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Editors

Creative Ways of Knowing in Engineering

The Engineers' Orchestra: A Conductorless Orchestra for Our Time

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Introduction

Engineering students often view performance skills—leadership, teamwork, and communication—as “soft skills.” Yet they are essential for advancing a professional career. To impart these skills, engineering educators recommend courses in the arts, humanities, and social sciences (AHS). Since a limited number of credit hours exist for nontechnical subjects in engineering curricula, educators focus on AHS topics most useful for engineers, many of whom will work in business and industry. The business community also values leadership, teamwork, and communication, often studying performing arts organizations as models worth emulating, such as the Orpheus Chamber Orchestra, a professional conductorless orchestra.

The raw material for these performing arts organizations can be found in colleges and universities worldwide; nearly all harbor musically talented students. Many of these talented musicians are also gifted engineers. Music-making has endowed these engineer-musicians with neurological benefits. Brain research has shown they are already primed for leadership, teamwork, and communication skills; thus they are excellent contenders for meaningful professional lives. It therefore makes sense for educators throughout the engineering community to nurture and encourage their engineer-musicians.

A project-based learning lab that builds upon the musical ability of student engineers can cultivate these skills necessary for professional and personal success. Such a lab exists at Olin College of Engineering. The Olin Conductorless Orchestra—an ensemble, minus conductor—features engineering students in collaborative, communicative, and leadership roles. It is the only conductorless orchestra composed of engineers—in the world. Yet as described herein, the rationale and blueprint for an orchestra where every member simultaneously leads and follows

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applies to diverse engineering schools large and small, East and West. Developed over the past 14 years, the OCO blueprint features a set of core values encouraging each player to be inquisitive, actively participatory, and ambitious. To emphasize these core values, OCO requires prospective members to rehearse with the ensemble as part of the auditioning process; at the same time, prospective members can ascertain whether OCO provides a good musical fit for them.

Other parts of the blueprint involve piece selection by the group, sight-reading sessions (where, for fun and challenge, students play music unknown to them), creative injections (brief humorous skits and activities that focus on some aspect of the orchestra or its repertoire), and board meetings to plan weekly rehearsal agendas—all geared to achieve peak concert performance. Professional string/wind/brass/percussion performers in the Boston area (“external guests”) and a faculty “guide-on-the-side” provide constructive feedback.

Just as a self-governing orchestra such as the Berlin Philharmonic has myriad constituencies that influence its operation (Lehman, 1999), OCO has external constituencies, including the Olin Offices of the President; Provost and Dean of the Faculty; Board of Trustees; Admissions; Student Affairs; and Development, Family, and Alumni Relations.

What does a conductorless model offer student engineers preparing for roles in a twenty-first century world? In a word—leadership—and the responsibility that goes with it. That responsibility includes taking the initiative to diagnose problems, learning to effectively communicate possible solutions, and testing/implementing the discussed changes (Seifter & Economy, 2001). In so doing, the students build scaffolding for effective teamwork.

Background

A conductorless orchestra is first and foremost a large team collaboration by individuals working toward a high performance goal. By design, no overarching figure exists to sculpt an interpretation and pull the performance together. Rather, the members themselves bring the concert to fruition. Such an orchestra exerts singular demands on each individual during rehearsals and performances: the musicians must actively listen to their parts within the context of a larger whole and adjust accordingly, without being told by a conductor. A clear example entails all players watching one another to ensure everyone starts and ends together. More nuanced examples involve adjusting balance, dynamic levels, and tempo by listening intently, eyes on others, and cueing.

Professional conductorless orchestras have existed in the past: the Russian ensemble Persimfans (Khodyakov, 2008) and the American Symphonic Ensemble performed in the early twentieth century (Oja, 2000). Today a number of all-string conductorless orchestras exist, with the Orpheus Chamber Orchestra (1972–present) distinguishing itself from these by including winds, brass, and percussion. The Orpheus Process, i.e., how the orchestra evolved a play book enabling professional

musicians to create a successful conductorless orchestra, has had significant cross-over application to business and management practices (Seifter & Economy, 2001). Might a student conductorless orchestra composed entirely of engineers be viable? Can it help educate an engineer? The answer is yes to both questions.

The Basic Argument

Research has shown that for engineers to move forward in their careers, they require cognizance and experience with leadership, teamwork, and communication (Osburn & Stock, 2005; Seat, Parsons, & Poppen, 2001). But why design deliberate programs and/or course requirements to develop this skill set specifically in engineering students? Though millions of university students major in the arts and humanities, little concerted effort exists to offer programs furthering their performance skills, especially in leadership and teamwork. Why do engineers require special treatment? Because research has shown that engineers in general exhibit field-independent behavior characterized by a desire to work alone, a reluctance to engage in social activities, and difficulty in detecting nuance (Seat et al., 2001; Witkin & Goodenough, 1977).

Engineering constituencies in business, industry, and government have noticed this field-independent behavior. They want twenty-first century engineers, preferably with multiple intelligences that encompass, in addition to math and science, skills in language, leadership, and team building (Miller, 2008; National Academy of Engineering, 2005; National Science Foundation, 1996).

When industry, business, and government call for changes, the Academy listens. Engineering educators have worked with social scientists, psychologists, business leaders, and human resources personnel to create programs that address performance skills (e.g., at the University of Tennessee). Others have consulted with and hired performing artists to develop these same skills (e.g., Cooper Union).

The business community often examines performing arts ensembles, especially music ensembles, as models for optimal organizational performance. Such ensembles aspire to collective virtuosity—the ability of a group to reach peak performance (Marotto, Roos, & Victor, 2007). Students can also experience peak performance. Once experienced, peak performance becomes a highly desirable outcome that students want to experience again: it brings joy and “flow,” as defined by Csikszentmihalyi (1996).

A student conductorless orchestra can reach collective virtuosity (i.e., peak performance by a group), as will be discussed with respect to the Olin Conductorless Orchestra. A necessary condition for collective virtuosity is transformational leadership, communication, and teamwork.

It is no accident that both the Orpheus Chamber Orchestra (a professional conductorless orchestra) and the Olin Conductorless Orchestra eventually evolved a distributed process of meaning-making leadership—a leadership style well suited for an array of teams in engineering, business, government, and academia. Such a

process enables team members to find value in, and make sense of, their efforts¹ (Drath & Palus, 1994; Hackman, 2005; LaBarre, 1998; Seifter, 2001; Seifter & Economy, 2001).

Effective leadership requires excellent communication and teaming skills. Research has shown that music-making confers certain linguistic advantages to musicians. These include enhanced listening comprehension, hearing, and signal discrimination (Patel, 2007). A conductorless orchestra builds upon these attributes by setting a culture of when and how to listen, when to talk, and when to refrain.

Music may also be a key component for teamwork, as if it is wired into our human DNA from primeval times. Research by Dunbar (2012) suggests that music evolved in early human societies when societal groups became too large for social grooming. Music provided social glue. Similarly, a conductorless orchestra may offer a natural way to tap into human team building.

Neuroscience has found additional benefits of music-making. Male musicians, for example, have a relatively larger cerebellum and corpus callosum than do male nonmusicians (Hutchinson, Lee, Gabb, & Schlaug, 2003; Lee, Chen, & Schlaug, 2003). An increase in the size of the cerebellum suggests that its role in cognitive function and motor coordination is enhanced due to structural changes in neurons and their synapses (Holtmaat & Svoboda, 2009). Similarly, a larger corpus callosum indicates greater connectivity between left and right hemispheres of the brain (Lee et al., 2003). Therefore, a musician may already be ‘hardwired’ for skills transfer, showing an increased ability to make connections and transmit learning from one domain to another.

These neurological benefits indicate that the engineer-musicians in our midst are likely well suited for strong performance skills. A conductorless orchestra gives them a lab to experience and absorb shared leadership, cooperative teamwork, effective (and efficient) communication while doing something they love.

As an academic course at Olin, OCO works as a project-based learning (PBL) lab where students operate the classroom and the faculty instructor functions as a professional guide on the side (“faculty guide,” for short). The members of the orchestra fill various roles such as ‘piece leaders,’ ‘section leaders,’ ‘navigators,’ and ‘transcribers.’ Elected piece leaders craft an initial interpretation of a work chosen by the orchestra. Section leaders, elected by their fellow players from each of the string, wind, brass, and percussion sections, help guide sectionals. Elected by the full orchestra as overall leaders, the navigators (usually two) work in conjunction with the faculty guide to ensure that rehearsals run smoothly and communication lines stay open within the group. For each new piece selected by the group, transcribers input the original score into Sibelius, a music notation program. The faculty guide then “reorchestrates” the original score to suit OCO’s instrumentation for any given semester. Because Olin is a small school, its orchestra includes non-traditional instruments and unbalanced choirs of woodwinds, brass, and strings. The faculty guide also brings in external guests—musicians external to Olin who play

¹ In the words of Drath and Palus: “[Meaning-making leadership is] the process of making sense of what people are doing together so that people will understand and be committed.”

professionally in the Boston area—so that student musicians hear additional perspectives on the music at hand. All OCO musicians work together with the navigators, piece leaders, section leaders, transcribers, faculty guide, and external guests to create a meaningful musical experience not only for the orchestra but also for its audiences.

In collaborating with each other, sometimes intensely and often with humor, the orchestra has risen to a higher level each year since its inception during fall 2002. The OCO rose to these higher levels due to an appreciation for leadership, skill, compromise, dialog, and respect for others. Furthermore, OCO students have consistently included some of Olin's finest engineers, mathematicians, and scientists.

A conductorless orchestra comprising engineering undergraduates can be successfully implemented at other engineering schools. The following pages show why and how such an orchestra makes sense for future engineers. They build an argument for a conductorless orchestra composed of twenty-first century engineer-musicians who will go on to collaborate, communicate, and demonstrate effective leadership throughout the world.

