Texas Music Education Research

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A Preliminary Investigation Into the Effect of Bell Cover and Filter on Pitch of Wind Instruments

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The Covid-19 pandemic has caused adverse effects on instrumental music teaching and concerts, including those involving wind instruments. Many schools now use bell covers and air filters during rehearsals and performances to help prevent aerosol transmission of disease. This study sought to examine if the use of these bell covers and filters might have an effect on mean instrument pitch. A sample of pitches in the low, middle, and high tessitura of each wind instrument were collected in three groups: no treatment, bell cover only, and bell cover with air filter. The data was then entered into the analytical software package "R." T-tests and Analysis of Variance were run on the data to compare the three groups. Additional comparisons of mean pitch deviation were also made as to instrument family (brass/woodwind) and note (low tessitura to high). The analysis showed that when using both bell cover and filter, there is a small degree of sharpness when compared to performing with no treatment.

The COVID-19 pandemic is the most significant event in recent world history. The first group of cases were publicly identified as coming from China on December 31, 2019; the first case discovered in the USA was on January 15, 2020 (Centers for Disease Control and Prevention, 2020). Although Western countries were slow to realize the speed of infectivity, the WHO declaration of global pandemic on March 11, 2020 quickly led to a reaction in all levels of government and civic institutions, including education. The first state in the USA to close its schools was Ohio, on March 16 (Mike DeWine: Governor of Ohio, 2020), quickly followed by the rest of the nation's educational institutions. On March 19, California was the first U.S. state to institute a "stay at home" order, followed by the other states to varying degrees.

Although it was suspected early in the pandemic that aerosol transmission was a possible cause of contagion (van Doremalen et al., 2020), research on such a means of transmission was not widely known until April 2, 2020, when the publication of a Chinese study on aerosol transmission involving victims seated at the same restaurant seemed to indicate how infectious COVID-19 was in aerosol (Lu et al., 2020). By August 7, the National Institutes of Health published research that linked the spread of COVID-19 definitively through aerosol transmission (Tang et al., 2020).

The pandemic caused an immediate, detrimental effect on both performing arts and music education, as performances and rehearsals were canceled throughout the world. Both performing artists and researchers immediately began investigating ways to remediate the aerosol spread inherent in large group music performance, especially in wind instruments. In the United States, a large group of researchers under the guidance of the National Federation of State High School Associations (NFHS) and the College Band Directors National Association (CBDNA) began research on the spread of aerosols in group music rehearsal and performance. In the second round of results released on July 31, 2020, recommendations were made that included seating musicians at least six feet apart, the use of masks, and bell covers for instrumentalists (National Federation of State High School Association, 2020b).

There already exists both experimental and educational research into these areas. Even by Monteverdi's era, it was known that inserting an object into the bell of an instrument raised the pitch, as this effectively shortens the length of the pipe (Baines, 2012). Griffin (2012) discerned that while an object placed in the bell generally sharpened the pitch, if the bell of a brass instrument is placed close to an object such as a music stand, this proximity flattens the pitch a little. The amount of sharpness from a mute inserted into the bell can raise the pitch as much as 1/4 of a half step (Baron, 2011). Snow (2006) noted that different mutes affect the pitch differently, depending on whether the mute was inserted into the bell or covered the bell.

Since the appearance of COVID-19, music education research has included investigation into disease mitigation amid efforts to keep music ensembles as active as possible. As bell coverings were discussed widely as one strategy against the spread of COVID-19, investigations began quickly to determine suitable materials for these covers and their effectiveness. Konda et al. (2020) suggested that cotton, natural silk, and chiffon were the best materials for filtration. Firle et al. (2022) recently investigated aerosol emission rates from wind instruments. In that study, it was determined that emission rates were comparable to that of singers, and that covering an instrument bell with a surgical mask did not reduce the spread of aerosols. An additional report from the National Federation of State High School Associations (2020a) gave the first specific recommendations for both bell cover material in multiple layers and an American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) rating of MERV-13. A very recent study using 16 woodwind and brass musicians from the Minnesota Orchestra (Abraham et al., 2021) also examined the spread of aerosols in wind instruments. In this study, Mellotone Acoustic Fabric (used commonly for speaker covers) and filter were used together. This study also concluded that one layer of filter was sufficient; multiple filter layers were shown to suppress the volume of a trumpet's overtones. If a mute or other object placed into the bell changes the pitch, does an object such as a bell cover or filter placed against the bell also change the pitch, and if so, can this change be perceived? In a study of six musicians researching perception of interval intonation, the subjects were unable to even distinguish whether intervals out of tune were either sharpened or flattened (Siegel & Siegel, 1977).

With the increasing use of bell covers and/or filters to reduce aerosol spread in rehearsals and performances involving wind instruments, this research focused on one aspect of performance, pitch (frequency). The intent of the experiment was to determine what effect, if any, bell covers and/or filters might have on the intonation (level of pitch) of wind instruments.

This study then sought to examine two primary issues:

1. Does pitch change when using both filter and bell cover?
2. Does pitch change when only using a bell cover?

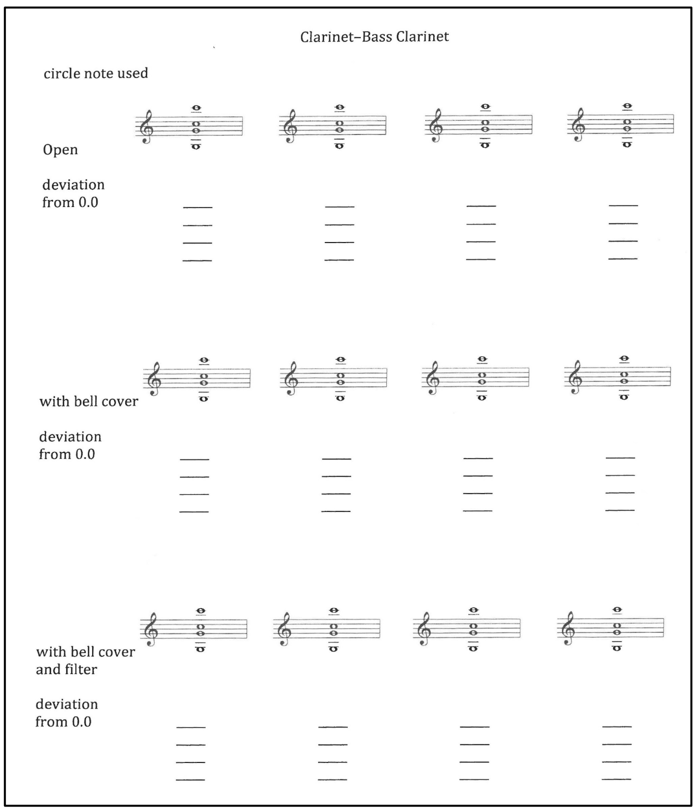
Method

First, we designed a data collection form (see Figure 1) for each wind instrumentalist in a large wind ensemble in the southwestern United States. The original data collection templates can be found at https://www.dropbox.com/s/7709yi1ftkjbqs7/DataCollectionForms.pdf?dl=0.

