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Understanding Singing Voice Timbre Through Quantitative Assessment

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Portfolio Introduction

In my work as a voice teacher, I encounter students who wish to study songs of varying genres. Local contest rules often require students to perform Classical (shortened from “Western Classical” for brevity) repertoire (Washington Music Educators Association, 2026). However, students in my own studio will choose to perform songs from musicals, American Top 40 charts, video games, or popular genres from the last three decades. In addition, my own students report not listening to Classical music, and therefore do not have the timbral awareness for singing in such a style. An unfortunate result is a mismatch between a repertoire’s standard aesthetic and familiar voice timbre. While voice teachers may be able to hear and adequately coach a student, common pedagogical texts do not explicitly mention “timbre” by name. The term “resonance” is not a perfect synonym (McCoy, 2019), but can be used interchangeably with “timbre,” therefore causing confusion. Registration terminology can complicate the matter even further when the terms “chest voice” and “head voice” dominate discussions of voice quality and contribute what Herbst refers to as “just noticeable differences” (2020, p. 178). With these conundrums in mind, it is where I begin my study in voice timbre research with the specific purpose of understanding where current literature stands. My research question is as follows: how is timbre quantitatively defined in different styles of singing?

Purpose and Justification

Aims

Through this research, I aim to gain a broader understanding of the ways vocal timbre is discussed, quantified, and applied in the voice studio. With students coming from various backgrounds and wanting to sing many different kinds of music, I hope to equip them with tools that give them agency and the ability to succeed (Brookfield, 2017; Moniz, 2024). In addition, I aim to build my knowledge and understanding of the sounds of non-Western singing styles. Although the demographic of my studio heavily leans white, middle class, and involves Western music, timbres not often seen in American musical culture may provide helpful insights to the various ways sound can be made. Ultimately, my goal is to serve more students by developing knowledge of timbre and curating a toolbox to transfer that knowledge appropriately.

Objectives

In order to parse the literature regarding singing voice timbre, my objectives must be simultaneously narrow and flexible. Ahead of solidifying my inclusion and exclusion criteria, I am asking the following questions to guide my research:

1. How does the study define “timbre”?
2. Are researchers using specific tools to quantify timbre?
3. What research exists that bridges the gap between literature and pedagogical application?

Q1 will guide the first steps of the research and ideally refine later searches, particularly as I begin searching for evidence of Q2. Q2 will take the most time, but should have the most impact on the review. It is within Q2 I might find technological tools to use in the studio, like VoceVista software which can provide useful acoustic feedback should I learn to use it correctly (Meyer, Nix, and Okerlund, 2021). Lastly, Q3 will help link theory to practice. As I write about the findings of Q3, I plan to implement strategies in the studio to test their validity and see how student experience changes. These questions will serve as my grounding points in order to not lose track of the research question and to continuously uncover applicable knowledge.

Expected Learning Outcomes

At the conclusion of this literature review, I will be able to:

1. synthesize and evaluate multiple definitions of timbre,
2. understand the quantifiable differences in commonly occurring singing voice timbres, and
3. evaluate the practical application of the methods explored in the literature.

In preliminary research, particularly in Siedenburg and McAdams (2017) and Howell (2025), it was clear that the various definitions of timbre were incomplete and more descriptive of what timbre was *not*. LO 1 will allow me to contextualize the literature and provide a background for why the research exists in the first place. LO 2 should result from understanding the results of and critically analyzing selected studies. LO 3 is ideally embedded in both the literature and from my analysis, and will be used to draw conclusions for teacher takeaways.

Timeline

This project is first broken into 3 separate stages for pre-planning:

- Stage 1: Initial gathering
- Stage 2: Refined gathering and coding

■ Stage 3: Analysis and write-up

Stage 1 is designed to identify key papers and refine the research question. During this time, I will use the general research topic, as well as the questions laid out in my objectives to collect the literature useful to my goals. Stage 2 will allow me to solidify my research question and refine the inclusion and exclusion criteria. Stage 3 would complete the project, though data collection may continue as needed. A detailed timeline is available in appendix 1.

Methodology

The Narrative Literature Review

Researchers agree that literature reviews are imperative to the research process but can lack the scrutiny and rigor required of standard research activities (Baumeister and Leary, 1997; Grant and Booth, 2009; Randolph, 2009; Snyder, 2019). Narrative literature reviews are the most common (Baumeister and Leary, 1997; Randolph, 2009), and therefore have a reputation for feasibility. While not exhaustive, narrative reviews can explore vast areas of literature to illustrate a field's general consensus or its lack thereof (Baumeister and Leary, 1997; Grant and Booth, 2009). Similar to a systematic review, they are a reputable research method for data collection and analysis within a particular field of study (Snyder, 2019). Due to time constraints, a true systematic review with meta-analysis would not be possible for this project. While not intended to be an integrative literature review, I used highly regarded books such as *Hearing Singing* (Howell, 2025) and *Practical Vocal Acoustics* (Bozeman, 2022) to allow for deeper understanding and crosschecking. An integrative review may have offered the opportunity to acknowledge new discussions in the field via grey literature, but the vast swath of white literature on voice timbre was satisfactory.

Data Collection

Studies were collected via the University of Wales Trinity Saint David Ex Libris search engine and Academia.edu. A full list of Boolean strings is available in appendix 2. The inclusion and exclusion criteria listed in figure 1 focused on acquiring research strictly related to singing voice timbre in the last 15 years that included quantitative data. Qualitative research was excluded given its irrelevance to the research question. More related research was obtained through berrypicking, snowballing, and pearl growing (Boell and Cecez-Kecmanovic, 2014). Academia.edu provided algorithmically chosen research of potential interest which was also subjected to scrutiny under the criteria. All eligible studies were considered so as to avoid

excluding important data from the review, even if it was contrary to other findings (Baumeister and Leary, 1997; Snyder, 2019).

Inclusion Criteria	Exclusion Criteria
• Singing voice • Timbre and perception studies • Genre-specific • Readily available in English • Quantitative or Mixed-methods • Peer-reviewed	• Pre-2010 (outside of historical sources) • Related to injured or rehabilitating voice • Did not address physiological or acoustic markers (with one exception) • Qualitative

Figure 1: Inclusion and exclusion criteria

Because the research question asks how timbre is quantitatively defined in different styles of singing, it was important to collect research that identified the measures of various sound profiles; priority was thus given to research fitting this criteria. The above criteria was designed to discover methods of application to teach singers a broad array of sounds that they can use expressively and with integrity. The included research that did not fit the criteria either provided further clarification on timbre (Siedenburg and McAdams, 2017) or was an initial piece of research which set the groundwork for future studies (Sundberg 1974; Stone *et al.*, 2003). While quantifiable variables *may* clarify definitions of *timbre*, that is not the intention.

