

Beauty in Engineering and the Performing Arts

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Abstract— This paper outlines the intersection of the Performing Arts and Engineering, and methods for successful inclusion of the arts in an engineering curriculum. Through a discussion of the classic ideas of Beauty and Art, parallels are drawn between the engineering design approach and the composition / creation approach common in the arts as a means to find common ground for engaging engineering students more fully into the arts as a life-long passion and possibly a career path.

Keywords—“engineering in the arts”, “engineering design and composition”, “music, theatre, and engineering, beauty

I. INTRODUCTION

It wasn't that many years ago that Engineering Faculty had very little to do with Liberal Arts Faculty; they viewed their spheres of interest at opposite ends of the spectrum. It was acceptable for the graduating engineer to go out in the world with the perspective that being able to build, modify or create something was all that mattered [1]. After all, the job of an engineer often is to design products or systems based on the technical skill gained through their education. The engineering design process [2] has been represented in many ways but can generally be distilled into an iteration of elements that include envision/design, construct, evaluate, and cycle back through redesign until a polished final product is achieved. The musical composition process is very much the same. Putting up a theatrical production likewise follows an envisioned approach that with the keen eye of a director is subject to iterative manipulation of staging, blocking, effects, all to fit within the constraints of a particular stage, abilities of those involved, and budget. And, we cannot disregard the same in the visual arts. History has shown us that the masters of creative genius were both “engineer” and “artist” – those who gave us the engineering marvels of the Egyptian Pyramids, the beauty of Michelangelo's Sistine Chapel Hand of GOD, the emotional delivery of Les Misérables, of course The Beatles, and the many designs of musical instruments and performance areas that support the arts. Why is it then that these creative endeavors are often seen as being at opposite ends of the educational spectrum? Both the engineer and the performing artist strive for essentially the same goals of beauty (which the

engineer may think of as aesthetics in design) and achieving desired functionality. Our technical university has made a concerted effort to allow our students to see beauty in many different forms that also achieve a required functionality.

II. BEAUTY

In many of their creations, both engineer and artist strive to create beauty. But what is BEAUTY? The dictionary[3] defines beauty as the quality present in a person or thing that gives intense aesthetic pleasure or deep satisfaction to the mind or the senses. The idea of beauty is not just a physical appearance of a person or object. Rather, it is an understanding that gives some perceptual experience to one's physical senses, intellect, and moral appreciation. Beauty in a person or object provides perceptual experiences of happiness, contentedness, or completeness. Beauty has traditionally been counted among the ultimate values, alongside goodness, truth, and justice [4]. Beauty can be thought of as a balance and harmony with nature. A finely engineered building, this is above canon for the sake of those inside it, can be considered morally “upright” for those whom it serves. It shows not only symmetry but also a rightful well-made-ness to those who inhabit it.

Let us inspect beauty in art. Many argue that art cannot be defined. Art [5] is often considered the process or product of deliberately arranging elements in a way that appeals to the senses or emotions that vary from person to person. It encompasses a diverse range of human activities, creations, and ways of expression, including music, literature, film, sculpture, and painting.

A dictionary definition of engineering [6] includes terms such as design and build, but also compose, mold, frame, fashion, and shape. Many engineering design approaches deliberately have the same approaches as displayed in art: achieving an overarching outcome through the collection and arrangement of what may otherwise be seen as unrelated elements of equations, physical properties, social impact, and stakeholder engagement.

III. ABOUT OUR UNIVERSITY

At the Colorado School of Mines (Mines) a group of faculty members have cooperated in working on the intersection of the Performing Arts and Engineering, and methods for successful inclusion of the arts in an engineering curriculum. Our panel consists of two engineering and two music professors all of whom have worked closely in collaboration at the university. Mines [7] is a public research university devoted to engineering and the applied sciences, and unique in that almost all degrees offered are technical degrees. Our degree offerings include the traditional earth sciences which serve as our historic foundation, as well as engineering and science/math arenas. These include geologic, geophysical, mining, and petroleum engineering as well as materials science (metallurgy), computer science, mathematics, and chemistry. Degrees are also offered in the traditional engineering topics of civil, mechanical, electrical, and chemical engineering, to name a few. Our students must complete a liberal arts component in their engineering curriculum and many chose the performing arts to partially fulfill this requirement. The performing arts fall under the non-technical department umbrella called Humanities, Arts, and Social Sciences (HASS). This department offers courses in language, international affairs, ethics, music and performing arts, literature, and philosophy. A wide range of music experiences are offered: band, orchestra, jazz band, choir. We also offer individual music instruction, classes in music theory, composition, and history. In addition, our students can receive a minor in Music Technology, or integrate a focus in music technology as part of a general B.S. in Engineering degree. Recently we have added a theatre class to augment our performing arts curriculum.