Templates for flute, oboe, clarinets (B-flat[1], and bass), the saxophone family (alto, tenor, baritone), trumpet, horn, trombone, euphonium, and tuba were created (see Figure 1). The templates have the following in common: four pitches per instrument; at least one low, medium, and high pitch unique to each instrument's tessitura; and at least one "standard" tuning note in the four collected pitches. The 37 instrumentalists who participated in the study were: five flutes, one oboe, six B-flat clarinets, one bass clarinet, two alto saxophones, two tenor saxophones, two baritone saxophones, nine trumpets, three horns, three trombones, one euphonium, and two tubas. All were college students with at least six years playing experience; about 65% were music majors.

Figure 1

Sample Data Collection Form (Clarinet)



For this research, musicians were given both a bell cover and a filter. These bell covers were customized to fit each instrument. As advertised on the manufacturing company website, they were all black in color and made from 7-ounce fabric of 80% nylon and 20% spandex. Prior to the experiment, all musicians except flutes placed the bell covers on the instruments and reported no difficulty of fit. As an alternative to bell covers for flute, the school purchased transparent, plastic shields to be placed on the head joint of the flute. The filters used were cut from white, Merv-13 air filtration material, and were about 2mm in thickness. Although the filters were cut to fit the bell of each wind instrument, students of larger instruments reported considerable difficulty

[1] "B-flat clarinet" (also known as "B-flat soprano clarinet" or just "clarinet") in this study refers to the most common instrument of the clarinet family.

fitting them under the bell cover without the material collapsing into the bell. Before data collection, the instruments were inspected to ensure that cover and/or filter fit only along the external circumference of the bell. Collection of data took place in November 2020 in the university's instrumental rehearsal hall.

Before testing each instrument, each student was asked to play for about ten minutes. No attempt was made by the researchers to tune the instrument before testing. Musicians all sat six feet away from the recording source, a 10.5-inch iPad Pro running iOS software version 14.3. The iPad was placed such that only the researcher, and not the student, could see the screen. For pitch collection and measurement, we used the measurement app Tonal Energy Tuner (version 2.0.1) with the following settings:

- transpose: C
- A= 440.0 Hz
- equal temperament
- "wind" mode, "medium" in-tune range, and "slow" damping
- "tone meter sensitivity" set to 9.0
- pitches were collected in "analysis" mode (see Figure 2)

For this experiment, "in tune" referred to a pitch that is neither sharp (higher) nor flat (lower) than the standard Equal Temperament pitch for that note. Each time the musician performed a pitch, a reading was taken to measure the variance from "in tune." A note played perfectly in tune would be measured as "0 cents" or "0," meaning the note would be neither sharp nor flat. For a note sharp to the pitch, the amount of sharpness was measured in hundredths of a half-step ("cents"). A musician performing the note 10/100 half-steps sharp was recorded as "+10." A musician performing the note 10/100 half-steps flat was recorded as "-10." Three seconds after the start of each pitch performance, the intonation (tuning) of each pitch was recorded onto the data collection form. Each datum was entered to the nearest cent. A sample reading for baritone sax is shown in Figure 2. In this case, the datum for this pitch was recorded as "-8."

Figure 2

Sample Data Collection from Tonal Energy: Irregular Waveforms From Verbal Instruction

For each instrument, pitch/data collection began with the instrument performing "open," with no bell cover, air shield, or filter. Beginning with the lowest of the four reference pitches, each musician was asked to perform each of the four pitches from the data collection form for about five seconds, with no vibrato. This baseline collection then consisted of four iterations per note, for a total of 16 pitches. Next, each musician was asked to place the bell cover (air shield for flute) on the instrument. Using the manner described above, each musician played another set of 16 pitches for the same four notes, in the same order. Finally, both the filter and bell cover were applied to instruments, except flute and horn. Each musician then played a final set of 16 pitches. For the flute and horn, no filter was used, as we considered the use of filter for these instruments inherently inappropriate. For flute and horn, pitches for "instrument plus bell cover plus filter" were neither performed nor analyzed.

After the data collection for instruments, there were (except for flute and horn) a total of 48 pitches collected per person. For the flute and horn, 32 pitches were collected per person. Since there were four iterations of each pitch collected, the four iterations were averaged together to produce a mean pitch deviation for that note. Each musician therefore played four pitches—each four times for a total of 16 pitches played—with an intonation mean calculated for each "open" pitch. The musicians then played 16 pitches (each of the four pitches played four times) using bell cover/air shield with an intonation mean calculated. Finally, all musicians except flute and horn played 16 pitches (each of the pitches played four times) using bell cover and filter with an intonation mean calculated. In a few cases involving brass instruments in the lower register, the pitch was unsteady even after three seconds of performance. In these unusual instances, the datum was not collected; the student was told to wait a few seconds, take a slow, deep breath, and try again. The collected raw data can be viewed at

https://www.dropbox.com/s/ws0whnrts79amkw/ResearchData.xlsx?dl=0.

With only the exceptions detailed above (flute and horn), there were then three conditions under which each note was played by each musician, a note with no alterations made to the instrument that served as a baseline for comparison, and two experimental conditions: a note played with a bell cover on the instrument, and a note played with both a filter and a bell cover placed on the instrument.

In this study, the two primary questions were whether or not there was a measurable change in pitch due to bell cover and/or cover and filter together on each instrument. In the event of a negative answer to questions one and two, the analysis would end in a "nothing to see here, move along" type of conclusion. However, because of the possibility of a positive answer to question one and/or two, we considered two additional variables: the family of the instrument (brass or woodwind) and the note relative to the tessitura of the instrument (low, low-middle, high-middle, or high). Readers whose expertise lies in a more musical than statistical direction may benefit if the process of determining how these factors affect the pitch change is described in some detail. When statistically modeling two variables such as family and note as done in this study, additional questions must be examined. The third question to be examined in this study is then: 3) Is there an interaction between the effects of family (woodwind or brass) and note (low-to-high tessitura) on intonation?

Of course, this is a complicated question. For example, it might be the case that a brass musician experiences a large increase in pitch on the lower notes and a slight decrease in pitch on notes higher in the instrument's tessitura, while a woodwind player might note a slight increase in pitch on the lower notes and a large increase in pitch on the higher notes. Such models might be helpful for prediction but make succinct interpretation difficult. Any question of "What is the effect of family?" must be immediately followed by a question of, "What is the effect for which note?" and vice-versa. If the answer to question three is negative, these "marginal" questions can be given meaningful answers without the need for follow-up, thus the final two research questions: 4) In the absence of interaction complicating interpretation, does the particular note being played by the musician have an effect on intonation? and 5) In the absence of interaction complicating interpretation, does the family (brass or woodwind) of the instrument being played by the musician have an effect on intonation?