Motivation

We all have a tendency to view life through a particular lens which in turn reflects our habitual ways of thinking and being. Yet even a cursory reading of history and literature shows that in fact each day, any given situation offers many possibilities. A great leader and communicator has nurtured a “cultivated self” able to detect the nuance of possibility (Senge, Scharmer, Jaworski, & Flowers, 2005). How can engineering students reach their professional potential and a cultivated self?

In the 1955 Grinter Report, engineering educators advocated integrating the arts, humanities, and social sciences into undergraduate engineering curricula (Froyd, Wankat, & Smith, 2012).

If the student is to be provided with a foundation upon which he may build a career of professional stature, his education must help him to seek his fullest development as an individual. [...]

His facility with, and understanding of, ideas in the fields of humanities and social sciences not only provide an essential contribution to his professional engineering work, but also contribute to his success as a citizen and to the enrichment and meaning of his life as an individual. (Grinter, 1994)

In the years since 1955, the same appeals continue to be voiced. For example, in 1990 J. Ben O'Neal, then a professor at North Carolina State University, wrote a piece in the IEEE Communications Magazine where he observed:

It is not uncommon to see engineers stranded in mid-career because of a narrowness of perspective and a lack of leadership qualities. Technical expertise is required, of course, and the universities do a reasonably good job of providing it. Most engineers are limited in their career not by a lack of technical knowledge, but by an inability to reason verbally, communicate their ideas to others, and furnish leadership. These skills seem to be better developed in the humanities than in engineering courses. (O'Neal, 1990)

Yet these appeals are not limited to the West. Calls for development of performance skills, specifically leadership, teamwork, and communication, are heard in many parts of the world. In a 1998 study comparing Turkish and North American engineering programs, Turkish educators noted the stronger emphasis on math and science at Turkish universities, but lamented the tendency to teach as many technical courses as possible while neglecting the arts, humanities, and social sciences. This predilection for the technical over the liberal arts has not only occurred in Turkey but elsewhere, presenting a “dilemma which a university in a developing country must resolve, if the aesthetic, psychological, sociological, and other cultural relations and consequences of scientific and technological development are to be taken into account” (Bilsel, Oral, & Pillai, 1998). Stating that the “importance of the humanities and social sciences in engineering education cannot be overemphasized,” the authors quote O’Neal as to the reasons why:

Humanities courses are also important for professional reasons. There is evidence that engineering and science courses do little to promote professional leadership. A [1986] study of leadership in the Bell System shows that, among people of comparable intelligence, those with an education in the humanities were judged to possess stronger leadership qualities than those educated as engineers. (O’Neal, 1990)

It is no secret, then, that the quality of performance skills in engineering graduates—including the ability to listen/write/speak effectively; resolve conflicts; work well in teams; respect diverse populations involving race, ethnicity, gender, and socioeconomic standing—concerns both industry and engineering educators (Seat et al., 2001). Thus, equipping and strengthening these traits in the undergraduate engineer becomes a necessity for all nations in an increasingly global environment.

Active listening, time management, exceeding expectations, flexibility, and respect for others are keys to leadership. All are developed in a conductorless orchestra. Without a conductor to cue them, musicians must listen and watch, dynamically adjusting to a constantly changing musical landscape. Outside of orchestra, these same engineer-musicians have to manage their time well enough to include practice and rehearsal sessions on top of an already rigorous academic schedule. Because the bar can always go higher in music, they know how to raise and exceed expectations. Yet each has to be adaptable and flexible enough to perform the group’s repertoire even if the interpretation of a given piece, e.g., the tempo decided upon by the orchestra, goes contrary to what they personally feel. In this way, they demonstrate respect for others.

Field-Independent Engineers

To further provide context for the value and usefulness of a conductorless orchestra, we have to consider why engineers are often stereotyped as possessing excellent ‘technical skills’ while lacking ‘people skills.’ Most communication breakdowns involving engineers occur because the engineer focuses on the details of the subject at hand and then expects others to follow suit (Osburn & Stock, 2005).

The typical engineering graduate likes to solve problems, dislikes unpredictability, likes structure, responds to challenge/competition, and has been rewarded for individual work (Seat et al., 2001). But life is messy, dynamic, unpredictable—often due to human action or inaction.

Scholarly research has supported these stereotypes through examination of the usual cognitive style of engineers, a style known as field independent behavior (Seat et al., 2001). By contrast, field-dependent children and adults respond more to external social cues and social situations than those who are field independent. Field-independent individuals have an “impersonal orientation,” show less interest in others, and prefer nonsocial environments. On the other hand, they work with greater autonomy, cognitive analysis, and structure (Witkin & Goodenough, 1977).

In light of the earlier research, it is not surprising that performance skills (leadership, communication, and teamwork) can pose problems for a number of engineering students. Given a predilection for finding the right answer, without ambiguity, they can become uncomfortable in situations characterized by unknown outcomes and unplanned responses, e.g., perceived disagreement or conflict (Seat et al., 2001).

A conductorless orchestra offers real-time experience with conflict resolution, decision-making, and brainstorming within an established culture—music—where give and take are part of the behavioral lexicon. In OCO, students resolve conflicts about interpretation by playing the various suggestions and then deciding on the basis of musical reasoning. ‘Excellence’ voting determines the outcome: each student votes for all suggestions he/she is comfortable with, rather than choosing just one. The OCO’s co-navigators are also elected through ‘excellence’ voting.

Field-independent engineers can also be uncomfortable with movement, yet physical gesture provides ease and efficient communication. Individual or group motion while playing helps a conductorless orchestra synchronize. Not only does movement connect performers with one another, it also connects their music-making with an audience. Here is a performance clip of OCO performing Dvorak’s Eighth Symphony at the 2014 Olin Exposition: http://bit.ly/OCO_Dvorak8. It demonstrates the communication (including gesture), teamwork, and distributed leadership enabling all to lock in for the exciting accelerando to the end.

Constituencies

Since the mid-1990s industry and governmental agencies have pointed out that engineering students ‘get’ math and science but many fall short on the social toolkit that will allow them to further their engineering talents. Performance skills enable engineers “to use their technical abilities as a part of a team, to understand conflict as a means for discussion instead of an angry confrontation, and to respect difference as a creative opportunity rather than an obstacle. To achieve success, today’s engineers must be team players who thrive while working with a variety of people having differing social, educational, and technical skills” (Seat et al., 2001).

Then President of Exxon Research Clarence Eidt reinforced this view in a speech entitled “Institution-Wide Reform: Toward a Coherent Plan” given at an NSF-sponsored colloquium on revitalizing engineering education in 1996:

“Appropriately prepared” Exxon employees have, of course, mastered the fundamentals of their chosen disciplines. But, they must have other qualities as well. We place a premium on employees who can communicate with those outside their disciplines, including non-scientists and non-engineers, who have the interpersonal skills for teamwork as well as leadership, who have the flexibility to grow and change as needs and demands change, and who will be able to serve the company in many different capacities over the years. We have to be aware of global interdependence in our world and an emphasis on teamwork over isolated individual activities. (NSF, 1996)

The 1996 NSF Report further supported Eidt’s view by advocating student engagement in activities that encourage cooperation, teamwork, and discourse to increase both comprehension of concepts and appreciation for discipline. As a case in point, disastrous consequences can result from their absence, as occurred on January 28, 1986. Before the Challenger space shuttle exploded shortly after launch on a cold Florida day, Morton Thiokol engineers tried to warn their managers about possible failure of the O-rings that seal joints on the solid rocket boosters. They made their case technically but ultimately unpersuasively. The managers in turn failed to adjust their mind-set when presented with technical evidence. They failed to listen. If the engineers possessed more of a performing arts bent, they might have instinctively done whatever necessary to convey the direness of the situation (Osburn & Stock, 2005).

Performing artists specialize in communicating content, whether abstract (as in music) or concrete (e.g., a theatrical story). They engage all their senses, mind, and body to communicate directly with an audience. Reaching the public across footlights often defines the success of their art. In doing so, they become increasingly adept at communicating with different people, developing the ability to sense and therefore adjust to the expectations of those listening.

Arts-Based Learning

The business sector is always looking for ways to create and manage effective teams and to inspire and motivate individuals. By periodically reviewing new learning and development approaches, businesses help ensure their individual employees and organizational structures stay fresh (Manning, Verenikina, & Brown, 2005).

Just as the Academy (e.g., Cooper Union) has employed performing artists to develop leadership, teamwork, and communication skills in engineering students, the business sector has also looked to performing arts ensembles as viable models for organizational restructuring. This is quite a reversal of the usual business–arts relationship where art groups solicit the financial graces of corporations. But in today’s world, that relationship has expanded (Seifter, 2001).

Why is arts-based learning effective? Why would Cooper Union and the business sector tap the performing arts to instill and motivate improved performance skills?

First, the process by which artists give feedback to one another, build teams, and rehearse carries over to business entities (Bartelme, 2005). Second, arts-based learning cultivates a “reflective intelligence”:

A valuable feature of aesthetic experience is the feeling of self-integration it induces. It is as if the harmony or unity of an artwork is replicated internally through a feeling that things have fallen into their proper places within a larger whole. This effect may be regarded as a kind of clarification, and it is often accompanied by the exhilaration that derives from the achievement of coherence among seemingly conflicting stimuli. The mind, as it were, is freed of clutter and can therefore act more decisively. (Smith, 1996)

Art fulfills the human desire for novelty and excitement by offering at its best, among the most pure and gratifying of human experiences. In addition to relieving tension and stimulating feelings of self-integration, aesthetic experience also develops perceptive and discriminatory capabilities. It stimulates imagination, which in turn fosters greater sensitivity to interpersonal relationships, e.g., by staying open, flexible, and cognizant of another's point of view. “Further consequences may be a disposition to entertain alternatives generally and to be more accommodating in one's outlook, that is, to transcend narrow-mindedness and stereotypical thinking. A cultivated aesthetic imagination ... will find application beyond aesthetic contexts” (Smith, 1996).

