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The Music of Engineering

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Abstract

The relationship between music and engineering can be measured. There is overwhelming empirical evidence that link these two fields, yet few researchers have studied the relationship. This paper is not about the artistic and technical applications of recording technology, but rather the progression of music that has fostered the engineering feats of today.

Music has motivated more than the heart of the engineer, it has driven the field of engineering. Without music, and specifically the graphical representation of music, our society would be much different. Music has progressed throughout time from the pre-written melodies of early man to the very complicated pieces of Bach, and beyond. Engineering, on the same time scale, has progressed from the invention of the wheel to the information age. Yet the correlation between the progression of music and the growth of engineering has previously not been clearly defined.

There are many studies on the relationship of music to mathematical abilities. In many elementary schools around the United States, classical music is played prior to exams so that students will achieve the best possible grades. This association is evident and measurable. Also evident is the reliance of music on mathematics. For example, a half note is equal to two quarter notes. The previous statement could not be possible without the use of mathematics. Thus, it is not a far leap to suggest that music is integral to mathematics, and likewise, mathematics is integral to music. As mathematics is the foundation of engineering, the relationship between music and engineering is taken for granted. Yet, this relationship, between music and engineering, is much more than the ability to perform better in mathematics. Without music, the field of engineering would not have progressed to its current state; the two fields share a correlation and interrelationship of progression in time.

This paper will show the relationship between music and engineering, from the early beginning of musical compositions, to the age of technology, and stress the importance of music history to the entire field of engineering.

1. Introduction

The disciplines, and even the students, of music and engineering seem very different. Music is classified as an art, a right-brained activity. Engineering, on the other hand, is a classification of its own, and considered left-brained. Socially, the disciplines are different as well. A student stating that he is an artist gives the listener a perception of the student that is vastly different than if he states that he is an engineer. Yet, it can be shown that the two disciplines, music and engineering, have been intertwined since the beginning of the human race. To go one step further, the progression of music has fostered the engineering feats of today. Consequently, it can be reasoned that today's music will cultivate the engineering practices of tomorrow.

This paper will show the relationship of music and engineering. It will also show that music has fostered invention, free-thinking, and, subsequently, the field of engineering.

2. Definitions of Engineering and Music

By reviewing the definitions of engineering and music, we find:

- Engineering is defined as the "application of scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems" [2]. The term engineering is derived from "Middle English enginour, from Old French engigneor, from Medieval Latin ingeniator, *contriver*, from ingeniare, to *contrive*, from Latin ingenium, *ability*" [2].

- Music is the "art of arranging sounds in time so as to produce a continuous, unified, and evocative composition, as through melody, harmony, rhythm, and timbre" [2]. Music is derived from "Middle English, from Old French *musique*, from Latin *musica*, from Greek *mousike (tekhne) (art) of the Muses*, feminine of *mousikos*, of the Muses, from *Mousa, Muse*" [2].

Interestingly, there were originally three Muses, Greek goddesses, and not all were musicians. Melete was the muse of meditation, Mneme was the muse of memory, and Aoede was the muse of song. Later another three muses were associated with an instrument, the lyre, with their names being the names of the lyre's strings: Nete, Mese, and Hypate [8]. Thus, even though the terms above, engineering and music, seem to have different meanings and roots, a case can be made that there is a relationship. Two of the Muses, for meditation (thought) and memory, can be applied to engineering. Likewise, the Latin root for engineering, *ingenium*, means ability, which is also necessary for music, as anyone with a tone-deaf sibling can attest!

3. ABET – Music Relationship

An interesting relationship between music and engineering was found by the authors' review of ABET criteria.

Reviewing the guidelines specified by the Accreditation Board Engineering Technology (ABET), one notices a correlation between these guidelines and music. In the ABET 2004-2005 criteria for "Accrediting Engineering Programs," the "Program Criteria for Electrical, Computer, and Similarly Named Engineering Programs" section states in "Criterion 3. Program Outcomes and Assessment" specifically that "Engineering programs must demonstrate that their graduates have: (a) an ability to apply knowledge of mathematics, science, and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (c) an ability to design a system, component, or process to meet desired needs; (d) an ability to function on multi-disciplinary teams; (e) an ability to identify, formulate, and solve engineering problems; (f) an understanding of professional and ethical responsibility; (g) an ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context; (i) a recognition of the need for, and an ability to engage in life-long learning; (j) a knowledge of contemporary issues; (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice" [1].