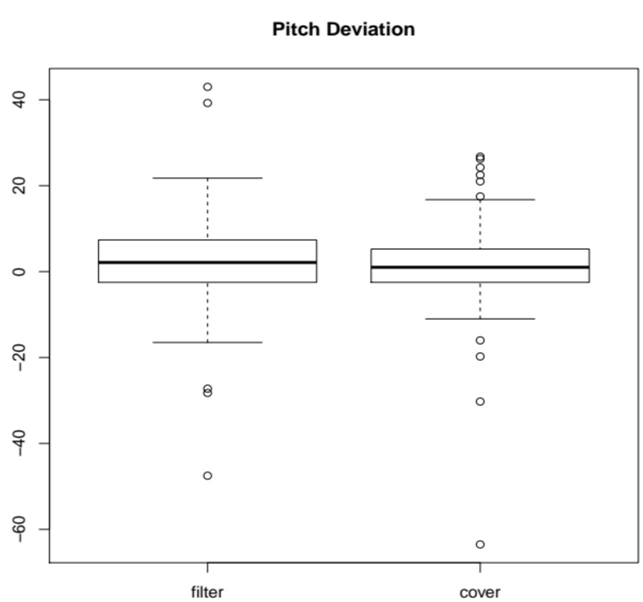
The data were assembled in a form that could be read by the "R" statistical program. R is a system for statistical computation, consisting of a language plus a run-time environment with graphic output, a debugger, access to certain statistical system functions, and the ability to run programs stored in script files (Hornik, 2017). The program was used to perform paired T-tests to address questions one and two, followed by F-tests from a two-way Analysis of Variance (ANOVA) model with interactions to address the rest of the questions. The purposes of the tests were to look for a significant non-zero mean difference between filtered and covered notes from the uncovered note and to determine if instrument family and the note played had an effect on any difference. The software package also produced graphics to accompany the linear models, some of which are shown here.

Results

We used a paired *t* test to answer questions number one and two. Figure 3 is a box-and-whisker plot analysis of pitch deviation for both filter and cover on the left side plot, and with cover only on the right, plotting for each instrumentalist the difference in pitch between the modified and unmodified (no cover, no filter) note. For both groups, a null hypothesis of a mean difference of zero (H_o: $\mu = 0$) was assumed, versus an alternative of a non-zero mean difference (H_a: $\mu \neq 0$).

Figure 3

Box-and-Whisker Plots of the Pitch Deviation (in Cents) in Both Conditions

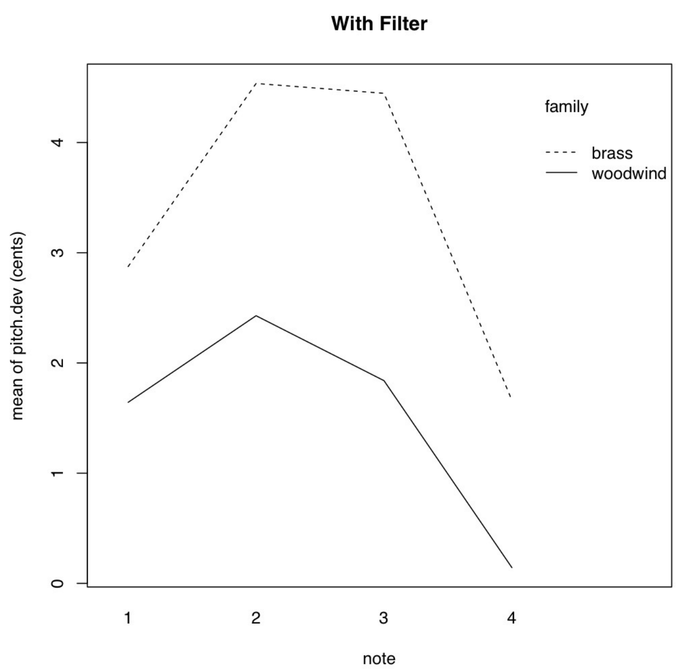


Musicians performing with a bell cover produced notes that were, on average, sharp 1.4 cents (SD=9.7) relative to the notes played on their unmodified instruments, though this difference was not statistically significant $t(143) = 1.72$, $p = 0.088$. A 95% confidence interval for the mean deviation in pitch for the cover alone was between 0.25 cents flat and 3 cents sharp. When performing with both a filter and bell cover, the notes were on average sharp 2.4 cents ($SD = 10.34$) relative to the notes played on unmodified instruments. This difference was significant, $t(111) = 2.50$, $p = .014$, even allowing for a Bonferroni adjusted cutoff of 0.025 due to multiple tests. A 95% confidence interval places this mean deviation between 0.25 and 4.00 cents sharp. The effect size here is small, $d = 0.23$, but given that the units here have physical meaning, they are interpreted later.

To answer questions three through five, there was an examination of the effects of family and note on pitch within only the filter/bell cover group of pitches, as this was the group in which was detected a difference. Recall that interpretation was complicated by the presence of any interaction between the effects of family and note on pitch. A trace of mean pitch deviation versus note played, by instrument family, is given in Figure 4, and suggests little evidence of any interaction.

Figure 4

Deviation of Pitch from the Mean by Note, Using Filter and Cover, Separated by Family



The data was analyzed using an Analysis of Variance, treating the note as an ordered factor, from low pitch to high pitch. Testing first for interaction, the computed result was $F(3, 104) = .024$, $p = .995$, leading to the conclusion for question three that there was no evidence of significant interaction between instrument family (brass or woodwind) and note (tessitura) on pitch.

In Figure 4, the brass family appears to have a sharper average deviation from uncovered pitch overall, and there is a higher average deviation from uncovered pitch on the two notes in the middle range of instrument tessitura versus the low and high note. Analysis of Variance again was used to test these differences for statistical significance. With regard to the note played, the computation of $F(3, 107) = .341$, gave a result of $p = 0.796$, concluding that the data indicated no reason to suspect that the higher average deviations observed in the middle of the instruments' tessituras was due to anything other than random chance. With regard to the instrument family, for the null hypothesis of no effect of instrument family on average deviation on pitch, the computation of $F(1, 107) = .895$, gave a result of $p = .346$. Again, the data indicated no reason to suspect any difference in mean pitch deviation between the brass and woodwind instrument families. Figures 5 and 6 give another look at the effect of note and family on pitch deviation.

