The purpose of this study was to review research studies in the area of string technique and pedagogy. Nearly 50 research reports were reviewed and categorized into those concerned with predictions of success in a string program, class organization, and the development of right- and left-hand position. Results of various studies were reported and implications for teaching were discussed.

Each and every day string educators are asked to decide how best to teach their students. Many base decisions on the ideas of influential pedagogues such as Shinichi Suzuki or Paul Rolland or recall the way that they themselves were taught. Teachers also draw from personal observations in the classroom and anecdotes from other teachers. Research in string education may also be used as a basis for choosing between alternative methods of instruction.

Many teachers, though, are unaware of the string education research that has been conducted and the direct implications of this research on everyday teaching. The studies cited in this article directly address commonplace problems and the results can serve to guide teachers in their decision making. String education research is a very young field and the purpose of The Journal of String Research is to highlight the need for string research and disseminate this research, not just to other researchers, but to string teachers.

The purpose of this article was to collect research focusing only on the teaching of string technique. Studies which reviewed method books or were descriptions of specific pedagogues, such as the Suzuki method, were not included. Also not included in this review were studies which developed and tested new methods which have not since been published and thus would not be widely available to the public school string teacher. This survey will focus on a number of questions which have, in one form or another, been explored by researchers.

- Can success in a string program be predicted based on students’ grades or physique?
- Do students learn faster when taught in homogeneous classes rather than a heterogeneous setting?
- Do students progress faster with individual instruction rather than class instruction?
• Is it beneficial for string students, other than cellists, to sit or stand while performing?

• Does a period of rote instruction before the introduction of notation aid in the development of technique?

• Does a period of rote instruction hinder the development of sight-reading abilities?

• Are students more successful in learning an appropriate bow hold when first taught to hold the bow with the thumb under the frog? At the balance point?

• Are students more successful when initially taught using short or long bow strokes?

• Are students more successful in learning spiccato when initially taught to hold the bow at the balance point?

• Is it beneficial to begin violinists and violists in a transverse (guitar) position before shifting the instrument under the chin?

• Is there an advantage to starting violinists in third position rather than first?

• Do finger placement markers aid in the development of left-hand position and/or intonation accuracy?

• Does teacher intervention aid in the correction of left-hand position?

• Does the presence of accompaniment aid students in developing rhythmic skills and/or intonation accuracy?

• Do chamber music experiences aid in the development of intonation accuracy?

• Do string players tend to perform certain pitches out of tune? Can intonation problems be anticipated?

• Does teacher intervention facilitate intonation accuracy?

• Does vibrato speed and width vary across instruments?

This article demonstrates that a foundation for string research exists. Many of the most hotly debated topics in string teaching have been researched. This article will also demonstrate the need for replication to solidify the research findings.
**Prediction of Success**

Prior to enrollment in a beginning string program, many teachers advocate screening students to determine which may be the most successful on a string instrument. Various tests of achievement and musical aptitude, as well as specific physical features have been used as possible predictors of success. Stancarone (1992) measured musical aptitudes (grades on standardized aptitude tests and dexterity tests), teacher-reported behavioral characteristics and classroom conduct, and academic achievement (report card grades and grades on a standardized achievement test) of 114 string students. He compared these measures with success in a string class, as determined by the number of pieces “completed”. Stancarone found that the best overall prediction of success in the string program was the combination of all aptitude and achievement variables ($R = .67$). The two single best predictors were scores on achievement tests ($R = .47$) and scores on the music aptitude tests ($R = .46$). It should be noted that this study consisted of subjects already enrolled in a string program and not students who were just beginning a string program. It is likely that many subjects who began instruction and subsequently dropped out were not represented in this sample.

Master’s (1979) measured muscular dexterity of grade school string students ($n = 56$) and university students enrolled in a string methods course ($n = 26$). Dexterity was compared with success on a string instrument (as measured by class grade) and found no significant correlation between muscular dexterity and performance competence on a string instrument for either the elementary or the university subjects.

While dexterity measures may not correlate highly with success in learning a string instrument, academic achievement and aptitude scores may help teachers determine which students will succeed on a string instrument.

**Class Organization**

There are many ways of organizing a beginning string class. Some teachers prefer to teach in a homogeneous setting, where students perform on one type of instrument, others prefer to teach in heterogeneous classes, where each instrument is represented. Opinions differ on whether a homogeneous setting, where the teacher can focus on technique and problems presented by one instrument, or a heterogeneous setting, which allows for an ensemble experience, is preferable. Van Camp (1989) investigated the achievement of 24 middle school, mildly mentally handicapped students taught either in a homogeneous or heterogeneous setting. Following the 12-week treatment period, subjects were rated on technique (body position, instrument position, bow hold on open string bowing), music (correct notes and rhythms, good intonation and tone, steady tempo, adequate left and right hand skills), and ear training. Van Camp found no significant differences in technique, music, or
ear training scores based on class setting.