One such application can be found in the synergy between music performance and engineering practice. Both are lifelong arts. An engineer's world is always expanding as new discoveries and methodologies come online. The same applies to a musician: the better one gets, the better the imagination. The bar always moves higher. These disciplines necessitate collective diagnosis, often under the pressure of a deadline, e.g., a completion date for an engineering project and a concert date for a music ensemble. Deadline pressure often leads to the experience of “pulling something out of one's hat,” i.e., finding a novel and fundamental solution to a pressing problem that might not occur without a deadline. Demonstration is critical to both disciplines. Engineers design, test, observe, and repeat the process till they get the best solution to the problem, given a set of constraints. Musicians test out different interpretations, revise, and refine in order to create a memorable performance. Finally, engineering and music demand practice—experiential practice. An engineer cannot be successful by book alone. He or she has to “practice engineering as a kind of performing art” (Felsing, 2007; Miller, 2008) to be an effective contributor. A musician has to step up to the plate and take action in order to make music.

Why Music Ensembles?

The business community has shown particular interest in the study of music ensembles, ranging from the string quartet as a self-managed team of four players (Gilboa and Tal-Shmotkin, 2012) to chamber and symphonic orchestras (LaBarre, 1998; Seifter & Economy, 2001). Businesses study these ensembles because, in the best cases, they successfully share leadership.

Writing in the *International Journal of Management Concepts and Philosophy*, Tovstiga, Odenthal, and Goerner argue that management can learn valuable lessons by studying musical performers and how they interact and communicate:

In many respects, an ensemble is not unlike a modern business organization. Both exist in real time to generate value of some sort, whether for a concert audience or a group of customers. Both rely on complex organizational processes, involving interaction between individuals and the collective. Both rely on knowledge creation and its exchange, much of which occurs in the tacit, invisible realm. And, both can fail to generate value. Perhaps the only difference between the two is that “failure” in the case of an ensemble is immediately apparent; business failures may become obvious only after some time. (Tovstiga, Odenthal, & Goerner, 2005)

Leadership can often be flexible in music ensembles where players assume leadership roles as necessary. “Leadership may manifest itself in interchangeable roles (for example, variable and interchangeable lead roles are taken on by individual quartet members on an as-needed basis—often as dictated by the music score). Potential conflict, when it does arise, is typically worked out through playing rather than through talk” (Tovstiga et al., 2005).

Flexible, collaborative leadership also defines the Orpheus Chamber Orchestra, a professional conductorless orchestra which has given numerous workshops for the business community on successful shared leadership (Seifter & Economy, 2001).

Even a large conducted orchestra can have a form of shared leadership. Conductor Benjamin Zander has spoken at length on his orchestral role, consulting with business organizations worldwide. Here he presents his “I am a contribution” view of stewardship, a process he has employed with the Boston Philharmonic, an engaged orchestra with an avid audience base:

Too much of the business world uses a narrow definition of success. I used it myself for a long time. I could not focus on what I had in front of me. I could think only about what else I ought to be doing, and whether that was enough. Then, one day, I had an epiphany. I realized that this is all a game we’re playing. It’s called “the Success Game”—or, I suppose, “the Success-Failure Game,” because failure follows success everywhere. The Success Game runs in an endless win-lose cycle—which means that the people in it live with a sense of anxiety and fear.

So I invented a new game, called “I Am a Contribution,” or “the Contribution Game.” It’s easy: You wake up in the morning, convince yourself for a few minutes that you are a contribution, and you go out and contribute. Then you go to bed and do it again the next day. What I’ve discovered since I started the Contribution Game is that people have an endless amount of energy for it. Sure, goals can be energizing—when you win. But a vision is more powerful than a goal. A vision is enlivening, it’s spirit-giving, it’s the guiding force behind all great human endeavors. Vision is about shared energy, a sense of awe, a sense of possibility. That’s what fuels the Contribution Game—and that’s what’s behind all great performances. (LaBarre, 1998)

Businesses find synergy with Zander’s experiential views. Though he is the authority figure for the Boston Philharmonic and ultimately held accountable, he is also in the trenches with his musicians, doing whatever it takes to make sense and meaning out of what they accomplish as a community of practice.

Peak Performance: Collective Virtuosity

All of engineering's constituencies—industry, government, business, and academia—value peak performance. From a management perspective, working groups that achieve peak performance share certain attributes: their members experience something transformational, what Csikszentmihalyi describes as “flow,” as being at “one” with what they are doing (Csikszentmihalyi, 1996). Peak performance often results in suspension of time, bonding the group together as they experience great joy and inspiration. Organizational literature has posited that “such experiences are gateways to increased creativity” (Marotto et al., 2007).

An orchestra provides an excellent laboratory for studying peak performance, which is by definition “action oriented.” An orchestra's very existence depends on the ability of its musicians to bring masterworks to life and reach across the footlights to an audience. In a conducted orchestra, the conductor creates the character of a work by establishing tempo, monitoring balance, ensuring clean entrances and cutoffs, imagining a wide range of dynamic levels, timbres, and textures (Marotto et al., 2007).

But in a conductorless orchestra, the musicians themselves make these artistic decisions. For students who have played in conducted orchestras throughout high school, the conductorless orchestra offers a challenging experience and the potential for an optimum experience where the clock slows down, or even stops altogether, such that the players are “in the moment” (Csikszentmihalyi, 1996). Preparing for and presenting concerts offers excellent opportunities for students to experience the concentration and focus that enables “flow” to occur. Moreover, a flow experience in one domain can serve as a transfer mechanism for experiencing optimal performance in another domain (Brandsford & Schwartz, 1999).

A traditional conducted orchestra often relies on the charisma and leadership of the conductor to catalyze peak performance, whereas in a conductorless orchestra, everyone brings something to the table. Leadership and support emanate from each player. If someone does not contribute, then little benefit accrues for the individual or group.

Relationships among the members of the ensemble contribute to peak performance. Hearing a beautiful solo during rehearsal and/or performance galvanizes others to produce their best. This happens repeatedly in music ensembles. For example, the opening cello solo in a reorchestration of the popular YouTube hit Danzon No. 2 was cited by OCO students as ‘setting the stage’ for a transcendent performance:

In between pieces before Danzon, I remember thinking about how much I had played already and wondering if I had enough left in me for Danzon. But as soon as Abe started in on his solo, all of those thoughts went away and I was engrossed in the music all the way through the big ending.

Group members are both soloists and active contributors in using their instruments, eyes, and ears to communicate with each other. Here a student describes his preparation:

Before the first note, I looked around the ensemble, making sure to make eye contact with other players starting with me but still noticing the excitement in everyone's eyes. I'm still not sure whether the cause of excitement was nearing the end of the [full concert] or the piece itself. Maybe it was a combination of both. I vaguely remember feeling the beat and relaxing the tension in both my hands; it's almost like surrendering yourself to the music, letting the flow of the music itself take your conscience (or subconscious) away on a stream. I gave the cue, and we started playing.

It was beautiful.

In communicating with one another, these student musicians form a community of practice. Their musical experience becomes collective. Collective virtuosity is defined as peak performance achieved by a group (Marotto et al., 2007), as evidenced by an OCO musician:

I could feel everyone be a part of the music, and for the first time in a while, I was a part of a group of musicians who play *music*, not a set of musical notes. In fact, the performance of Danzon was the epitome of an ensemble playing music. Playing music that way transcends both the audience and the performers, and that experience is what I'd call a reward for an excellent performance.

What started as a subset of orchestra and my solo carried on through the next ten minutes or so, where we were intensely focused and had the same exact goal and idea as to where we wanted to go and how we wanted to end this piece—*with a bang*.

So, we did.

Collective virtuosity can emerge when the ensemble puts interpersonal differences into the background and its members focus on a larger purpose than themselves—the ensemble performance. In doing so, the group realizes that their sense of community and collective virtuosity can “co-exist with conflict, competition, and difference.” In fact, how the group members interact with each other and engage with their work will ultimately enable or preempt collective virtuosity (Marotto et al., 2007). As another OCO student observed:

There was a lot of leadership in Danzon, but even more support. For every solo and cue, there were a dozen other musicians listening, following, and providing backup. This was facilitated by strong communication and helped bring our performance to the next level.

Such engagement can happen across a stage. Interaction can even occur with the performers' backs to one another. In many OCO performances, the timpanist could be heard and seen leading from the rear of the concert space, giving 110% of himself. As a result, the other players caught the energy coming from his timpani strokes and the precision of his beat. The timpanist was totally focused and at ‘one’ with the other players as he led them with his precise, clear beat.

Collective virtuosity can also be destroyed, as when a player enters at the wrong time. Then the spell or story being woven by the musicians is interrupted. Though the musicians catch on and the performance moves forward, the spell is broken (Marotto et al., 2007). So the player works harder for the next performance, as do the others: since they have each experienced flow at one time or another, they want to experience it again. Collective virtuosity is addictive—a joyful memory—“What made our performance most memorable to me was how we worked together to produce high quality music.” (Student response May 19, 2013)

Teamwork

A conductorless orchestra provides a teaming experience. In fact, it resembles the Self-Managed Team (SMT) defined as a “group of employees that is responsible for a whole product or process, that does work that involves designing, evaluating and performing, takes possession of the results, and manages many of the things for which supervision or management are usually responsible” (Attaran & Nguyen, 2000).

SMTs under certain conditions can be very successful. They encourage shared and rotated leadership among team members. Each member accepts responsibility for team output and delivery goals, resulting in high commitment levels. Furthermore, “each team member must develop qualities of a leader such as risk taking and receptivity to new ideas and directions, in addition to technical expertise” (Gilboa & Tal-Shmotkin, 2012).

Many best practices for teamwork cross between the domains of business and the performing arts. To help a team reap the benefits of collaborative work and avoid pitfalls, at least one person must remain vigilant (Rouse & Rouse, 2004). In OCO those persons are the co-navigators and the faculty guide. Each brings experience from respective domains. For instance, the co-navigators understand the college's student culture better than the faculty member, while the faculty guide has professional experience.