Figure 5

Plot of Pitch Variability of all Instruments by Note, from Lowest Pitch to Highest Pitch

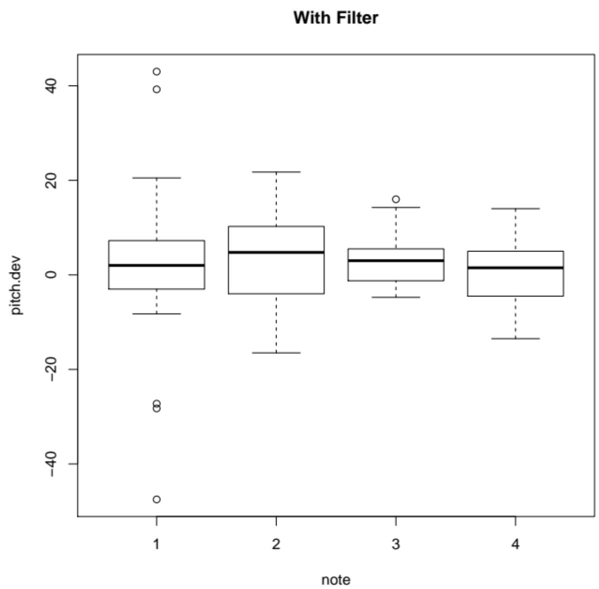


Figure 6

Box-and-Whisker Plot of Pitch Deviation from Mean, Using Cover With Filter, by Family

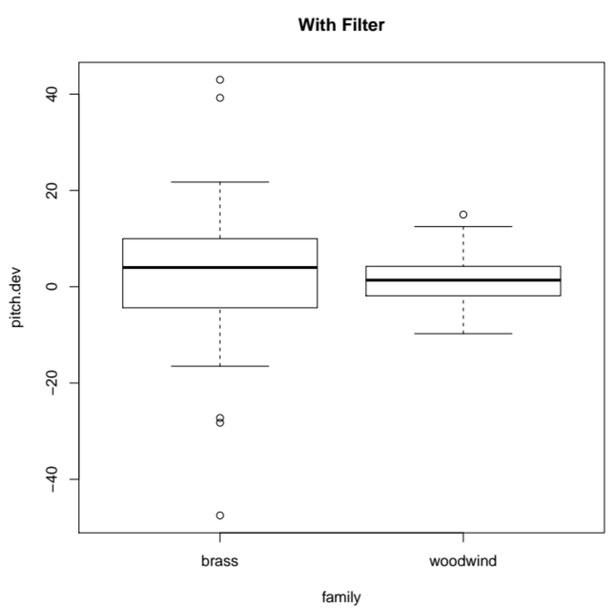
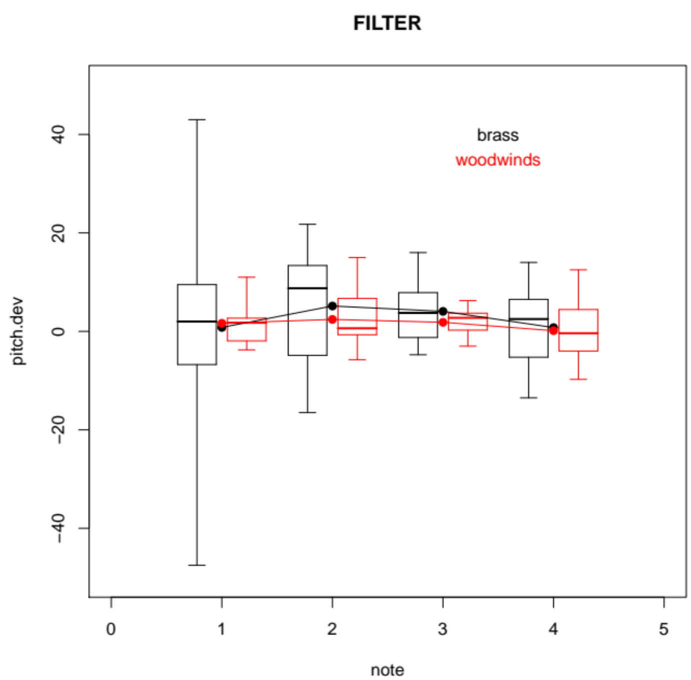


Figure 7, a version of Figure 4 with the raw data boxplots superimposed over the means, gives an indication that while the variability is perhaps higher in brass instruments in general, the variability is quite a bit larger when considering the lowest note in each instrument's tessitura. Bearing in mind that this extra variability might mask a small difference, the Analysis of Variance was recomputed, excluding the lowest note. The conclusion again was that there was neither a significant interaction between instrument family and note, $F(2, 70) = .05$, $p = .95$), nor a significant marginal effect of either instrument family, $F(1, 72) = 1.14$, $p = .29$, or note, $F(2, 72) = .988$, $p = .38$.

Figure 7

Box-and-Whisker Plot of Pitch Variance (in Cents) for Filter With Cover, Taking Into Account Both Ordered Pitch (Low to High) and Instrument Family



In summary, the use of both a cover and a filter made the mean pitch a little sharper. The use of bell cover alone caused a smaller variability in mean pitch, but was not consistent in either direction. The answers then to questions one and two are: yes, the mean pitch changed a little and no, the use of a cover alone had no significant effect. The answers to questions three, four, and five are: there was no significant difference on mean pitch intonation when looking at the role of family or tessitura. There was also no interaction between family and the note being played.

Discussion

This research suggested there is a slight tendency for the mean pitch to sharpen when using both a bell cover and filter. Will a listener perceive this level of sharpness? There is a considerable body of research already published regarding pitch discrimination, especially as to the ability of a musician to determine whether a pitch is sharp or flat. Some research has shown a tolerance for sharpness (Geringer & Sogin, 1988) that relates to these findings. If indeed the use of bell cover and filter has some inclination to sharpen the pitch of wind instruments, this change of intonation would be more tolerated by the ear. The register or octave of the instrument producing the pitch should also be considered. This research suggested a tendency for lower-pitched instruments to be more varied in pitch when using a bell cover and filter. There has been some research done already as to the ability of musicians to play in tune when a pitch stimulus is given by a higher-pitched instrument, compared to a lower-pitched instrument (Byo, Schlegel, & Clark, 2010). In that study, participants were asked to tune to a flute, oboe, clarinet, and tuba. The results of that study suggested participants were more likely to play out of tune when responding to the reference pitch from the tuba. In our study, when using both a filter and cover, the biggest pitch deviation sharp from an uncovered note came from the tuba; the biggest pitch change flat from an uncovered note came from the trombone. The implications of the compounding of error of improper tuning from an incorrect reference pitch are clear.

The next consideration was the amount of mean pitch deviation. In the findings of this research, when using both cover and filter, the mean pitch deviation was about 2/100 of a half-step sharpness, colloquially known as "two cents sharp." How well can a musician hear such a small difference in tuning? Regarding this topic, there is already extant research. In the areas of music perception or psyschophysics, the term used for the ability of at least half a population to hear a detectable difference in pitch is just-noticeable difference, abbreviated as "JND." The JND for frequencies below 500 Hz (below C5) is about 3 Hz and the JND for frequencies above 1000 Hz is approximately 0.6% of the frequency of the note (Kollmeier, Brand, & Meyer, 2008). We then compared two pitches from this study, one from a lower-pitched instrument and one from a higher-pitched instrument. For the tuba, we examined one of the pitches collected, B-flat2 (116.54 Hz), a common tuning note for bands. If the tuba were to perform this note two cents (2/100 of a semitone) sharp (the possible pitch mean variation with bell cover and filter shown in our research), would a listener be likely to hear the difference? A sharpness of two cents to this pitch would result in the tuba playing 116.68 Hz. This difference would certainly be far less than what would be perceived as JND. In this case, a JND of sharpness for the tuba performing B-flat2 would be 119.54 Hz. The two tubas in our sample played this particular note only 0.75 cents sharp and 1.25 cents flat (averaging 0.25 cents flat for this particular note) when playing with filter and cover, although it should be noted that across all notes the tubas played as much as 43 cents sharp and as much as 28.25 cents flat, suggesting that in practice there may be a substantial variation from the mean of -0.25 cents in this study.

