Research Literature in Technology, Voice Instruction, and Music Education

Draft

ABSTRACT

Voice educators have a long history of the use of technology as a teaching aid, although some bias against technology exists. Because of the relative scarcity of research in the use of technology to teach voice, some of the most pertinent information apropos to the profession comes from the literature in music education, including programmed instruction and computer-assisted instruction. After a discussion of this historical background, the article highlights modern-day technologies that are approachable to the average teacher without specialized equipment including the Internet, auto-accompaniment software, and spectral analysis. Because information the use of medical technology such as the laryngoscope exists in abundance, this article does not highlight these uses. A history of the use of technology to teach voice gives the practitioner grounding into what is possible and what may be possible in the future.

INTRODUCTION

Sundberg (1990) asks a pertinent question: "What's so special about singers?" (p. 107). He notes that researchers often avoid singing as a subject for research because the special nature of voice production makes general conclusions about applications of scientific research problematic. He answers his own rhetorical question by noting differences in the use of the singing voice compared to normal speech. Sundberg concludes that singers are viable subjects for voice research.

The nature of the voice lesson is an intimate relationship between the teacher and the student with the tradition of singing passed down by word of mouth from teacher to student. Some teachers of voice have traditionally shown a bias against scientific method in the voice lesson. This aversion to scientific method increases with the presence of strange, untested technologies that find their way into the modern voice lesson. Other teachers of singing are more open to technological aids in the voice studio. Teachers who have access to technology have found novel ways of incorporating the technology into their practice routines.

Early Medical Experimentation

In his history of laryngeal investigation, Moore (1937/91) provided an early view of the scientific study of the voice. Development of the laryngoscope, an instrument used to view the vocal folds, began in 1807 with Buzzoni. However, the first "real success" (p. 267) was by the singing teacher Manuel Garcia, who used a dental mirror to view the larynxes of his students. Early laryngeal investigation was more important to speech teachers than singing teachers, but the techniques are applicable to both. Moore reviewed the development of apparatus and summarized the results from early experimentation. The improvements included techniques such as magnification, binocular viewing, photography, motion pictures, and stroboscopy. These early uses of technology in the study of voice set a historical precedent for modern uses of technology in vocal pedagogy.

In his report on the evolution of the discipline, Von Leden (1990) provided a first-hand account of voice science in the middle part of the 20th century. According to Von Leden, before World War II little interest in scientific voice care existed. The medical community was more interested in surgical procedures than scientific investigation, while speech pathologists were more concerned with problems such as stuttering and articulation. The influx of scientists such as Fröschels, Weiss, and Moses to America from Europe during and after the war improved the quality of research in the United States.

Philosophical Differences

Early notice of the use of technology included controversy over the philosophical basis behind the teaching of voice. Some traditional views of voice pedagogy draw from centuries-old traditions Italian teachings (Bidoli, 1947) which incorporate the extensive use of imagery and imagination (Wilcox, 1945). The advent of scientific method and instrumentation led to a dichotomy of thought within the profession.

In 1953, Wollman articulated this dichotomy by dividing the philosophy into the categories of empirical, or those methods derived from experiential phenomena, and scientific, including the study of anatomy and acoustics (see Hisey, 1970). The scientific viewpoint gained acceptance in the 1940s. By 1948, the NATS "Fundamental Requirements for Teachers of Singing" contained a series on "Orientation Lectures on Physics and the Acoustics of Musical Sound" (p. 8).

The advent of the scientific method in the study of voice had its detractors. In 1951, McLean supported a more spiritual approach to the teaching of singing with this statement:

> THE STUDY OF VOICE and vocal mechanism has degenerated from the quest of spiritual law and the utterances of eternal verities to a material, mental attitude based purely on the

> phenomena produced by a PHYSICAL INSTRUMENT ONLY. In like manner, with the automotive salesman, minutely describing the "entrails" of the newest car.
>
> The history of the world is a chronicle of discoveries of deeper laws than those produced from physical phenomena. . . . There remains an EXISTENT SOMETHING not included in our concept of mechanical movement. The fact is, we are dealing with a LIVING INSTRUMENT, not a dead one. Can an instrument which expresses the SPIRITUAL FORCES of man in action be measured by an earthly yardstick? (p. 7) [emphases supplied by McLean]

By the 1950s, technology had earned a permanent place in society. In 1953, Gilliand noted the prevalence of technology with the statement, "The presence of technological advancements found in many other walks of life has, to no small extent, become associated with the Fine Arts" (p. 7). A modern technician might view his statement as an acknowledgment that the so-called "new" technologies in the arts have been commonplace for at least the past 50 years. Gilliand goes on to meliorate the differences in the two philosophies by paying homage to the unseen forces which shape the singing process, " . . . the belief in God constitutes one of the salient facets of our philosophy of teaching" (p. 7), but making clear that the Divine represents only one portion of the process of the teaching of singing. Von Leden (1990) stressed a new interdisciplinary approach that had occurred by the 1957 first International Voice Conference at Northwestern University.

In the 1960s, the application of scientific voice study became better defined and more approachable to the voice teacher, but resistance still existed. Madsen (1965), while acknowledging the "mystery" associated with the teaching of voice, chided the profession for not following standard scientific principles such as continuous questioning of assumptions, sharing of ideas, and learning from peers. Scientific method came under fire as findings from controlled studies challenged the assumptions of long-held beliefs.

In 1968, Appleman found that 25% of NATS members supported voice science, while 25% rejected the process and would not support inclusion of voice science into the suggested foundations for teachers of singing (the remaining 50% were ambivalent). Despite advances in attitude toward voice science, Appleman still defined voice science and pedagogy as separate elements and echoed issues from the profession concerning whether scholarship and knowledge of teaching methods actually aid vocal pedagogy. He divides voice professionals into disparate groups of scientists and "executionists."