Students (n = 52) enrolled in a university string methods course were subjects in Kantorski and Ellsworth’s (1988) study. Subjects received a total of three weeks of instruction on violin, viola, cello, and bass either in homogeneous, homogeneous in pairs (classes of either upper strings or lower strings), or heterogeneous classes. Following the treatment period, subjects were scored on visual performance (left-hand position, right position, general posture, bow contact point, whether the bow was parallel to the bridge) and aural performance (tone and intonation). Though Kantorski and Ellsworth reported no significant difference by group either in the overall performance scores, visual scores or aural scores, they did report a significant interaction in aural performance scores by instrument and group. Based on an interpretation of the interaction graph, violinists taught in the homogeneous setting performed better than violinists in the other classes. Cellists and bassists taught in the homogeneous in pairs setting performed better than cellists and bassists in the other classes.

Though the populations used by Van Camp and Kantorski and Ellsworth were vastly different, neither study found a significant difference in achievement between students taught in a homogeneous setting and those taught in a heterogeneous setting. The university students, though, may perform with better tone and intonation when taught in a homogeneous or homogeneous in pairs class.

Keraus (1973) sought to determine whether private rather than class instruction facilitated technical development. The subjects were either enrolled in Suzuki classes (n = 16) consisting of between three and five students or received only private lessons (n = 20) through the Suzuki program. After 41 weeks of instruction, the researcher reported no significant differences in performance ability between groups. Students receiving class lessons performed on a similar level to those receiving private instruction. Since the small Suzuki classes do not compare to the larger classes encountered in the public schools, the results of this study may not generalize.

Many teachers show a preference for asking violinists, violists, and bassists to either sit or stand while playing, but the effects of body position have only been studied in reference to bassists. Dennis (1979) recorded university bassists (n = 7) performing with three different body positions: Bass Standing Method; Student Standing Method; and Student Sitting Method. One major difference in these positions is that when the player is upright, the bass contacts the players’ leg which is not the case in the bass upright position. Dennis found no significant difference in intensity between the three methods of supporting the bass.
Dennis (1984) replicated the above study measuring performance quality and muscle tension, rather than intensity, of 40 university bass players. Each subject performed an orchestral excerpt with electrodes (placed both arms and upper and lower back) recording muscle tension. Subjects either performed using the Bass Standing Method (n = 8), Student Standing Method (n = 21), or the Student Sitting Method (n = 11). There was no significant difference in performance quality or muscle tension between the different methods of supporting the bass. Dennis also looked for an interaction between methods of bass support and bow hold (German v. French), but found no significant interaction.

The question of whether a lengthy period of rote instruction should precede the introduction of notation is a point of controversy in string education. Many method books include optional sections of rote instruction for use by teachers who wish to delay the introduction of notation. Glenn (1999) assigned 42, sixth-grade beginning string players to one of two groups: rote or note. Though the two groups were taught by the same teacher using the same method book, for the first three months of instruction the rote group learned all melodies by imitation without the use of notation. The note group, after a two week introduction to playing the instrument, were instructed in note reading and all melodies were learned using written notation. Following one year of instruction, students’ position and technique, tone quality, intonation, pitch and rhythmic accuracy, and sight-reading were rated. Glenn reported no significant differences in playing ability between groups. The three month period of rote instruction did not aid in development nor did the early exposure to note reading hinder development either on the prepared pieces or in sight-reading.

Though there are many ways to organize a beginning string class, based on the above findings, there was no quantifiable advantage to any of the choices. Similar development will occur when using rote or note instruction, heterogeneous or homogeneous classes, private or class instruction, or seated v. standing position.

**Right-Hand Technique**

A number of influential pedagogues have suggested ways of teaching beginning string students a proper, relaxed bow hold. Suzuki asked young students to hold the bow by placing the right thumb under the frog rather than bent between the frog and the stick, while Rolland advocated teaching the bow hold at the balance point first then gradually moving the hold towards the frog. Jensen (1990) taught 24 university students enrolled in beginning string technique classes either a traditional bow hold, a bow hold which placed the thumb under the frog (later the thumb was moved into a traditional bow hold), or a bow hold at the balance point (which was gradually moved towards the frog). After six weeks, subjects were rated on bow hand shape, bow
placement, elbow flexibility, aural rating of sound point and resonance, short bow control, long bow control, control of direction, control of speed and dexterity. Jensen reported that subjects who learned the traditional bow hold had a significantly superior hand shape than subjects in the other groups. Subjects who first learned the bow hold at the balance point had a significantly better hand shape than those who initially placed the thumb under the frog.