Mean pitch deviation of an oboe performing a note in its upper tessitura, using bell cover and filter, was examined next. The note C6 (1046.50 Hz) for the oboe was the highest pitch collected with both a bell cover and filter (recall that in this study the flute did not use a filter). The difference between the frequencies of C6 and C-sharp6 is 62.23 Hz, and one cent difference in pitch from C6 to C-sharp6 is 0.6223 Hz. If the JND for this frequency is 0.6%, that would mean for a listener to perceive the C6 as "sharp," the C6 would have to be played at 1052.78 Hz, 6.28 Hz sharper than the standard C6 pitch. The JND of sharpness for C6 is then ten cents, but the average in this instance suggests that one would expect the oboe performing C6 with both bell cover and filter to be about three cents sharper, significantly less than the JND for this pitch. Again though, it should be noted that the variability of the actual pitch deviations observed around the average pitch deviation casts a shadow of doubt when considering only the average. The actual pitch deviation observed when an oboe played C6 with cover was 8.75 cents, only slightly lower than the JND of ten cents.

Planning for and compensating for a small mean pitch deviation of two to three cents in an ensemble setting may therefore be both unnecessary and impractical, given time constraints inherent in school rehearsal settings. Nevertheless, the actual pitch deviations that occur due to the inherent variance about that mean may veer into a range detectable by trained musicians, and cause noticeable issues for both musicians and listeners.

Recommendations

The most obvious limitation in this study was the small sample size. Would there be less, about the same, or more deviation with a population of, for example, over a hundred musicians sampled? What we hope to inspire from this research is a larger study involving several universities in diverse locations. As university setting in this study is a smaller Division 2 NCAA school, and the ensemble has in it both music and non-music majors, does the level of university have an effect on pitch mean, deviation from mean, or degree of intonation? Again, this is an unknown; we encourage other researchers to continue to examine these problems at different levels of higher education institutions. As we found a mean deviation of about two cents sharpness when using both bell cover and filter, one must evaluate how likely it is a listener could discern such a change. Since pitch discrimination varies by training and experience, this topic is appropriate for further research. A further recommendation arises from the huge variability in the performed pitch around the overall mean, particularly among the brass instruments in the lowest register. We recommend that for brass musicians with less experience, the lowest note in any future study be moved to a slightly higher pitch (for example, B-flat1). Because it seems likely that the Covid-19 pandemic will continue to affect instructional practice, the use of bell cover or cover with filter will probably continue to some degree. It is our hope that this research inspires other musicians and mathematicians to work collaboratively on the effects of these instrument modifications on pitch. Finally, as ten of the student musicians spontaneously opined that the tone quality was noticeably different when using both filter and cover, a related and important area of further research would be the effect on timbre of using an air filter and bell cover.

Keywords: music, Covid-19, filter, bell, cover, pitch, instrument, JND

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Adjustments of Elementary Music Instruction for Students with Disabilities: A Pilot Study

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Elementary music specialists teach all students in all grades at their schools, which requires the preparation of a variety of lessons simultaneously. As a result of seeing 100% of the student population, elementary music teachers host more students with disabilities than a general classroom teacher would in their class. Depending on the severity of students' disabilities, some students require alterations to general music lessons. In this study, we surveyed regional elementary music teachers (N = 15) to discover what disabilities were prevalent in their classes and if activities were adjusted. By examining the characteristics of the disabilities listed in the Individuals with Disabilities Education Act, we split disabilities into three groups: physical, cognitive, and emotional and behavioral disabilities. We surveyed elementary music educators on the prevalence of disabilities in their classrooms, to what degree educators adjusted their instruction for those students, and whether growth was seen in those students through musical instruction. Results revealed that all educators tailored their instruction in some way to serve students with disabilities. Educators mostly adjusted in the planning beforehand and while teaching their students. The most overall growth (musical, academic, and social) was seen in students with emotional and behavioral disabilities. Further research is needed in elementary music curriculum adaptation and modification, including pre-service and in-service music teacher training in working with students with disabilities.

Since the Education for All Handicapped Children Act (EAHCA) in 1975, students with disabilities have received increasing support and interactions through the American public school system. In 1990, EACHA was changed to the Individuals with Disabilities Education Act (IDEA) and was amended twice (1997, 2004) to provide appropriate education to students in their least restrictive environment. In addition, IDEA ensures that *all* children deserve safe schools, and educators should have adept resources for their students (Kauffman et al., 2017). Disabilities listed under categories in IDEA are autism, deaf-blindness, deafness, emotional disturbance, hearing impairment, intellectual disability, multiple disabilities, orthopedic impairment, other health impairment, specific learning disability, speech-language impairment, traumatic brain injury, and visual impairment (IDEA, 2004). By examining the disabilities' characteristics, disabilities fall into three groups: physical, cognitive, and emotional and behavioral disabilities (see Table 1) (Kauffman et al., 2017).

Table 1

Disabilities Categorized by Characteristics (Kauffman et al., 2017)

Physical Disabilities	Cognitive Disabilities	Emotional and Behavioral Disabilities
Visual impairment	Autism spectrum disorder	Autism spectrum disorder
Deafness	Specific learning disability	Emotional disturbance
Deaf-blindness	Intellectual disability	Multiple disabilities
Orthopedic impairment	Traumatic brain injury	
Speech language impairment	Multiple disabilities	
Multiple disabilities		

Note. Due to the nature of some disabilities, certain disabilities may appear in more than one characteristic group.

Over the years, public school music educators have experienced an increase in students with disabilities in their classrooms, especially elementary music teachers who teach 100% of the student population in a school (Hoffer, 2017).

Most research in music education on this topic focuses on teacher and music student attitudes, perceptions, and preparedness for teaching. Findings supported continued growth in K-12 teachers' attitudes and perceptions of teaching students with disabilities (Allan, 2022; Jones, 2015). Even though elementary music teachers are more likely to host students with various disabilities, relatively few studies focus on elementary music teachers' attitudes and perceptions toward teaching students with disabilities (Grimsby, 2020b; Scott et al., 2007). Grimsby (2020a) and Majerus and Taylor (2020) interviewed elementary music teachers and focused on the collaborative opportunities and needs between paraprofessionals and music teachers. Draper's (2021) findings further supported Grimsby (2020a) and Majerus and Taylor (2020) and reinforced the need for increased collaboration among music teachers, families, administration, and the special education team. Hammel and Hourigan (2017) agreed that collaboration should expand beyond the music teacher and paraprofessionals and that teachers should possess a positive attitude toward these students. Specifically, they stated success in teaching students with special needs requires an openness to working with members of a team, an inclusive philosophy and attitude, and "a great deal of time and effort as we seek to provide each student with what he or she needs to have the opportunity to succeed" (p. 98).