As reliable studies began to appear, the profession took notice. With the exception of a 1952 article concerning the singer and television (Beier), articles on specific technologies (as opposed to a general support or denial of technology) were scarce. Studies such as Taff's 1965 acoustic study of vowel modification, Large's 1968 study of acoustical measures of female chest register, and Smith's (1970) investigation of electromyographic measurement of vibrato gave concrete examples of voice science and vocal pedagogy.

In 1994, Cleveland concluded that the preceding 25 years had been the most productive period for the study of the singing voice. He surveyed prominent voice scientists, voice teachers, and medical doctors to determine a consensus of the most significant findings concerning the singing voice and the most important advances in the research. He discussed topics such as the singer's formant, vibrato, formant tracking, registers, subglottal pressure, singing synthesis, and voice classification as they relate to commercial singers, amateur singers, and classical singers. Technological developments specifically manufactured for voice research (such as real-time spectral analysis, stroboscopy, and inverse filtering) have enhanced the proficiency of the voice professional. He identified the most important contributors to the field to be: William Vennard, in the area of singing teacher research; Wilbur James Gould and Robert T. Sataloff, for creating productive learning environments; Sundberg and Ingo Titze, for presenting scientific contributions; and Minoru Hirano, for important medical contributions. The most significant development to be an integration of divided groups of professionals into a common interest, with growing acceptance from teachers of voice.

Voice science has continued to advance in scope and acceptance. With the publication of the Journal of Voice in 1987, a format existed for the presentation of voice science and the interdisciplinary nature of medical technology, acoustic instrumentation, and vocal pedagogy in the analysis of the professional voice. The instrumentation for the study of the voice now existed and the experimental process had a historical basis upon which to draw. For the first time the experimenter did not need to devise methodology without prior example (Cleveland, 1994). Cleveland reflects the growing acceptance with these comments:

> "A few short decades ago, science received a bad name among the practical users of voice because they could not see that science was helping them at all. . . . Today, we are witnessing a greater trust from the singing teachers that science may have valid information to be shared in the studio and the education of teachers, as well" (p. 23)

Modern voice science has an interdisciplinary nature, using all manner of technology including acoustic measures and electron microscope (Brewer, 1989). The design, development, implementation, and evaluation of electronic technology to aid in the analysis and teaching of voice is of importance to voice professionals. Otto (1984, 1991) has prepared checklists of research articles containing descriptions of the use of mechanical and electronic research tools for the study of voice.

Gould and Korovin (1994) comment upon the advances in voice research as reflected by the increase in the number of voice conferences and the increase in the number of voice laboratories. Specific laboratory research includes advances in analyses of respiratory systems, laryngeal function, visual analysis (stroboscopy), acoustic analysis (including spectography and the use of modern recording techniques and the DAT), application of the computer, aerodynamic function, glottography, ultrasound, electromyography, supraglottal (x-rays and MRI to explore areas above the glottis), auditory function, and a combination of techniques. These techniques allow for a quantitative analysis of the voice.

One of the most influential texts on the science and art of clinical care was edited by Sataloff (1997). This encyclopedic work contains articles by many contributors, who write on subjects such as history, basic science, clinical assessment, and medical applications of voice science. Although not specifically limited to technology, the work contains much insight on the use of mechanisms to study the voice.

Technology and Music Education

The broader body of music education has traditionally been more accepting of music technology than voice educators have. The use of what we would consider to be a computer as an aid to musical understanding began as early as 1949 (Bronson, 1949). One of the first references to music technology in the music education literature is represented by an article on trends in research by Jones (1957), who writes:

> The artifacts of the society—television, electronic brains, radar, better printing and visual aids, automation, improved household appliances, new highways—will all have an effect not only upon the nature of education but also upon the problems that will face educational research workers. (pp. 21-22)

Although terms such as "electronic brains" and the potential use of radar for music research may seem quaint to the modern reader, Jones was prophetic in his prediction of the impact of technology upon the discipline of music education.

Even before high-speed modern computers, technological aids to music education came in many forms. In 1964, Shelter evaluated the use of available audio-visual media such as records, filmstrips, and school public address systems as an aid to music education.

Roller published one of first article in the music education literature that contained the word "computer" in 1965. In the 1960s, the use of computers in education was associated with Programmed Instruction (PI). PI was based on the principles of behaviorist psychologists such as Thorndike and Skinner (based in turn on Socratic method and Cartesian deduction) first applied to teaching machines by Pressey in the 1920s (Hutcheson, 1967). In PI, teaching materials are broken down into small, graduated steps placed in a logical sequence. The program elicits a response from the student, who receives immediate reinforcement. The teaching machine is self-contained, so that the student can work at her own pace. Experiments in this period associated with technology almost exclusively fell into the PI category and concentrated on basic skills of musicianship. One study in this period with application to singing is Kanable's 1969 comparison of PI with classroom teaching of sight singing, a study that showed no significant difference between the two methods.

In the 1970s, the label Computer-Assisted Instruction (CAI) became current for Programmed Instruction using a computer. CAI had not gained the respect of the profession as a whole, but proponents hoped that significant results would still appear in the future (Lincoln, 1969). Replicability was an important element of measurement of validity for the behaviorist-minded researchers and CAI offered the rare opportunity for almost exact replication of an experiment (Deihl, 1971). Although limited by cost and availability of technology, new techniques such as the use of light pens (Allvin, 1971) and the potential for information retrieval systems were beginning to expand the scope of what music educators could accomplish beyond the still-ingrained atomistic mindset (Deihl & Partchey, 1973). The use of technology for information processing in music (e.g. Edwards & Douglas, 1972; Lane, 1974) would set the stage for later developments applicable to today's Internet technology.

By the 1980s many in the profession were suggesting that music technology was "coming of age" (McGreer, 1984, p. 12). Many studies had found no significant difference or even a superiority of computer-based instruction over traditional materials (McGreer). The use of computers to teach music was heavily influenced by the Programmed Logic for Automated Teaching Operations (PLATO) system designed at the University of Illinois at Urbana-Champaign (Hair, 1977). PLATO technology was incorporated successfully in Hoffstetter's Graded Units for Interactive Dictation Operations (GUIDO) system (Hoffstetter, 1981).