For successful teamwork in a small ensemble such as a string quartet, the players must address three questions:

1. Designate a leader or pursue a democracy, i.e., decisions made by consensus?
2. What is the role of the second violinist? Typically the second violin parts are less demanding than the first violin parts yet the second violinist has to be as good as the first violinist to assure quality. This is why many quartets today switch the roles of the first and second violinist from one piece to the next.
3. If conflicts arise, do we choose confrontation or compromise? (Rouse & Rouse, 2004)

These earlier questions also apply to a conductorless orchestra. The OCO resolved the first by electing co-navigators who, among other duties, try to keep the group on task. The piece leaders and section leaders also help guide rehearsals and keep a good balance between talking and playing, with the emphasis on playing.

The OCO answered the second question by realizing that, at one time or another, each musician functions as a ‘first’ or ‘second’ violinist. As a result, the entire orchestra interchangeably fulfills these roles. The faculty guide reorchestrates pieces so that each player has solos and therefore experiences the importance of being supported—both musically and personally. When accompanying another musician who has a solo, OCO musicians listen to how the soloist is shaping the phrase, e.g., where s/he makes a crescendo, and then they adjust the dynamics of accompanying parts to ‘lift up’ the soloist, similar to how a male dancer supports and carries a ballerina through her role.

The typical OCO player (if there is such a thing) loves music, rises to a challenge, enjoys musical collaboration, makes suggestions, learns when to listen and when to speak up, likes solving musical problems (e.g., how to stay together through a tricky passage), learns how to give useful feedback and take initiative—all of which are among the necessary interpersonal skills of a self-managed team (Gilboa & Tal-Shmotkin, 2012).

Still, OCO has had its share of confrontations in the past. So to solve the third question, the musicians initiated a group audition to ensure not only that its musicians play well but also that they ‘play well’ together. Collaboration is central to excellence in any ensemble. Though the musical score provides expectations for the musicians, it does not spell out every detail; much room exists for interpretation. Listening to recordings of how other ensembles interpret a score can provide context (Rouse & Rouse, 2004). Both the score and recordings help resolve differences regarding interpretation, along with musical reasoning based on harmony, counterpoint, and orchestration.

But a larger question looms: Why might music provide an excellent way to achieve team building? In other words, *is there something in our human DNA that would make music a particularly apt conduit for teamwork?*

Among the many aspects of human behavior and cognition that can be counted as universals, music and dance are perhaps the most striking. Every culture boasts something that is instantly recognizable as music; every known culture dances. While there has been considerable interest in the psycho-biological underpinnings of musical ability and appreciation, and some interest in the timing of its origins, the one aspect that has proved unusually intractable has been its function (Dunbar, 2012).

Robin Dunbar, Director of the Institute of Cognitive and Evolutionary Anthropology at the University of Oxford, admits that though disentangling the evolutionary history of music poses difficulties, “careful consideration of the role of music in human social life suggests that its original function is most likely to have been associated with social bonding, once group sizes became too large to be adequately bonded using grooming alone” (Dunbar, 2012).

As a primate specialist, Dunbar also posits that music evolved from laughter, a vocal behavior unique to humans and chimpanzees. Just as laughter served as a grooming (bonding) tool, music also provided social glue and eventually, a natural bridge to language. The latter evolved as human group size increased toward levels where language inevitably became the mechanism for group bonding and cohesion (Dunbar, 2012).

Thus, current anthropological research suggests that music-making provides a natural conduit for human bonding. It follows that a conductorless orchestra offers a natural environment for collaboration, where students build, sustain, and contribute to a team.

Leadership

Common understandings of leadership center on two models: dominance and influence. In the dominance model, one person takes charge and others accept his or her leadership, at least initially, because the leader appears to have the best plan for

proceeding forward. Winston Churchill in the early days of World War II embodied dominant leadership as he rallied his people to defend their nation and preserve liberty. In the influence model of leadership, the leader moves an organization forward by persuasion, by making the better argument. Abraham Lincoln coaxed the American Congress, sometimes member by member, to ratify the Emancipation Proclamation of 1863, freeing all slaves during the American Civil War. Leadership, whether by dominance or influence, usually focuses on the example of a powerful individual taking charge.

This aspect of leadership is like the whitecaps on the sea—prominent and captivating, flashing in the sun. But to think about the sea solely in terms of the tops of waves is to miss the far vaster and more profound phenomenon out of which such waves arise—it is to focus attention on the tops and miss the sea beneath. And so leadership may be much more than the dramatic whitecaps of the individual leader, and may be more productively understood as the deep blue water we all swim in when we work together. (Drath & Palus, 1994)

An orchestra includes an array of knowledgeable musicians all focused on making good music together, yet all bringing varied personalities, ethnic, religious, and economic backgrounds into the mix. A leader of such a group might ask, according to the dominance and influence models of leadership:

- a. How can I take charge of this talented and disparate group of people?
- b. How can I influence them to work together harmoniously?
- c. How can I make them accept my influence willingly, without having to resort to authoritarian methods (which won't work with them anyway)?
- d. How can I make good things happen for this ensemble and accomplish our goals?
- e. In short, how can I implement effective leadership? (Drath & Palus, 1994)

Yet another model for leadership exists that includes a meaning-making process—one that arises out of a group's realization and desire to make meaning, to make sense of what they want to achieve. As is well known, people resist committing to something they do not understand. One reason why the business world has studied artists for valuable lessons in leadership may be because artists have to reach out beyond the self to convey a vision. Thus, artists face an 'understanding' or 'making sense' barrier on a daily basis and ask, "How do I transform my private meaning into public meaning?" (Drath & Palus, 1994)

In a community of practice, however, a leader of the meaning-making process has to shift from the question "How can *I* make things happen?" to asking:

- "What do *we* need to do to make things happen?"
- "How can *I* figure out the best ways to participate in the process of *us* making it happen?" and
- "How can *I* help guide *our* activities toward the creation of significance?" (Drath & Palus, 1994)

J. Richard Hackman echoes (Drath & Palus, 1994) when he writes:

A leader cannot make a team be great, but a leader can create conditions that increase the chances that moments of greatness will occur—and, moreover, can provide a little boost or nudge now and then to help members take the fullest possible advantage of those favorable conditions. (Hackman, 2005)

Leadership that not only focuses on sense- and meaning-making but also ensures that “the team’s basic performance conditions *are* sound [thus helping] team members take the greatest possible advantage of their favorable circumstances” is the leadership model adopted by the Olin Conductorless Orchestra. This leadership is practiced by the co-navigators, piece leaders, and section leaders, assisted by each member of the orchestra and the faculty guide. Charged with enabling meaning- and sense-making to occur for the entire orchestra, the faculty guide and the co-navigators are ultimately held accountable for assuring the social and musical success of the orchestra. Thus, they might ask the following questions:

1. What is the nature of this group of people?
2. What is the most effective process of leadership for this group at this time? How might that process change as the group develops into a community of practice with a shared history that will unfold during this academic year?
3. How can we, as holders of some authority, participate productively in this process of leadership? (Drath & Palus, 1994)

In successful meaning-making, the leadership process becomes more distributed, resulting in influence as a beneficial outcome. Effective meaning-making leadership increases feelings of significance experienced by those in a community of practice. The question then for an authority figure is not how to get people to do what is necessary but rather how to participate in the structuring of the ensemble so that “people marginal to its practice are afforded the means to move toward the center of that practice. In other words, how can the contribution of each person in the community of practice be made increasingly important and increasingly appreciated for its importance?” (Drath & Palus, 1994)

In this “meaning-making” model, the leader(s) participate in the group, listen to its members as they discuss the task at hand, and understand the nature of their goal and its deliverables, i.e., why the goal matters, why the task at hand makes sense. Such participation helps lay the groundwork to create meaning for everyone’s work. The leadership role becomes an empowering one, helping the group to make sense of the project and grasp its significance, or to paraphrase Hackman (2005), “creating the conditions for success.” Understanding the group’s goal as meaningful provides powerful motivation for everyone to work individually, and together. Their reward lies in the process of reaching their goal, and/or attaining the goal itself, thus bringing meaning to their professional or personal lives, and sometimes both (Drath & Palus, 1994).

A community of practice has a social character in that people work in tandem toward a goal. But “they are united by more than membership in a group or category.” They are united by the “the power of shared activity to create shared knowledge and shared ways of knowing.” Such a community, here a conductorless orchestra, focuses on the group’s interpreting, anticipating, rehearsing, and planning together. Relative standing within the ensemble can shift depending on the topic at hand, according to an individual’s time spent, expertise with that topic, and instrument (Drath & Palus, 1994).

Meaning-making can involve “influence” leadership when students take the advice/suggestions of other students in the group deemed more knowledgeable at a

given time (e.g., piece leaders), as well as external guests and the faculty guide, whose combined professional experience can address remaining issues or concerns. Thus, together all participate in the sense- and meaning-making process.

Finally (Drath & Palus, 1994) ask: “So what about traditional leadership development? Should we abandon individual training in leadership? We think not.”

If, in the past, leaders have been trained to exercise leadership, they will now be trained *to participate* in leadership [emphasis added]. This is something like the difference between training an athlete in the individual skills of a sport and training that athlete in the team skills of the sport. Usually the individual skills are learned first. So it may be with leadership. Young supervisors and managers may need to learn the individual skills of leadership and later, as they approach higher levels of management, learn the community-oriented, meaning-making capacities, such as: (1) the capacity to understand oneself as both an individual and as a socially embedded being; (2) the capacity to understand systems in general as mutually related and interacting and continually changing; (3) the capacity to take the perspective of another; and (4) the capacity to engage in dialogue.

Sounds like a recipe for success in life where an engineer can navigate through uncharted waters, while fulfilling his or her potential at any given time. Through experimentation and feedback, the Olin Conductorless Orchestra evolved a distributed process of meaning-making leadership.