Regardless of teaching level or scenario, research findings revealed music teachers consistently lack training, knowledge, and resources on disabilities and teaching students with disabilities. Research showed this is the case for pre-service and in-service teachers (Allen, 2022; Hammel & Hourigan, 2017; Jones, 2015). Research involving fieldwork, coursework, or service-learning opportunities working with students with disabilities reflected an increase in pre-service teachers' attitude, knowledge, and confidence in teaching these students (Bartolome, 2013; Colwell &

Thompson, 2000; Hammel, 1999; Hourigan, 2007, 2009; Reynolds et al., 2005; Salvador, 2010; VanWeelden & Whipple, 2005). Hammel and Hourigan (2017) provided two challenges for universities: music-specific special education coursework and fieldwork opportunities. First, college professors lack experience and expertise in teaching students with disabilities. Second, there is little to no room for additional coursework in music education degree requirements and accreditation standards.

Despite the need for increased pre-service training, the opportunity for professional development for in-service teachers is available and effective (Allen, 2022; Hammel & Hourigan, 2017; Jones, 2015). McCord and Watts (2010) found informal peer training on students with disabilities as the most common among surveyed general music, band, choir, and orchestra teachers. While there are often fewer music-specific professional development sessions, in-service teachers benefit from any training on special education (Cooper, 1999; Grimsby, 2020b; Linsenmeier, 2004; VanWeelden & Meehan, 2016).

To create the least restrictive environment for students with disabilities, teachers must adapt, accommodate, or modify materials, space, time, and instruction.

McCord and Watts (2010) surveyed general music, band, choir, and string teachers and found that 85% of music teachers adapted goals and objectives for students with disabilities; however, only 9% of surveyed teachers felt competent in their skills to do so. According to Grimsby (2018), accommodations "allow students to learn the same material…with additional supports in place" (p. 382). She shared that modifications alter the material for the student to show understanding differently from their peers. Hammel (2017) recommended four "overarching teaching techniques to consider when adapting curricula. These four techniques include modality, pacing, size, and color" (p. 8). Few studies assess elementary music teachers' knowledge of what types of disabilities are in their classrooms and if and when adaptations occur in classes with these students. Knowing the prevalence of disabilities in elementary music classrooms and if and when teachers make adjustments for students with disabilities can guide administrators and researchers on specific professional development training for elementary music teachers, thus increasing the quality of music education for students with disabilities.

The purpose of this study was to identify types of disabilities in elementary music classrooms in the central Texas region and identify if and when lesson adjustments occurred for these students. Research questions include:

1. What are the most frequent disabilities seen by elementary music teachers in the central Texas region?
2. Are teachers more likely to plan *exclusively* ahead of time for adaptations, adjust instruction *while* teaching, or perform a combination of planning ahead of instruction *and* adjusting during instruction based upon the three categories of disabilities?
3. To what degree, if any, do teachers adapt instruction based upon the three categories of disabilities?
4. Do elementary music teachers see students' academic, musical, and/or social growth in each category of disabilities?

Method

Participants

Participants ($N = 15$) were certified elementary music teachers in Texas attending a regional Texas Orff-*Schulwerk* workshop. Each participant was a certified elementary music teacher in Texas. Participants' years of teaching experience ranged from 1 to 16 ($M = 5.4$, $SD = 4.14$).

Surveyed educators were from five local school districts in central Texas. Five participants had earned a master's degree ($n = 5$). Only five educators ($n = 5$) reported taking a special education course during college.

Procedure

During a break in the workshop, attendees were informed of the descriptive research study's purpose and invited to participate. Participants completed the survey on paper or through the online survey program questionpro.com. Paper surveys were collected. These responses were entered into the online system and aggregated with the online survey data. Survey questions included teaching experience, the prevalence of disabilities in their classrooms, and lesson modifications for students with disabilities (see Figure 1). The survey had 21 questions based on content validated by literature. Survey questions were screened, reworded, and vetted by a former elementary music teacher. The survey was divided into four sections: demographic and general information, physical disabilities questioning, cognitive disabilities questioning, and emotional and behavioral questioning. For each disability group, there were questions about the population of students with disabilities in their classroom, possible frequency and degree of adjustments, and growth seen in students through musical instruction. Questions were kept consistent between each group of disabilities to collect thorough and congruous information. Participants had unlimited time to complete the survey and were given a sticker as compensation. Participants finished the survey within 10 minutes.

Figure 1

Survey Given to Educators

Adapting Elementary Music Curriculum for Students with Disabilities

Circle the answers that best apply to your teaching experience. Please note survey continues on the back.

1. What is your ISD? ________________________
2. How many years have you been teaching? ____________________
3. What is your highest level of education? **Bachelor** **Master** **Specialist** **Doctorate** **Other**
4. Did you take a class on special education at any point in your university course work? **Yes** **No**
5. What disabilities are you aware of in your classroom (as categorized by the Individuals with Disabilities Education Act?
   a. Specific learning disability (dyslexia, dyscalculia, written expression disorder)
   b. Other health impairment (OHI, includes ADHD)
   c. Autism spectrum disorder
   d. Emotional disturbance (may include anxiety, schizophrenia, bipolar disorder, obsessive-compulsive disorder, and depression).
   e. Speech or language impairment (SLI)
   f. Visual impairment, including blindness
   g. Deafness
   h. Hearing impairment
   i. Deaf-blindness
   j. Orthopedic impairment (includes cerebral palsy)
   k. Intellectual disability
   l. Traumatic brain injury
   m. Multiple disabilities
   n. I do not have students with disabilities in my classroom.
6. Do you adjust your curriculum based on the specific disabilities of each student?

Yes, always **Yes, sometimes** **No** **I do not have students with disabilities in my classroom.**

This survey continues on the back side.

Physical Disabilities

Physical disabilities can range from orthopedic, casts, wheelchairs, limb differences, blindness, deafness, etc.

7. Do you have students with physical disabilities in your classroom? **Yes** **No**
8. Regarding students with physical disabilities, are you more likely to plan ahead of time for modifications or adjust while teaching?

   Plan ahead of time **Adjust while teaching** **Both plan and modify**

9. On average, how much do you modify activities for students with physical disabilities?

   Eliminate activity **Greatly modify** **Slightly modify** **Do not modify**

10. Have you seen growth in students with physical disabilities? **Yes** **No**
11. In what areas, do you see growth in these students with physical disabilities?