Gillespie (1988) taught 50 university students enrolled in a string methods class spiccato bowing using two different approaches: initially holding the bow at the balance point and gradually moving towards the frog, or using a conventional bow grip. Following the treatment of 90 minutes of spiccato instruction over a period of six days, the subjects’ spiccato was video-taped and rated on height of bounce, horizontal motion, quality of sound, finger motion, placement of bow on string for tempo, amount of bow hair on string, consistency of bounce, wrist motion, arm motion, balance, interaction between shoulder, elbow, wrist, and fingers, and left-hand shape. Gillespie reported a significant difference between groups only on bow placement (knowledge of the optimal place to touch the string), with subjects who initially held the bow at the balance point while learning spiccato scoring higher than subjects who used a conventional bow hold. Learning spiccato bowing, then, may be aided by holding the bow at the balance point and gradually shifting the bow hold towards the frog.

Lowe (1973) rated the tone quality of beginning string players who were either taught using long bow strokes (n = 9) or short bow strokes (n = 6). Lowe reported no significant difference in tone quality between subjects in the long and short bow instruction groups. It may not be surprising that the average length of bow stroke was longer for subjects in the long bow stroke group, however according to Lowe, subjects who were instructed with long bow strokes developed more bowing problems than those in the short bow stroke group. So while there was not an immediate difference in tone quality between students initially instructed in long and short bow strokes, long-term considerations may be important when choosing between the two methods of instruction.

Rosenbaum, Weber, Hazelett, and Hindorff (1986) conducted numerous experiments to determine whether repeated patterns were easier to replicate if the sequence was variable or fixed. Each violinist was asked to play D, E, F#, G repeatedly with a fixed or variable bowing pattern. In the fixed pattern, all four notes were hooked in a down bow. In the variable pattern, three notes were hooked on the up bow and then three notes were hooked on the down bow. The three note bowing pattern was found to be more difficult than the four note pattern. Removing fingering from the equation, the violinists were asked to perform a consistent bowing pattern (see Figure 1a), a variable pattern (see Figure 1b), and a fixed pattern that was the same length as the
variable pattern (see Figure 1c). The researchers reported that the variable bowing pattern was more difficult than the two fixed bowing patterns.

![Figure 1a. Fixed bowing pattern](image)

![Figure 1b. Variable bowing pattern](image)

![Figure 1c. Fixed pattern of similar length to variable bowing pattern](image)

Learning the traditional bow hold from the start, at least for university-aged beginners, resulted in a better bow hold than either starting the hold at the balance point or starting with the thumb under the frog. Placing the bow hold at balance point, though may facilitate learning spiccato bowing. Though tone quality is not affected by starting beginners either with long or short bow strokes, it is possible that long bow strokes may cause other bowing problems.

**Left-Hand Position**

By using verbal feedback, Salzberg and Salzberg (1981) attempted to remedy incorrect left-hand positions of five elementary school string students with consistently incorrect left-hand positions (defined as the left hand having more than two contact points with the instrument, bottom joint of the forefinger and the top joint of the thumb). All students received three different types of feedback: corrective feedback, (a verbal reminder to fix left-hand position every 30 seconds during a two-minute period), positive feedback (received every 30 seconds during a two-minute period), and intensive positive feedback (received four times per minute for 10 minutes). In both positive feedback groups, if no correct hand position was initiated by the subject, the teacher adjusted the subject’s left-hand position and when the correct hand position was maintained for three seconds, the teacher praised the left hand. The researcher concluded that corrective feedback and positive feedback had minimal effect on left-hand position. Intensive positive feedback produced a more durable and drastic effect on left-hand position.
A number of popular method books suggest that it may be beneficial to start beginning violinists and violists in a transverse, or guitar, position before the instruments are moved into place under the chin. Slayman (1965) asked fourth-, fifth-, and sixth-grade beginning violinists to practice pizzicato fingering drills in either a conventional violin position or in transverse position. Every two weeks, each subject was asked to play a D major scale as fast as possible. If a mistake was made, the subject would be asked to perform the scale at a slower tempo. The tempo at which the scale could be performed correctly served as the achievement score. Slayman found that the subjects who performed the scale in transverse position generally performed significantly faster than violinists in conventional position. Only the first achievement test showed no significant difference between groups. Slayman concluded that fingering was facilitated by holding the violin in a transverse position.