Positionality and Bias

I acknowledge the ontological position that timbre can be described in objective measures, despite descriptions and metaphors being legitimate tools to help a student make certain sounds (Bozeman, 2022). In addition, my positionality as an insider or outsider, privilege status, and gender identity shape my relationship to the research (Goundar, 2025). Hence, I acknowledge as a singer and teacher of numerous styles that there is an inherent bias *against* the notion that one style is more correct than another, possibly resulting in nebulous findings. The privilege I hold as a white middle class practitioner with higher degrees has placed me in a position wherein I identify with the music studied in a large majority of literature. As an outsider to non-Western music styles, I must carefully approach the results I come to after evaluation (Yip, 2024). Lastly, as a hearing cisgendered soprano, I may identify with results and pedagogical application, but must defer to alternative literature and the experience of other singers whose perception and range differ from mine.

Both Grant and Booth (2009) and Randolph (2009) acknowledge that narrative reviews are subject to bias, given that the author draws their own conclusions, and that these conclusions may differ from other reviews covering the same material. In order to mitigate bias, I designed explicit inclusion and exclusion criteria, deliberately searched for partnered or contradictory studies, and questioned my own confirmation bias (Baumeister and Leary, 1997).

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Review

Introduction: Defining Timbre

It is imperative that voice teachers ask what they hear in a singer to critically explore the voice quality and timbre, as well as the functions leading the singer to accomplish that timbre (Perna, Redman, and Glasner, 2024; Moniz, 2024). While the language used to describe said sound can be subjective, certain aspects of that sound can be objectively measured by Long Term Average Spectrums (LTAS), electroglottographs (EGG), Magnetic Resonance Imaging (MRI), and other tools (Sundberg, 1974; Stone *et al.*, 2003; Echternach *et al.*, 2010; Echternach *et al.*, 2014; Guzman *et al.*, 2015; Kayes and Welch, 2017; Gill *et al.*, 2020; Capobianco *et al.*, 2025). Therefore, this review seeks to answer the following question: how is timbre quantitatively defined in different styles of singing?

Perhaps the most commonly cited (and criticized) definition of timbre comes from the American National Standards Institute (ANSI), which describes timbre as “that attribute of auditory sensation which enables a listener to judge that two sounds, similarly presented and having the same loudness and pitch, are dissimilar...” (Howell, 2025, p. 37). Many agree that timbre is perceptual in nature, but this is where the general consensus ends (Sundberg, 1974; Siedenburg and McAdams, 2017; Howell, 2025). Timbre is directly related to frequencies, which are perceived by the musician as pitch. This is proven when two differently timbred instruments are pass-filtered at the fundamental frequency; when that frequency is drastically changed, the timbres change (Siedenburg and McAdams, 2017; Howell, 2025). Therefore the ANSI definition is both incomplete and problematic given that it asserts timbre is *different from* pitch.

Complicating things further, the term itself may be incorrectly and interchangeably used with other voice related topics (Siedenburg and McAdams, 2017). Timbre is often synonymized with the registration choice a singer makes, either intentionally, as with yodeling, or not, as in Classical singing (McCoy 2019). I will agree with Howell’s controversial assertion that there are

no registers - only qualities (2025) - as there are far more vocal tract contributions to timbre beyond glottal configuration. Throughout this review, registration terms such as *chest voice*, *head voice*, *fry*, or *falsestto* will be avoided unless required by the literature.

Overall, timbre is a complicated topic. The aim of this literature is not to define the term, but to understand how voice scientists and pedagogues study quantitative domains of singing voice timbre. The above points serve not to challenge the literature, but to contextualize it.

The Acoustics of Belting

Belting, not unlike timbre, is a pedagogical term with multi-layered meaning and has numerous components which allow the ear to perceive it as such (McGlashan, Thuesen, and Sadolin, 2017). This is seen in studies where expert listeners consistently identified the difference between operatic singing and belting (Stone *et al.*, 2003; Kayes and Welch, 2017). This may seem like a frivolous finding, that timbre begins with perception and identifies two sounds that might be different. Given the ANSI definition, it is easy to stop here, where timbre is neither loudness nor pitch, but that which distinguishes two unique sounds.

However, Stone *et al.* used other tools to measure the female singer's adaptation to different styles of singing (2003). LTAS data show that frequency bands for a Broadway-style American National Anthem were higher in decibels above 800Hz than the operatic style. This trend continued for the upper harmonics for the remainder of the sample (Stone *et al.*, 2003). It is important to note that Stone *et al.* was able to replicate characteristics of the belt timbre without specifically requesting it; the singer in this study was instructed to sing with a Broadway-style, and therefore may or may have employed belting strategies with integrity (Lebowitz and Baken, 2011). Despite this, the findings from Stone *et al.* have been replicated in later studies identifying acoustic characteristics of the belt sound.

Kayes and Welch (2017) found that musical theater singers had higher spectral peaks at and above 1000Hz. They note that the peaks found at 1000Hz were likely due to the high prevalence of the note C5, or 500Hz, making 1000Hz the second harmonic, or H2 (Kayes and Welch, 2017). It has been established that a defining quality of belt is a strong H2 (Titze, Maxfield, and Walker, 2016; Titze, 2018; Herbst, Story, and Meyer 2025), which aligns with the findings of Stone *et al.* (2003). Figure 2 shows spectrographic evidence of such phenomena. It should be noted that in the case of Herbst, Story, and Meyer (2025), the voicings were computerized, and not as a result of human voice.

