

Seeing Voices: A Dynamic, Interprofessional Approach to Teaching Performing Arts and Speech-Language Pathology Students About Vocal Anatomy and Physiology

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Summary: Objectives. *Seeing Voices* was an interprofessional, technology-enabled, large-scale, teaching and learning event developed to address the need to improve voice students' knowledge of laryngeal anatomy and physiology toward understanding and maintaining vocal health. *Seeing Voices* trialed a novel interprofessional educational approach, collected both quantitative and qualitative data about student experiences of laryngostroboscopic examination, and built a databank of laryngeal recordings for future student learning.

Methods. *Seeing Voices* involved two 3-hour seminars in a large, university lecture space, run by an interprofessional team (speech-language pathologists, vocal coach, Ear Nose and Throat consultant) with quality equipment projecting laryngeal images to large screens with expert commentary in real time. Participants were 18 students who volunteered for laryngeal examination (9 per seminar) and student attendees (n = 175) from performing arts courses (classical singing, contemporary, jazz, musical theater, acting) and a speech-language pathology course. A quantitative evaluation of knowledge gained was undertaken using a Qualtrics survey. Results from pre (n = 175; performing arts = 120; speech-language pathology (SLP) = 55) and postevent (n = 99; performing arts = 56; SLP = 43) questionnaires were received from the students who attended. Interviews were collected from 15 of the 18 student volunteers about their experiences of nasendoscopic evaluation and data were analyzed using qualitative description and qualitative content analysis.

Results. Quantitative results demonstrated a strong trend toward increased knowledge following attendance at the event across year cohorts for both student groups. Qualitative interviews highlighted the value in seeing multiple examples of normal laryngeal functioning across different vocal techniques in real time. For those undertaking nasendoscopic examination, simultaneously seeing and feeling laryngeal maneuvers used in training appeared to promote understanding of their own vocal mechanism and the purpose of different vocal techniques.

Conclusions. *Seeing Voices* offers a novel way to improve interprofessional collaboration, and engagement with, and understanding of, laryngeal anatomy and vocal health by students in performing arts and speech-language pathology courses.

Key Words: Vocal anatomy and physiology–Interprofessional education–Speech-language pathology students–Performing arts students–Laryngeal imaging.

INTRODUCTION

Vocal training and vocal care in voice students requires a team approach¹ and there have been calls for more interdisciplinary learning and teaching opportunities with greater focus on the anatomy and physiology of the vocal mechanism.^{2,3} This is particularly important considering both acting and singing students are at increased risk of voice disorders and vocal pathology due to the demands of

their training⁴⁻⁷ as Kwak et al⁸ wrote: "...singers would benefit from more structured instruction in vocal health in a collaborative effort between voice teachers, physicians, and speech pathologists" (p. 195). However, knowledge of the vocal mechanism has been found to be poor among voice students,⁹ including for classical singing^{10,11} and acting.^{3,4} Barriers related to time, funding, and availability have been reported as impacting on the provision of vocal health education for voice students.¹¹ Manning and Blanchet⁹ also found that students were not always aware of the role of speech-language pathology (SLP) and were at risk of vocal misuse during their college years. They reported that new first year voice students knew less about voice than more senior students, but that both groups still engaged in negative vocal behaviors. Nacci et al¹² carried out a range of assessments, including laryngostroboscopic evaluation, the Voice Handicap Index,¹³ and assessments of reported reflux with 56 first year singing students and 60 healthy non-singers. They found 60% of the singing students had pathological findings compared to only 20% of the control group; 18% of the students with organic lesions,

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14% with laryngeal edema, 35% with functional changes such as incomplete glottic closure and 16% with increased supraglottic tension. Noting a relative lack of research on the vocal health of newly enrolled singing students, Nacci et al suggested:

Because of the high percentage of such disorders in subjects attending the first year of singing school, it would be desirable that every subject who is going to start a singing course undergo videostrobolaryngoscopy to ascertain the healthy condition of the vocal folds. (p.141)

Only a small number of publications to date have specifically developed interdisciplinary teaching and learning opportunities addressing vocal health using laryngeal imaging. Two examples^{3,14} describe collaborations in university programs between performing arts and speech-language pathology students. Goldberg et al³ discussed the shared content in speech and voice for students of acting and speech-language pathology at Southwest Minnesota State University. They organized six joint sessions with 15 students from each of the two courses with a range of activities including pre-post testing on vocal anatomy and function, a lecture, perceptual analyses, and a “focus more specifically on the effects of students’ visual and tactile learning about the vocal mechanism through endoscopy” (p.341). While the endoscopy was only available for six of the students, all 30 had a chance to watch the screen and ask questions as the vocal tasks were completed. Myers et al¹⁴ described a collaboration at the University of Utah, between the Musical Theatre Program (MTP) and Communication Sciences and Disorders (CSD). The CSD (speech-language pathology) students learned how to conduct voice screens and the MTP students had an opportunity to learn about their laryngeal anatomy and vocal health through videostroboscopy, perceptual and acoustic assessment, and educational resources for vocal health. Myers et al. suggested that vocal health screenings are “an excellent way for students to pull back the curtain and directly address the mechanics of their own voice production” (p. 217).

