What Science Is and What it Is Not

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In their first article together as associate editors for the *Journal of Singing*, Meyer and Nix explore what science is and what it is not. Importantly, they discuss why singing teachers should care about this distinction.

Editors' note: *This article marks the start of a new column for the* Journal of Singing, *Practical Voice Science. We come to this work as active academic teachers of singing and voice pedagogy who are also involved in research and in mentoring the work of graduate students in voice performance and pedagogy. As such, we constantly examine and re-examine the quality and, most importantly, the relevance of scientific exploration of the voice to singing and the teaching of singing. We both owe a huge debt of gratitude to our mentors, one of whom is Dr. Ingo Titze, who as of May 2023 has written 197 columns and articles during 43 years of service to this journal. We begin our work together on this column with a mix of awe and respect for what has come before us and an excitement for the future.*

> What is a scientist after all? It is a curious man looking through a keyhole, the keyhole of nature, trying to know what's going on.[1]

> Equipped with his five senses, man explores the universe around him and calls the adventure Science.[2]

> Science is a way of thinking much more than it is a body of knowledge.[3]

> Science, my lad, has been built upon many errors; but they are errors which it was good to fall into, for they led to the truth.[4]

> Science is an ever-changing, dynamic interface, and in order to use it there must be a willingness to learn and change and evolve.[5]

Visit your nearest drugstore or supermarket, and on the shelves, you will see products that are "scientifically proven" to grow hair or soften your skin or help ease the discomforts of arthritis (or if you are really lucky, all three at once). Search on YouTube$_{TM}$ for "Singing Voice Lessons," and videos appear with claims about "science-based" exercises which can help you sing like a pro in five minutes. Scroll through your favorite online newspaper, and chances are high that you will find the text "According to a recent scientific study . . ." at the beginning of at least one article. All of these common uses of the word "science" center around trust: trusting that a product will work; trusting that voice teachers knows what they are doing; trusting that an aspect of human experience is valuable and meaningful; trusting that science equals a truth upon which you can depend, perhaps for your very life. Yet as we see in the examples above, science tends to be used in common speech without a lot of thought about what the word really means. So we begin this new column with a few fundamentals: What science is, what science is not, and why should singing teachers care?

WHAT SCIENCE IS

> Science: 1. knowledge about the structure and behavior of the natural and physical world, based on facts that you can prove, for example by experiments; 2. the study of science; 3. a particular branch of science; 4. a system for organizing the knowledge about a particular subject, especially one that deals with aspects of human behavior or society[6]

Science is thus both a knowledge base and a process for creating new knowledge. Many of the misconceptions about science stem from a lack of understanding about the scientific method, which is the process through which new knowledge is discovered. The scientific method is a cyclical process in which observations are made, prior research literature is consulted, research questions are formulated, hypotheses are made (based on observations and prior investigations), an experimental method is devised to test the hypotheses (more on that below), data is collected and analyzed, results are compiled, and conclusions are drawn; then the process begins again. In testing a hypothesis, many types of studies use *independent variables* (components that are changed or controlled in scientific experiments) and *dependent variables* (components that respond—or not—to changes in the independent variables).

When talking about data collection, it is important to discuss the two broad categories of data: *quantitative* and *qualitative* data. Quantitative data is that which can be counted or measured against some calibrated standard, is expressed through numbers, and is objective. Qualitative data is about ideas, concepts, attitudes, and opinions; in other words, it is subjective—how an individual or a population thinks, feels, and interprets some aspect of existence. Qualitative data is expressed through language. To use a singing voice as an example, a soprano might have a frequency vibrato rate of 5.5 Hz and a frequency vibrato extent of plus or minus 50 cents on her [o] vowel. Those are measurable quantities, so vibrato rate and extent are quantitative data about a singer's voice. Whether such a rate is pleasing to listeners or is considered stylistically appropriate within the context of a Mozart aria is subjective and would be qualitative data about a singer's voice or their performance.