By blending these criteria with music, a definite relationship can be seen, as in Table 1. In this table, suppose "engineering" was substituted with "music." Table 1 shows that a relationship can be made between the concepts of engineering and the concepts of music. Interestingly, by substituting "music" for "engineering" in some of ABET's criteria, one sees the relationship quite clearly.

Table 1. Relationship between ABET Criteria and Music
(Imagine substituting "Music" for "Engineering")

ABET Criterion 3 Specification	***Relation in Music***
(a) an ability to apply knowledge of mathematics, science, and engineering	Mathematics and music are related; notes for example are whole or a fraction
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	Music is composed, analyzed and interpreted
(c) an ability to design a system, component, or process to meet desired needs	Music is played on instruments, specifically designed to "meet desired needs"
(d) an ability to function on multi-disciplinary teams	An orchestra is a multi-disciplinary team (winds, strings, etc.)
(e) an ability to identify, formulate, and solve engineering problems	Musicians must be able to understand problems that occur in music (such as level of crescendo)
(f) an understanding of professional and ethical responsibility	Musicians must be professionals and ethical; changing music to fit the musician is frowned upon
(g) an ability to communicate effectively	Music is about communication
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context	Learning music is a difficult pursuit and a broad education is necessary to fully understand all its complex parts
(i) a recognition of the need for, and an ability to engage in life-long learning	Music is a life-long pursuit
(j) a knowledge of contemporary issues	Music is contemporary as well as historic
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	There are certain techniques, skills, and tools that musicians must apply for their practice

4. The Connection of Music and Engineering

Music and engineering have been interwoven from the beginning of man. Which of these disciplines arrived first in the evolution of mankind is still being debated. It is interesting to note though that the general history of music and engineering is similar. Music and engineering were developed for the following reasons: (1) Communication; (2) Survival; and (3) Entertainment [3].

4.1. Communication

Music and engineering were both started for communication purposes. Music was a form of communication between members of tribes, and still is in some primitive societies. Drums pounded out different messages across miles to inform others of some event. Likewise, smoke signals, an engineering feat, were produced for the same reason.

4.2. Survival

In order for ancient man to survive, he needed to use all of his tools, including music and engineering. A specific tune from a conch shell may indicate a warning; and a blow dart may save a warrior.

4.3. Entertainment

After the needs of communication and survival were satisfied, people could relax and use their musical and engineering accomplishments for entertainment. More ornate musical compositions and other inventions, such as toys, came into being.

Thus, music and engineering share the same history, the progression from communication and survival needs to entertainment. The next two sections briefly discuss the different paths in history of music and engineering.

5. Music History

The history of music is divided into different periods: Pre-Antiquity (to 3000 BC); Antiquity (3000 BC-500 AD); Middle Ages (500-1400 AD); Renaissance (1400-1600 AD); Baroque (1600-1750 AD); Classical Style (1750-1800 AD); Romantic (1800-1900 AD); 20th Century and Modern Music (1900-present). These periods are grouped such that the music of the period is very different that the periods before and after, indicating a definite change in music [6].

5.1. Pre-Antiquity and Antiquity (3000 BC-500 AD)

Not much is known about these periods with respect to music. It was believed that there were muses who spoke poetry, not sang, but this belief may be changing. Recently, a possible Neanderthal flute made from bone was discovered. This flute, which dates back approximately 45,000 years, has four holes and three are similar to the musical Do, Re, Mi scale [17]. Researchers are debating whether the holes were engineered or created by some other means.

5.2. Medieval (500 AD-1400 AD)

Prior to 1200 AD, music consisted of chants which were sung in churches. These chants were called plainsong or Gregorian chant, and sang *a cappella* and in Latin. Around 1200 AD, musicians started to sing these plainsong melodies in parts. The interesting thing to note about this music period is that compositions became more mathematical. To sing in harmony requires a working knowledge of notes, space, and time. In this period more instruments are being engineered: flutes, recorders, drums, bagpipes, trumpets, harps, lutes, and guitars.