This article describes a project, *Seeing Voices*, which addressed the need highlighted in this literature review to find ways to support voice students to understand their vocal mechanism better in order to prevent pathology. Through *Seeing Voices*, we evaluated the experiences of both speech-language pathology and performing arts students of laryngostroboscopic examination in an inter-professional, technology-enabled, large-scale event with expert commentary in real time. The aims were to explore the potential of a novel educational model for improving students’ knowledge of laryngeal anatomy and physiology; increase interprofessional collaboration and understanding about maintaining vocal health; capture both quantitative and qualitative data about the experiences of flexible nasendoscopic and stroboscopic examination; and build a databank of recordings of laryngeal imaging for future student learning. The reason for the final aim of the project

was the identified need for teaching materials which high-light fibreoptic nasendoscopic examination of the normal larynx, with and without stroboscopy. While some videos are available for teaching, the team wanted to have more dynamic images from untrained and trained singers and actors showing laryngeal structure and function during regular vocal maneuvers, for example, warm-up exercises, vibrato, singing through the *passaggio*, de-constriction, and visualizing *twang* or jaw thrust.

METHODS

Background to the project

Seeing Voices was carried out at Edith Cowan University (ECU) in Western Australia, in the affiliated Western Australian Academy of Performing Arts (WAAPA). It was supported by an ECU Learning and Teaching Grant (#27259) and received ECU ethics approval (#22431) to run the event and collect quantitative and qualitative data to evaluate the work. The project was led by the first author (speech-language pathologist) and run with an interdisciplinary team of colleagues: vocal coach, a speech-language pathologist with experience with voice disorders, Ear Nose and Throat (ENT) consultant, and technical support. The event was sponsored through the loan from Olympus of high-quality equipment for flexible fibreoptic nasendoscopy and stroboscopy, and images were recorded, retained, and stored in a secure drive at the university.

Participants

Participants in the project were 175 WAAPA and ECU speech-language pathology students. Sitting in the lecture theater were also 50 others: staff members from across the different courses, professional performers from the community and private practitioners. Participants attended one of two 3-hour seminars, one held in the morning and one in the afternoon. From the overall student cohort, 18 students who volunteered to undergo fibreoptic nasendoscopy were recruited prior to the event, nine for each of the two seminars, with a balance of male and female students, and including three from speech-language pathology with untrained voices, two speech-language pathology students with trained voices, and 13 voice students (acting and singing) from different genres and year levels.

Procedure

Seeing Voices was held in a large, tiered lecture space. All students who attended gave written consent through a specially developed link to an online form on their mobile phones to agree to the filming of the event. Students were also given the option to complete a brief pre-event Qualtrics questionnaire (<https://www.qualtrics.com>) on their level of knowledge of laryngeal anatomy and physiology and a postevent Qualtrics questionnaire to record how they felt their level of knowledge may have changed. All 18 student volunteers received a participant information form and completed a written consent form to ensure

they understood the nature of their participation—the choice to have a topical nasal anesthesia, a live scope by an ENT in front of an audience, projection of the images on large screen, retention of the scope images for a future teaching resource, and an interview following the event to discuss their experiences of undergoing laryngeal examination. The first two authors opened the event, introducing the range of students in the room and providing a brief introduction to the roles of the members of the voice team, and the anatomy of the larynx through a powerpoint presentation. While this was happening, the first of the volunteers received their topical nasal anesthesia. For the scope, each student was seated at the front of the lecture theater and guided informally through various exercises and vocal techniques by the second author, a WAAPA voice teacher. Students had the scope in place for around 5–10 minutes and they directed the ENT as to what they felt comfortable to do. There were two fiberoptic nasendoscopes available and the voice specialist worked with the ENT, undertaking sterilization and infection control procedures with one nasendoscope while the other was being used so that each of the nine students could be examined. The laryngeal images were projected up on large screens to demonstrate how the volunteers' vocal folds functioned in a range of tasks (chosen in advance by the *Seeing Voices* team), including phonation at different pitches and volume, glottal attack, throat clearing, coughing, laughing, singing (chest, head, and falsetto registers), siren, warm-up/cool-down exercises, de-constriction exercises (yawn-sigh, silent giggle), sustained /i/, twang, hum, sob, glottal fry, and straw phonation. The dynamic images displayed during the examination were explained by the ENT doctor, voice coach, and expert speech-language pathologist to the audience live with opportunities for them to ask questions or try different maneuvers. Over the course of two 3-hour sessions a total of 35 videos were recorded, featuring between five and six different vocal tasks on each. The descriptions of the larynx during these maneuvers have been recorded but these are not presented in this paper.