As a highly selective school, one in ten applicants enroll at Mines. The student body includes about 4900 undergraduate and 1500 graduate students. Almost 30% are female and 11% are international. Minorities count for 19% of the student population. Our performing arts classes draw from the entire student population and often attract higher percentage of females than the school average. Our music classes are popular, usually fully enrolled and often have a waiting list. The class sizes range from 35-45. Our band has 115 students, orchestra has 78 students, and choir with 75 students.

IV. CURRICULAR OPPORTUNITIES

Along with our technical courses central to the major of each of our students, we offer an array of courses to fulfill the liberal arts requirement. Many students choose performing arts courses. We purposefully integrate the performing arts with technical topics in both liberal arts as well as engineering design courses. Some students are motivated to go beyond the required liberal arts component seeking a minor in music or music technology.

A. Music Technology

Our Music, Engineering, and Recording Arts Minor (MERA) is designed for students interested in the crossover between music and related engineering skills. Specifically, students in the minor program must take five required courses: Audio/Acoustical Engineering and Science, Music Technology, Music Traditions of the Western World, Real World Recording Seminar, and Music Technology Capstone.

An additional three credit hours in either music theory, band, choir, orchestra, or jazz band are also required. A similar integration of music technology and engineering studies can also be achieved through a more integrated approach of a B.S. in Engineering (BSE) with a Focus Area in Music, Audio Engineering, and Recording Arts – the ‘music’ component is thus an integral part of the engineering degree curriculum. Emphasis within the minor or BSE creates an opportunity for the student to research/experience the impact of engineering on music as an art form, music as a technology driver, and music as an industry. Throughout, students are exposed to the refinements and developments that engineering has created in the field of recording, production, sound reinforcement and product design, as well as, the interplay between the arts and technology. The discovery of connections between current music and engineering practices is stressed. The final outcome is a skilled and informed studio technician/musician in present day studio conditions.

The important idea observed in these classes is the concept that development of art requires technology, and that technology requires art to have a target to advance toward. The technical advancements in the recording industry evolved to allow for the correction of “Human Error.” The technology allowed us to strive towards achieving an ideal, an “immortal” product. When phrased to our engineering students in these terms, our students begin to understand how both design and art can express the concepts of beauty. If we expand this to other artistic fields, the artistic impact of cinema, theater, dance have evolved due to technological innovations such as intelligent lighting, stage technology (flying harnesses and rotating stages), and emerging holographic presentations.

Again, the technology allows the artists to achieve a goal that was previously unattainable, and the art asks the technology to grow and evolve to meet this demand.

B. Theater Course

Recognizing the natural extension of the music-engineering integration into another performing arts sector, that of theatre, in Spring 2019 a new series of courses in the theatre arts was launched, the first being Theatre Technology, Production, & Performance. The course was fully enrolled at 30 students within minutes of being opened for registration. This course starts with the basics of theatre space, tools and safety, production analysis, the scenic design process, all of which was transferred into a final performance, showcasing the pathway of engineering technology into performance. The engineering aspects came to fruition and sparked a creative outlet for these students when set and staging moved into electrical theory, stage lighting, sound design, mechanical contraptions, and even costume design. Since the inception of this first course, an additional offering in Acting, Locution and Public Presentation is now included in the Fall 2019 schedule. Acting through realism is a natural fit for engineering students to gain the confidence to present to clients and large audiences. This class also filled within a few minutes of open registration.

C. Engineering Design

At Mines, students are exposed to the Engineering Design Process beginning in their first year through the Cornerstone Introduction to Design course. This course leads students

through the concept of open-ended problem solving, teamwork, technical solutions, and non-technical constraints. A good engineering design is seen as “beautiful” to both the designer and the customer.

Throughout the curriculum, generally in studio courses, the engineering design process is reinforced. Finally, during the senior year, the students participate in a two-semester sequence of Capstone Design.

A good engineering design is seen as “beautiful” to both designer and customer/consumer. A typical mistake in the design process is for the designer/engineer to design what they see as being functional or as meeting their personal view of the needs of the project. The Mines’ design programs emphasize user input and ancillary stakeholder engagement. The term “beautiful”, as relates to design in the theatre space, is based on its definition of “pleasing the senses or mind aesthetically” or “of a very high standard; excellent”. Emphasizing and incorporating stakeholder engagement is an exercise in having the students pick apart and assess what the audience hears, sees, and senses environmentally (temperature and air). The theatre course is an intentional merging of engineering design instruction within the confines of and understanding of the theatre space and audience as key stakeholders. This course structure allows us to actively engage and immerse our engineering students instead of having just an elective course in theatre. We believe that in doing so, we are actively integrating the arts and engineering.