Communication

Clearly, our previous discussions regarding leadership and teamwork are predicated upon good communication, especially skill with speaking, writing, and listening. So one wonders: Does music-making develop language skills either directly or indirectly? The answer is yes. “Like language, music is a human universal in which perceptually discrete elements are organized into hierarchically structured sequences according to syntactic principles” (Patel, 2003). Furthermore, playing in musical ensembles enhances human hearing, enabling the ability to discriminate a desired signal from background noise. Studies also suggest that music can improve grammatical skills, aural comprehension, and the ability to differentiate between language that commands and language that questions (Enrenberg & Wolinsky, 2010).

Aniruddh Patel, author of *Music, Language, and the Brain*, studied the relationship between music and language from the standpoint of cognitive neuroscience. Patel’s research has established that there are areas of the brain that process both music and language, i.e., music and language share deep and critical connections, both cognitively and neurologically (Patel, 2007).

As has been emphasized for at least 60 years, facility in expression—written and oral—is a professional necessity and an overall personal asset for engineering students (Grinter, 1994). Music-making activates many of the same brain areas as language and enables musicians to discern syntax. Syntax in language governs how sentences are built from words. A musical syntax guides how pitches and rhythms combine to form musical phrases in various styles, genres, and cultures. Whether processing musical or linguistic syntax, the brain appears to access the same neural

circuits. According to Patel, “You can have overlap in the machinery that puts the pieces [the building blocks of language, i.e., words, or the building blocks of music, i.e., pitches and rhythms] together. They may be different pieces, but the machinery that puts them together is shared” (Enrenberg & Wolinsky, 2010).

Specific evidence provided by the imaging studies of Dr. Daniela Sammler of the Max Planck Institute confirms “a co-localization of the early detection of musical and linguistic syntactic errors within the bilateral superior temporal and perhaps in the left inferior frontal lobe, as proposed by previous fMRI [functional magnetic resonance imaging] and MEG [Magnetoencephalography] data. Overall, [our] present study adds (within-subject) [as opposed to between subjects] anatomic evidence to theories of shared syntactic processing in music and language” (Sammler et al., 2009). In other words, human detection of syntax errors in music and language occur in the same part of the brain, suggesting musicians may already be predisposed to effective language and syntax.

Additionally, by virtue of playing in a conductorless orchestra, musicians gain an appreciation for when and how to listen, when and how to talk, e.g., by acknowledging another musician’s point of view. As is well known, both professional and student orchestras want to spend more time making music than talking about it.

Neurological Benefits

Why would it be in a nation’s best interest to nurture its engineer-musicians? Why enable their talents with an Engineers’ Orchestra, a conductorless orchestra to call their own?

Neuroscience research examining brain structure and activity has shown that music training changes the brain in lasting and positive ways (Enrenberg & Wolinsky, 2010). Research shows long-term motor skill activity results in structural changes to animal cerebellums. So one wonders what might happen to the cerebellums of practicing musicians.

A 2003 study found “a significant difference in absolute and relative cerebellar volume between male musicians and nonmusicians. Relative cerebellar volume correlates positively with intensity of musical training throughout life in the male musician group” (Hutchinson et al., 2003). Generally speaking, when a region of the brain increases in size due to some type of training (such as practicing an instrument), the increase in brain size due to the training is associated with stronger and/or a larger number of synapses, and perhaps even more neurons (Gage, 2002; Holtmaat & Svoboda, 2009; Reader & Laland, 2002). Conversely, deterioration of synapses due to aging or disease is associated with cognitive problems, memory loss, changes in mood, and other alterations in brain function (Morrison & Baxter, 2012; Terry et al., 1991).

Neuroscientists Lee et al. (2003) studied the relative size of the corpus callosum (CC)—the main band of interhemispheric axonal fibers in the human brain—in the brains of male musicians and nonmusicians. The corpus callosum functions as the

key transfer and integrator of information between the right and left hemispheres of the brain. Lee, Chen, and Schlaug found that

... male musicians had larger anterior CC than male non-musicians. This finding replicates the result of our previous study, and based upon anatomical and developmental research, suggests that male musicians might develop greater interhemispheric connectivity and increased hemispheric symmetry between motor areas and other frontal brain regions. The early commencement of intensive instrumental training during critical time periods of callosal development might trigger these differences. (Lee et al., 2003)

Daniel Levitin, author of *This is your Brain on Music*, summarizes earlier findings when he says that the human brain processes music throughout both hemispheres (Levitin, 2007). Thus, it is reasonable to assume that a musician's brain has developed more fully than if music training had not occurred. According to Levitin, as paraphrased by (Enrenberg & Wolinsky, 2010), "Playing an instrument, in particular, is an ensemble activity. It involves paying attention, proactive skills like thinking ahead, remembering, coordinating movement and interpreting constant feedback to the ears, fingers and, in some cases, lips." Clearly, music-making involves a complex array of processes. Neuroscientist Laurel Trainor, Director of the Auditory Development Lab at McMaster University in Hamilton, Canada, explains why: playing an instrument "engages basically most of your brain." Control processes such as memory, motor skills, attention, and executive function are all enhanced by music training (Enrenberg & Wolinsky, 2010). Furthermore, musicians typically develop highly desirable traits including discipline, steadfastness, dedication, and a certain comfort level with performing before audiences. In short, they are likely already primed for leadership, teamwork, and communication skills.

Skills Transfer

As noted in the previous section, neuroscience has already established that both the cerebellum and the corpus callosum are relatively larger in the brains of male musicians compared to nonmusicians. Therefore, a conductorless orchestra pulls together musically talented engineering students already predisposed to physiological transfer via enhanced interhemispheric connectivity of the corpus callosum and an increased number of neurons and synaptic contacts within the cerebellum. Such an orchestra allows these engineer-musicians, already predisposed to physiological transfer, to also experience transfer through the "preparation for future learning" perspective of Brandsford and Schwartz (1999). But first we have to define transfer. One definition is "the ability to directly apply one's previous learning to a new setting or problem (we call this the Direct Application theory of transfer)" (Brandsford & Schwartz, 1999).

Brandsford and Schwartz offer an alternative to the Direct Application theory. They call their perspective on transfer "preparation for future learning." It builds upon Direct Application theory by widening the scope to include learning that occurs when students solve problems via experimentation, research, critical commentary, and revision.

The “preparation for future learning” perspective values and assesses a student’s ability to learn given the resources provided. “When organizations hire new employees they don’t expect them to have learned everything they need for successful adaptation. They want people who can learn, and they expect them to make use of resources (e.g., texts, computer programs, colleagues) to facilitate this learning. The better prepared they are for future learning, the greater the transfer (in terms of speed and/or quality of new learning)” (Brandsford & Schwartz, 1999).

Preparation for future learning occurs when students first wrestle with a concept or design on their own, after which they become more receptive, curious, and appreciative of what an expert has to offer (Brandsford & Schwartz, 1999). A conductorless orchestra enables “preparation for future learning” because students first engage with the music themselves. Then professional musicians comment on their work. This process facilitates knowledge and skill transfer.

A “scaffolding of the learning experience” whereby students hear different points of view on a given topic promotes learning (Catterall, 2005). In addition, OCO supports this scaffolding on a weekly basis whereby students first learn from one another, suggesting and trying out different ideas for a given piece. Learning is then supplemented by other points of view resulting from different sets of musical experiences, e.g., audiences and professionals.

Finally, there is evidence of correlations between scientific success and musical hobbies that enable idea transfer. A 20-year study conducted between 1958 and 1978 by Bernice Eiduson examined 40 male scientists and their work habits, hobbies, time management skills, and attitudes toward the arts, humanities, and social sciences, as well as toward science. She interviewed these scientists (including four who went on to win Nobel prizes) four times during the 20-year period. Then in 1988, the 38 living subjects filled out a lengthy questionnaire regarding their “use of various forms of thinking (e.g., verbal, visual, kinesthetic), their avocations, forms and extent of physical exercise, and when they were most likely to have significant scientific insights (e.g., while working on a problem directly, while working on other problems, while relaxing, on waking)” (Root-Bernstein, Bernstein, & Garnier, 1995).

Eiduson then statistically analyzed the interview and questionnaire responses with respect to the scientific impact of each scientist to determine whether any correlations existed between “scientific success and avocations, preferred modes of thinking, use of time, energy, or related factors.” The results indicated that

significant correlations existed between scientific success and particular modes of thinking (especially visual ones), between success and various hobbies (especially artistic and musical ones), ..., and between success and the efficient use of time to manage many competing vocational and avocational demands. We conclude that successful scientists have highly integrated networks of enterprise, whereas less successful colleagues tend to have fewer nonscientific activities that they do not integrate. They develop nonfunctional networks of enterprise in which activities compete against, rather than sustain, each other. (Root-Bernstein et al., 1995)

Before embarking on her research, Eiduson privately expressed “great skepticism that any connection might exist between hobbies, artistic proclivities, and scientific

work.” Thus, no positive interviewer bias existed with respect to the interview results. The survey revealed that “musical hobbies (e.g., musical composition, collecting records, singing, and playing an instrument) were generally associated with reported use of visual images while problem solving.” The study also showed a “significant association between solving problems while working on different, related problems and being a high publication citation cluster scientist.” One of these highly ranked scientists was asked if his hobbies affected his scientific work. He replied,

[Suppose] someone is getting interested in musical problems. He may then apply what he finds there back to his scientific research. That’s something which may affect very much the result. I think it’s good. I think for a scientist who is working very hard, anything is good which brings from time to time another angle about general ideas into the picture. (#11, 1958). (Root-Bernstein et al., 1995)

Music, in general, and a conductorless orchestra, in particular, offer students such an angle, bringing various perspectives into their realms of thinking due to diagnosing and solving problems in rehearsals and practice sessions.