Each student's recordings were saved, and students were offered a copy of their scope recording and a laryngeal imaging report. This report was based on the American Speech and Hearing Association *Template for Laryngeal Imaging*.¹⁵ Students were encouraged to retain this baseline data as reference points for laryngeal and vocal health in their future careers. Laryngeal imaging screening forms were completed by the speech-language pathologist and ENT for all the student volunteers, providing baseline information on oral-nasal-laryngeal structure, (for example, noting a nasal polyp in one student and a bifurcated uvula in another), vocal fold integrity and tissue health, mobility of vocal fold edge, vocal fold closure, phase symmetry, mucosal wave, and supraglottic activity. Given that this was a live event with a focus on teaching rather than assessment, data collection for each student volunteer was not fully standardized. However, every opportunity was taken to showcase a variety of vocal techniques as they

occurred, providing participants with an understanding of the laryngeal dynamism and complexity for each task and the sensations reported when undertaking the task in different styles. Any students who needed ongoing referral for newly identified issues were alerted to this. The recordings were retained in a secure research drive for the planned development of a freely available *Seeing Voices* teaching resource for both speech-language pathology and performing arts students, teachers, and practitioners.

In addition to the audience survey feedback, all 18 student volunteers who underwent fiberoptic nasendoscopy and laryngostroboscopy were interviewed for their reflections on the experience of participating in *Seeing Voices*. The speech-language pathology students were interviewed by the first author and the performing arts students by the second author. Interviews were recorded and transcribed verbatim. The data were analyzed through qualitative description and a qualitative content analysis,¹⁶ an inductive approach which “entails the presentation of the facts of the case in everyday language” (p. 336). Interviews from the two cohorts were transcribed, and the content in the data was summarized through the creation of codes from the participant data, organizing related codes into categories that shared common meanings, and also quantifying how often these categories occurred among the participants.¹⁷

RESULTS

Survey results

Qualtrics results from pre (n = 175; performing arts =120; SLP=55) and postevent (n = 99; performing arts=56; SLP=43) questionnaires were received from the students who attended. **Figure 1** illustrates the raw numbers and percentages for the two cohorts of students across the 4-year levels in relation to the level of knowledge about vocal anatomy and physiology before and after the *Seeing Voices* seminar. The students from the Bachelor in Performing Arts (Acting, Musical Theater, and Performing Arts - contemporary, jazz) were part of a 3-year degree so the column for the fourth year in **Figure 1** only applies to three final year students doing the 4-year Bachelor of Music (Classical Performance). The speech-language pathology students were part of a 4-year degree. While the number of students completing the postevent questionnaire was lower than ideal (some students left before the end, for example, to attend other classes, and two performing arts students provided incomplete answers to the questionnaire) and varies greatly across categories, the results indicate a trend to increasing ratings of knowledge postevent particularly from *basic* to *reasonable*. Almost a quarter of students (23.68%) in their first year of the performing arts course rated their knowledge pre-event of vocal anatomy and physiology as *minimal* and just over 55% as *basic*. There was strong shift to *reasonable* postevent (64.84%). Approximately 70% of third-year performing arts students also rated their knowledge as *minimal* or *basic* pre-event and their shift to greater knowledge was also evident (78%