Musical **Academic** **Social** **Other** ____________________

Cognitive Disabilities

Cognitive disabilities can include autism, speech language impairments, brain injury, developmentally delay, etc.

12. Do you have students with cognitive disabilities in your classroom? **Yes** **No**
13. Regarding students with cognitive disabilities, are you more likely to plan ahead of time for modifications or adjust while teaching?

    Plan ahead of time **Adjust while teaching** **Both plan and modify**

14. On average, how much do you modify activities for students with cognitive disabilities?

    Eliminate activity **Greatly modify** **Slightly modify** **Do not modify**

15. Have you seen growth in students with cognitive disabilities? **Yes** **No**
16. In what areas, do you see growth in these students with cognitive disabilities?

Musical **Academic** **Social** **Other** ____________________

This survey continues on the next page.

Emotional and Behavioral Disabilities

Emotional and behavioral disabilities can include anxiety, bipolar disorder, depression, OCD, ODD, ADHD, etc.

17. Do you have students with emotional or behavioral disabilities in your classroom? **Yes** **No**
18. Regarding students with emotional or behavioral, are you more likely to plan ahead of time for modificatio or adjust while teaching?

    Plan ahead of time **Adjust while teaching** **Both plan and modify**

19. On average, how much do you modify activities for students with emotional or behavioral disabilities?

    Eliminate activity **Greatly modify** **Slightly modify** **Do not modify**

20. Have you seen growth in students with emotional or behavioral disabilities? **Yes** **No**
21. In what areas, do you see growth in these students with emotional or behavioral disabilities?

Musical **Academic** **Social** **Other** ____________________

Thank you for your participation.

Results

The number of educators with each IDEA disability category in their classrooms varied (see Table 2). The disabilities with the highest frequencies were other health impairment (*N*=15), autism spectrum disorder (*n*=14), emotional disturbance (*n*=14), and specific learning disability (*n*=13). Following in prevalence were speech-language impairment (*n*=11), intellectual disability (*n*=10), multiple disabilities (*n*=9), hearing impairment (*n*=8), and orthopedic impairment (*n*=8). The least common disabilities were visual impairment (*n*=6), deafness (*n*=3), traumatic brain injury (*n*=3), and deaf/blindness (*n*=0).

Table 2

Prevalence of Disabilities in Surveyed Educators' Classrooms

Disability	Number of educators (*n*)
Other health impairment	15
Autism spectrum disorder	14
Emotional disturbance	14
Specific learning disability	13
Speech language impairment	11
Intellectual disability	10
Multiple disabilities	9
Hearing impairment	8
Orthopedic impairment	8
Visual impairment	6
Deafness	3
Traumatic brain injury	3
Deaf-blindness	0

Regarding adjustment of lessons as a whole, 40% of educators (*n*=6) answered they *always* tailored their teaching based on the specific disabilities of each student, while the rest (*n*=6) answered they *sometimes* did. Of the educators who had students with physical disabilities (*n*=11), a majority of participants (*n*=7) slightly adjusted their activities while the rest of the participants (*n*=4) greatly adjusted their activities. Most educators (*n*=7) reported planning beforehand *and* while teaching students with physical disabilities. The remaining educators (*n*=4) adjusted *solely* while teaching. No educators answered that they only planned ahead without any changes while teaching. When assessing their students, almost all educators of students with physical disabilities (*n*=10) saw growth in their students. The most cited form of growth seen was social (*n*=10), followed by musical (*n*=8), and academic (*n*=2).

Of the educators of students with cognitive disabilities (*n*=14), seven reported greatly adjusting their activities, while the other seven slightly adjusted their activities. Most of these educators altered their lessons by planning beforehand *and* while teaching (*n*=9). The others adjusted *while* teaching (*n*=4) and *solely* by planning beforehand for adjustments (*n*=1). Nearly all educators (*n*=13) saw growth in students with cognitive disabilities. The most growth reported was musical growth (*n*=13), followed by social growth (*n*=11) and academic growth (*n*=6).

All participants (*N*=15) taught students with emotional and behavioral disabilities. Most educators (*n*=13) slightly adjusted lesson activities, while the rest (*n*=2) greatly adjusted activities. Most educators (*n*=9) planned alterations just before teaching *and* while teaching. The remaining educators (*n*=6) only adjusted *while* teaching. Regarding growth in students with emotional and behavioral disabilities, all educators saw social growth (*n*=13) as the most common, while growth (*n*=11) closely followed, and academic growth (*n*=6) was the least common.

Discussion

The educators in this study represented a variety of educational backgrounds, teaching experiences, and prevalence of students with disabilities in their classrooms. Only one-third of surveyed teachers (*n*=5) took a course on students with disabilities in their educator preparation programs. This finding aligns with existing research (Allan, 2022; Jones, 2015); furthermore, Allan's (2022) analysis of existing literature found not much had changed in preservice coursework on exceptional learners from 1999 to 2010 (Hammel, 1999; Salvador, 2010).

There was not a survey question asking where teachers received their degrees or if they were certified through traditional or alternative means. Because five educators took a course on students with disabilities, perhaps many of the surveyed teachers were certified in Texas or received alternative certification. In Texas, Educator Preparation Programs (EPP) must embed special education topics into existing coursework. Teachers who were certified through Texas EPP or alternative means likely received information on students with disabilities throughout their coursework. The central Texas region surveyed for this study includes a military base and R1 university, which can bring working spouses certified outside Texas. This may contribute to the five music teachers who took an undergraduate special education course.

Of the educators with master's degrees (*n*=5), only three completed a special education course. The area of graduate studies and students with disabilities is recent and growing, with results suggesting positive perceptions, increased confidence, and increased knowledge and skill in working with this population after completing a course or field experience (Culp & Salvador, 2021; Davila, 2013; Smith & Wilson, 1999). Further research is needed in graduate music education programs that offer or require courses for students with exceptionalities.

To answer the first research question regarding the most frequent disabilities seen by elementary music teachers in the central Texas region, we surveyed teachers (*N*=15) at a regional workshop. Table 2 reveals the prevalence of disabilities in surveyed teachers' classrooms, with cognitive and emotional and behavioral disabilities being the most common. This finding aligns with McCord and Watts (2010) and Frisque et al. (1994), who found that cognitive and emotional and behavioral disabilities are the most common in music teachers' classrooms.

The second and third research questions sought to answer if teachers were more likely to plan *solely* ahead of time for adjustments, tailor instruction *while* teaching, or perform a combination of planning ahead of instruction *and* adjusting during instruction. These questions also assessed how much alteration were done based upon the three categories of disabilities. To answer these questions, we surveyed educators on whether alterations occur for the three categories of disabilities (physical, cognitive, and emotional and behavioral). Overall, all educators adjust instruction for students with disabilities, and most changes are made beforehand *and* while teaching. This aligns with McCord and Watts (2010), who also found that most surveyed educators adapt their instruction, goals, and objectives at some level for students with disabilities.