Beginning violinists in third, rather than first position may aid in the development of left-hand position as well as intonational accuracy. For children with small hands, the notes in third position lie closer together and the left arm does not have to extend as far as in first position. Further, it is more difficult to relax the wrist into a flattened position since the body of the instrument blocks this movement. Cowden (1970/72) taught 37 fourth-grade, beginning violin students for 16 weeks. Half of the subjects received third position instruction for 11 of the 16 weeks and first position instruction for the remaining five weeks and half were instructed in first position for 11 of the 16 weeks and third position for the remaining five weeks. Subject were then rated on intonation and rhythmic accuracy while performing a piece in first position, a piece in third position, and a piece which incorporated a shift between first and third position. Cowden reported no significant differences between the groups. The order in which the positions were taught had no effect on intonation or rhythmic abilities.

Maag (1974) compared the intonation accuracy of 146 fourth- and fifth-grade beginning string players who were taught using either diatonic or pentatonic melodies, but found no significant difference in intonation between the groups. Based on Maag’s results, there was no intonational advantage to eliminating semitones in beginning instruction.

To aid left-hand position as well as intonational accuracy, many teachers advocate placing markers on the fingerboard of string instruments which function much like frets on a guitar giving a visual indication of general finger placement. Smith (1985) placed finger markers a major second and a perfect fourth above the open strings of six students enrolled in a string methods course. Six other students did not use finger markers and the remaining six used finger markers for only the first eight weeks of the 16-week study. Subjects’ intonation was assessed at the end of eight weeks and at the end of
sixteen weeks. Smith reported no significant difference in intonation accuracy between groups and found no significant improvement in intonation over the course of the semester for any of the groups. Finger placement markers neither aided nor hindered intonational accuracy significantly. The fact that intonation did not improve over the course of the semester may be due to a ceiling effect since the subjects were all music students at a university. Thus, Smith (1987) replicated the procedure of this study using fourth- and fifth-grade beginning string students and assessed intonation over the course of one school year.

Twelve intact classes (n = 64) were assigned to one of three groups: finger markers, no finger markers, finger markers for 16 of the 32 weeks. Subjects’ intonation was assessed every eight weeks. Smith reported that intonation accuracy increased significantly over the course of the study for subjects who did not have finger placement markers, but did not significantly increase for subjects who utilized finger placement markers. Because there was a significant decline in intonation accuracy after week 16 for the subjects who had recently had finger placement markers removed, Smith concluded that finger placement markers did not significantly aid in the development of intonation accuracy.

Bergonzi (1991/1997) conducted a similar study, but randomly placed finger markers a major second and a perfect fourth above the open string on the instruments of half of 68, sixth-grade, beginning string students. Subjects were randomly assigned to the treatment groups without regard to intact classes, thus some students in the same class would have finger placement markers and others would not. Subjects were rated on intonation accuracy as well as tone quality, consistency of tempo, rhythmic accuracy, musical expression, ability to play patterns by ear, and sight-reading after 18 weeks of instruction and again after 34 weeks. After 18 weeks of instruction, subjects with finger placement markers demonstrated superior intonational accuracy when performing melodic patterns by ear and after 34 weeks of instruction, Bergonzi reported that students with finger markers performed significantly more in tune than those without finger markers both when sight-reading and when performing prepared pieces. Finger placement markers, though, did not have a significant effect on overall performance scores, overall sight-reading and imitation accuracy when performing by ear, nor did finger placement markers have a significant effect on left-hand technique.

Smith found that finger placement markers had no effect on the intonation for the college-aged musicians who may have utilized pitch matching skills obtained though years of musical study rendering the finger placement markers superfluous. For the younger students in Smith’s study, the process of developing intonation may just be delayed by the use of finger markers. Students who did not use finger markers showed a significant increase in
intonational accuracy throughout the study. Students who had the markers removed during the study showed a marked decrease in intonational accuracy. Bergonzi, on the other hand, reported that finger placement markers aided intonation accuracy on some tasks, though not on overall intonation scores.

Piano accompaniment is also utilized by teachers to aid in the development of intonational accuracy and rhythmic consistency. English (1985) surveyed 117 string educators concerning their use of piano accompaniment during rehearsal. Only 16 stated that they did not use piano during rehearsals. The accompaniment provided in the teaching manual, personal ad lib., or playing student’s parts on the keyboard were the most commonly used forms of accompaniment. Though the majority of teachers advocated using accompaniment for at least part of a rehearsal, it could be argued that an overuse of accompaniment creates student dependence which counters any benefit to intonation or rhythmic consistency. English taught 42 fourth-grade string players either with no piano accompaniment, piano accompaniment 100% of the rehearsal, or piano accompaniment 50% of the rehearsal. Following nine weeks of treatment, subjects were rated on intonation and rhythmic consistency. Subjects who performed without accompaniment had significantly better intonation and greater rhythmic consistency than subjects in the other groups. Subjects exposed to accompaniment for 50% of the rehearsal had superior intonation and rhythmic accuracy to those in the 100% condition.