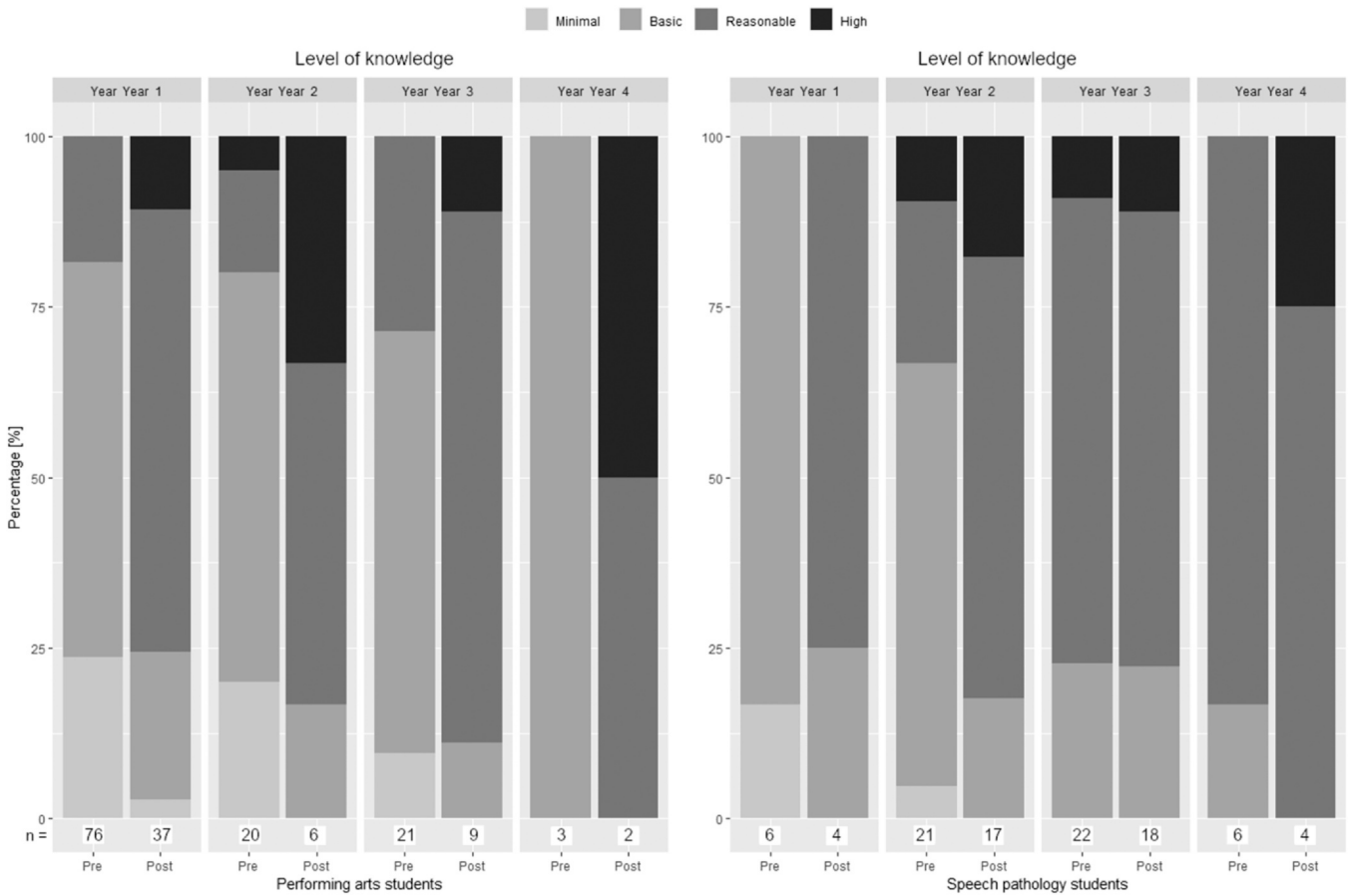


FIGURE 1. Pre-post evaluation results on level of knowledge by students.

TABLE 1.
P Values for the Pre-Post Results by Year Group Using Fisher's Exact Test for Count Data

Year	Student Group	
	Performing Arts	Speech-Language Pathology
1	0.000*	0.03 [†]
2	0.03 [†]	0.01 [†]
3	0.008 [‡]	1
4	0.1	0.66

* Significance levels: $P < 0.001$.
[†] Significance levels: $P < 0.05$.
[‡] Significance levels: $P < 0.01$.

reasonable and 11% high). A similar trend was also seen for the speech-language pathology students in the first 2 years. By the third and fourth year, level of knowledge about vocal anatomy and physiology was generally rated more highly, which is expected considering these students would, by then, have been exposed to lectures and perhaps practicum experiences related to voice. The seminar did not appear to make much difference to student ratings in the third-year cohort but the positive responses for the fourth-year students may reflect a strengthened transition from theoretical to practical application of their knowledge

through viewing normal laryngeal function in nine people, with trained and untrained voices, with explanations in real time.

Seeing Voices was run as a non-experimental, teaching and learning event and so it was not surprising that the numbers of survey responses pre and postevent were not controlled. However, we attempted some inferential statistical analysis. To account for the uneven number of responses in each group, violating the assumptions of normality and equal variance, parametric tests were deemed inappropriate and were not conducted. Instead, Fisher's Exact Test for Count Data was utilized to examine the pre-post results by year group (level of knowledge) among the two different student groups: performing arts and speech-language pathology. The results are summarized in Table 1. In the performing arts student group, there were significant differences between the pre and post results in year 1 ($P = 0.000$), year 2 ($P = 0.03$), and year 3 ($P = 0.008$). However, in year 4, the difference was not statistically significant ($P = 0.1$). For the speech-language pathology student group, significant differences were found between the pre and post results in year 1 ($P = 0.03$) and year 2 ($P = 0.01$). In years 3 and 4, no significant differences were observed ($P = 1$, $P = 0.66$). These findings indicate notable differences in the pre-post results among the year

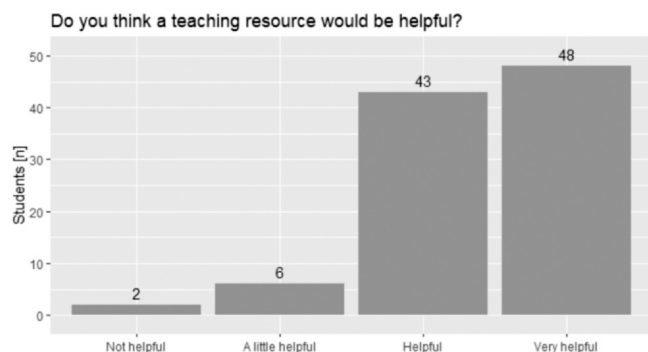


FIGURE 2. Student support for databank of *Seeing Voices* nasendoscopic videos as a teaching resource.

groups within each student group. The performing arts group showed significant improvements in years 1, 2, and 3, while the speech-language pathology group demonstrated significant improvements in years 1 and 2.