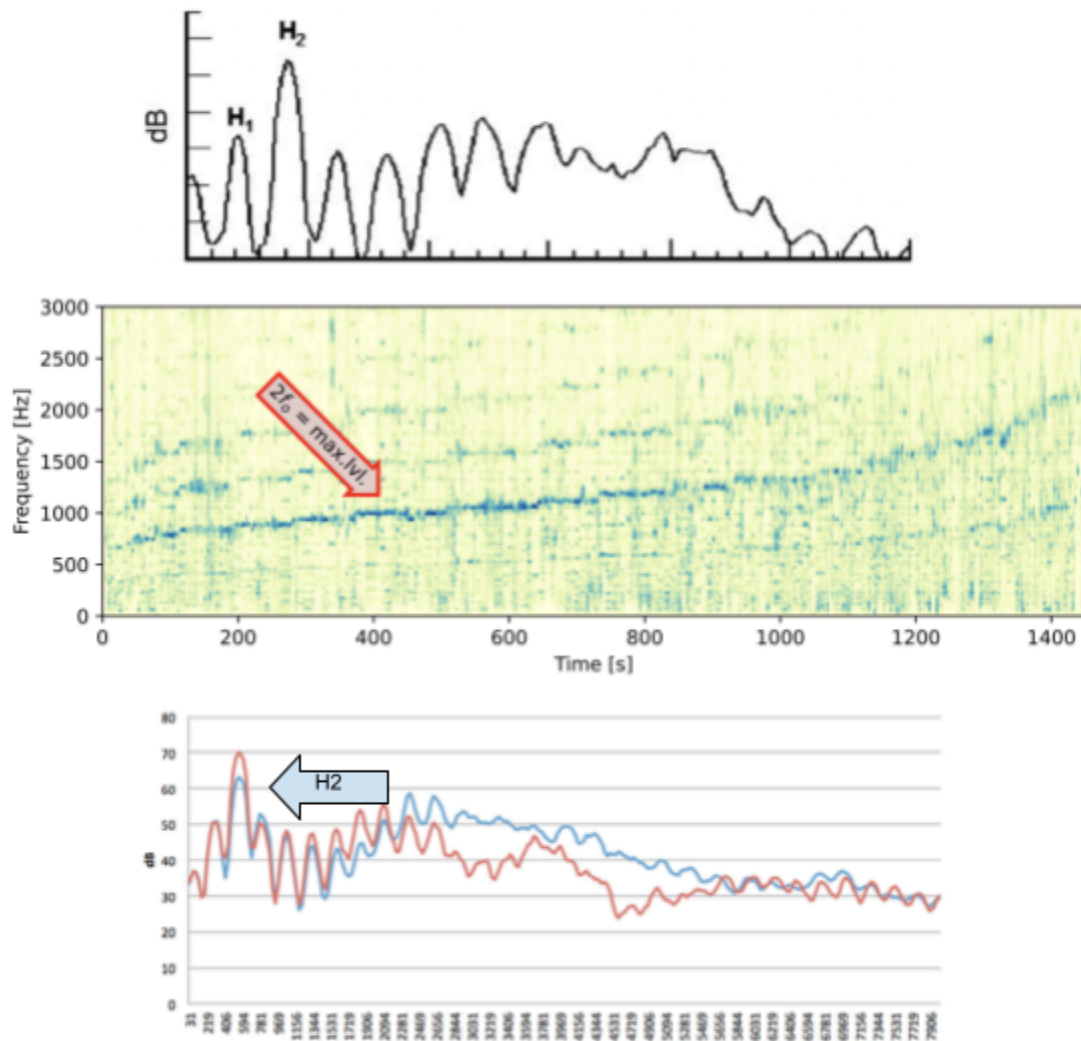


Figure 2: TOP: LTAS of belt from Lebowitz and Baken (2011); MIDDLE: Spectrogram of computerized belt from Herbst, Story, and Meyer (2025); BOTTOM: LTAS comparing the belt styles of Overdrive and Edge from McGlashan, Thuesen, and Sadolin (2017).

Though much of the literature refers to belting as one quality, Lebowitz and Baken recognize that belting is multifaceted, with “potentially limitless variations” (2011, pg. 164). Such steps are being taken to identify possible variations; McGlashan, Thuesen, and Sadolin (2017) identify two different styles of belt as *Overdrive* and *Edge*, each of which have their own distinctive characteristics (in performance, Overdrive may sound more shout-like, and Edge more scream-like). They found a statistically significant difference on the LTAS between Overdrive and Edge, where Overdrive had more spectral energy than Edge below 2kHz; this changed above 2kHz, where Edge had a statistically significant difference than Overdrive in both male and female voices (McGlashan, Thuesen, and Sadolin, 2017). This data disproved their hypothesis that the LTAS profiles of the two sounds would not be significantly different,

providing more credence to the perceptual intuition that belting styles could sound different from one another.

The aforementioned studies which identify belting as having more spectral energy in the higher frequencies contribute to the perception that belting is bright (LeBorgne *et al.*, 2010). This is explained by *absolute spectral tone color*, where

“two or more simple sounds (e.g. a sine wave, single harmonic of a complex tone, or narrowly notch filtered band of noise) of identical frequency, regardless of their sources, will produce an identical tone color percept independent of other spectral fluctuations considered aspects of timbre” (Howell, 2016, pg. 29).

These simple sounds emit a vowel-like quality depending on the frequency of the sound. The range of vowel percepts are shown in Figure 3.



Figure 3: “Approximate Ranges of ‘Vowel-like Colors’ for a Simple Sound” from *Parsing the Spectral Envelope*, Howell, 2016

Higher frequencies, when filtered as simple sounds, emit a sound that can be perceived as ~i (Howell, 2016). Howell acknowledges the anthropomorphic nature of these identifications which can muddy the waters when parsing an understanding of timbre (2016). However, the inherent brightness of /i/ in comparison to /u/ is an historical precedent mimicked even in nature (Howell, 2025). It would be easy to say that in order to achieve a brighter, beltier sound, one simply needs to modify the vowel toward /i/ (as may be anecdotally stated) by slightly manipulating the tongue shape. The reality is much more complicated. Herbst, Story, and Meyer (2025) assert that different vowels need to be modified at different pitches in order for the second harmonic to be boosted by the first formant. It is also feasible to use affect and speech-related sounds to create the desired vocal aesthetic. Phrases like “hey, taxi!” and “how dare you?” when spoken with emotional intent may naturally inspire belt-like qualities (Spivey and Saunders Barton, 2018; Bozeman, 2022). In the case of the word “taxi,” the /ae/ vowel is especially poised to emit a belt-like quality between the pitches G4 and E5 because the second harmonic is boosted by the first formant (Titze, 2018).

The Physiology of Belting

In order to achieve belting timbre, singers must shape their vocal tract in such a way that the second harmonic can be boosted. Researchers have regarded this general shape as trumpet- or megaphone-like in nature (Echternach *et al.*, 2014; Titze, Maxfield, and Walker, 2017; Titze, 2018; Ragan, 2020). This shaping can aid in providing brass and twang as it raises a singer's first formant frequencies, often allowing H2 to be strengthened in the process. Some researchers claim chest registration is required for the belt sounds, as in the case of Lebowitz and Baken (2011) who directly relate a high closed quotient (a marker of chest registration) to the acoustic outcome. The following research paints a broader picture and takes into account the whole vocal tract whose specific areas of widening and narrowing accomplish the belt aesthetic.

A pilot study explored the different ways a belt aesthetic could be achieved in a female music theater performer (Echternach *et al.*, 2014). While, like Stone *et al.*, this study had only one participant, researchers were able to gather physiological data on the difference between "heavy belt" and "head voice" (Echternach *et al.*, 2014, p. 2). Results showed that the performer utilized a larger jaw opening (and therefore wider lip opening), narrower pharynx, and higher larynx position for their heavy belt than while singing with head voice. In combination, these features ultimately create a shortened vocal tract that mimics the megaphone shape mentioned previously.