The profession in general was not as optimistic about the value of technology. Stabler (1986) reported that articles on instructional technology in the Bulletin of the Council of Research in Music Education declined from 10% of all articles published in a time period from 1976 to 1980 to two percent from 1981 to 1985. The height of educational technology research in this particular publication was from 1963 to 1969, when 13% of the articles concerned instructional technology. Prohibitive costs, steep learning curves for programming and use of the technology, and the inability of the technology to facilitate differing learning styles were all factors which affected the disenchantment with technology during this time period.

In the late 1980s and early 1990s, advances in computer technology would again create interest in technology as a vehicle for music instruction. In 1984, Apple Computers, Inc. released the Macintosh computer, which would revolutionize the way people interact with computers. The Macintosh featured the first widely available Graphical User Interface (GUI) (originally invented by Xerox Palo Alto Research Center) which used the now-commonplace mouse and its "point-and-click" technology. The GUI is more intuitive and supportive of differing learning styles than the traditional line entry model of earlier computer interfaces. Apple's competitors soon followed suit.

In addition, in the 1980s a technology known as Musical Instrument Digital Interface (MIDI) made it possible for the computer to communicate with an electronic keyboard. MIDI technology is standard in today's electronic keyboards and numerous CAI programs. Interactive audio also has potential for learning (Adams, 1990). These and other studies suggest that students learn better when they interact with the technologies in a meaningful way.

MODERN USES OF TECHNOLOGY IN MUSIC EDUCATION AND THE VOICE

The use of technology in modern music education is so broad that a complete review of its uses is beyond the scope of this project. Many published texts go into detail on the possible uses of technology for educators and resources for educators interested in music technology have become available. Print resources include Williams' and Webster's (1996) overview of music technology and Rudolph's (1996) book specifically aimed at music educators. Many sources include resources aimed at music education organized around the National Standards (e.g. Piper, 1996).

I will now summarize several technologies that I believe will have an effect on the profession in the near future. The first discussed is the pervasive influence of the Internet on education and the society in general. The second is the use of auto-accompaniment software to substitute for human accompanists in rehearsal and performance situations. The third is the use of spectral analysis and other visual representations of the voice through computers. I will conclude with a few studies that use technology to teach voice in unique ways.

Please note that I do believe that the use of medical technologies such as laryngoscopes will continue to be of great importance to the profession. However, a body of research already exists on these technologies (see Otto 1984, 1991). Because the use of these technologies is out of the reach of the average voice teacher due to prohibitive costs of equipment and specialized training, I will not highlight these technologies at this time.

Internet

One aspect of technology of interest to the profession has been the use of distance learning as applied to music education. Distance learning existed since even before the spread of the Internet (Fonder, 1992; Hugdahl, 1984) because distance learning techniques are sometimes the only way that the geographically isolated student can access information on music (McMahon, 1985). The on-line communications and other advances with technology are also effective for use by the handicapped. Distance learning can be effective when a teacher cannot be present.

Distance learning took on a new character beginning in 1989 when an international network of computers known as the Internet was made accessible to many without high-level technical knowledge through an entity known as the World Wide Web (WWW). In 1993 the National Center for Supercomputing Alliance (NCSA) released the first widely available WWW browser called Mosaic. Mosaic allowed the user to navigate through the virtual “space” of the WWW using simple techniques with a mouse, reinforced with multimedia and graphical cues. In the modern vernacular, the terms Internet and WWW have become synonymous.

The fact that one cannot turn on the television or open a magazine without an onslaught of information the World Wide Web has not escaped music educators. The prevailing thought in music education is that computer use will continue to increase (Nolan, 1994), and that music educators are committed to the integration of technology into the classroom (Glenn, 1990). Music educators have taken notice of the phenomenon and the increased presence of technology in their schools. A recent survey by the National Center for Education Statistics (1997) found that in the fall of 1996, 65% of public schools in the United States had access to the Internet. The Internet has taken the place of what many hoped interactive television (Rees & Downs, 1995) would accomplish.

Although schools are dedicated to increasing Internet access for their students, doubts remain among practicing teachers as to whether the technology improves education. A recent survey showed that practicing teachers do not believe that the Internet improves children’s classroom performance, research abilities, or performance on standardized tests (Barber, 1997). Barber cites the lack of relevant and organized material as a major limitation of the Internet. Critics of the Internet would rather see the money spent on textbooks or other more traditional materials (Jackson, 1997). They compare the proven record of accomplishment of traditional materials with the unproved promises of the new technology. In fact, the concern that technology may have a negative effect on music is as old as the technology itself (Kaegi, 1973). Many worry that the technological explosion may be turning us into a nation of spectators, rather than participants, in music (Elliot, 1990).

The Internet has attracted the attention of many voice professionals. In 1995, Repp completed a study that explored the various avenues for research in voice that were available on the Internet. He found considerable interest about technology, but also discrepancies. The impact of technology exists in college music departments across the nation, but voice departments are often late to embrace the technology.

Experimental data on the voice and the Internet is extremely limited. In 1997, Repp completed a report of the extent which the attitudes of pre-service music teachers were affected by an Internet-based presentation of a voice relaxation process known as the McClosky technique for vocal relaxation. The respondent group felt that computers were important to music education, but some doubts exist as to whether the computer can teach something as intimate as the voice technique. As the Web becomes more ingrained into the society, hard research on its use will no doubt increase.

Auto-accompaniment

One of the most exciting uses of technology in the applied lesson format that has become feasible in the recent past is the use of technology as an accompanist. Since a piano accompaniment is standard in many vocal performances, teachers have been forced either to play the accompaniment for the student—a process which has the potential for distracting the teacher—or hire an accompanist if one is not supplied, which can lead to financial difficulty.