Students postevent ($n = 99$ across both cohorts and all levels of knowledge) also responded to a question about whether a teaching resource, focused on imaging vocal anatomy and physiology, would be valuable for their learning and there was a very clear response in favor of this (see Figure 2).

Free-text responses were also collated from the postevent questionnaires and analyzed through qualitative content analysis. The top three aspects of the seminar reported as beneficial by respondents were seeing live how the larynx moved and changed to respond to requests from the voice coach; having the opportunity to see the projected image of a range of larynges; and having an opportunity to ask questions about what was on the screen and see responses in real time.

Interview data from the performing arts student volunteers

Of the 18 student volunteers [for details of volunteers from both WAAPA and SLP courses, see Table 2], 13 were students from singing or acting courses at WAAPA. In the 2 weeks following the seminar, the second author ran 11 brief 5-minute video-recorded interviews (unfortunately two students were unavailable) which informally followed the topic guide in Table 3. One of the recordings was damaged and could not be viewed. Therefore, this section is based on the data from 10 interviews. Participants gave permission for their data to be used for research and teaching.

The content analysis of the participants' interviews revealed a number of common categories. Table 4 lists these common categories and the number of participants who raised elements related to each one.

Reactions to the process of being scoped

Throughout the interviews, all the participants talked about their experience of the nasendoscopic examination and expressed positive and negative emotional responses to the process of being scoped. Negative responses included

nervousness before the examination (Annabelle and Talia), fearing the procedure might be painful (Anabelle), or that they might discover damage to their vocal folds (Anabelle, Harry, and Justin). Having had the imaging, several students talked about their reaction to seeing inside their own bodies, as Michaela said: "I was really surprised how they looked... going down my own throat and getting to see inside my own body was just really strange". Annabelle stated: "it's just shocking to see... my voice!" Three participants noted the vulnerability of being so exposed in front of the audience (Talia and Justin) and Jeff noted that: "it was very vulnerable cause no one sees that part of you... it's just something you're not meant to see." One participant, Isabelle, found the procedure overwhelming, stating that she was "stressed and tense," and that she felt like her emotions were affecting her laryngeal movement. This emotional reaction was evident during her examination with Isabelle feeling uncomfortable, so her scope was discontinued. Far more numerous were positive reactions to the experience. For example, Jeff called the experience "weird" but also explained that the "experience was great" and "wonderful to see." Many of the comments were positive expressions: "great," "good," "fun," causing "excitement," "enjoyment," or how the participant "loved the experience." Others stated how they were "glad to have had a scope done" and that they "found the experience of *Seeing Voices* educational" or "useful". Other participants emphasized their experience that the scopes were "not painful." Talia said: "Getting a scope, for any singer, it's like amazing to know exactly what's going on" and Jed suggested that "everyone should get a scope."

Beyond these positive comments, one of the most common codes relating to positive reactions expressed by four of the male participants was the reassurance they gained from the experience regarding their vocal health. Harry, Jed, Jeff, and Justin all expressed doubts over what they might find and were expecting some level of damage, such as Justin's desire to know whether his vocal folds were "torn" or Jeff finding that "it was cleaner than I expected." As Harry stated, the scope gave him "biological proof that I was not wrecking my cords every time I sang" and proof that he was using correct technique.

Seeing inside and learning about anatomy and function

These two key categories were raised frequently across the interviews. Several participants highlighted the benefit being able to see inside their own vocal tract and see it in motion. Talia commented how useful it was to see her larynx on the scale seen in a large lecture theater: "Seeing it on a big screen, I was like oh, there she is!" Annabelle had: "previously guessed what is happening in the vocal tract" so it was "useful" though "surprising" to see inside. Harry said it was "interesting to learn how airflow passes through the cords and how they vibrate" and that the process enabled him to "gain an overall knowledge of the anatomy and function of the voice" in a way that was "easier to

TABLE 2.
Seeing Voices Participants Who Volunteered for a Nasendoscopic Procedure