5.3. Renaissance (1400 AD-1600 AD)

The Renaissance period shows a birth of musical compositions. A multitude of brass instruments appeared during this time. Wealth brought families to hire their own musicians, solely to provide entertainment. Operas became popular during this time as well. Technically, the Renaissance music period is known for its extension of speech, texts, and personal emotion.

5.4. Baroque (1600 AD-1750 AD)

During the Baroque period, music became complicated, ornamented melodies. The music was dramatic, flowery, emotional, and reflected the spirit of the times. Technically, music contained formal order based on repetition and ornamentation. In this period, new types of compositions, such as concertos, sonatas, cantatas, operas, and oratorios, for many different combinations of instruments and vocal ranges were created.

5.5. Classical (1750 AD-1800 AD)

After the complicated Baroque period, the Classical period emerged. This period contained a new, cleaner sound. Music compositions were based on simple short themes, unlike the Baroque period. During this period, composers exploited graduated sound and space, repetition, and simplification of music.

5.6. Romantic (1800 AD-1900 AD)

The Romantic period was a time of independence from the simplification of the Classical period. Composers expressed love in their music: love of nation, love of nature, love of man, along with the spirits of immortality and independence. Interestingly, the piano became the most popular instrument.

5.7. 20^{th} Century and Modern Music (1900 AD-present)

The music from the 1900's to today has shown searches for new experiences. There has been radical experimentation, deregulation, and permissiveness.

6. Engineering History

The term "engineering" is from a Latin word meaning ingenious [5]. The history of engineering is rich, as rich as the history of music, with a great number of changes occurring in the last few centuries.

Some texts separate engineering into different periods: Agricultural Age (up to 1745 AD); Industrial Age (1745 AD-1954 AD); and the Information Age (1954 AD-present) [4]. This is very simplistic though and leaves out many different events during these

periods. Others break down time into the following periods: Stone Age technology (to c. 3000 BC); The Urban Revolution (c. 3000 BC-500 BC); Greek/Roman Technology (500 BC-AD 500); Medieval advance (500 AD-1500 AD); Middle Ages (1500 AD-1750 AD); Western technology (1500 AD-1750 AD); The Industrial Revolution (1750 AD-1900 AD); Early 20th Century Technology 1900 AD-1945 AD); and the Computer Age (1945 AD-present) [11]. The authors believe this is a more thorough representation of the history of engineering and is elaborated in the subsections below.

6.1. Stone Age technology (to c. 3000 BC)

Stone Age engineering includes a few noteworthy inventions, one being the wheel. Whether or not this is one of man's oldest inventions is not yet proven, as described below in Section 7.

6.2. The Urban Revolution (c. 3000 BC-500 BC)

When people moved to urban communities, instead of being by separate isolated tribes, more inventions came into being. The Sumerians and Egyptian created writing systems, which is a method of communication, one of the three reasons for development given in Section 4 above.

6.3. Greek/Roman Technology (500 BC-AD 500)

During this time period, people traded more frequently. Anarcharis of Scythia invented the first ship anchor during this time in 592 BC. With ships, one needs navigation, and around this time period one of the first permanent light houses, Pharos of Alexandria, , was built in about 300 BC. Of course, entertainment, one of the three reasons for development given in Section 4 above, came into the forefront, as evident by the invention of ice cream by the Persians, around 400 BC.

6.4. Medieval advance (500 AD-1500 AD)

Communication still be at the forefront of technology, books became popular. Book bindings were invented in 500 AD and book printing came along later in 700 AD. People were still trading via boat, as evident by the invention of the canal lock in 983 AD.

6.5. Middle Ages (1500 AD-1750 AD)

Not to forget survival, one of the four reasons for development given in Section 4 above, the first instance of stone bullets appeared in 1514 AD.

6.6. Western technology (1500 AD-1750 AD)

Obviously weaponry was popular, but different engineering pursuits also came into being, as evident by the development of the compound microscope in 1590 AD and the thermometer in 1593 AD.

6.7. The Industrial Revolution (1750 AD-1900 AD)

The Industrial Revolution was started by one engineering invention: the steam engine. James Watt engineered this in 1765, but more will follow about him in Section 11.2.