Questions remain about the musicality of the use of technology. Tarabella (1993) suggests that the interaction between the performer and the instrument "implies the existence of a Zenic unity [emphasis his] which starts at the deepest levels of will and creativity and leads to a set of biomechanic events which, transferred to a musical instrument, determines the global musical result" (p. 179). Schloss and Jaffe (1993), while warning against the dangers of "too much" technology (p. 183) and reminding us that part of the experience of the audience is intertwined with virtuosity, still conclude that the interaction of performers and technology can be a powerful combination. Research on recorded music (Price, 1995; Wapnick & Rosenquist, 1991) suggests that the presence of electronic timbres does not change the attitudes of listeners toward the music presented.

Perhaps the natural aversion to computer accompaniment comes from the models we have observed in the past. Few trained musicians would consider the cultural phenomenon of Karaoke to be acceptable in a serious performance. Until recently the most advanced auto-accompaniment software, including Band-In-A-Box (Gannon, 1998), although far more adaptable to musical situations than simple Karaoke, had no way to interact with the performer. Truly interactive software was made available with the introduction of Vivace (Coda, 1998). The newest software allows the computer to react to the tempo nuances of the performer through a microphone (see Coleman, 1988; Fuchs, 1965; Price & Sataloff, 1988; Titze & Wihholz, 1993).

Three studies exist concerning the auto-accompaniment software Vivace (SmartMusic). All of the studies centered on instrumental music. Ouren (1997) documented the effect of Vivace on the playing skills, musicality, and attitude of eight middle school students. The interaction with the software elicited a positive reaction in musical responsiveness, a sense of accomplishment, and a feeling of success in preparation and performance. Tseng (1996) investigated qualitatively the interaction of 10 college flute students with the Vivace system. Specific areas of concern were past experiences of performing and computers, the effect of Vivace on practice, and the reaction to Vivace as a teaching tool. Participants agreed that the software aided in music learning, performance preparation, intonation, and stage presence, although some technical problems occurred. Sheldon, Reese, and Grashel (Unpublished) investigated differences in performance quality among three groups of instrumental music education undergraduates who received no accompaniment, live accompaniment, or digital accompaniment.

Although no studies on the use of intelligent auto-accompaniment for the voice exist, Wu (1997) explored the impact of Karaoke, a technology with some common characteristics. He describes the popular use of prerecorded accompaniments in Taiwan and other Chinese cultures. The transformation of passive listeners into active participants in music allows for a musically creative role for leisure activity. Karaoke brings together ancient Chinese philosophy of participation in music with modern technologies.

Spectral Analysis

The use of visual aids to education has long accepted as effective. Modern technology allows us to use computer-based visual aids in the studio. The voice can be represented by spectral analysis, or breaking the sound into its component parts. The term “spectral analysis” comes from the analogous function of a prism which can break light into its components.

Spectral readings are often graphed with amplitude on the vertical axis and frequency on the horizontal axis, so that the power of particular portions of the voice spectrum can be observed (Titze, 1991). Another way of representing the voice is through a spectrogram that produces a graph with frequency on the vertical axis and time on the horizontal axis. The relative amplitude of the various frequencies increases the density of the reading (a darker color), or with a different color altogether (Miller & Franco, 1991). The spectrogram has the advantage of showing changes over time, such as changes in a vowel spectrum or wavy lines showing vibrato. Sometimes the three measurements of frequency, amplitude, and time combine in a three-dimensional graph, or waterfall.

Central to the study of spectral analysis and the voice is the issue of formants. Formants are natural peaks in the spectrum of a singer's voice which occur as a result of the natural resonance of the cavities and bones of the head and neck (which amplify certain frequencies) and the absorption of other parts of the vocal tract, such as the tongue and soft palette (which tend to dampen certain frequencies). The trained singer can manipulate these formants to produce differing tone qualities (Fox, 1984). Spectral analysis has shown the presence of a peak in the sound spectrum of trained singers around 3000 Hz which allows the singer to be heard over an orchestra (Schutte & Miller, 1983). A proficient singer will adapt the formant frequencies by manipulating the placement of the jaw, tongue, and other articulators (known as modifying the vowel) in order to produce a more resonant tone (Miller & Franco, 1991; 1992). Female singers are particularly proficient at modifying the tone to produce an increase in energy, and therefore, amplitude and perceived volume (Cleveland, 1992; 1994b). Spectral analysis allows the teacher of voice access to objective data on the tone of the student.

Research Studies on the Voice and Spectral Analysis

Technology allows the voice scientist to investigate specific measures of voice production and control the number of variables associated with a study of the voice. Because of the nature of scientific inquiry, phenomena which are difficult to measure such as artistic expression are usually factored out (Schutte, 1989). Of the myriad of possibilities for voice measurement, those most accessible to the voice teacher must be safe, with no invasive procedures, and affordable, without excessive specialized equipment.

Early studies of spectral analysis concerned the discovery of the nature of the physics of the voice. Miller and Schutte (1983) investigated resonance patterns in a tenor singing the same pitch with different register characteristics. The researchers found a surprising similarity in the frequency balance of the registers. Ågren and Sundberg (1978) investigated the differences between female altos and male tenors singing in the same range. Two altos and two tenors performed a folk tune in an anechoic chamber with the results compared through spectral analysis. The female voice is higher in fundamental frequency content and with a greater distance between the third and fourth formants.

Specific strategies for improving the voice developed as the technology improved and as voice scientists became more proficient at interpreting the results. Miller and Schutte (1990a) discuss the role of reinforcement from spectral analysis as applied to the singing voice. The authors query as to why, despite the established fact that formant tuning to enhance the voice has been proven to be effective, spectrum analysis has not has a great impact on vocal pedagogy. The work builds on Sundberg's (1973) work to determine the most efficient placement of the formant frequencies of the individual singers. Because a sung pitch does not contain all possible harmonics, if the formant is not tuned to a frequency which is a multiple of the sung pitch, the resonant effects of the formant are not apparent. Limitations to these methods include the use of techniques that are not natural to the singer and the need for experience required for interpretation. Miller and Schutte (1990b) also investigated formant tuning in the singing technique of a professional baritone. They investigated the tuning of the first two formants with the fundamental frequency as measured within the vocal tract of the singer with a catheter, rather than with a microphone.