Guzman *et al.* (2015) narrowed their area of study in non-Classical singers to laryngeal height, laryngeal compression, and pharyngeal compression, as the latter two variables which would hypothetically contribute to the megaphone shape. In general, measurements of anterior-posterior narrowing were nearly times higher than those of medial narrowing; these measurements were heightened with loud singing. Rock singing showed the most anterior-posterior and medial narrowing, pharyngeal constriction, and highest laryngeal height compared to pop and jazz, despite each style of singing having some amount of increased narrowing. While Echternach *et al.* studied different vocal aesthetics, the results were similar. Though the subjects were instructed to sing in a pop, rock, or jazz style, and not necessarily Broadway-style belt, it can be assumed that overlap in the styles would occur. Such musicals as *Six*, *American Idiot*, and *Guys and Dolls* would utilize aspects of the respective styles; training singers in such roles would elicit the need for various aesthetics.

McGlashan, Thuesen, and Sadolin (2017) further identified areas of narrowing within six different levels of the vocal tract. Levels 3 (arytenoid and cuneiform cartilages, epiglottis and aryepiglottic fold) and 4 (the "piriform fossa and posterior pharyngeal wall of the hypopharynx")

showed narrowing for both Overdrive and Edge, yet Edge showed more narrowing and constriction overall (McGlashan, Thuesen, and Sadolin, 2017, pg. 3). For example, the vocal folds were still visible on laryngoscopic imaging for Overdrive singing, but were nearly covered by the false folds in Edge singing. In addition, the larynx was in a higher position for Edge, further shortening the vocal tract. These findings corroborate Guzman *et al.* when considering that Edge has similarities to a rock sound. While it is not the scope of this paper to discuss the parameters of rock singing (or of its subgenres) it is worth noting that, as with belt strategies, other general forms of vocalizing will require more nuance depending on a singer's goals.

If in belting styles the general goal is to shorten the vocal tract and create a megaphone shape from glottis to lips, it would then make sense that singers could train this timbre on /a/ or /ae/. These two open vowels widen the mouth and raise the tuning of the first formant to boost H2. Titze (2018) argues that a similar phenomenon occurs when the second formant boosts H4, which can occur on the vowels /i/ and /e/. These vowels' second formant frequencies lie above approximately 2.5kHz; therefore higher fundamental frequencies may benefit from these interactions (Titze, 2018). Such a timbre is possible because of the further narrowing of the vocal tract that both vowels accomplish. While this particular strategy seems like acoustic theory rather than physiological function, singers and composers alike would benefit from knowing that belt-like timbres can be achieved with fronting and rounding of the tongue at higher pitches. While this review is not designed to be a definitive statement on the timbral outcomes of harmonic-formant relationships, it is another example that belt-like qualities are not sourced from a strict vocal tract shape (Guzman *et al.*, 2015; McGlashan, Thuesen, and Sadolin; 2017).

Herbst, Story, and Meyer (2025) note that, while the conventional megaphone shape and general use of speech-like vowels will be broadly useful in belting, these strategies are unlikely to be useful across the whole pitch range. Their computer simulation results found that most speech-like vowels were only able to give a belt-like perception within the range of a fifth. The exception to this rule were the open vowels, /o/, /a/ and /ɔ/, whose perceptual belt-like range extended nearly an octave (Herbst, Story, and Meyer, 2025). Therefore, vowel modification is still necessary depending on the sung pitch, given that the open vowels make up only a percentage of language. Curiously, their results indicated that the pitch range for unmodified vowels was between 220-330 Hz, ending where chest registration begins to transition to head registration (Herbst, Story, and Meyer, 2025). However, while chest voice is advantageous to creating a dominant second harmonic, vowel modifications at a specific pitch can cause enough of an impact on the timbral output while using whatever laryngeal configuration is available to the singer (Titze, 2016).

The Acoustics of Classical Singing

Classical singing has perceptually different acoustic outputs from contemporary styles of singing (Stone *et al.*, 2003; Kayes and Welch, 2017). These perceptual differences can be explained by differences in spectrographic imaging which show that different harmonics are more pronounced (Ferguson, Kenny, and Cabrera, 2010; Ritzerfeld and Miller, 2017; Capobianco *et al.*, 2025). One such area of note appears in the approximate area of 2.5–4.0kHz, where the clustering of the third, fourth, and fifth formants occur (Ritzerfeld and Miller, 2017; Capobianco *et al.*, 2025). This phenomenon, referred to as the Singer’s Formant Cluster (SFC), has been documented since at least 1977 when Sundberg published “The Acoustics of the Singing Voice” where he noted the perceptual differences a singer would encounter with a successful SFC (Sundberg, 1977). As Sundberg notes, the acoustic models which appear in Classical singing differ from that in contemporary, or speech-like, styles; therefore the perceptual experience is different (1977). LTAS imaging in figure 4 shows the SFC peaks that contribute to perceptual differences.

The contribution of the SFC can be considered as brightness or auditory roughness, depending on the frequency of the fundamental (Howell, 2025), providing clarity and ring to the otherwise darkened vowel to which Sundberg refers. This band of energy is ~i-like in quality. While SFC’s acoustic outcome is among the aspects which define the Classical aesthetic, Howell questions its terminological application when brightness and buzz is the desired output (2025). Though the term SFC may be mechanically ambiguous, there is research that functionally explains the phenomenon which will be discussed in an upcoming section (Titze, Maxfield, and Walker, 2017; Gill, *et al.*, 2018).

When spectra with SFCs are pass-filtered to identify only the clustered formants, the resulting sound ranges from bright to outright buzzy (Howell, 2025). While the brightness can be accounted for in its ~i-like quality, the buzz is a result of *auditory roughness*. Auditory roughness is not to be confused with a rough-sounding voice quality associated with dysphonia, extended voice techniques, or deliberate aesthetic choices. Rather, auditory roughness occurs when two or more pure tones have frequencies within 12.5Hz or fewer, and has been described by voice teachers as sounding like crickets (Bernard, *et al.*, 2022; Howell, 2025). This buzz does not inherently define the SFC, and can also occur in contemporary styles of singing, particularly in those which are defined by strong higher harmonics within 12.5kHz of each other. It should be noted that the SFC is most often observed in lower voice ranges and is rare for high soprano singing. (McCoy, 2019; Howell, 2025; Liu and Wang, 2025). This is because a large majority of

the soprano's repertoire involves such a high fundamental frequency that few harmonics are likely to be seen in the 2.5-4.0kHz range (McCoy, 2019).