Bergonzi (1991/1997) found a similar result when he divided intact classes of sixth-grade, beginning string students (n = 68) into harmonization and no harmonization groups. During one school year, half of the intact classes played with a specially-developed audio-tape accompaniment. Following 18 and 34 weeks of instruction, students were assessed on technique, including left-hand position, and musical criteria which included intonation, tone quality, consistency of tempo, rhythmic accuracy, musical expression, sight-reading, and aural imitation. On the first assessment (week 18) Bergonzi reported that subjects who were accustomed to harmonic accompaniment played significantly less accurately in tune than subjects who generally performed without accompaniment. Though Bergonzi reported no significant difference in intonation, left-hand position, or the ability to play melodic patterns by ear after week 34, students who practiced with harmonizations had higher overall performance scores than students who had not.

Geringer (1978) asked university string players (as well as wind players, keyboard players, and vocalists) to perform a major scale twice; once with piano accompaniment and once without. Scales performed with accompaniment showed less pitch deviation from equal temperament than those performed without accompaniment. Garman (1992) found a similar result when he asked university string players to perform a melody in different accompaniment conditions: unaccompanied, unison or octave doubling, single
voice harmonization, and triad or seventh chord harmonization. Garman reported that intonation was significantly better when the performers were accompanied rather than unaccompanied with the preferable accompaniment consisting of triads and seventh-chords. The accompaniments used in the Garman study were played either in the same register as the melody or an octave removed from the melody. Garman reported that the effects of register depended on the accompaniment condition and instrument. In general, there was more total pitch deviation when the subjects were accompanied in a distant register.

As in Garman’s study, Kantorski sought to identify which type of accompaniment would best aid intonation accuracy. Each subject performed ascending and descending whole-tone tetrachords in the upper and lower registers of their instruments with four different types of accompaniments: unisons, thirds, two octaves, two octaves and a third. There was a significant difference by groups, register, accompaniment interval, as well as a significant interaction between register and accompaniment interval. Kantorski found that unisons were performed with less total cent deviation in the upper register than lower register, but the upper register produced higher cent deviations for the other accompaniments. Cent deviation was the smallest in the lower register when the accompaniment was two octaves. While Garman found that an accompaniment consisting of triads was preferable to one consisting of a bass line or unisons, Kantorski found that when string players performed in a high register, unison accompaniment significantly aided intonation accuracy.

English (after nine weeks of treatment) and Bergonzi (after 18 weeks of treatment) both found that subjects performed better when accompaniment was absent. Bergonzi’s results, though, suggest an acclimation period during which young beginners to adjust to accompaniment since the presence of accompaniment appeared to aid intonation after 34 weeks of instruction. These results are not supported by Garman (1992) or Geringer (1978), both of whom found that the presence of accompaniment increased intonation accuracy. It is possible that there are differential effects of accompaniment on intonation accuracy. Elementary school subjects were studied by English and Bergonzi, whereas Garman and Geringer studied college string students. It is possible that certain populations, such as young beginners, may be hindered by the use of accompaniment while older string players may benefit from accompaniment.

Some teachers advocate including chamber music experiences to aid in the development of intonation accuracy as well as to develop independence in performers. Carmody (1989) compared the intonation of junior high school string players (n = 47) who played only in large ensembles with those who played in both chamber music ensembles (defined as any conductorless combination of instruments with one player per part) as well as large ensembles. Subjects who participated in chamber ensembles performed
significantly more in tune than subjects who did not have chamber music experiences.

The first step in correcting intonation problems is to identify the problems that tend to exist with string players. Almost without exception, researchers measuring intonation tendencies reported that string players tended to perform sharp (Geringer & Witt, 1985; Papich & Rainbow, 1974; Salzberg, 1980; Small, 1937; Sogin, 1989; Sogin, 1997; Yarborough & Ballard, 1990). Only two results contradict this general finding: Garman (1992) found that while violinists, violists, and cellists tended to deviate to the sharp side, bassists tended to perform flat and the subjects used in the Lader (1977) study exhibited a tendency to perform flat.

Sogin (1989) measured 48 university and professional string players’ intonation on ascending and descending pitch sets (E flat, F, G sharp, A sharp) with and without vibrato. Sogin reported that while both ascending and descending pitch sets tended to be performed sharp, regardless of instrument or vibrato condition, the descending pitch sets were performed significantly sharper than the ascending. Also, Sogin (1989) found that for a held pitch, the end of the note will be performed significantly sharper than the beginning of the note. This finding was supported by Geringer and Sogin.