To illustrate, a past senior design team of five students were tasked to design and build a theatre set piece inspired by a rotating, multi-room depiction of a two-story house, both interior and exterior, as seen in a production of *Noises Off*. Criteria given to the student design team, beyond the general set concept, were that it be a robust modular and sturdy piece, and that it be generic enough to be usable in multiple theatre productions. The main engineering challenge was adapting it to fit in a storage space the size of a shipping container and that it be portable enough to be moved to various performances locations in the campus community by fitting it into the bed of a pickup truck and then fit through a double wide door. Making the set piece modular addressed this space constraint and goal of robustness. Overall, the project required attention to mechanics of materials and the structural systems of mechanical or civil engineering. The final design document provided detailed construction drawings and cost analysis and required showing proof that the design met local building codes. The team also built a full-scale prototype to test the mechanics of materials, modularity, portability, and ease of stage set-up.

Another senior design project was the design of a lighting and sound support grid structure to be used in a new black-box rehearsal and performance space. The intention was to determine the weight and load distribution for suspension from existing ceiling/roof structural members under load from a variety of lighting options (theater and stage style lighting along with additional house lighting), AC junction boxes, speaker arrangements on the same grid, to accommodate performances given from four areas of the floor space with associated audience arrangement in part or all the remaining space. The grid location, and associated speaker locations

needed to work around existing ceiling acoustical elements. The load analysis showed that the existing roof supports were inadequate on their own and would require reinforcement. The student team also determined the electrical needs concentrated at a light/sound booth location and wiring demands when tied into an existing 3-phase circuit panel.

D. Travel

In an initiative to expand our engineering students’ perspective and to help them understand that culture can contribute to the success or failure of engineering and scientific projects, the President of Colorado School of Mines, Paul Johnson, has encouraged international experience for all of our students. Mines recognized that our graduates will be working in a multi-cultural and interconnected world, often as agents of change, and thus need to gain cultural awareness of the people and communities where they will be working [8]. In response to this school-wide initiative, we have established a travel program that includes both engineering and performing arts components. This unique international travel program, headed by Drs. Klimek and Skokan, received the 2018 Michael P. Malone International Leadership Award from the Association of Public and Land-Grant Universities in recognition of outstanding accomplishments in bringing global perspectives to higher education.

For the last seven years, students have had the opportunity to investigate cultural connections through international travel during spring break. When the demand is great enough, we offer a semester-long preparatory area-study class for credit. If a credit class is not offered, the students meet regularly during the semester prior to the trip to learn about the history, culture, government, and educational systems of the country that we will visit. On average, 50 students take the opportunity to embark on a 10-day trip. Our travels to date have included Italy, Ireland, Jamaica, Vietnam, Portugal, and Peru. In each trip, students have experienced performance opportunities and have visited engineering schools and industries. Our industry visits have varied from the Tuff Gong Recording Studio in Jamaica, a luthier specializing in Baroque string instruments in Rome, a working lead/zinc mine in Ireland to Proctor and Gamble diaper assembly plant in Vietnam. It was interesting that in all industry visits, both the technical and aesthetic components were emphasized. Our performance opportunities were both as performers and as audience. For example, in Peru, our small ensemble instrumental students gave concerts at a home for the elderly, a school for the handicapped, a university experimental mine, a rural village, and a minerals museum. In Poland, our vocal ensemble gave concerts at a salt mine, at a home for the elderly, and at an elementary school. In Vietnam, our students attended a multi-media performance and the historic opera house in Ho Chi Minh City. However, one of the most transformative experience, as reported by our students, has been their connection with their peers at universities. Another example of the transforming results of this type of travel experience can be observed from a trip to Rome. One Civil Engineering student, Martha, at St. Peter’s Basilica in Rome, while awaiting to play in performance, found herself idly analyzing the marble wall panels near her seat. Then she stopped herself abruptly, explaining to us later, “I’m accustomed to looking at materials for what they are. For

once in my life, I needed to look up and realize the great building I was in, the great building that I had a chance to perform in! I never thought this day would ever happen for me.”

V. CONCLUSION

Both Engineers and Artists have the same goal: the communication of beauty in its classic sense. We at the Colorado School of Mines have given our technical students opportunities to practice the arts through music and theater performance, as well as, music technology experiences. Our goal is that our students see beauty in all that they do. Our goal is that they feel empowered in their technical field through a realization of how they design and present their work for the betterment of the community around them. We want to graduate a polymath [8]: a term we translate as the non-traditional artist/engineer.

VI. REFERENCES

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