If expert listeners are able to distinguish between Classical and contemporary sounds, yet the SFC is not required for at least one voice type, then there must be another acoustic

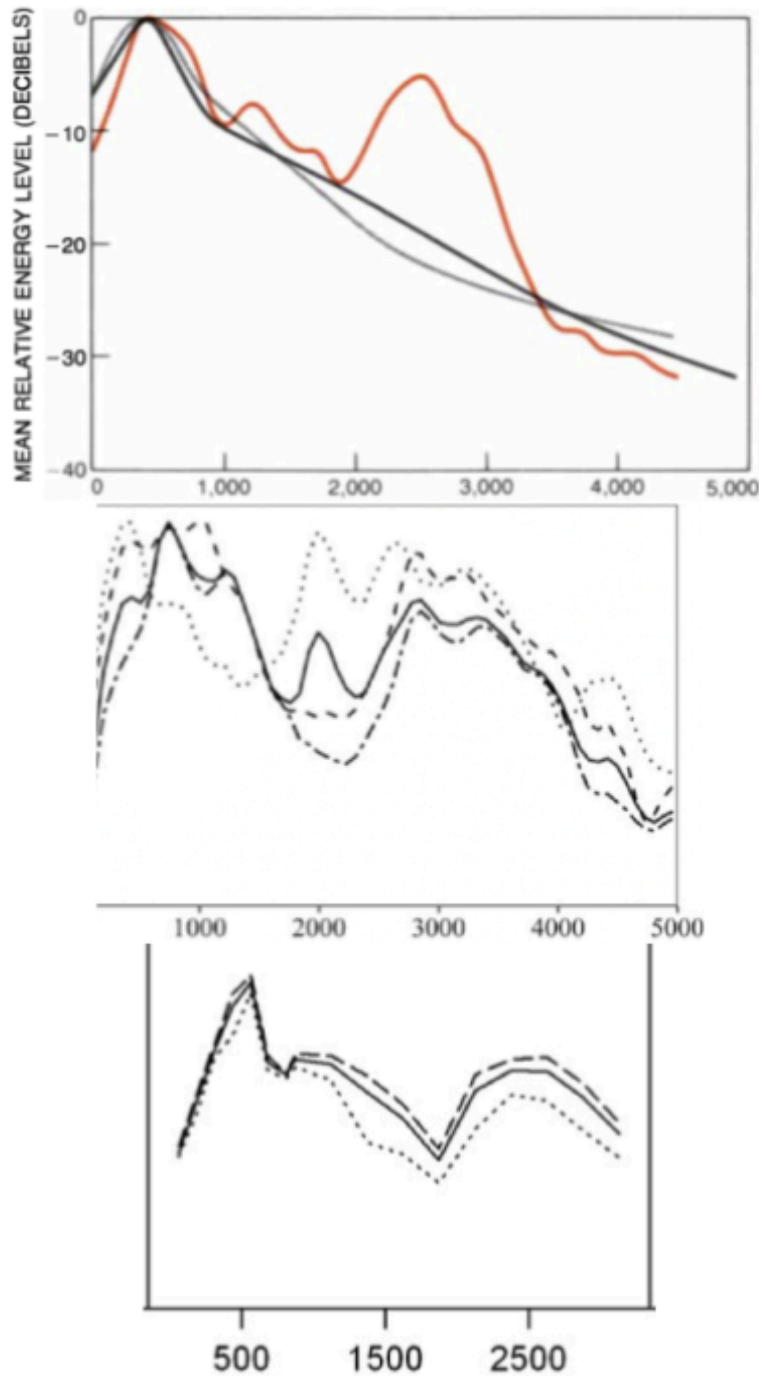


Figure 4: TOP: Jussi Björling SFC (Sundberg, 1977); MIDDLE: tenor SFC (Liu and Wang, 2025); Bottom: Baritone SFC (Johnson and Kempster, 2011)

defining property of Classical singing. Stone *et al.* (2003) identifies in their study that the deciBel level of the fundamental (or the immediately perceived sung pitch) in opera singing was higher than that of the Broadway-style. Harkening back to Howell's vowel-like colors, one can surmise that the fundamental, when pass-filtered as a simple sound, will have a tone color that sounds like an ~u (fig. 3). This quality also explains Sundberg's reference to the "darkened vowel sound" (1977, p. 89). Naturally, much Classical soprano repertoire sits above the note C5, the note at which a simple frequency will change timbre from ~u to a more open (but still warm) ~o percept (Howell, 2016).

The phenomenon of the dominant fundamental has been captured in other studies as well, and is apparent in figure 4. Ikävalko *et al.* found that the fundamental was higher in opera singing than other non-Classical styles, resulting in a darker and warmer timbre than other styles (2024). Because this study was done in female singers with relatively higher fundamental frequencies, it is likely that the prominent fundamental was due to its strengthening by the first formant. Such a strategy had been earlier documented by Henrich, Smith, and Wolfe (2011), who identified other strategies for lower voices, reporting that tenors and baritones tuned their first formant to boost the second or third harmonic. Though it may seem as though a boosting of higher harmonics would negate the warmth of the dominant fundamental, Bozeman reminds us of a key principle of absolute spectral tone color; the first formant is always in contact with the treble clef staff where the timbral percept is a warm ~u, thus contributing to overall warmth (2017).

Foremost of the difference between the two timbral outcomes is the difference in general vocal tract shape. While contemporary styles rely on a megaphone or trumpet shape, Classical styles rely on its inverse (Henrich, Smith, and Wolfe, 2011; Titze, Maxfield, and Walker, 2017; McCoy, 2019; Ragan, 2020). The next section will discuss the physiological assessments for timbral outcomes and provide more tactile and applicable strategies to help singers achieve their aesthetic goals.

The Physiology of Classical singing

The consensus that Classical singing relies on the *inverted* megaphone shape involves greater nuance due to the various areas of flexibility within the vocal tract (Titze, Maxfield, and Walker, 2017). Mainka *et al.* (2015) used MRI imaging to measure the area of particular regions of interest, including the area and volume of the endolaryngeal and hypopharyngeal regions (fig. 5). The endolaryngeal area and volume both increased when singing as opposed to speaking. The difference in the two vocalization modes were *not* statistically significant, but the area and

volume showed a positive correlation with one another (Mainka *et al.*, 2015). The lack of statistical significance aligns with other research that an inherently larger epilaryngeal (or endolaryngeal) is not desired for the Classical aesthetic (Sundberg, 1974; Titze, 2012; Ikävalko *et al.*, 2024). It has long been hypothesized that the SFC relies on a 1:6 ratio of epilaryngeal volume to pharynx volume (Sundberg, 1974). While the narrowed epilarynx is key, the widening of the pharynx provides more surface area for a singer to manipulate.