6.8. Early 20th Century Technology 1900 AD-1945 AD)

The early 20th century brought exciting discoveries. One of the most important was the airplane, invented in 1903 by the Wright brothers. Another invention created at the end of this time period started the next time period, the Computer Age. This invention was the MARK I, fundamentally the first computer, in 1944.

6.9. The Computer Age (1945 AD-present)

A good example of an invention in this time period is the Apple II, essentially the first home computer, created in 1977 by Steve Jobs and Steve Wozniak.

6.10. Why Start at 3000 BC?

Sometime around 3000 BC, the pace of development quickened [5]. Simple tools were followed by wedges, wheels and levers, which furthered technology. After this age, the Greeks and Romans made significant contributions, such as the screw, ratchet, and water wheel. During the next period, other ingenious inventions were created including the mechanical clock and iron casting. Transportation developments followed with the railways. Later, other inventions, such as the computer, became staples in society. Note that there is no "best" invention; one invention leads to another. This is the question of this paper: Did engineering or music come first? The authors believe engineering is based on music.

7. Which Came First: Wheel, Flute, or Something Else?

Is the Neanderthal flute actually a flute? Researchers are trying to answer this question. The holes have not been determined as natural or artificial as of yet. If the flute was made by man with technical aids then it may be the oldest invention, dating back approximately 45,000 years. The invention of the wheel dates back to 4000 BC [18], or thereabouts, depending upon the source, but nontheless does not come anywhere near the time of orgin of the Neaderthal flute. Some believe that the item is a flute, whereas others believe that

the holes were made by a carnivore. Unfortunately, there are no traces of either method evident on the bone [17].

Recently cave art has appeared that also puts the date of the wheel at a much later time. Three, small, carefully made figurines carved from mammoth ivory between 30,000 and 33,000 years ago were found in Germany [10]. Given this information, it is possible that music may have been invented prior to art work. It may be a short leap to assume then that music may have spawned art work development. Certainly, a flute would not have been engineered if music did not exist in some form prior to its invention.

8. Engineering Comes First in the Christian Bible

Interestingly, the Christian Bible discusses engineering before music. Cain builds a city in Genesis 4:17, obviously an engineering feat. Many generations afterwards, the first musician and blacksmith, an engineer of sorts, appear. Genesis 4:21-22: "His brother's name was Jubal; he was the father of all who play the harp and flute. Zillah also had a son, Tubal-Cain, who forged all kinds of tools out of bronze and iron" [15]. Naturally, just because music was not mentioned first, does not mean that it didn't exist first.

9. The Vibration of Music

A note is determined by the number of vibrations per second created. Pitch refers to the high-low quality of a musical sound and is determined by the frequency of the tone, the number of vibrations per second. A note in a higher octave has twice the vibes. The ratio between the octaves, then, is 2:1. It is interesting to note that almost all music scales have simple ratios: 2:1 (octave); 2:3 (fifth note of scale); or 3:4 (fourth note of the scale) [9]. It does not seem rational that mathematics existed first, and based upon fractions, or some other concept, music expounded. Rather, it seems more likely that music was created and from that, people actualized mathematical concepts to be able to analyze music and produce more music.

Vibrations are measurements used in engineering, as are ratios. As stated above, it is plausible that from the use of music, these concepts were studied from an engineering aspect.

10. Music Periods and Engineering Periods

Juxtaposing the influential periods of music and engineering, similarities between these different eras can be seen. It appears that a musical period has a direct relation upon engineering and technology. These relationships can be seen in Table 2. The inventions came from [16].