The Olin Conductorless Orchestra

What in the life of an Engineering School makes a conductorless orchestra possible? First, a universal call throughout industry for engineering graduates who can work well in teams, assume leadership, and communicate effectively. At Olin, these were founding precepts of the College. During the first week of meetings in fall 2000 when Olin’s Founding Faculty of 12 sat together and started discussing possible avenues for the curriculum, these three performance skills were front and center. They were weighted heavily because the National Academy of Engineering and industry were insisting that engineers of the twenty-first century be multidimensional, i.e., able to not only work on multidisciplinary projects in large global teams but also poised to assume leadership and communicative roles. Much more would be expected of twenty-first century engineers than what had previously sufficed due to globalization and the exploding tech revolution.

Second, it is a well known though anecdotal truism across many nations that students gifted in math and science are often talented in music. Citing this, the Olin College Dean of Admission’s first question to a newly hired Assistant Professor of Electrical Engineering and Music during the summer of 2000 was, “Okay, where’s the Olin Orchestra?” This was not on the professor’s to do list or contract. But the new Dean had concluded that an orchestra would be essential for a college that did not exist yet because of the often observed math–music connection. (Olin’s inaugural class of students matriculated in the fall of 2002 and graduated in 2006.)

So what did a conductorless orchestra offer an engineering school? Why not a conducted orchestra? In the early days of Olin, the Leadership Team of the College encouraged the Founding Faculty to think imaginatively and try out bold ideas. They

emphasized the importance for engineering students to function well in teams as conveyed by various constituencies. There were already several conducted orchestras at neighboring colleges and universities, any of which would be open to Olin students. Did it then make sense to start yet another conducted orchestra? Given the emphasis on teamwork, would a conductorless orchestra make more sense and have greater meaning for a new engineering college? The answers were yes and so OCO started in the fall of 2002 as part of a music composition/performance course with five students—on oboe, clarinet, bassoon, violin, and cello—a faculty clarinetist, and the faculty guide on piano. (The following year four trombones passed the audition and entered the orchestra, but there was still only one violin!)

Making Musical Decisions

Diversity in an orchestra includes instrument category, musical experience, gender, nationality, cultural attitudes, cultural values, and personality. This very diversity offers an orchestra the chance to develop a creative interpretation and understanding of the musical score.

Idea generation and idea integration are critical components for any effective team, and particularly a conductorless orchestra: they are predictors of successful ensemble performance (Boerner & Gebert, 2012). We find that OCO's diversity produces creative and motivational ideas that are often adopted by the group. These ideas are not only musical but also organizational, e.g., cueing is tackled by all and shows multiple points of view based on factors as mundane as where players are seated (sightlines), and more diverse factors such as instrument type and musical experience (some players have never cued before). Organizational ideas such as a group audition/orientation session and the implementation of co-navigators emanated from musicians representing different sections (strings, winds, brass, percussion)—each of whom had distinctive attitudes and values—yet all contributing toward the same goal: to design an excellent, well-functioning ensemble that enjoys making music together at an advanced level.

Many musical attributes need to be interpreted for the performance of a given work, including tempo, balance, dynamics, articulations, and expression marks. In a conducted orchestra, these are not typically discussed among all the players in an open forum. Yet OCO's full and sectional rehearsals center on these points. Technical issues germane to the different instrument families are resolved in sectional rehearsals. These include bowings (e.g., the bow arms of the string players have to move in the same direction for synchrony and coherence), articulations (e.g., the winds need to match attacks on notes so they come in together), breathing (e.g., the brass have to decide on a plan for staggered breathing during passages with long held chord tones). All of the above are necessary for attaining a cohesive ensemble sound. Yet the musicians have to remain flexible and motivated enough to develop and even change previously agreed upon musical and technical points.

A “Typical” Season

Each fall the orchestra passes through stages: rehearsing and performing with new members who have never played in a conductorless orchestra, working to prepare pieces for the first fall concert, listening to recordings of that concert to improve performance for the second fall concert (usually 1–2 weeks later), adding more pieces to the OCO repertoire in preparation for the Olin Exposition—a college-wide exhibition of student work. The best performance of the semester usually occurs at the Olin Fall Exposition.

Each spring the orchestra learns new repertoire and perfects the fall repertoire in preparation for 3 weeks of concerts for Olin’s Candidate Weekends—a college-wide effort to welcome and evaluate selected high school seniors for Olin Tuition Scholarships. (Every admitted student to Olin receives a 2-year Olin scholarship.) Additional concerts occur off campus that feature the new repertoire and some of the fall repertoire, as selected by students. The best concerts of the year tend to be one of the Candidate Weekend concerts (standing room only for the past 9 years), an off-campus concert, and the final concert at the Spring Olin Exposition.

Figure 1 shows the OCO musicians prior to the first fall concert in October 2015. They quickly coalesced just 7 weeks into the term with Beethoven’s *Prometheus Overture*, as can be heard in a videotape recorded by Joseph Hunter (Asst. VP for External Relations and Director of Communication) http://bit.ly/OCO_Prometheus. During spring ’16, OCO attained another personal best with a complete performance of a major orchestral work—the final movement of Dvorak’s *Ninth Symphony* in a concert for the Needham Lions Club http://bit.ly/OCO_Dvorak9th. (Though only audio exists for this performance, Joe Hunter created a “music video” using photos taken during AY15–16.)

Whenever the orchestra starts a new work, it passes through a rehearsal phase and then as the piece improves, a more motivated and creative phase. Finally, the orchestra reaches for, and sometimes attains, an inspirational phase, usually close to

Fig. 1 The Olin Conductorless Orchestra, fall 2015 (Photography: Michael Maloney)



a concert. Inspirational phases have occurred more often since 2013 in large part due to changes that encouraged bonding and shared leadership throughout the ensemble. The group built a cooperative environment defined by two dimensions: “warmth and support (mutual estimation) and a high level of cohesion (absence of conflicts)” (Boerner & Gebert, 2012).

Strategies and Blueprint

With each year, OCO strives to transform individual musical talents into collective creativity. To do so, its distributed leadership has to

- Recognize when change is necessary,
- Encourage new and fresh ways of looking at problems, and
- Initiate unconventional and innovative behavior (Boerner & Gebert, 2012).

When acknowledging that change is necessary, the orchestra restructures itself. To solve unproductive contention in the past, OCO changed its organizational structure, requiring a group audition for all members, adding informal and fun bonding activities, such as weekly OCO dinners, timely rehearsal breaks, and movie nights, as well as outlining new ways for repertoire selection. As an example of unconventional, innovative behavior, the co-navigators for 2012–2013 sent out rehearsal agendas and requests that always included something humorous in their sign-off. Figure 2 shows a photo that accompanied the following solicitation for feedback after a recent OCO concert:

Let us know your ideas as soon as possible (while the performance is still kind of fresh in your mind)! Your musical rats, Philicia and David

Such unconventional emails resulted in a desirable outcome: students read and responded to them.

Fig. 2 Image accompanying an email sent by the co-navigators (Photography: © Ellen van Deelen. All rights are reserved.)



Gradually students and faculty alike learned that “the types of behavior in which people engage are infinite. But the range of useful behaviors, which make an effective contribution to team performance, is finite” (Belbin, 1993). Any orchestra, and especially a conductorless orchestra, has to set a productive, effective culture. Once set, it gets passed down from older to newer members. If it remains positive, then great benefits accrue. If it becomes negative, then problems bloom further and the orchestra has to reevaluate itself (King, 2006).

As many ensembles can attest, lethargic behavior and distracting personalities can derail an orchestra. Though these behaviors may occur from time to time, OCO's experience has been that their effects dissipate when others step forward into leadership positions during rehearsal—contributing energy, diagnosis, and suggestions on an as-needed basis. For instance, an often quiet student may speak up to rally a flagging rehearsal by suggesting a novel approach to the music at hand, sometimes with a quip. The orchestra has also devised activities through the years to keep rehearsals varied and exciting. Humorous skits and sight-reading enliven the group, giving players more spirit and focus for the work ahead. Fun and/or challenging activities called “creative injections” have become some of the most requested additions to a rehearsal. For example, students will mix up the different sections of the orchestra so that a French horn player sits next to a violinist or a flutist next to a cellist. Interleaving players from different instrumental families (a kind of “musical chairs”) enables bonding with those from other sections of the orchestra. It also allows them to hear parts more clearly.

Interview data with respect to smaller musical groups shows that “establishment of a leader within a student ensemble is perhaps the most difficult, yet crucial part of building up an ensemble. Arguably, a leader can only fulfill his or her role effectively if the remaining members of a group oblige, allowing that person to take control” (King, 2006). The OCO avoids these issues because its leadership is ‘spread out’ across the orchestra. Over its 14 years, OCO developed a similar strategy to the (Drath & Palus, 1994) distributed leadership of sense- and meaning-making. Having flexible role behavior helped the group maintain an effective working environment (Belbin, 1993), where idea generation increased from a few players to virtually all. An appreciation and respect for setting a meaningful culture can stay with students the rest of their lives; they will bring these experiences to bear on future teams, group projects, and activities, whether in the workplace, among friends, while playing sports, or within their own families.

In sum, as the Olin Conductorless Orchestra evolved, so did its blueprint. In 2006, guidelines were established to give structure to the group. These included the positions of a navigator, piece leaders, and section leaders. As the orchestra grew and the competency of the musicians increased, the model evolved yet again, focusing on the following points:

1. An improved organizational structure now with co-navigators in addition to piece and section leaders and an OCO Board (all students invited to attend) responsible for drafting rehearsal agendas and mapping progress.
2. Core values that encourage each player to be inquisitive, actively participatory, and ambitious.