Wilson (1982) developed an instrument to condition the singer's ring, which appears around the fourth formant in the trained voice. The ring allows for a singer to project over an orchestra and is a component of a mature, professional voice. Participants sang isolated vowel sounds with differing degrees of ring and nasality. The device was able to discriminate from among the different vocalized sounds.

At the time of this publication, Nair (1999, in press) was in the process of publishing a book and accompanying CD-ROM containing strategies for the incorporation of spectral analysis technology into the voice studio. Anticipated chapters include information on acoustics, feedback in the voice studio, the spectrogram, and the EGG.

Electroglottography

Electroglottography was one of the first techniques for analysis of the voice. Electroglottography to determine measurements of glottal closure developed in the 1940s and became feasible in the 1950s. The device has the advantages of providing objective quantitative data that is free from the influence of supraglottal resonance (absorption of the vocal track and resonance from hard bony structures) at a low cost and without invasive medical procedures. The device functions on the principle that since human tissue is a better conductor of electricity than air is, an electric current applied across the larynx will vary in resistance (or impedance in this case because of the use of alternating current) as the vocal folds close, according to Ohm's Law. The electroglottogram usually consists of two small electrodes placed on the neck on the sides of the larynx. The instrument produces an electroglottogram, which measures the closure of the glottis over time. Analysis of the EGG signal often takes place in a qualitative examination of the signal.

Many authors have investigated the validity of electroglottographic research and the voice. Baken (1992) reported upon principles of the electroglottograph, validity of the its techniques, and recommendations for standardization of research in the area. Baken recommends the use of EGG as part of routine vocal assessment, but warns of validity questions when determining Closed Quotient measurements (the relative amount of time the glottis stays closed). Colton and Conture (1990) warn against the challenges of using EGG in clinical studies. They begin with a thorough literature review with over 200 references concerning EGG from its inception in 1940 to its present-day uses. Procedural challenges can occur with variations in electrode placement, degree of contact with the skin, and movement during the recording process.

Standardizing Results

Even with the long tradition of voice analysis techniques, interpreting data can be difficult for the average teacher. Titze (1994) called for standardization of acoustical voice analysis in order to educate, simplify, conserve time and effort, and certify results. Consensus may be possible in acoustic phenomena such as loudness and pitch and design of standardized test utterances, fundamental frequency, database formats, calibration techniques, and nomenclature. Possible liabilities for standardization include oversimplification of the process, which limits the scope of research, prematurely adopting ambiguous or erroneous standards, and the problems in enforcing standards. Holmberg, Hillman, Perkel, Guiod, and Goldman (1995) compared techniques of voice measurement to determine how they relate to each other. They determined which easily accessible measurements of voice (such as acoustic analysis) could substitute for measurements that are difficult to obtain. The study found that acoustical analysis could substitute for more difficult to obtain data if prescribed formulations exist. Once standards are set and inexpensive acoustical models substitute for sophisticated hardware, possibilities for voice analysis by practicing teachers become more feasible.

One hurdle for use of voice analysis in the studio is the established fact that singers do not register within norms for voice as established by the medical profession. Radionoff (1996) investigated whether normal voice functions for trained singers differ from published voice norms. He collected and compared acoustic, phonatory, and respiratory data from 28 voice students. The current norms for 59% of the measures were in error when compared to this subject group. Radionoff concludes that normative data for singers needs to be collected from a large group so that accurate data can exist to aid in clinical study and pedagogical decisions. Novák and Vokˇrál (1995) worked to establish parameters of voice measurement for voice professionals. They established a need to determine objective evaluation of future professionals because of the importance of healthy function for singers.

Other Technologies

As the use of technology increases, voice specialists work to design voice teaching methods that do not fit into the three categories enumerated above. Technology can impart knowledge-based information on voice-related issues. One example is Simpson's (1996) investigation of the effectiveness of the presentation of opera through the technological areas of video and audio. In a vocal anatomy presentation to undergraduate music students with differing learning styles, Ester (1992) compared computer-assisted instruction with traditional lecture. Ester (1994) also developed a HyperCard stack called Hyperactive Vocal Anatomy to teach laryngeal anatomy to undergraduate music majors. He cites the growing interest in voice science and the importance of an understanding of vocal anatomy in voice teaching. Ester found the program an effective tool for teaching anatomy.

Rossiter and Howard (1996) considered real-time visual reinforcement for voice development in prospective professional voice users in their development of a computer-based biofeedback device. The authors define a need for the study of high-end voice users such as singers. Cited research also suggests visual reinforcement strengthens the learning process.

Bailey (1993) devised an electronic method to treat nasality in classical singers. Nineteen lower-voice males were asked to sing into a KAY Nasometer, which consist of two microphones, one nearer the mouth and one nearer the nose, attached to the head with a harness. The input from the two microphones contrast to determine the amount of sound that carries through the nasal passages, or nasalance (as opposed to the less technical term, nasality).

CONCLUSIONS

The future of technology in voice education depends upon an interdisciplinary approach among all involved. Brewer (1989) constructed a descriptive matrix to reflect voice research that shows the interrelation of the unsolved problems, academic disciplines, and research tools pertinent to the profession. Of the 59 unsolved problems enumerated, the areas most pertinent to the present study are: voice training standards, the role of biofeedback, techniques of song preparation, scientists' study of voice, information exchange among physicians, scientists, singers and teacher, ease of transition stage to classroom, and the role of electrical superconductors in research. Brewer identifies 36 disciplines that work together in the study of voice. The disciplines most pertinent are acoustics, computer science, performing arts, and vocal pedagogy. He then factors in the research tools for voice science, including computers, software, artificial intelligence, information networks (The Internet was not viable at the time of Brewer's writing, but the WWW would fit into this category), electroglottography, and speech synthesis. The matrix Brewer produces is an organized way to chart the interrelationships among the various disciplines and technologies available to the scientist.