Geringer and Sogin (1988) asked 16 string players (along with 32 other instrumentalists) to perform an ascending major scale using long tones. Though all subjects tended to perform sharp, Geringer and Sogin reported that as a pitch was held, intonation became significantly sharper. As with the Sogin study, the presence or absence of vibrato did not significantly affect intonation accuracy.

Intonation, as well as vibrato, was also studied by Papich and Rainbow (1974). After studying four violinists, four cellists, and five bassists performing both solo and with a group, the researchers noted a tendency for all subjects to play sharp. The researchers also noted that in solo performances there was little or no pitch adjustment, but when the same piece was performed with a group, the subjects constantly adjusted the pitch until a consensus was reached. This consensus pitch tended to be lower than solo pitch.

The effects of notation and scale degree were studied by Yarborough and Ballard (1990). Thirty-five university string players were asked to perform five-note scale patterns in which pitches common to two different patterns functioned either as a leading tone or a third. Thus, the researchers could determine whether function affected intonation. Further, the accidentals in some patterns were notated as flats while others were notated as sharps. Yarborough and Ballard found no significant difference in pitch deviation by direction (ascending or descending) or accidentals (notated as flats or sharps). Pitches were also performed similarly regardless of whether the pitch
represented a leading tone or the third scale degree.

Greene (1936) recorded unaccompanied performances by six professional violinists in an attempt to determine whether the natural intonation of a string player would most closely approximate equal-temperament, pure, or Pythagorean tuning. Though pitches and size of intervals fluctuated from all three tuning systems, Greene concluded that the natural tuning of a violinist was closest to Pythagorean tuning. He found that the direction of the interval, ascending or descending, had no effect on the intonation of the interval nor did the duration of the pitches involved. Generally, major seconds and major thirds were larger than expected in natural and equal-tempered tuning; minor seconds and minor thirds were smaller than expected. Greene replicated his study in 1937 and found a similar result. The average interval size more frequently approximated those expected in Pythagorean tuning rather than equal-tempered or natural tuning.

Nickerson (1949) attempted to test earlier findings that ensemble tuning closely approximated that expected by Pythagorean tuning rather than equal-tempered tuning. Nickerson asked 24 string players, all members of professional quartets, to perform a melody twice, once unaccompanied and once while performing in a quartet. Nickerson reported that thirds and sixths were sharper than would be expected in equal-tempered tuning. Solo performances were sharper than the ensemble performances. The major thirds and sixths were closest to the size expected in Pythagorean tuning.

Though the above researchers concentrated on intonation during performance, researchers have also investigated the initial tuning of open strings. Geringer and Witt (1985) asked 60 high school and 60 college students/professionals to tune to tape-recorded tones produced by a professional oboist who was viewing a chromatic tuner at the time of the recording. The subjects were randomly assigned to one of three stimulus conditions: tuning pitch = 440, tuning pitch was 25 cents sharp, or tuning pitch was 15 cents flat. The researcher found significant differences between age groups and a significant interaction between pitch and age. Regardless of tuning stimulus, both the high school and the college subjects tended to tune within 5 cents of 440. The only exceptions were high school students who tuned an average of 10 cents sharp when the tuning pitch was 440 and the college and professional subjects tuned an average of only 16 cents sharp when the tuning pitch was 25 cents sharp, thus showing a tendency to lower the tuning pitch towards 440. Though nearly every study of intonation tendencies has determined that string players tend to perform sharp, Geringer (1978) sought to determine whether knowledge of the tendency altered the tendency itself.

After performing a major scale, Geringer told half of his subjects of the tendency for string players to perform sharp. This information was given to the randomly selected subjects regardless of whether the performance was sharp
or not. All subjects were then asked to replay the scale. There were no significant main effects or significant interactions involving verbal inducements. Though the tendency was for all subjects to perform sharp, those performing in the knowledge that musicians tend to perform sharp did not alter performance intonation. Based on the results of Geringer’s study, verbal instructions and the knowledge of the sharp tendency does not result in more accurate intonation.

Salzberg (1980) tested not only verbal feedback, but also aural feedback and no feedback conditions. Fifty subjects were asked to perform a scale, an arpeggio, double stops, and a melody, then either received contingent verbal feedback, heard a tape-recording of their performance, heard a recording of a model performance, were allowed one minute of free practice, or performed the tasks again without interruption. Following the treatment, subjects performed the tasks again. The mean intonational deviation of the contingent verbal feedback group was significantly lower than the tape-recorder group, however it did not significantly differ from the free practice and control group. The two treatments which involved aural presentations of the task appeared to negatively affect intonation. Thus, free practice and no instruction may be almost as effective as contingent verbal feedback, and aural models may actually hinder intonation accuracy. The finding that verbal feedback is no more effective in developing intonation accuracy than free practice is supported by Lader.