3. Clear expectations about commitment, attendance policy, shared goals, and productive behavior.
4. Individual auditions plus Group Audition and/or Orientation Session to ensure people not only have individual skill but also ‘play well’ with others.
5. Repertoire selected by members using ‘Excellence’ voting.
6. Bonding activities outside of rehearsal such as OCO dinner nights, movie nights, field trips, etc.
7. Fun (and surprise) activities during rehearsal such as “creative injections” and sight-reading.
8. Open communication lines for feedback on how things are going for each member in the orchestra. What’s working well, what could be changed/more effective?

In a successful conductorless orchestra, each member not only has to talk the ‘cooperative’ talk but also walk the ‘collaborative’ walk. As Terry Bacon (2004) wrote in a piece for the *Journal of Business Strategy*: “You are how you behave.” His is a powerful message for engineering students, many of whom will go into business-related fields. Yet the message goes far beyond business and applies to every facet of our lives. The old adage, “Actions speak louder than words” has a corollary in virtually every culture.

Customers don’t believe what you tell them. They believe what you do. Behavior is genuine. It is the purest form of the expression of your *intent*, your priorities, and your feelings. No matter what language you use to describe your business and products, no matter what promises you make or how sincerely you tell customers you want their business, the truth about you will always emerge in how you act. You are how you behave. (Bacon, 2004)

A Conductorless Orchestra as Project-Based Learning (PBL)

A conductorless orchestra offers a project-based learning (PBL) lab for performance skills—leadership, teamwork, and communication—much in the same way PBL has resulted in greater retention and understanding of technical subjects by engineering students (Froyd, 2011; Froyd et al., 2012).

PBL originated in the Medical School at Case Western Reserve University. It generally encompasses the following attributes:

- Posing the goal/problem before students have learned anything
- Providing “just in time” learning
- Empowering students with selection of learning goals, resources, assessment, etc.
- Enabling students to work cooperatively in small groups (with or without a tutor present in each group)
- Engaging students actively in the learning process, e.g., students teaching one another and giving feedback (Woods, 2006).

- Maintaining standards with a “Guide on the side,” i.e., a teacher who monitors the process/progress and gives feedback

A conductorless orchestra encompasses all of the above. “Just in time learning” is provided by the piece leaders, faculty guide, and external guests. Students select their own repertoire before any music is learned. They provide feedback on the rehearsal process in real time and via email in preparation for the next rehearsal. The musicians work in one large group comprising all sections of the orchestra—winds, brass, strings, and percussion—and also in smaller units. Students teach one another since each brings a level of expertise to the music-making process.

The faculty guide has several roles similar to those responsibilities described by Drath and Palus (1994), specifically, doing whatever it takes to help the ensemble reach its goals and maintain standards. For smaller colleges such as Olin, the faculty guide also reorchestrates repertoire chosen by the orchestra. This is necessary because the students often select works originally written for large orchestras (80+ players). These pieces have to then be reorchestrated for much smaller ensembles (12–23 musicians) playing an array of instruments where the traditional balance among winds, brass, and strings is often askew. Knowing the capabilities and aspirations of each orchestra member, the faculty guide tailors the reorchestrations to create the best group sound possible with a nonstandard instrumentation. As an example, in his *Ninth Symphony* Dvorak wrote climactic passages that take the first violin section—typically 16–18 players—into the stratosphere. But in spring 2016 OCO only had six violins. Though the OCO violinists could technically play these parts, the results would have been thin and anticlimactic in comparison with the intended large violin section. So to achieve these climactic passages, the faculty guide scored the stratospheric lines for both glockenspiel and piano (right hand in octaves), doubled at the octave below by all six violins so that their overtones would support the glockenspiel (a high bell-like instrument) and piano. The results can be heard at the YouTube link http://bit.ly/OCO_Dvorak9th cited earlier.

As a PBL course, OCO undergoes a process analogous to a hands-on technical lab. As preparation for the hands-on lab (analog: an upcoming performance), students take a Pre-Lab test (individual practice to learn parts), assimilate Just-in-Time Learning (musical and interpretive analysis, e.g., through discussion), complete a Virtual Lab (orchestra rehearsals), and Hands-on Lab (concert performance).

As the final step in a PBL hands-on lab, students take a Post-Lab test. In OCO, the Post-Lab corresponds to follow-up rehearsals that address music or sections from the concert requiring more rehearsal as the group prepares for the next performance.

How does a conductorless orchestra as PBL move beyond the classroom? In the twenty-first century, teams will be increasingly tasked with providing solutions through multidisciplinary research rather than searching for answers within a single discipline. These complex problems will often require large teams. A conductorless orchestra enables student engineers to experience and contribute to a large group dynamic before entering the engineering work place, thus helping to jumpstart careers.

Possible Alternatives

If educators wish to create something close to a conductorless orchestra, they could begin by organizing chamber music groups comprising student engineers. Many of the same strategies and benefits provided by a conductorless orchestra also apply to piano trios (violin, cello, piano), string quartets (2 violins, viola, cello), piano quintets (2 violins, viola, cello, piano), and so on. Perhaps these chamber groups could eventually coalesce into a conductorless orchestra.

If no musical skills are available, other performing arts ensembles could be established, such as a theater ensemble. Again, many strategies and advantages already described with respect to a conductorless orchestra would apply to a theater group.

Though all of the above alternatives employ tried and true methods devised by educators and businesses for developing performance skills, these substitutes lack the cachet of a conductorless orchestra—a truly novel ensemble that catches the eyes and ears of others. At Olin, OCO has been affectionately referred to as “Olin’s only varsity sport.” It is unique in the world as the only conductorless orchestra composed of engineers, a statistic we hope to change. On the other hand, many of Olin’s peer institutions have one or more choirs, *a cappella* groups, chamber music ensembles, and conducted orchestras. All of these ensembles provide meaningful and fun music-making experiences for students, yet none is unique. When OCO members go on job interviews, they are routinely asked by potential employers about their OCO experiences. A conductorless orchestra offers a singular experience to an engineering student and interviewers realize this.

Audiences also comprehend the distinctiveness of the enterprise. A conductorless orchestra can move and inspire constituencies such as alumni, parents, philanthropists, and audiences both internal and external to the university. For example, OCO performs every spring for each of three Olin Candidate Weekends sponsored by the Admissions Office. After one such concert, a mother of a scholarship candidate wrote in an email:

I had expected to get a feel for the curriculum, students, physical plant, which I did, but I never imagined how much impact the performance of the Olin Conductorless Orchestra would have on my experience; it seemed to offer a beautiful symbolic representation of what the school is all about. I was moved to tears by the performance. I hope the members of the Orchestra know how truly amazing and transporting it is to hear music played collaboratively, without a conductor. From my perspective, the unique quality of the sound seemed to emerge from both the musicians’ capacity to be intuitive about each other, modulating tonality and volume to achieve a balance, and a shared intense focus on the nuances of the pieces. I thought about how the qualities needed to achieve such a beautiful performance are what every good leader needs to cultivate.

I tried to articulate something of what I felt to one of the orchestra members, but I think I was embarrassingly way too choked up to be clear—after all, I am a nervous mother with her first child going off to college! The musical performance was like no other that I have ever experienced. I hope that you will share my reflections with these wonderful musicians.

In comparison with coursework or workshops, a conductorless orchestra offers 'messier' problems. It exposes students to more unpredictable situations within a student-driven structure with scaffolding from faculty. Understandably, a self-managed team with 4–6 members is easier than a larger one, say with 22 members. Yet in today's world, the trend is toward larger teams, not smaller entities.

Fortunately, a conductorless orchestra model is transportable to other schools. Keeping in mind that OCO started off with just five students, a faculty clarinetist, and faculty guide at the piano, educators can successfully implement the model elsewhere. A blueprint already exists, as discussed in these pages, much of it directly transferable to other institutions.

The Engineers' Orchestra

The idea of "possibility," the notion of "what if?" lies at the heart of adaptability and flexibility, two characteristics demanded of persons young and old in this new century. Asking "what if?" implies an openness and curiosity about what might develop, what might ensue as a result of agency. And agency involves change. The power of "possibility" transfers to any domain. Possibility thinking encompasses problem solving and problem finding, including both convergent and divergent thinking. What constitutes "possibility"? Innovation, action, development, depth, risk, serious play, and posing questions all comprise necessary components of possibility thinking (Zander & Zander, 2000).

To date, a conductorless orchestra composed of engineers does not exist outside of Olin College. It represents a new idea. Yet performing arts ensembles, in general, and conductorless orchestras, in particular, are now studied by business leaders and academia as innovative labs for the development of performance skills—leadership, teamwork, and communication—and as models of organization for the business community (Bartelme, 2005; Gilboa & Tal-Shmotkin, 2012; Hackman, 2005; Lubans, 2006; Manning et al., 2005; Seifter, 2001; Seifter & Economy, 2001; Smith, 1996; Tovstiga et al., 2005).

Such performance skills cannot be viable without action on the part of the musicians. Music requires continued development as performers rehearse to bring works to the highest performance level possible. The bar is always moving upward. More broadly, bringing musical works to higher performance standards exemplifies lifelong learning, where lifelong learning is understood as a process that "encourages all adults to continue to seek new skills and knowledge." Lifelong learning remains a critical need for the world at large (Galal, 2008).

Furthermore, transfer as described by Brandsford and Schwartz (1999) occurs in a conductorless orchestra. Not only is depth required to continually revise and raise the performance bar for a musical work, but in the process, depth is also cultivated. "Depth transfer" can occur when professionals work with students, *after* students have first acted on their own to shape the interpretation of a given work. In doing so,

students lay the groundwork for future learning from others who bring additional views and expertise to the table.

As any performer is aware, performance implies the possibility of failure. Audiences comprehend the success/failure dichotomy, one of the reasons why live concerts, as opposed to recordings, can have listeners on the edge of their seats. A conductorless orchestra involves more risk taking by student musicians than that required by a conducted orchestra. Many of the decision-making processes rest with them, such as cueing, staying together, and establishing tempo. During rehearsals, they answer one another's questions. Often these questions focus on trying out different interpretive ideas, hence the 'play' component inherent in possibility: playing with or trying out different ideas and combinations. For instance, OCO exemplifies the 'play component' when it rearranges its seating for better balance and group sound, or when it plays "musical chairs" by mixing up its seating for challenge and fun, as alluded to earlier.