Titze (1986) states that the value of all the " . . . charts, graphs, gadgets, and gizmos in the studio" (22) will not be solved until research is undertaken from the stand-point of someone trained in voice education rather than voice science (e.g., Cleveland, 1988; 1989a; 1989b Titze, 1985). Titze (1986) provides a metaphor for singing based on the use of technology to improve athletics by rigorous measurement and the use of new technology. If Titze's metaphor does indeed carry over into the art of singing, then someone will have to take the first step in the process.

Although some bias against technology exists in the profession, aids to the teaching of voice have been with us for hundreds of years, have improved greatly in sophistication, and will continue to evolve as a legitimate part of the process of the teaching of voice. The three modern technologies I have highlighted here, the Internet, auto-accompaniment software, and spectral analysis are intermediate stages in the development of technology to teach voice. Designers of voice-related technology should be aware of the long history of the technology, so that we may learn from the past in order to provide better tools for the future.

REFERENCES

Adams, S. M. (1990). Interactive audio as a resource for music courseware development. Quarterly Journal of Music Teaching and Learning, 22, 112-115.

Allvin, R. L. (1971). Computer-assisted instruction: A look at the potential. Journal of Research in Music Education, 19 (2), 131-143.

Appleman, R. (1968). Whither vocal pedagogy? The Bulletin of the National Association of Teachers of Singing, 14 (4), 17-21, 34.

Bailey, R. (1993). Electronic method for training nasality in classical singing. Journal of Research in Singing, 17, 31-48.

Barber, A. (1997, March 11). Net's educational value questioned: Few in schools think it helps kids learn. USA Today, D4.

Basken, R. J. (1992). Electroglottography. Journal of Voice, 6, 98-110.

Beier, C. (1952). The singer and television. The Bulletin of the National Association of Teachers of Singing, 8 (5), 4, 15.

Bidoli, E. D. (1947). Old methods of voice teaching versus new ones. The Bulletin of the National Association of Teachers of Singing, 3 (3), 3.

Brewer, D. W. (1989). Voice research: The next ten years. Journal of Voice, 3, 7-17.

Bronson, B. H. (1949). Mechanical help in the study of folksong. Journal of American Folklore, 62, 81-86.

Cleveland, T. F. (1988). Teach and sing with high-tech. The NATS Journal, 45 (1), 27-28.

Cleveland, T. F. (1989a). Multisensory feedback systems in the teaching of voice: A student case study. The NATS Journal, 46 (1), 26-28.

Cleveland, T. F. (1989b). Student observations on a new teaching device. The NATS Journal, 45 (4), 28-31.

Cleveland, T. F. (1992). What is formant tracking? The NATS Journal, 49 (1), 28-29.

Cleveland, T. F. (1994a). A clearer view of singing voice production: 25 years of progress. Journal of Voice, 8, 18-23.

Cleveland, T. F. (1994b). A closer look at formant tracking. The NATS Journal, 50 (3), 41-43.

Coda. (1999). SmartMusic. [software]. available: [online]. http://www.codamusic.com (access date: 16 February 1999).

Coleman, R. F. (1988). Comparison of microphone and neck-mounted accelerometer monitoring of the performing voice. Journal of Voice, 2, 200-205.

Colton, R. H., & Conture, E.G. (1990). Problems and pitfalls of electroglottography. Journal of Voice, 4, 10-24.

Deihl, N. C. (1971). Computer-assisted instruction and instrumental music: Implications for teaching and research. Journal of Research in Music Education, 19 (3), 299-306.

Deihl, N. C., & Partchey, K. C. (1973). Status of research: Educational technology in music education. Bulletin of the Council for Research in Music Education, 35, 18-29.

Edwards, J. S. (1972). Model computer-assisted information retrieval system in music education. Journal of Research in Music Education, 20 (4), 477-483.

Elliot, C. A. (1990). Singing in America: Reviving a tradition. Music Educators Journal, 76, 24-26.

Ester, D. P. (1992). The effectiveness of CAI and lecture as instructional strategies for teaching vocal anatomy and function to undergraduate music students with different learning styles. (Doctoral Dissertation, The University Of Nebraska - Lincoln, 1992). Dissertation Abstracts International, 54, 01-a, 0121.

Ester, D. P. (1994). The design, development, and evaluation of Hyper Vocal Anatomy: Teaching laryngeal anatomy via CAI. Journal of Research in Singing, 18, 41-50.

Fonder, M. (1992). Band lessons by mail: A look at musical correspondence schools of the early twentieth century. The Bulletin of Historical Research in Music Education, 13, 1-8.

Fox, W. (1984). A brief comparative study of formant frequencies of six tone qualities. The Bulletin of the National Association of Teachers of Singing, 50 (5), 16-19.

Fuchs, V. (1965). The microphone and head resonance. The Bulletin of the National Association of Teachers of Singing, 12 (2), 12-13, 35.

Gannon, P. (1998). Band-In-A-Box. [software]. available: http://www.pgmusic.com (Access Date 6 July 1998).

Gilliand, D. V. (1955). Beliefs and knowledge in the teaching of singing. The Bulletin of the National Association of Teachers of Singing, 12 (1), 7.

Glenn, K. (1990). Music education in tune with the times: Greeting the 1990s. Music Educators Journal, 77, 21-23.

Gould, W. J., & Korovin, G. S. (1994). Laboratory advances for voice measurement. Journal of Voice, 8, 8-17.

Hair, H. I. (1977). PLATO said my answer was terrific! Music Educators Journal, 63 (5), 55.

Hisey, P. D. (1970). Scientific vs. empirical methods of teaching voice. The Bulletin of the National Association of Teachers of Singing, 27 (2), 14-17, 44-45.

Hoffstetter, F. T. (1981). Computer-based aural training: The GUIDO system. Journal of Computer-Based Instruction, 7 (3), 84-92.

