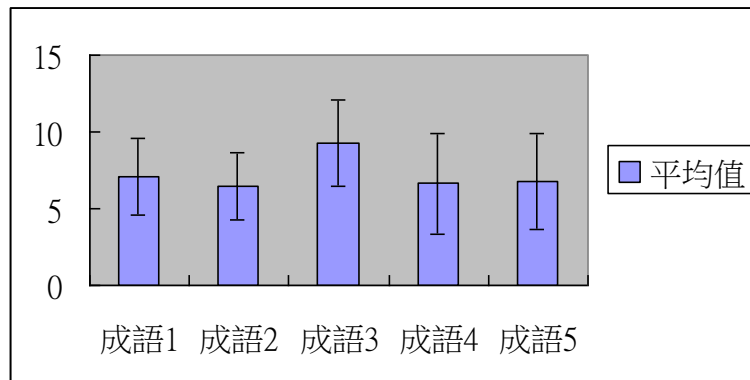
7. 學生與教師頻譜圖數值差的均方根 (root mean square) 圖



8. 六位學生的成語指標 m 的平均值與標準差圖



9. 五句成語的學生指標 m 的平均值與標準差圖



陸、討論

一、長母音[e] [i] [o] [u]較短母音[æ] [ɪ] [ɔ] [ʊ]在相同時間內的波數較少，與長母音發音時間較長，前半段口腔繃緊，但後半段口腔放鬆，而短母音發音時間較短，口腔一直保直繃緊有關。由此可得知長母音的頻率較低，短母音的頻率較高。但在頻譜圖

上，因為母音都在低頻的範圍，因此不易看出長母音和短母音頻率分佈的差別。

二、有聲子音[b] [d] [z] [ð] [g] [v] [dʒ] [tʃ]較無聲子音[p] [t] [s] [θ] [k] [f] [ʒ] [ʃ]在相同時間內的波數較少，與有聲音以聲帶發音，而無聲子音以氣發音，無聲帶震動有關。由此可知有聲子音的頻率較低，無聲子音的頻率較高。在頻譜圖上，可明顯看出有聲子音和有聲子音頻率分佈的差別，有聲子音在低頻的分配較多，而在高頻的分配較少；無聲子音在低頻的分配較少，而在高頻的分配較多。

三、5 個英語句子發音的指標 m 中，以甲同學的平均值最小，代表和老師的發音相差最少，以丁同學的平均值最大，代表老師的發音相差最多。6 位同學的發音中，以” What’s your name? ”這句的平均值最小，代表和老師的發音相差最少，以” Good morning. ”這句的平均值最大，代表和老師的發音相差最多。

四、捲舌聲母ㄐ、ㄑ、ㄒ較不捲舌聲母ㄒ、ㄑ、ㄐ，在同樣的波型中有高頻的小波，顯示捲舌音在高頻的部分較強，不捲舌音在高頻的部分較弱，與捲舌音共振的口腔空間較小，不捲舌音共振的口腔空間較大有關。在頻譜圖中亦可以發現，捲舌捲舌聲母ㄐ、ㄑ、ㄒ較不捲舌聲母ㄒ、ㄑ、ㄐ，在 20000Hz 左右有較高的分貝值。

五、5 句成語的發音中，以甲同學的平均值最小，代表和老師的發音相差最少，以丁同學的平均值最大，代表和老師的發音相差最多；6 位同學的發音中，以” 天氣悶熱 ”這句的平均值最小，代表和老師的發音相差最少，以” 老師您好 ”這句的平均值最大，代表和老師的發音相差最多。

柒、結論

一、英語音標中長母音的頻率較低，短母音的頻率較高。

二、英語音標中有聲子音的頻率較低，無聲子音的頻率較高。

三、5 個英語句子的發音中，以甲同學和老師的發音相差最少，以丁同學和老師的發音相差最多；6 位同學的發音中，以” What’s your name? ”這句和老師的發音相差最少，以” Good moring. ”這句和老師的發音相差最多。

四、國語注音中聲符捲舌音在高頻的部分較強，不捲舌音在高頻的部分較弱。

五、5 句成語的發音中，以甲同學和老師的發音相差最少，以丁同學和老師的發音相差最多；6 位同學的發音中，以” 天氣悶熱 ”這句和老師的發音相差最少，以” 老師您好 ”這句和老師的發音相差最多。

捌、參考資料及其他

一、光碟資料

1. 公共電視，科學玩很大(日本製作)節目，聲音的形狀單元。
2. 康軒出版社，英語教學電子書，Hello Darbie，KK 音標發音示範。

二、書面資料

1. 小天下雜誌社，未來少年，2014 年 3 月份，24-36 頁，聲音的奧秘。
2. 中華民國第 53 屆科學展覽會作品說明書，國小組生活與應用科學，Eureka!!! 我分辨出來了！～招出假東西的新方法～。

三、網路資料

1. 國語日報社網站，ㄅㄆㄇ發音練習，<https://www.mdnkids.com/bOPOMO/>。
2. 錄音程式 Audacity 官方網站，<http://audacity.sourceforge.net/download/?lang=zh-TW>
3. 截圖程式(FastStone Capture)官方網站，<http://www.faststone.org/FSCaptureDetail.htm>

【評語】 080108

較無有效利用軟體結果分析說明發音方式，且比較基準點不夠客觀明確。