Lader (1977) attempted to determine whether four different types of feedback would aid intonation. Forty university string players were asked to practice three pitches while receiving feedback either visually (from looking at a strobe tuner), visually and verbally (from a teacher), aurally (by pitch matching), aurally as well as verbally, or verbally only. Though subjects generally performed more in tune after feedback, none of the various feedbacks were more effective than the others in aiding intonation. Codding, on the other hand, found that verbal feedback was more effective than no feedback and even preferable to visual feedback when correcting intonation problems.

Codding (1987) chose 57 university students enrolled in beginning guitar classes who had difficulty tuning open strings. All subjects tuned the open strings on the guitar to the best of their ability then either received visual feedback by observing a computer monitor which displayed the accuracy of their tuning, verbal feedback received from an instructor, or received no feedback. Following the treatment, the strings were mistuned and subjects were asked to retune the guitar without the aid of either the visual or verbal feedback. Subjects in the two treatment groups showed a significant improvement in their ability to tune the guitars. Though subjects who received visual treatment did not tune as well on the posttest as they did during treatment, tuning was markedly improved from pretest. Subjects who received verbal instruction not only appeared to retain the training, but posttest cent
deviation scores were lower even then the treatment tuning scores, suggesting that verbal instruction has a greater long term effect on tuning accuracy.

Sogin (1997) also investigated the effects of contingent verbal feedback on intonation, but varied the vocabulary of the teacher. Eight students enrolled in a university string methods course were asked to perform two exercises. After each exercise, intonation errors were discussed referring either to pitch names or to which finger performed the incorrect pitch. The subjects were asked to perform the exercises again. All subjects received both types of feedback in a random order. Sogin reported that subjects performed more accurately when the instructor used finger numbers rather than pitch names.

Generally, string players tend to perform sharp and solo performances tend to be sharper than ensemble performances. Knowledge of this tendency, though, does not appear to have an effect on intonation accuracy. When correcting intonation, verbal feedback from an instructor, specifically in reference to finger numbers rather than note names, may be more beneficial than aural feedback or pitch matching. Visual feedback using an electronic tuner may also facilitate accurate intonation, but verbal feedback may have a more stable, long-term effect.

**Vibrato**

Many early studies sought to describe exemplary vibrato by measuring the mean speed and ranges of vibrato in cycles per second of a small number of professional violinists (Cheslock, 1931; Hollingshead, 1932; Small, 1937; Reger, 1932). Small (1937) determined that the average vibrato speed was 6.5 cycles per second (range: 6.1 to 6.8). Cheslock (1931) reported a mean vibrato speed of 6.4 cycles per second (range: 5.5 to 7.0). The average speed of the eleven professional recordings studied by Hollingshead (1932) was slightly faster (7.14 cycles per second) ranging from 4.1 to 11.11. Reger’s (1932) subjects included studio teachers, university students and professional performers as well as violists and cellists. Reger found that the average speed of vibrato for the professionals was 6.92 cycles per second, 5.95 for violin teachers, and 6.35 for violin students. The average speed for the cellists was 6.28, 6.21 and 6.54 respectively. One teacher was experienced on both the violin and viola, but vibrato speed was nearly identical on both instruments. Papich and Rainbow (1974) did find a difference in vibrato speed between instruments with bassists averaging four vibrato cycles per second (range: 4 to 4.5), five for cellists (range: 4.5 to 5.5), and 6.5 for violinists (range: 6 to 7).

Small (1937), Hollingshead (1932), Reger (1932), and Papich and Rainbow (1974) all reported the average width of vibrato was approximately a quarter-tone. Reger (1932) reported that teacher’s vibrato was slightly narrower (.21 of a step) and students was an average of .19 of a step. Bassists in Papich and Rainbow’s (1974) study performed with a narrower vibrato which
approximated an eighth of a tone. When Reger asked the students and
teachers to perform long sustained notes first softly than loudly, he found that
the speed and width of the vibrato increased with intensity. Small (1932) and
Reger (1932) attempted to determine if there was a relationship between the
speed of the vibrato and width, but both found the two to be independent.

Weber (1995) measured muscle movements in the vibrato motion of four
violinists and four violists. The subjects were either professional string players,
college music majors, or string educators whose primary instrument was violin
or viola. Weber found that there was significantly more motion in the forearm
muscles which controlled the wrist than in the muscles controlling the elbow.
He reported that there was no significant difference in the vibrato motions of
violinists and violists. Weber also reported a significant difference in vibrato
motion between rest and playing position.

Gillespie (1993) taught 35 undergraduates enrolled in a string methods course
vibrato using two instructional approaches: fixed bout, where subjects were
instructed to keep their wrist in contact with the instrument when practicing
vibrato and then to attempt to transfer that motion to first position, or movable
bout, where subjects learned vibrato by simulating the stationary bout of the
instrument with the index finger of the right hand. Arm motion, wrist motion,
flexibility of fingers, and vibrato motion were rated significantly superior for
subjects who learned using the movable bout approach.