Holmberg, E. B., Hillman, R. E., Perkel, J. S., Guiod, P. C., & Goldman, S. L. (1995). Comparisons among aerodynamic, electroglottographic, and acoustic spectral measures of female voice. Journal of Speech and Hearing Research, 38, 1212-1223.

Hugdahl, E. O. (1984). Hello operator, give me my teacher: The principles of distance learning applied to music education. ISME Yearbook, 11, 153-158.

Hutcheson Jr., R. J. (1967). Programmed instruction and music education. Missouri Journal of Research in Music Education, 2 (1), 9-52.

Jackson, D. Z. (1997, February 14). Never mind the Internet, Bill—give us some textbooks. Boston Globe, A23.

Jin, S. H. (1995). The design of instructional material for teacher education: A tutorial program for computer-mediated communication. (Masters Thesis, University of Houston, 1995). Masters Abstracts International, 33-03, 0702.

Jones, R. S. (1957). Current trends and new directions in educational research. Journal of Research in Music Education, 5 (1), 16-22.

Journal of Voice (1987). Voice: A new specialty. Journal of Voice, 1, 1.

Kanable, B. (1969). An experimental study comparing programmed instruction with classroom teaching of sightsinging. Journal of Research in Music Education, 17 (2), 217-226.

Kaegi, W. (1973). Music of our time: A victim of technology? ISME Yearbook, 1, 95-99.

Lane, W. S. Jr. (1974). The application of information science technology to music education materials. Journal of Research in Music Education, 22 (4), 251-257.

Large, J. W. (1968). An acoustical study of isoparametric tones in the female chest and middle registers in singing. The Bulletin of the National Association of Teachers of Singing, 15 (2), 12-15.

Larsen, A. M. (1980). An overlooked teaching aid: Films can make the difference. Music Educators Journal, 67 (4), 32.

Lincoln, H. B. (1969). The computer and music research: Prospects and problems. Bulletin of the Council for Research in Music Education, 18, 1-9.

Madsen, C. K. (1965). Toward a scientific approach. The Bulletin of the National Association of Teachers of Singing, 12 (2), 22-23, 34.

McGreer, D. M. (1984). The research literature in computer assisted instruction. Update, the Applications of Research in Music Education, 3 (1), 12-15.

McLean, C. (1951). Causes for confusion in the teaching of singing. The Bulletin of the National Association of Teachers of Singing, 7 (6), 15.

McMahon, O. (1985). The influence of mass media developments on the early music education of geographically isolated children in Queensland. ISME Yearbook, 12, 88-92.

Miller, D. G., & Schutte, H. K. (1983). Spectral analysis of several categories of timbre in a professional male (tenor) voice. Journal of Research in Singing, 7, 6-10.

Miller, D. G., & Schutte, H. K. (1990a). Feedback from spectrum analysis applied to the singing voice. Journal of Voice, 4, 329-334.

Miller, D. G., & Schutte, H. K. (1990b). Formant tuning in a professional baritone. Journal of Voice, 4, 231-237.

Miller, R., & Franco, J. C. (1991). Spectrographic analysis of the singing voice. The NATS Journal, 48 (1), 4-5, 36.

Miller, R., & Franco, J. C. (1992). A brief spectral study of vowel differentiation and modification in a professional tenor voice. The NATS Journal, 49 (2), 7-9.

Mobley, E. D. (1996). Interactive multimedia in the classroom. Music Educators Journal, 82 (4), 22.

Moore, P. (1937). A short history of laryngeal investigation. The Quarterly Journal of Speech, 23, 531-564. Reprinted in (1995). Journal of Voice, 5, 266-281.

Nair, G. (1999). Voice—Tradition and technology: A state-of-the-art studio. Available: [online]. http://www.users.drew.edu/gnair/SOAV.htm (Access date: 14 July 1999). San Diego, CA: Singular Publishing Group. (in press).

National Association of Teachers of Singing. (1948). Fundamental requirements for teachers of singing. The Bulletin of the National Association of Teachers of Singing, 5 (1), 7-8.

National Center for Education Statistics. (1997). Advanced Telecommunications in U.S. Public Elementary and Secondary Schools, Fall 1996. In Press. [on-line]. Available: http://www.ed.gov/NCES/pubs/97944.html (Access Date: 20 April 1997).

Nolan, E. C. (1994). Creativity with instant feedback. Technology. Teaching Music, 2, 36-37, 55.

Novák, A., & Vokˇrál, J. (1995). Acoustic parameters for the evaluation of voice of future voice professionals. Folia Phoniatrica Logopoedia, 47, 279-285.

Otto, T. M. (1984). Checklist of recent research, no. 8: Research techniques & instrumentation. Journal of Research in Singing, 6, 45-49.

Otto, T. M. (1991). Checklist of recent research, no. 20: Research techniques & instrumentation: Articles containing detailed descriptions of the use of electronic and mechanical research tools: (Update of checklist no. 8). Journal of Research in Singing, 14, 55-59.

Ouren, R. A. (1997). The influence of the Vivace accompaniment technology on selected middle school instrumental students. (Doctoral Dissertation, University of Minnesota, 1991). Dissertation Abstracts International, 58, 07-a, 2456.

Piper, C. (1996) Music Education Resource Links (MERL). [on-line]. available: http://www.cs.uop.edu/~cpiper/musiced.html (Access Date: 17 April 1997).

Price, B. P., & Sataloff, R. T. (1988). A simple technique for consistent microphone placement in voice recording. Journal of Voice, 2, 206-207.

Price, H. E. (1995). Effects of sampled and synthesized timbres on opinions of musicians and nonmusicians. Bulletin of the Council of Research in Music Education, 127, 142-148.

Radionoff, S. L. (1996). Objective measures of vocal production during the course of singing study. (Doctoral Dissertation, Michigan State University, 1996). Dissertation Abstracts International, 57, 05-a, 1906.

Rees, F. J., & Downs, D. A. (1995). Interactive television and distance learning. Music Educators Journal, 82 (2), 21.