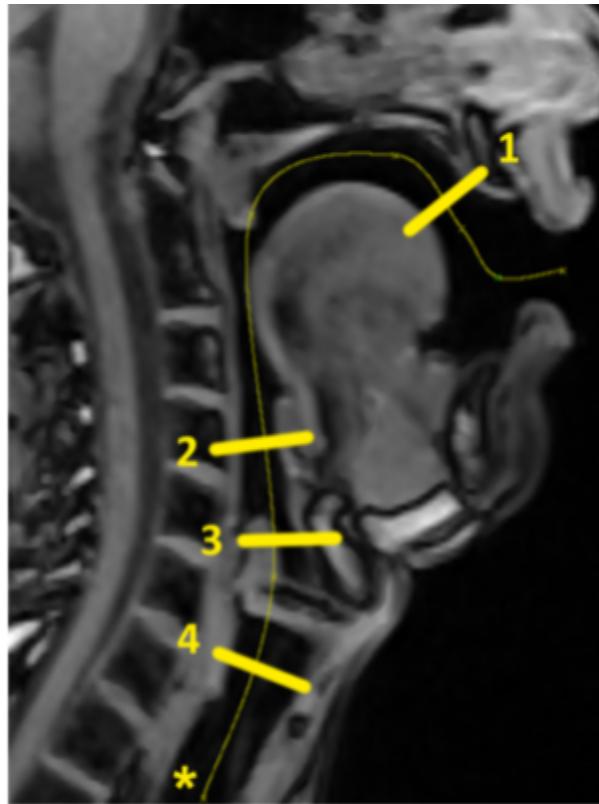


Figure 5: Regions of the vocal tract (Mainka *et al.*, 2015)

While Mainka *et al.* (2015) did not determine a statistically significant increase in the endolaryngeal area between speaking and singing in male voices, a partner study from Lyubarskaya *et al.* (2024) showed different results for Classical sopranos. Results found that depression of the larynx resulted in a widening of the endolaryngeal area, therefore increasing the larynx-to-pharynx ratio more than that of the low voices studied by Mainka and colleagues. While Lyubarskaya *et al.* did not explore higher pitches (the pitches at which new acoustic strategies need to be implemented), there was nonetheless a difference in the way female singers configured their vocal tract to achieve the desired timbre (2024).

Laryngeal height has also been discussed as a key component of Classical timbre (Echternach, 2010; Mainka, 2015; Ikävalko, 2024). A lowered larynx lengthens the vocal tract

and allows a singer to achieve a darker and warmer sound (Echternach *et al.*, 2010; Henrich, Smith, and Wolfe, 2011; Mainka, 2015). In utilizing the extrinsic muscles of the larynx and maintaining gentle bodily alignment, a singer can choose to use the vertical position of the larynx to alter the acoustic output of their voice (Ragan, 2020). Echternach *et al.* noted that laryngeal height allowed tenors to adjust registration, particularly when moving from chest voice to mixed voice to falsetto, although these adjustments were small (2010). The larynx was seen to raise as tenors moved to falsetto so as to raise formant frequencies, a finding which had been observed in earlier studies (Echternach, 2010).

One such area of note is the much-discussed velopharyngeal opening (VPO). Gill *et al.* found that a slight VPO contributed to high LTAS peaks in the singer's formant region (2018). They acknowledge that a wide VPO is not desired for Classical singing because it produces a nasalized quality and lowers spectral energy in the 2-4kHz range. However, it is not ideal for singers to maintain a consistently narrow VPO simply because language does not allow for it; navigating nasalized consonants such as /m/ and /n/ with vowels requires specific timing (Gill *et al.*, 2018). Martell, Lastowiecka, and Bae considered velopharyngeal timing and found that trained Classical sopranos were able to consistently time their VPO in both singing and speaking (2025) for adequate intelligibility without sacrificing voice quality. Further studies may discover if untrained sopranos and other voice types (both trained and untrained) would replicate these results.

Raising formant frequencies (particularly of the first formant) may not always be the desired choice in Classical repertoire for many singers, as the timbre can resemble that of a yell (Bozeman, 2022). In addition, the harmonics of higher frequencies become more spread apart through the second, third, and fourth formants, thereby making the SFC an impossible task (Liu and Wang, 2025). Therefore, high voices must manipulate other areas of the vocal tract to achieve the warmth, brilliance, and ring associated with the Classical sound. For sopranos, raising the first formant to track H2 is a useful and powerful acoustical tool. This can occur with vowel modification and jaw opening (Enternach *et al.*, 2010; McCoy, 2019; Bozeman, 2022; Liu and Wang, 2025). Both actions modify the vocal tract by shortening it and have potential to distort the perceived vowel. McCoy (2019) writes that this is not inherently a problem when a composer understands the limitations of the human voices. He cites Verdi's use of the Italian word *sara* in the soprano aria "Caro nome" as appropriate for melismatic passages extending up to B5, or approximately 988Hz. Consequently, voice teachers can use the /a/ and /ae/ vowels to achieve adequate formant tuning above C5. Both vowels have first formant frequencies between 600 and 1200Hz, therefore allowing the fundamental (and sometimes H2) to be

adequately boosted, and providing the ring and buzz associated with high intensity Classical singing.

Beyond the Dichotomy

The aforementioned literature makes it tempting to categorize voice use into two broad categories, belting and Classical, considering they often exist at opposite ends of the timbral spectrum, bright and dark respectively; this would be a mistake. Even authors identify that there are numerous timbres within both styles, and that styles are not inherently on one end of the spectrum or the other (McGlashan, Thuesen, and Sadolin, 2017; Aaen and Sadolin, 2024; Capobianco *et al.*, 2025). Blurring the lines even further is the idea that similar timbral evidence can exist in different styles; timbre's covariability with pitch and loudness means that two styles of similar loudness may be acoustically and physiologically similar (Siedenburg and McAdams, 2017; Ikävalko *et al.*, 2024).

The Complete Vocal Technique framework describes Edge as “a somewhat aggressive sound with a more screamy character” (McGlashan, Thuesen, and Sadolin, 2017, p.2), making it comparable to Classical insofar as both styles are generally loud (Ikävalko *et al.*, 2024, p. 11). Similar to these two high-sound pressure level styles is *Kulning*, a traditional herding call from certain regions of Sweden which requires sounds to be carried over long distances in outdoor settings (Ecklund, McAllister, and Pehrson, 2013; Ikävalko *et al.*, 2024). Both Classical and Kulning showed a strong fundamental, but Classical evaluations were marked by a strong H3 and H4 and Kulning showed more spectral energy around H5. Ikävalko *et al.* surmise that this difference was likely due to the difference in tongue and laryngeal positions (2024). In Kulning, the larynx was slightly higher than in Classical and slightly lower than in Edge. It is also possible that the tongue dorsum positioning was higher in Kulning than in Classical, yet still lower than in Edge; this measurement is to be taken lightly, considering that the three participants varied greatly in that particular measurement. Regardless, this preliminary study highlighted a folk style of singing which shares traits with two commonly researched sounds, yet cannot be described as being more similar to one than the other because it requires different shaping to achieve its timbral outcome. It is worth noting that, in addition to small sample sizes, studies of Kulning in controlled acoustic environments may show different results than field recordings due to recording conditions. To this author's knowledge, it is unclear whether these findings would be replicated with other folk singing styles; this is a potential area for future study.