Quantitative data collection involves having some means of measurement. In designing an experiment, investigators have to make sure they have the necessary equipment capable of accurately measuring whether changes in the independent variables result in changes in the dependent variables. It follows that to make accurate measurements, a researcher must be able to check that the equipment they are using provides internally consistent results given the same input and that the results are consistent with some external fixed standard (e.g., the equipment must be calibrated), so that the results can be compared to other studies measured with similar equipment. Qualitative data collection also involves having some kind of instrument or consistent procedure and is often achieved through the use of surveys (which can be tested for validity) and interviews.

There are two broad categories of studies: those which are descriptive and those which are analytical. Descriptive studies examine specific aspects or characteristics in a population. This is often seen in medical case reports (detailing a patient's history, symptoms, diagnosis, treatment, and outcomes) or case series, where several clients with similar experiences are grouped together. Analytical studies, on the other hand, come in one of two types: observational or experimental. One of the authors (Nix) led an analytical cross-sectional study which looked at vibrato rates and extents for five vowels performed in three ways by college voice majors. No interventions to change the singers' voice production were made; data was collected merely to see what the vibrato rates and extents were for singers in the cohort (college voice majors in the United States). Had there been an intervention of some kind, for example, one in which data was collected on the singers' vibrato characteristics (pre-test), the singers underwent a standardized training protocol, and then were retested (post-test), the study would have been experimental in nature: what is the effect, if any, of training regimen "X" on college voice students' vibrato rates and extents?[7]

After data is collected, the data may undergo a series of tests of significance. Tests of significance help us to understand the probability that the results are not due to chance. Many studies use a 95% probability standard to say a result is significant; that is, there is a 95% or greater probability that the results are not due to chance. This is commonly notated in the literature as 'having a p value of 0.05 or less ($p>0.05$).' Some fields use a higher threshold to determine significance, such as a 99% probability (p value of 0.01 or lower). There are many different kinds of tests to use; consulting with a statistician during the experimental design portion of the study to determine which kinds of tests are appropriate, given the type of data being compared, is essential.

Finally, there is peer review. After an experiment has concluded, researchers prepare presentations and scientific papers to share their work with colleagues. It is at this point that other researchers external to the team doing the experiment are given access to the results to review the quality of the work; has the research team designed the experiment correctly, given the research questions? Were there adequate controls in place to ensure that the data was collected and analyzed accurately and ethically? Do the results prove or disprove the research team's hypothesis? Have the researchers put their results in context with other prior work in the field? Reviewers make determinations about which studies are selected for presentation at conferences and publication in journals; as such, they serve as gatekeepers for what is disseminated through traditional academic channels. Reviewers can also provide valuable feedback to research teams about how to improve their work in the future.

This overview helps us to understand in general terms what science is. For a clearer picture, however, it is useful now to examine what science is not.

WHAT SCIENCE IS NOT

Science does not provide hard facts or ultimate truth. Instead, it tries to explain how the world works using theories and models that are rigorously tested.[8] If they survive testing, the theories are temporarily accepted. In contrast, some singing voice teachers look to science to prove their instructional methods are correct. This is a common philosophical difference between voice teachers and researchers: science does not typically set out to prove what we already believe to be true.[9] Though their approaches differ, pedagogues and scientists often collaborate successfully. Diverse, interdisciplinary teams working in an atmosphere of mutual respect often produce science that advances our understanding of the functional basis of singing.

Science is neither simple nor static. In the second century, Ptolemy's geocentric theory explained that the sun and stars orbit the Earth. This was the accepted scientific belief for over 1300 years, but thanks to Copernicus and others, our knowledge changed. We also know that the Earth is round. But is it really?

> If you were to measure the diameter of the Earth across our equator, you'd get a value: 7,926 miles (12,756 km). If you measured the diameter from the north pole to the south pole, you'd get a slightly different value: 7,900 miles (12,712 km). The Earth is not a perfect sphere, but rather a near-spherical shape that bulges at the equator and is compressed at the poles.[10]

For many years, voice pedagogy texts stated that registers were physically caused by vocal fold vibration characteristics. Today we know that is not the whole truth.[11] Science helps us question long held assumptions: what we thought was right may in fact be wrong, and the more we learn, the more there is to know.[12] Readers of this column are encouraged to be skeptical of simple answers from authoritative persons: "This [insert concept here] applies to all singers, of all genres, all the time." True experts rarely offer absolutes, but instead use qualified language to discuss what they know. Complex questions are usually addressed in voice science with three somewhat annoying words, "Well, it depends."