Only 11 of the surveyed educators taught students with physical disabilities, and most educators (*n*=7) slightly adjusted their activities while the rest (*n*=4) greatly changed their activities. Survey results also indicated that most alterations (*n*=7) for students with disabilities were made before students arrived *and* while teaching. The remaining educators (*n*=4) made changes *exclusively* while teaching. Results suggest that teachers provide an informal diagnostic assessment for students with physical disabilities entering the music room. Grimsby (2018) stated, "Students with a physical/orthopedic disability may or may not have additional learning disabilities" (p. 390). Because the severity of any disability ranges, many educators may not adjust for the day's lesson. Perhaps teachers who plan beforehand *and* while teaching try to accommodate assistive devices, such as wheelchairs, walkers, and canes. Of the educators who slightly adjusted their lesson activities (*n*=7), only four answered that they implemented lesson alterations during planning and while teaching. The remainder responded that they *only* adjust while teaching. How and when educators make alterations is an area of further research.

Half of the educators (n=7) who answered they taught students with cognitive disabilities (n=14) admitted to adjusting their activities greatly. In contrast, the other half of educators indicated that they only slightly adjusted their activities. In addition, results suggest that most alterations (*n*=9) were made before student arrival *and* while teaching. The remaining educators indicated they primarily adjust *while* teaching (*n*=4) or *solely* before student arrival (*n*=1). A factor to consider regarding the level of changes made by educators is the severity of each disability, ranging from mild, moderate, severe, and profound (Grimsby, 2018). Hammel (2017) explained that adjustments for cognitive disabilities may be related to pacing and presentation of materials. Students might require repetition of material, learn better from a different presentation modality (visual, aural, or kinesthetic), or struggle with reproducing and synthesizing material. Educators might find some restructuring more effective in their planning or more effective while teaching. Student responses to different accommodations may also vary due to the severity of their disability. This is an area of further research.

All surveyed educators taught students with behavioral and emotional disabilities. Almost all educators (*n*=13) slightly adjusted their activities, while the remaining educators (*n*=2) greatly adjusted their activities. Results show that most educators (n=9) altered their activities before student arrival *and* while teaching. The remaining educators (*n*=6) answered that they made changes *solely* while teaching. While Chen (2007) found that teachers had positive results planning in light of students' behavioral characteristics, behavioral and emotional disabilities have an unpredictable, multilayered nature that may make planning beforehand tricky or even futile. Lewis and Doorlag (2006) explained that the aims of accommodations for students with behavioral and emotional disabilities are often to help regulate behaviors and help students identify the consequences of positive and negative behaviors. The ultimate goal for educators in these situations was to "identify and assess situations that may be difficult for students before they reach a point of crisis" (Hammel, 2017, p. 72). Due to the nature of these disabilities, it is reasonable to assume that teacher planning and alterations frequently vary between students and student responses.

Research question four queried if elementary music teachers saw academic, musical, and social growth in students in each category of disabilities. Nearly all educators (*n*=13) reported social, musical, and academic growth in their students with disabilities. Across disability categories, social growth received very high scores. Specifically, social growth was the highest category in students with physical disabilities (*n*=10) and students with emotional and behavioral disabilities (*n*=13). One educator freely responded and said growth in confidence and self-esteem was observed in a student with physical disabilities. In another free response, an educator stated they observed growth in self-behavior management. This finding aligns with Grimsby (2018), who also saw social growth in her experiences in teaching students with disabilities. Social growth was the second-highest growth category in students with cognitive disabilities (n=11). Kalgotra and Warwal (2017) found that music intervention that included a range of activities from singing, chanting, and playing a drum effectively avoided violent, destructive behavior in students with intellectual disability. The strong social growth across disability categories may be credited to the diverse and collaborative opportunities elementary music classrooms offer in movement, performance, and listening activities (Küpana, 2015). This observation is congruent with research supporting the natural connections between music and social-emotional learning (Donovan, 2020; Edgar, 2017; Raschdorf et al., 2021; Varner, 2019).

The survey respondents were also asked whether they observed musical growth in their students with disabilities. It was the highest growth category for students with cognitive disabilities (n=13) and the second-highest growth category for students with physical disabilities (n=8) and emotional and behavioral disabilities (n=11). It is expected for all students, including students with disabilities, who receive music instruction at school to experience musical growth. Regarding musical growth in students with disabilities, there is little research. Draper (2017) observed four students with specific learning disabilities or speech-language impairments in a music class and found these students performed singing or playing instruments accurately or mostly accurately and answered music theory and literacy questions correctly. While the current study did not individually assess musical growth in students with disabilities, surveyed teachers observed musical growth in their students with disabilities, which is consistent with Draper's (2017) results. The topic of musical growth in students with disabilities is an area of future research.

Academic growth was seen the least in all three categories of disabilities (physical, cognitive, emotional and behavioral). This could be because the elementary music teacher is not with the students much outside the music classroom to know if academic has occurred. Like musical growth, academic growth is expected since all students in elementary schools should experience academic growth. While it is unknown whether participation in music classes increases students' academic growth, Darrow and Armstrong (1999) concluded that music classrooms were able "to provide a positive environment in which students with autism can succeed academically while behaving appropriately" (p. 17). Whipple (2004) conducted a meta-analysis and found music to be supportive in assisting students with autism, yet it is not established if music is the cause of increased academic achievement in students with autism or other disabilities.

This study was completed as a starting point for future research in this area. It laid the foundation to assess educator interaction with students, action in adjustments, and knowledge of working with students with disabilities. With this knowledge, future studies can address the specific needs of teachers in this area. Future research will aid the needs and questions precisely articulated by educators active in the profession of teaching to benefit them, their students, and their students' learning. More specifically, practical research can be conducted to explore the general climate surrounding working with students with disabilities.

Limitations of this study include the limited sample size and generalizability. Further research includes replicating this study with a larger sample size of statewide or nationwide elementary music teachers to allow for generalizability in findings. Expanding this research will allow for further advances in the study of music education for students with disabilities without limitations. In addition, more research can be conducted to assess educators' knowledge of the characteristics and standard adjustments for disabilities in their classrooms. Lastly, future research monitoring musical growth in students with disabilities through assessment would add more depth to these studies.

In conclusion, music education for students with disabilities contributes to their growth. Music is a powerful tool that can benefit children of all ages and abilities (Fix, 1999). Researchers can assist in exploring the frequency and magnitude of growth that educators observe in their students. Assessing how educators tailor their instruction for students with disabilities in their music classrooms can also lead to more knowledgeable and better-equipped educators. One participant stated:

> The music classroom is a generally inclusive setting where the teacher and peers often adjust to accommodate and include learners with special needs. It is a beautiful thing to witness. That being said, thinking of those special needs prior to instruction is critical to student success for all learners.

By incorporating all students in the classroom in the best way possible, educators are making way for a new generation of robust, meaningful music education.

Keywords: students with disabilities, elementary music instruction, prevalence of disabilities, growth (musical, social, and academic)

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