Narasimhan and Aishwarya (2023) identified quantitative aspects of Carnatic singing, where vocalists train three separate registers ranging from low, middle, and high. The middle

and high registers, *Madhya sthayi* and *Taara sthayi* respectively, were of particular note. They found that the average fundamental frequency was higher and the harmonic-to-noise ratio was also lower in *Taara sthayi*, possibly a result of incomplete glottal closure likely to occur at higher frequencies. This probability was further suggested due to *Taara sthayi* having more spectral energy at the fundamental than H2 (Narasimhan and Aishwarya, 2023). Without seeing the spectrum, it is unknown *how* dominant the fundamental is. Depending on its contribution, the timbre of *Taara sthayi* may have more warmth than *Madhya* as a result of a dominant fundamental. This cannot be claimed for certain, given that Narasimhan and Aishwarya do not provide further spectral details. While this study does not aim to compare the *sthayi* of Carnatic singing to that of Western Classical or belting, it is possible to surmise that similar vocal tract adjustments to accomplish an aesthetic task. Given the dominant fundamental, there may be evidence of the inverted megaphone shape. Further studies discussing spectral parameters of Carnatic registration may result in a deeper understanding of the available sounds a singer of any style can make.

Also known for its characteristic brightness and straight tone, Thai Classical singing combines words and wordless syllables, known as *uan* (Latartara, 2012). Through spectral analysis, Latartara analyzes audio recordings of prolific Thai singers performing the five basic *uan* to understand their timbral qualities (2012). The two vowels /ə/ and /ʉ/ (as in “could”) are spectrally different. The former contains a strong H2 and H3, the latter a dominant fundamental and H2. The timbral differences can be attributed to the perceived brightness of higher frequencies and darkness of lower frequencies (Howell, 2016). The three consonants /ng/, /h/, and /y/ contain more spectral nuances due to differences in pitch and noise. Respectively, these consonants are typified by a strong fundamental, bright aperiodicity (noise), and bright pitch. Latartara argues that the combination of the *uan* contributes to the brightness of Thai classical singing, particularly because phrases are dominated by /e/ and end with /y/. The darker and warmer sounds (/ʉ/ and /ng/) provide color and contrast (2012). Similar to Narasimhan and Aishwarya, there is no consideration of the vocal tract configuration which would produce the desired, but the steady presence of brightness could indicate any combination of a high tongue dorsum, narrow pharynx, and raised larynx. More research is needed to determine how singers shape the vocal tract to achieve the characteristic Thai Classical sound.

Ultimately, both researchers and teachers must understand the Western bias in the literature. The above examples of non-Western analyses of singing should not be taken as the final truth on aesthetic qualities because they do not examine the sounds of a culture as a

whole. There were other studies that met the inclusion criteria while examining timbres of singing in various musical cultures, but due to word constraints could not be included.

Limitations

There is a conundrum to address before the conclusion of this review; timbre is *covariable* with pitch and loudness (Seidenburg and McAdams, 2017; Howell, 2025). In being expressive, singers will change loudness, vibrato rate, breath noise, and many other forms of vocalization which affect the listener's perception. That inter-style timbre can be flexible is evident in McGlashan, Thuesen, and Sadolin (2017) and Capobianco *et al.* (2025), both of whom acknowledge that belting and classical singing cannot be categorized as one thing, and that these styles contain a palette of appropriate tone colors available to a singer.

Furthermore, it is important to address that acoustic and physiological analyses provide clues as to what the listener's ears are hearing. Simply put, spectral analysis allows for practitioners to understand the steady state theory of voice production (Bozeman, 2022; Howell, 2025), and the vocal tract sets the conditions for timbre. Therefore timbral awareness begins with the listener. To suggest otherwise would deny the experience of the listener (Seidenburg and McAdams, 2017). It is the listener who identifies and names the sound.

Conclusion

The research acquired for this review identified two major trends in timbral studies. First, much of the research focused on two main styles: belting and Western Classical. Other studies examining traditional cultural sounds are still held in comparison to the aforementioned styles. Future research in timbre should consider sounds beyond the Western tradition to elevate equally legitimate styles of singing. More studies comparing various genres, like Ikävalko *et al.* (2024), would also benefit the field by building bridges between what is familiar and new. Such research could have implications not just for voice pedagogy, but for other musicological fields.

The second trend identified in the research is that quantifiable timbral data can be categorized via acoustic or physiological measures. Studies that covered both aspects provided concise if-then explanations that allow for pedagogical application (Stone *et al.*, McGlashan, Thuesen, and Sadolin, 2017). Though the research trends beyond simplistic and generalizing style terms, future research could help distill objective measures into pedagogically applicable terminology. Complete Vocal Technique has started this work (McGlashan, Thuesen, and Sadolin, 2017), yet the techniques for accomplishing sound outputs remain behind a 3-year

course and paywall. While acknowledging the rights to intellectual property, more singers might be served if such teaching tools were more easily available to practitioners.

Acoustic and physiological measures may help explain the outcome of a voice, but these measures are likely to be lost in translation to voice students. Qualitative studies on perception and terminology can fix the problem and could bridge theory to practice. Though this review intentionally excluded qualitative data, it should be noted that more subjective studies on timbre perception and terminology are occurring (LeBorgne *et al.*, 2010; Aaen and Sadolin, 2017). Ultimately, no one route, objective or subjective, will fully equip teachers and singers with all knowledge of timbre. The full spectrum of research will refine and deepen understanding of the sounds heard across time and cultures.

Critical Reflection

I set this research question for myself as a professional challenge, and a challenge it was. Gibbs's (1988) model of reflecting on emotions during the process was enticing, but it did not seem to fully encapsulate how it impacted me as a voice teacher. Therefore, Brookfield's book *Becoming a Critically Reflective Teacher* became the framework for reflection when I realized that the challenge was in "the sustained and intentional process of identifying and checking the accuracy and validity of...teaching assumptions" (2017, p. 3). Brookfield provides four lenses of reflection for educators: the students' eyes, colleagues' perceptions, personal experience, and theory (2017). It is through these lenses I will evaluate my learning.

Students' eyes

As a student embarking on research in dense content, I relied on my own comprehension, study abilities, and personal connections to understand new information. This was simultaneously frustrating and liberating; frustrating because I lacked guidance on the subject matter, yet liberating because when I learned something new, it was my own doing. Brookfield regularly weighs student-led learning with teacher-led instruction (2017). Throughout this review, I had to navigate that balance by knowing when to keep digging for understanding and when to curb frustration by connecting with more knowledgeable practitioners.