Name	Course	Voice Type	Year Level
Isabelle	Bachelor of Acting	Soprano	2nd year
Justin	Bachelor of Acting	Baritone	3rd year
Michaela	Bachelor of Acting	Alto	2nd year
Jay	Bachelor of Acting	Baritone	2nd year
Joanna	Bachelor of Acting	Alto	2nd year
Talia	Bachelor of Music Theatre	Soprano	3rd year
Andy	Bachelor of Music Theatre	Baritone	3rd year
Jed	Bachelor of Music Theatre	Tenor	3rd year
Annabelle	Bachelor of Music Theatre	Soprano	3rd year
Harry	Bachelor of Music Theatre	Baritone	3rd year
Ciara	Bachelor of Music Theatre	Alto	3rd year
Brandon	Bachelor of Music Classical Voice	Baritone	4th year
Jeff	Bachelor of Performing Arts	Baritone	1st year
Alice	Bachelor of Speech Pathology	Alto	1st year
Carol	Bachelor of Speech Pathology	Soprano	1st year
John	Bachelor of Speech Pathology	N/A	2nd year
Philippa	Bachelor of Speech Pathology	N/A	4th year
Shelley	Bachelor of Speech Pathology	N/A	4th year

TABLE 3.
Seeing Voices Interview Topic Guide Questions

Tell me about your voice use currently as a student professional voice user? (for those students where this was relevant)

- What kinds of vocal activities/challenges do you currently manage (as a singer/actor)?

Tell me a little about your knowledge about your voice prior to this session.

- What did you know about the anatomy structure and function of the voice
- What did you know about keeping your voice healthy?

Tell me a little about your experience of participating in *Seeing Voices*.

- What do you feel you learned from the experience?
- How did you feel about the nasendoscopic examination?
- Were there any aspects about the visualization of your larynx which surprised you?
- Was the experience what you expected?

Is there anything particular you would have preferred to have been done differently?

How do you feel a teaching resource, made up of some of the video-recorded information, might influence performing arts/speech pathologist student learning?

Is there anything else that you would like to add?

understand... than it is from books and scopes on the internet.” In relation to vocal tract function, Jeff discovered that “different types of singing” caused the larynx to move

in different ways. A few of the participants (Brandon, Harry, and Talia) also benefited from the public nature of the *Seeing Voices* event, commenting that it was interesting to see how individual vocal tract structures differed between people, especially in relation to age and voice type (such as high voices and low voices), and being able to compare their larynx to fellow students whose singing voice they knew well. Only one participant, Isabelle, was doubtful about the experience, stating while it was “interesting to see what the vocal tract really looks like” she just saw “a lot of movement in her throat” and “didn’t understand what it meant.”

Technique knowledge

Participants talked in general on the knowledge they gained about how the vocal tract functions in relation to different vocal techniques. Annabelle, Brandon, and Justin all discussed the value of performing different techniques under laryngeal imaging and learning what laryngeal movements occurred with each technique. Brandon reported that the laryngeal imaging allowed him to see what his vocal tract was doing in real time so that he could “identify and fix issues” and “cultivate certain sounds.” Talia said she gained: “knowledge of exactly what I’m doing when I’m singing high.” Participants also commented on what they learnt about vocal tract function when performing specific techniques beyond generic “surprise” or “interest” in the observed movements, such as in the case of coughing and speaking. Examples are given in [Table 5](#).

Vocal health and the importance of warm-ups

Many of the participants mentioned an increased understanding of the importance of vocal health strategies.

TABLE 4.
List of Categories the Participants Discussed During the Interviews

Categories	Number of Participants Who Commented on Category
Reactions to the scope	10
Seeing inside	7
Anatomy and function	3
General technique knowledge	3
Specific technique knowledge	7
Vocal health knowledge	4
Importance of warm-ups	3
Making connections	5
Seeing, hearing, and feeling	3
Application of knowledge	5

Brandon and Justin both discussed learning about the importance of hydration after seeing the amount of phlegm they had when scoped. Jeff already knew a little about vocal care, but the experience clarified its importance. He reported that he now understands how important it is to practice vocal care “especially when going into shows.” Justin, Jeff, and Michaela all discussed how the process of laryngeal imaging helped explain the value of doing warm-ups and led them to understand what each warm-up exercise is physically targeting. Michaela detailed how she now understood how essential warm-ups are to maintaining vocal health and “are important so your voice can move the way it’s meant to.” Since *Seeing Voices*, she reported changing her basic warm-up, increasing it in length, and focusing on warming up all areas of her voice to avoid possible damage.

Making connections

Several participants discussed how *Seeing Voices* helped them to clarify and solidify prior knowledge and

understanding of vocal tract function from lectures. As Jed stated, “Seeing the movement of your own larynx was a different experience than previous exposure through lessons, diagrams, and videos.” The laryngeal imaging in an educational setting allowed him to solidify this knowledge and helped him understand how his vocal control influenced physical movement.

Seeing, hearing, and feeling

Several of the participants (Isabelle, Jed, and Joanna) discussed the connection they made to Seeing, Hearing, and Feeling, a concept Sharpe and Haydn Rowles¹⁸ use to understand how to control physical function in accent work. The process of laryngeal imaging allowed these participants to connect sense and hearing to the visual perspective of their vocal tract, allowing them to gain greater control and reduce poor technical practices, such as in Joanna’s reduction in constriction.