Exemplary vibrato appears to be between six and seven cycles per second,
slightly slower for cellists and bassist and cover a width of approximately a
quarter-tone (or an eighth of a tone for bassists). Violists’ and violinists’
vibrato do not appear to significantly vary. When teaching vibrato, a movable
bout approach appears to produce a superior vibrato than a fixed bout
approach.

**Conclusion**

There are countless questions asked each and everyday by string educators.
The purpose of applied research is to address these questions and attempt to
provide answers. For teachers who screen students prior to the start of
instruction, academic achievement and aptitude scores may indicate whether a
child will succeed or not on a string instrument. Measures of dexterity, though,
may not be good predictors of success.

Once students are enrolled, the teacher may choose to organize beginning
string classes in a multitude of ways all of which produce a similar level of
development for beginning string students. Students will develop at a similar
pace regardless of whether they are taught in a homogeneous or
heterogeneous setting or in private lessons or in small classes or are seated or
in a standing position. Students will also progress equally well regardless of
whether a lengthy period of rote instruction or notation is introduced quickly by
the teacher. It should also be noted that this lengthy period of rote instruction
does not affect students’ ability to sight read music.

When teaching beginning students to hold a bow, the traditional method may
be the most effective, at least with older beginners. Holding the bow at the
balance point and slowly moving the hand towards the frog may facilitate the
teaching of the spicatto bow stroke. Many method books have chosen to
introduce rhythms which use shorter rather than longer bow strokes favored by
older methods. Though students will develop similar tone quality using both
short and long bow strokes, the current practice of teaching short bow strokes
first may eliminate other bowing problems commonly developed by young
string players.

While there appears to be no advantage to beginning string students in third
rather than first position or using pentatonic rather than diatonic melodies,
there may be an advantage to starting beginning violinists and violists in
transverse position. Though it remains to be seen whether this aids in
developing correct left-hand position, transverse position apparently facilitates
faster fingering especially in the young beginners. It is not clear from the
research whether fingerboard markers aid in the development of left-hand
position and intonation accuracy. It is possible that these markers may aid
younger beginners while having no affect on older beginners. A similar
statements may apply to the use of accompaniment. Younger beginners may
find the accompaniment distracting while older beginners may perform more
accurately in tune in the presence of piano accompaniment. Performing in
chamber ensembles, though, does appear to aid the development of intonation
accuracy.

When teaching students to perform accurate intonation, teachers should be
aware of well-documented tendencies. String players have a tendency to
perform sharp and become sharper over the course of long tones.
Unfortunately, knowledge of this tendency does not necessarily aid the
students in correcting the pitch. Modeling the correct pitch may also be of little
use in correcting intonation. Contingent verbal and/or visual feedback may be
the most effective ways of correcting poor intonation.

Exemplary vibrato has been described in many studies and a consensus of
opinion can be reached. Vibrato speed should be between 5 and 7 cycles per
second and the width should be approximately a quarter-tone (for bassists’ the
width should be approximately an eighth-tone). The knowledge that the mean
vibrato speed lies between 5 and 7 cycles per second is especially important
for teachers who teach vibrato by first establishing a beat (e.g., m.m. = 60
beats per minute) and then asking students to subdivide the beat with vibrato
cycles. Since the average vibrato motion is approximately six cycles per
second, this would appear to be the ideal subdivision. It would seem
impractical to extend the subdivisions to 8 or 10 cycles per second. One other method of introducing string students to vibrato is to perform the motion with the instrument in rest position. This may not be wholly productive since the muscle motion is different in transverse position. The teaching of vibrato may be facilitated by teaching a movable bout approach (where students simulate the stationary bout of the instrument with the index finger of the right hand).

Some of the research findings detailed in this article will be hotly contested. Both string teachers and researchers must be reminded that one study does not “prove” anything. Just one case in point, Glenn (1999) found that beginners develop at a similar rate regardless of whether there is a lengthy period of rote instruction or if notes are introduced relatively quickly. Many teachers will disagree with the finding based on personal experience, but research is necessary to support this perception. Duplication of Glenn’s study may constrict her findings. Conversely, the teaching field may have to alter instruction if Glenn’s results are supported by a number of studies.

There are many questions asked by string teachers that have not been addressed by researchers. Does the use of a shoulder rest aid left-hand position? Is one method of vibrato instruction more effective than another? Are there other predictors of success in a string class? String teachers must continue to ask questions of researchers and researchers must continue to add answers in order for the field to grow.

References


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