Reese, S., & Davis, A. (1998). The systems approach to music technology. Music Educators Journal, 85 (1), 24-28.

Reid, C. L. (1984). Science and vocal pedagogy. Journal of Research in Singing, 7 (2), 22-33.

Repp, R. S. (1995). Internet Research Tools for Vocalists. [on-line]. Available: http://camil40.music.uiuc.edu/Projects/tbmi/rrepp/vocal/muslist.html (Date Accessed: 8 November 1998).

Repp, R. S. (1997). Preservice music educators' attitudes towards an Internet-based presentation of the McClosky technique for voice relaxation. Proceedings of the Technological Directions in Music Learning, Fifth International Conference, 1997, San Antonio, TX: IMR Press.

Rogers, K., & Almond, F. (1970). A bibliography of materials on programmed instruction in music. Journal of Research in Music Education, 18 (2), 178-183.

Roller, G. (1965). Development of a method for analysis of musical compositions using an electronic digital computer. Journal of Research in Music Education, 13 (4), 249-260.

Rosenthal, R. K. (1996). Using Claire to assess vocal pitch matching: An exploratory analysis. Illinois Music Educator, 56 (3), 57-62.

Rossiter, D., & Howard, D. M. (1996). ALBERT: A real-time visual computer tool for professional vocal development. Journal of Voice, 10, 321-336.

Rubin, L. S. (1988). What do voice trainers need from voice scientists, and what should voice scientists know about voice trainers? Journal of Voice, 2, 99-101.

Rudolph, T. E. (1996). Teaching Music with Technology. Chicago: GIA Publications, Inc.

Sataloff, R. T. (1997). Professional voice: The science and art of clinical care. 2nd edition. San Diego: Singular Publishing Group, Inc.

Schloss. W. A., & Jaffe, D. A. (1993). Intelligent musical instruments: The future of musical performance or the demise of the performer? Interface, 22, 183-193.

Schutte, H. K. (1989). Measurements of vocal function. NATS Journal, 46, (2), 9-13, 41.

Schutte, H. K., & Miller, R. (1983). Differences in spectral analysis of a trained and untrained singer. The Bulletin of the National Association of Teachers of Singing, 40 (2), 22-23, 27.

Sheldon, D. A., Reese, S, & Grashel, J. (Unpublished). The effects of live accompaniment, intelligent digital musical accompaniment, and no accompaniment on musicians' performance quality.

Shetler, D. J. (1964). Some problems in the evaluation of new teaching media. Bulletin of the Council for Research in Music Education, 2, 23-28.

Simpson, E. H. (1996). The effects of technology-assisted visual/aural feedback upon pitch accuracy of senior high school high school students. (Doctoral Dissertation, University of Hartford, 1996). Dissertation Abstracts International, 57, 03-a, 1070.

Smith, E. C. (1970). An electromyographic investigation of the relationship between abdominal muscle effort and the rate of vocal vibrato. The Bulletin of the National Association of Teachers of Singing, 26 (4), 2-17.

Stabler, D. G. (1986). A content analysis of the Bulletin of Research in Music Education, 1963-1985. (Doctoral Dissertation, University of Illinois at Urbana-Champaign, 1986). Dissertation Abstracts International, 47-09a, 3352.

Sundberg, J. (1973). Observations of a professional soprano singer. Systems Technology Limited, 1, 14-24.

Sundberg, J. (1990). What's so special about singers? Journal of Voice, 4, 107-119.

Taff, M. E. (1965). An acoustic study of vowel modification and register transition in the male singing voice. The Bulletin of the National Association of Teachers of Singing, 12 (2), 8-11, 35.

Tarabella, L. (1993). Guest editor's introduction to the special issue on man-machine interaction in live performance. Interface, 22, 179-182.

Titze, I. R. (1985). Biomechanics: The new frontier in voice research. The Bulletin of the National Association of Teachers of Singing, 41 (5). 24.

Titze, I. R. (1986). High tech in the studio? The NATS Journal, 42 (5), 22.

Titze, I. R. (1991). What can a power spectrum tell us about the voice? The NATS Journal, 47 (5), 18-19.

Titze, I. R. (1994). Toward standards in acoustical analysis of voice. Journal of Voice, 8, 1-7.

Titze, I. R., & Winholz, W. S. (1993). Effect of microphone type and placement on voice perturbation measurements. Journal of Speech and Hearing Research, 36, 1177-1190.

Tseng, S. A. (1996). Solo accompaniments in instrumental music education: The impact of the computer-controlled Vivace on flute student practice. (Doctoral Dissertation, University of Illinois at Urbana-Champaign, 1996). Dissertation Abstracts International, 57-04a, 1536.

Von Leden, H. (1990). Pioneers in the evolution of voice care and voice science in the United States of America. Journal of Voice, 4, 99-106.

Wapnick, J., & Rosenquist, M. J. (1991). Preferences of undergraduate music majors for sequenced versus performed piano music. Journal of Research in Music Education, 39 (2), 152-160.

Welch, G. F., Howard, D. M., & Rush, C. (1989). Real-time visual feedback in the development of vocal pitch accuracy in singing. Psychology of Music, 17, 146-157.

Wilcox, J. C. (1945). Can we reconcile pedagogic differences? The Bulletin of the National Association of Teachers of Singing, 2 (1), 2-3.

Williams, D. B., & Webster, P. R. (1996). Experiencing Music Technology: Software, Data, and Hardware. New York: Schirmer Books.

Wilson, J. R. (1982). An electronic instrument for conditioning the singing formant. Journal of Research in Singing, 5, 18-32.

Wollman, A. M. (1953). Empirical method versus the scientific. The Bulletin of the National Association of Teachers of Singing, 9 (4), 20.

Wu, J. Y. (1997). Between traditional music practices and contemporary musical life: A study of the Karaoke phenomena in Taiwan. (Doctoral Dissertation, University of California, Los Angeles, 1997). Dissertation Abstracts International, 58-10a, 3733.