A conductorless orchestra opens up the 'what if' question to educators. Such an orchestra can provide students with an opportunity to experience 'possibility,' take action, and bring something to fruition. It reinforces individual and group capacity for managing life's challenges, offering an environment where asking questions, assuming agency, and rising to the occasion are more the norm than the exception.

Playing in a conductorless orchestra is a lived experience that not only introduces student musicians to different styles of music but also to the varied backgrounds and perspectives of their peers. Students enhance their ability to work and communicate with others. Furthermore, the effective and "invested" leadership and teaming skills required in a conductorless orchestra can radiate outwards to the larger engineering student population and community as a whole.

Summary Remarks

Though engineering students, and even their professors, can view performance skills—leadership, teamwork, and communication—as "soft skills," they are in fact essential for advancing a professional career (Osburn & Stock, 2005; Seat et al., 2001).

Frank Barnes (1994 cited Bilsel et al., 1998), recipient of the 2004 Gordon Prize awarded by the National Academy of Engineering, summarized the reality:

In terms of graduation, it is often the technology-based courses that help the students get the first job, the science course that helps them keep it five years out, and the social science and humanities courses that help them move up into top management.

An understanding and appreciation for leadership, teamwork, and communication prove necessary for engineers to advance in the profession beyond the entry level, i.e., beyond the fifth year of employment. *Performance skills allow engineering school graduates to reach their full potential as professionals, citizens, and individuals* (Grinter, 1994; NAE, 2005; NSF, 1996; O'Neal, 1990; Osburn & Stock, 2005; Seat et al., 2001).

Reaching one's full potential embodies much of human aspiration, yet in general, the student engineer is not born with these skills. In fact, engineers may be predisposed to the opposite side of the psychological spectrum. Research has shown that engineers often suit a cognitive style known as field independence, i.e., they prefer to solve problems alone rather than with others, they like unambiguous answers, and they favor nonsocial environments (Osburn & Stock, 2005; Seat et al., 2001; Witkin & Goodenough, 1977).

Engineering educators have pinpointed courses in the arts, humanities, and social sciences as necessary for giving engineers the tools to navigate problem solving, ambiguity, and social endeavors associated with multidisciplinary projects. Industry, nonprofits, accreditation, and government agencies continue to call for the cultivation of performance skills so that engineers can assume leadership, team, and communicative roles. Twenty-first century engineering projects will require these traits due to the global, multidisciplinary nature of the tech revolution (ABET, 1997; Grinter, 1994; Miller, 2008; NAE, 2005; NSF, 1996; O'Neal, 1990). Having these skills empowers engineering graduates to fulfill their promise as creators and contributors to society, enabling them to thrive professionally and personally (ABET, 1997; Erdil & Bilsel, 2005).

Consequently, many engineering schools have allocated a greater amount of the undergraduate engineering curriculum to the arts, humanities, and social sciences. Others have created programs that specifically address performance skills, including the use of performing artists to teach leadership, teamwork, and communication (Osburn & Stock, 2005; Seat et al., 2001).

The business community has also turned to performing arts ensembles to help restructure their organizations to improve the very same skill set. Study of performing arts ensembles has yielded valuable lessons for implementing distributed leadership, as well as models for successful teamwork and communication within an organization (Gilboa & Tal-Shmotkin, 2012; Hackman, 2005; Smith, 1996; Tovstiga et al., 2005).

In particular, the Orpheus Chamber Orchestra, a professional conductorless orchestra has evolved a collaborative process where leadership is spread across the entire organization, and communication skills are refined in order to enable efficient and productive rehearsals that lead to well-received performances (Hackman, 2005; Seifter, 2001; Seifter & Economy, 2001).

Significantly, a student conductorless orchestra at Olin College of Engineering has evolved a similar strategy for distributed leadership. The Olin Conductorless Orchestra functions as a conduit for experiencing peak performance (collective virtuosity), transformational leadership, teamwork, and effective communication. Overall, the OCO offers a sense- and meaning-making process of leadership that is shared by a community of practice (Drath & Palus, 1994). It also serves as a natural environment² for students to build, sustain, and contribute to a large team. Students

²Natural in the sense that current anthropological research suggests that music-making evolved as a medium for human bonding once a societal group became too large for grooming (Dunbar, 2012).

figure out when to say something and when to refrain. As a result, the orchestra spends more time making music than talking about it. Moreover, due to the absence of a conductor, students learn to actively listen. These performance skills transfer according to the “preparation for future learning” perspective of Brandsford and Schwartz (1999).

But why not just teach these competencies in other coursework? Certainly engineering educators, working with colleagues in business, the arts, humanities, and social sciences, can create programs to address performance skills. Yet if we widen engineering education scholarship to include the results of brain research, we find that recent work in neuroscience suggests the student musicians in our midst are already primed for developing effective leadership, teamwork, and communication. Neuroscientists have established that male musicians have a relatively larger cerebellum and corpus callosum than male nonmusicians. A larger cerebellum implies greater motor coordination and improved cognitive function, i.e., the ability to analyze and reason. A larger corpus callosum suggests more interaction and transfer between the brain’s two hemispheres, since the corpus callosum connects both hemispheres (Hutchinson et al., 2003; Lee et al., 2003). Musicians also enjoy linguistic advantages over nonmusicians, according to neuroscientists Patel (2003, 2007), Sammler and colleagues (2009).

Clearly, engineer-musicians have become adept at time management, discipline, and the quest for excellence. Music is a demanding (and at times, unforgiving) art. Perhaps all the earlier traits account for why Olin faculty have consistently remarked that OCO includes some of the brightest and most engaging students at the College. These engineer-musicians are already wired for professional and social success. The raw material is present, ready to be further developed through bonding activities, individual practice, group rehearsals, and performances, all of which underpin a conductorless orchestra.

In short, our future leaders, team players, and communicators may very well be found among engineering students who also happen to play instruments. Thus, it is in the best interests of educators to nurture their engineer-musicians, encouraging them to take their talents along as they embark on 4 years of engineering study. It is a shame when students, facing pressure or disapproval from others, park their gifts in “long-term parking,” only to return 4 years later to reclaim them. By then the keys are rusty.

Yet it does not have to be this way. In fact, great benefits accrue to students who take their musical talents with them as they proceed through engineering school and beyond. They can use these talents—their musical intelligence—to develop the essential performance skills needed to sustain, advance, and create meaning in a chosen career.

Musical intelligence constitutes one of the eight intelligences identified by Professor Howard Gardner of Harvard University, along with logical/mathematical, linguistic, spatial, intrapersonal, interpersonal, bodily/kinesthetic, and naturalist intelligences (Gardner, 1983, cited Miller, 2008). These intelligences reside in every human; they work together in practice to allow problem solving and invention within a given culture—much of what engineering is all about (Miller, 2008).

Citing the National Academy of Engineering's vision of engineering in the twenty-first century (NAE, 2005), Miller (2008) concludes that these eight intelligences will likely inform the engineer of 2020:

... to produce the engineer of 2020 we may need to broaden our focus beyond the traditional linguistic and logical-mathematical intelligence that is currently dominant in engineering education. Certainly these will continue to play the central role in engineering, but the other intelligences associated with artistic and social endeavors may need to be elevated significantly within our value system, in everything from the criteria for admission of students ... [to] the relative balance between technical and non-technical content in our academic programs.

The advent of a conductorless orchestra within an engineering program represents a new and ambitious endeavor that elevates additional intelligences to the same plane as the logical/mathematical. It brings together students from different ethnic, socioeconomic, and religious backgrounds. Such diversity strengthens the Academy and the profession. As is well known in the United States, diversity also brings challenges. Optimally, a nation would function as one team, with all working toward myriad goals that benefit citizens, en masse and in parts, taking into account the various needs of different regions and peoples. On the world stage, such an ideal team has been elusive because of the sheer size of the endeavor. But we already know that future projects in engineering will involve large multidisciplinary teams, solving messier and more complex problems.

The conductorless orchestra model offers a large team laboratory for students to experience and practice shared leadership, teamwork, and communication, while working towards definable goals—musical performances before audiences of peers, experts, and music aficionados. Such a lab would be a substantive complement to performance skills already being taught within the engineering curriculum. In fact, the two models (orchestral environment and classroom) could collaborate and grow stronger as a result of a two-pronged dedication to improving students' grasp of a valuable professional skill set.

When students of differing cultural and economic backgrounds have the opportunity to experience masterworks, i.e., great pieces of art, bonds form among them that transcend boundaries. Students experience both the creative process and the leadership process (one of making sense and meaning from the work at hand) all within the same ensemble, all of whose members have the same goals: performing classical masterpieces while experiencing the attendant joys and challenges.

As is recognized worldwide, classical music has its own culture—a transcendent culture that crosses borders and allows people to lead with, team with, and communicate with one another. Possessing a universal language and syntax, its lexicon has traveled far and wide. Thus, classical music provides a creative umbrella that allows diverse people to come together under the aegis of a shared culture and language—the language and culture of music. Moreover, when students have to adapt to new environments and cultures, their capability for skill transfer as “preparation for future learning” can deepen at a time when they have to reconsider or even let go of previous behaviors and beliefs. This kind of transfer allows more profound connections than the simple repetition of behavior in another environment (Brandsford & Schwartz, 1999).

In conclusion, establishing The Engineers' Orchestra as part of engineering curricula at home and abroad cultivates appreciation for—and experience with—leadership, teamwork, and communication. Our students will inherit and shape the future of all nations. In the historically recurring absence of effective governance, collaboration, and interaction across East and West, we as educators have to start somewhere. A conductorless orchestra provides access and opportunity for engineering students to lead, team, and express—three traits that will carry them far into this new century—for the benefit of all.

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