Application of knowledge

The final common category related to the participants applying the knowledge that they had learnt to their everyday practice or to other techniques. Annabelle and Jed both discussed how the knowledge they gained from *Seeing Voices* subsequently was transferred to their singing lessons, with Jed stating that this led to a few “break-throughs” in his technique. Jed also reported transferring what he had learnt about laryngeal movements of specific techniques to any new techniques he was learning. While Isabelle had difficulty with the scoping process, she also discussed how she learnt to *open her throat* more and use that concept in performances.

Interview data from the speech-language pathology student volunteers

Of the 18 volunteers in *Seeing Voices*, five were studying in the SLP course (four female and one male). Two of the students (Alice and Carol) were already professional

TABLE 5.
Examples of Linking Specific Vocal Techniques to Anatomical and Functional Knowledge

Vocal Technique	Student	New Learning
Producing an airy or breathy sound	Brandon	That the “vocal folds weren’t fully closing” when producing a breathy sound.
Beatboxing	Jeff	Surprise at the amount of laryngeal movement required to produce beatboxing.
Constriction	Joanna	“Learnt what constriction actually looked like.” Said she now understands how to reduce habitual constriction.
Control	Justin	Realized that he has a lot of control over his voice, stating that it solidified that “voice control isn’t random, that you can control everything.”
Laryngeal height	Jed	Learned what a <i>high</i> and <i>dropped</i> larynx physically means and feels like.
Open throat	Jed	Now understands the term <i>open throat</i> and what “giving your larynx more space” physically entails.
Vibrato	Talia and Harry	Learnt that vibrato involved the pharyngeal wall muscles moving in and out, and not the breath (Harry) or a physical up down motion of the larynx (Talia). Talia also learnt that she was producing vibrato correctly and not using her tongue to create the technique.

singers and Alice had previously completed formal classical singing training:

... there was nothing around your voice and the anatomy and how it works and how to care for it. It was just sing and then hope for the best. And lots of people come out of the voice course with nodes and vocal issues.

The SLP students were asked the same questions as for the WAAPA students (Table 3) and there were commonalities with their responses, for example, the reaction to being scoped for the first time. Philippa said: "I was nervous, what I have let myself in for? I thought it would be ten times worse than what it was." John was surprised by the feeling of the scope: "I'd say the spray was a bit of shock. I think within 5 minutes, everything was numb. It was like I'd swallow saliva and it felt like nothing was there. That was weird." Carol reported: "It's an unusual sensation having something shoved up your nose. As it goes down, you kind of worry when it gets to the right spot, am I still going to be able to do the normal things with my throat and face?"

There were, however, some differences related to professional perspective. For example, all the students commented on their reasons for volunteering to have a scope and one main reason was to reassure future voice clients about ENT examination. For example, Shelley said: "If I ever recommend it, I can say I have had one and you will find it is fine." Similarly, John reported: "After graduating, if I have a client that has to go do one, I can say I've had it done, this is what it's like, and it's kind of cool." Another reason was the recognition that *Seeing Voices* was an unusual learning opportunity, but one where SLP students were perhaps more reticent to participate than the performing arts students. Philippa made this point: "And because everyone's going to see my larynx now, it's going to be used which is great and I felt if no one does it, who's going to learn? So, I thought no, I'm going to put my hand up and take a look at mine!"

Several students also talked about *Seeing Voices* as an interprofessional opportunity and a chance to learn more about the needs of professional voice users. Both Shelley and Philippa had worked previously in the school system and commented on how little information was given to teachers on vocal care. Philippa had experience of work-related vocal fatigue. Shelley explained that it was important to understand the needs of vocal performers and valued the expertise of the voice coach:

I think if you had just done speech-language pathology, we know what we already know... our world... but to relate it back and watch the difference in the knowledge of the people we will be servicing one day, even to understand the workload, warm up and warm down, that is embedding so much of that knowledge. These are awesome strategies to preserve that voice...

Finally, students talked about how *Seeing Voices* enabled linking theory to practice. Carol explained: "I felt it

was really helpful to see the mechanics of it in real life rather than just a diagram... When I look at a diagram, I'm always like how is this oriented? Is this upside down? Which angle is this?" Alice was also impressed with the live imaging: "It was weird, crazy so much is going on down there... the tiny things producing all this sound." John described the event as "fascinating" and was particularly surprised at the dynamism of the structures:

...especially in the students that just talked. They got them to speak random sentences. How much movement was back there! It's like the epiglottis was just flapping around like crazy... like, wow. But you can't feel it, the back of the tongue, the epiglottis, the amount of movement. It's a lot.