Lastly, and this deserves particular emphasis, voice science is *not* only for elite genius-level experts. Singing pedagogues may feel that colleagues with more education, intelligence, or experience are the only ones who can understand voice science. This is by no means the case. Some aspects of voice science are fairly easily understood and applied. Others require patience, study, and repeated exposure. It is hoped that this column will convince readers old and new that voice science is for all of us.

WHY SHOULD SINGING TEACHERS CARE?

This may be a strange question to read in this column, but the arguments *against* incorporating voice science into singing instruction are strong. It is observed that nearly every elite singer of the past was trained without an awareness of voice science. The teachers' well-developed ears, years of experience, and intimate knowledge of the repertoire guided students' vocal development. Scientific tools were not needed.

Another argument against incorporating voice science in our teaching is the limited nature of our instructional time. Voice lessons are short, and the tasks are many. We work on breathing, strengthening the muscles of the vocal mechanism and ensuring their optimal coordination, vocal tract configuration, vowel modification, text articulation, body awareness, and a host of mental skills. Singers also need experience in acting, movement, musical styles, language and diction, career navigation, and many other things. If we cannot articulate why voice science should be included in our practice, perhaps it would be best to leave it outside the studio door.

One of the common arguments in favor of voice science relates to vocal health. Familiarity with the scientific basis of the instrument may help us prevent vocal injury, or so we hope. Though it seems reasonable, this argument does not stand up to scrutiny. Our bodies, like our voices, are unique. For example, two friends can go to a sporting event and shout for their team; one of them develops a vocal injury just a few minutes into the game, whereas the other shouts for hours on end without any ill effect. Biology is not fair, and some lucky people seem to have bulletproof larynges.[13]

Terminology is another common argument in favor of voice science. Many pedagogues use proprietary language when teaching singing. We speak "Singereze" with our students, and they (hopefully) understand what we want to say. But colleagues in neighboring professions who do not understand "singereze" (e.g. speech language pathology, laryngology, and psychology, for example) are left out of the conversation. The standardized terminology of voice science helps interdisciplinary colleagues all speak the same language.

Other arguments in favor of voice science center around the concept that knowledge is power. We associate education with a general sense of control, and therefore it follows that the more we know about the voice, the better we may be able to control it for artistic purposes.[14] This view is easily refuted by the historical evidence, however. Elite singers with no scientific understanding of the voice have enjoyed long careers over the centuries. Knowing what is happening in our bodies may or may not help us in performance.

Why then should voice teachers consider incorporating science into their instruction? The benefits to general health, terminology, or education are worth noting, but given our limited instructional time, should voice science indeed be left outside of the studio?

The most persuasive argument comes from the world of sports. In 1896, athletes from fourteen countries met in Athens, Greece for the first modern Olympic Games. Champions set world records that were the pinnacle of athletic performance.[15] As impressive as these historical records were, student athletes in average high school programs achieve similar levels of performance today.[16] How is this possible? Advances in running surfaces, shoes, and other types of equipment have improved performance to some extent, and elite athletes have been getting larger, thanks in part to improved nutrition.[17] But generally speaking, the human species has not evolved in the last 127 years. What has happened is that science has revolutionized the training of athletes. Kinesiologists, physiologists, nutritionists, psychologists, physicians, strength and conditioning specialists, (and many others) all use science to create individualized training regimens that help athletes achieve ever greater levels of performance. In the near future we may see a similar revolution in the training of singers.

Advances in voice science may lead to a world in which the teacher's experience and intuition are enhanced by individualized scientific tools that help *all* singers – elite vocal athletes and beginning amateurs alike – more efficiently reach increased levels of performance. The goal of this column is the discussion of these emerging scientific tools and their practical application in singing.

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NOTES

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