Ultimately, this review made me realize how much I *did not know*. I am successful at identifying discrepancies between a singer's sound and their aesthetic desires, but my toolbox for handling these discrepancies is light. If my tools were not working, I would simply move on, denying the student an opportunity to respond or give feedback if they chose. Brookfield is not entirely surprised by this: "Because of our power to...sanction student progress it's not

surprising that people are understandably reluctant to be honest with us.” (2017, p. 63). I am seen as the authority on what constitutes correct singing (despite the fact that I do not believe in such a thing). It is therefore my responsibility to graciously and humbly provide space for immediate student feedback to assure the student that I am listening to their needs and adopting a lesson model dedicated to their learning, not my teaching.

Colleague's Perceptions

As a classroom teacher, I had built-in professional learning time with other music teachers where we shared resources, wins, and challenges. I am no longer afforded such a luxury as a private teacher, and therefore must create opportunities with colleagues to engage in conversation about voice timbre. Brookfield notes that it is easy to fall into hegemonic patterns where dominant theories persist (2017). Practically speaking, I will need even more collegial conversations to help me navigate the content. I began the review with my own assumptions but even researchers were not always in agreement on their assumptions. This, in addition to comprehending the content, was a challenge.

For example, two different articles made contradictory claims about the relationship between chest voice and belting. Lebowitz and Baken (2011) claim that belting may be the result of maintaining glottal closure (extending the chest register) to a higher pitch, yet Titze (2016) emphasizes that using a vowel with a high first formant has a larger impact on the extent to which H2 is boosted. It is my job as the voice teacher to hold these two perspectives to create options for singers. At the same time, Brookfield states that collegial engagements often confirm opinions that may not have been shared aloud because they go against common thought (2017). Titze's paper is thus affirming because in my experience, I can achieve belt timbre without firm glottal closure. The amalgamation of Brookfield's insights and the literature have given me confidence and language to explain my experience.

Personal Experience

I was struck by Brookfield's reflections on graduate studies, particularly that it “should make us much more aware of the power we wield in our own classrooms and how that power is exercised ethically” (2017, p. 156). As stated above, my knowledge as a teacher is rarely questioned in the studio, and if left unchecked, this lack of feedback can be destructive. This study, and by extension graduate studies as a whole, have given me the opportunity to wrestle with challenging content. Often I would struggle to finish reading papers when the content involved statistical analysis I did not understand. Brookfield affirms this feeling, that it is

challenging to be in a student's position of not understanding content (2017). As uncomfortable as it was to engage with unfamiliar concepts, it was unavoidable given what I hoped to accomplish from learning outcomes 1 and 2 (to synthesize and evaluate multiple definitions of timbre; to understand the quantifiable differences in commonly occurring singing voice timbres). Not only would I need to overcome the discomfort of learning something new, but I would do it with the ever-present reminder that I would earn a grade. In doing so, I grew as a student and as an empathetic teacher.

Theory

It was important to me to identify as many different styles of singing while collecting research to review. As already stated, much of the aforementioned literature addresses Western styles, which contributes to the larger narrative that some singing is more legitimate because it is backed by peer-review. This is precisely the hegemony that Brookfield encourages us to dismantle when reflecting through critical theory, or the study of power structures in society (Rogers, 2011). It was frustrating that I could not collect enough non-Western studies to stand alone for in-depth analysis; this was partially due to time constraints, but in reality, very few non-Western styles were represented in searches. Brookfield, however, sees an opportunity, that "...theory sometimes also introduces us to new vistas that broaden our understanding and force us to reappraise old assumptions" (2017, p. 174). When I continue timbral research in the future, I will diligently question the available literature to investigate the extent it perpetuates a colonialist narrative.

Conclusion

Though I mention in my reflection feeling frustrated and lost, I could not adequately synthesize these feelings without framing them in the context of being a teacher. In addition, Gibbs's (1988) model asks the reflector to make judgement calls on their experience, which calls into question the value of each learning opportunity. After all, this research is to make me a better teacher, so every negative and positive experience led to learning something valuable, making this review a net positive experience.

I can proudly say that I have achieved my learning outcomes. I understand the various definitions of timbre, decipher the tools used to quantify it, and extrapolate strategies from the literature for students. At the end of it all, I am proud of what I have learned, but not yet satisfied. This review neglected discussions of voice production, detailed sound qualities, and the impacts of hearing loss, and other styles of folk singing, all of which are discussed in the

literature (Ragan, 2020; Howell; 2025). My investigations into timbre are not over; they have only just begun.

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Appendix 1

Project Timeline

September

- ☐ Compile initial papers on timbre and the singing voice
- ☐ Begin to refine research question
- ☐ Identify inclusion/exclusion criteria
- ☐ Identify type of literature review

October

- ☐ Solidify research question
- ☐ October 10: Identify at least 10 papers that help answer research question
- ☐ Begin coding process
- ☐ October 20: Identify at least 15 papers that help answer research question
- ☐ October 22: Write introduction
- ☐ October 24: Begin program of study section
- ☐ October 27: Finish purpose and justification
- ☐ October 28: Finish aims and objectives
- ☐ October 29: Finish learning outcomes and timelines
- ☐ October 31: Identify at least 20 papers that help answer research question

*November

- ☐ November 3: begin data organization in outline
- ☐ November 10: deadline for full outline - begin writing
- ☐ November 17: Goal word count - 1500
- ☐ November 24: Goal word count - 3000

*December

- ☐ December 1: Goal word count - 4900
- ☐ December 2-5: Finish reflection
- ☐ December 5: Submit draft
- ☐ December 8-23: Edits
- ☐ December 26-31: Final Touches

January

- ☐ Jan 1 or 2: Final submission

*This timeline was delayed after an extension was granted due to extenuating circumstances.

Appendix 2

Boolean Strings

Text	Database	Date
"Singing voice timbre"	UWTSD Ex Libris	17 September, 2025
Singing voice AND timbre"	UWTSD Ex Libris	17 September, 2025
voice timbre AND singing NOT model NOT comput*	UWTSD Ex Libris	17 September, 2025
Singing psychacoustics	UWTSD Ex Libris	18 September, 2025
"Parsing the spectral envelope"	UWTSD Ex Libris	18 September, 2025
"Parsing the spectral envelope"	Academia.edu	18 September, 2025
Belting AND timbre	UWTSD Ex Libris	24 September, 2025
timbre AND Classical AND singing	UWTSD Ex Libris	1 October, 2025
"Singer's formant cluster"	UWTSD Ex Libris	8 October, 2025
Classical singing AND acoustics	UWTSD Ex Libris	8 October, 2025
"Long term average spectrum" Classical singing	UWTSD Ex Libris	12 October, 2025