Finally, Shelley highlighted the value of rethinking her lecture material following the seminar:

So, to actually watch the different ways that those vocal cords were moving in that time... and the glottal fry, to see what they did. I found that really interesting. To line that all up in your mind... I have written 'glottal fry' in assignments I could not tell you how many times. I've listened to it on YouTube quite a few times to understand it. But to actually see it when you're doing it and repetition over the top of it, your practical knowledge starts to kick in and you go ahh, the theory is now marrying with the practical and now I actually get it. So, you did that embed, embed, embed.

Discussion

Seeing Voices was an opportunity for students to see a variety of nasendoscopic and stroboscopic dynamic images from multiple volunteers on a large screen in real time with expert commentary. The feedback suggests this was a valuable learning opportunity, providing positive experiences for both performing arts and speech-language pathology students. The project brought students together through the interprofessional seminar to enable them to appreciate and understand each other better, for example, allowing the SLP students see and hear the demands, power, and skill of the trained voice, and helping the performing arts students to recognize the SLP role in voice care. Students appreciated that the normal larynx varied greatly between people. They were able to view the flexibility and coordination of structures during different vocal maneuvers. The experience provided students with valuable information regarding their own vocal health and technique. This work provides a possible way to bring laryngeal imaging into the classroom, addressing the situation reported in previous research¹⁹ that only between 30% and 55% of performing arts graduates seek an ENT opinion when experiencing vocal difficulty, with the majority instead blaming their technique (between 55% and 65%) or increasing hydration or vocal rest (85–90%). Establishing pre-existing positive experiences with laryngeal imaging, offered as a teaching tool rather than purely for diagnostic purposes, could increase this engagement.

The survey results suggest that attending the event contributed to students' understanding and knowledge of laryngeal anatomy and physiology. They also highlighted some differences between the two cohorts of students because of their disciplinary perspectives, particularly with some performing arts students appreciating laryngeal structures and movement for the first time, and SLP students consolidating and perhaps applying knowledge learned in their final 2 years of training through the experience. The student volunteers reported that the experience of having a nasendoscopic examination was worthwhile and positive. Conducting laryngeal imaging on a large screen where students could explore different techniques, ask questions, and see others undergo the same process, appeared to promote understanding of how their own voice works and the purpose of different vocal techniques. The opportunity to view a range of images in a short space of time is an important aspect of *Seeing Voices* because even if students had attended ENT previously for a laryngeal examination, they would only have seen their own larynx and only in a restricted range of maneuvers reflecting the needs of the assessment rather than those used in singing training. This suggests that laryngeal imaging can be an educational experience for students to understand laryngeal function in vocal techniques such as a warm-up. In addition, the opportunity to see the dynamism of one's own voice as one is performing or trying a technique is important as not only do performing artists have limited knowledge of their vocal anatomy and function, alongside poor knowledge of vocal hygiene,²⁰ but they also have low sensorimotor awareness of this area,¹⁰ leaving them vulnerable to laryngeal difficulties during their careers. Having an opportunity for *seeing*, *hearing*, and *feeling*, as noted earlier, in relation to their own voices may improve understanding of vocal function. The findings from the interviews suggested some performing arts students transferred what they learnt from the experience to their daily practice and performance routines, indicating that an event like *Seeing Voices* has the potential to create a sustained impact from the experience.

There were some aspects that could have been improved in the way the seminars were run. The lower numbers of post-event surveys were a limitation to the study reflecting clashes with other classes and some students leaving before the end. We suggest that 2 hours may be a better length for future *Seeing Voices* seminars, rather than 3, still allowing time to cover introducing the range of students in the audience, highlighting the roles of the members of the voice team, the brief powerpoint presentation (together around 30 minutes), and the viewing of the nine volunteers (90 minutes). With hindsight, we would also recommend that all the experts running the session in a large lecture theater have lapel microphones, rather than just amplifying one facilitator at a time, to make sure the comments across the team are easily audible.

The large-scale, large-screen nature of the event attracted interest from speech-language pathologists, professional voice users in the community and university staff, as well as students. It was also reported in the national Australian

media,²¹ bringing the issue of vocal health and voice care to wider public attention.

Conclusion

Seeing Voices was a teaching and learning event which explored the value of a novel educational model for improving students' knowledge of laryngeal anatomy and physiology. It encouraged interprofessional collaboration and understanding about maintaining vocal health; captured both quantitative and qualitative data about student experiences of flexible nasendoscopic and stroboscopic examination; and built an initial databank of recordings of laryngeal imaging for future student learning in a variety of disciplines and courses. *Seeing Voices* offers a way to enhance engagement with and understanding of laryngeal anatomy and vocal health by students in performing arts courses to reduce the high documented incidence of vocal pathology in these students. It may also result in better knowledge by speech-language pathology students about the range of normality of laryngeal anatomy and physiology in non-pathological, normal (or perceived as normal) voices of performers, and help them to understand the challenges for, and needs of, professional voice users.

Declaration of Competing Interest

None.

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