Table 2. Music and Engineering Periods, Composers, and Inventions

Music Periods & Some Composers (if known)	Engineering Periods & Some Inventors	Some Inventions
Pre-Antiquity (up to 3000 BC)	Stone Age technology (to c. 3000 BC)	Wheel, art work
Antiquity (3000 BC-500 AD)	The Urban Revolution (c. 3000 BC-500 BC)	Sumerian & Egyptian writing systems, smelted iron, papyrus roll, Julian calendar
Middle Ages (800-1400 AD)	Greek/Roman Technology (500 BC-AD 500) Medieval advance (500 AD-1500 AD)	Books, magnetic compass, clothing buttons, eyeglasses, mechanical clocks, windmills, modern glassmaking, sawmill
Renaissance (1400-1600 AD) • Palestrina (1525-1594) • Claudio Monteverdi (1567-1643)	Medieval advance (500 AD-1500 AD) Middle Ages (1500 AD-1750 AD)	Golf balls, spinet, oil painting, printing press, billiards, water thermometer
Baroque (1600-1750 AD) • Antonio Vivaldi (1678-1741) • Johann Sebastian Bach (1685-1750) • George Frederic Handel (1685-1759)	Western technology (1500 AD-1750 AD)	slide ruler, steam turbine, adding machine, calculating machine, piano, steam engine, fire extinguisher
Classical Style (1750-1800 AD) • Franz Josef Haydn (1732-1809) • Wolfgang Amadeus Mozart (1756-1791) • Ludwig van Beethoven (1770-1827)	The Industrial Revolution (1750 AD-1900 AD)	Electric telegraph, cotton spinner, cotton gin, bifocal glasses, steamboat, gas turbine, gas lighting, smallpox vaccine, battery
Romantic (1800-1900 AD) • Franz Schubert (1797-1828) • Felix Mendelssohn (1809-1847) • Frederick Chopin (1810-1849) • Robert Schumann (1810-1856) • Franz List (1811-1886) • Richard Wagner (1813-1883) • Giuseppe Verdi (1813-1901) • Johannes Brahms (183301897) • Richard Strauss (1864-1949) • Peter Tschaikovsky (1840-1893)	The Industrial Revolution (1750 AD-1900 AD)	Steamboat, armored warship, electro-magnetic motor, sewing machine, revolver, power tools, ether anesthesia, vulcanized rubber, telegraph, passenger elevator, oil well, roller skates, oil pipeline, typewriter, structural steel bridge, electric dental drill, mimeograph, telephone
20th Century and Modern Music (1900-present) • Stravinsky (18882-1971) • Bela Bartok (1881-1945) • Arnold Schoenberg (1874-1951)	Early 20th Century Technology 1900 AD-1945 AD) Computer Age (1945 AD-present)	Computer, DNA sequencer, television, microwave ovens, scotch tape

One question that comes to mind when viewing Table 2 is whether or not these inventions would have been created if not for the music of the time? More than one engineer has had his roots solidly in music. The next section discusses two of these.

11. Musical Engineers

There have been engineers who have been not only inventors, but also musicians, or musical instrument makers. One engineer that had his roots solidly in music from birth, used his musical knowledge to create technology: Charles Wheatstone. Another was known as the "Mathematical Instrument Maker": James Watt.

11.1. Charles Wheatstone

Charles Wheatstone was very influential in the field of optics, yet he did not start out as an engineer. He was born in February 1802 to a family that build and sold musical instruments. He used this early knowledge and eventually wrote his first scientific publication, *New Experiments in Sound*, on the topic of acoustics. From this beginning, he later studied electricity, optics, and vision, and patented many of his inventions [7]. In Charles Wheatstone, a direct correlation between his knowledge of music and eventual engineering pursuits is seen.

11.2. James Watt

James Watt was the official instrument maker of the Glasgow University in Scotland in 1757; he used his mathematical genius to create high-quality harps, flutes, bagpipes, and organs. Creating church organs led James to working with water pumps. James added a separate vacuum steam condenser, to the water pump at the time and vastly improved the device. Watt's steam engine is said to be the turning point of the industrial age. He continued with his inventions, including a forerunner to the modern photo-copier. James also scientifically determined the exact measurements of one horsepower, which is named in his honor, 'watt' [12]. Here we see another direct correlation between music and engineering.

12. Conclusion

This paper has discussed in brief the histories of music and engineering. It has also showed a correlation between the two, and given an example of two respected engineers who started out in music.

It is the authors' belief that music has motivated more than the heart of the engineer, it has driven the field of engineering. It has been shown that a Neanderthal flute may exist, which would change the view of engineering in the context of history.

Music and engineering have progressed throughout time almost in a one-to-one relation: music has advanced from the pre-written melodies of early man to the very complicated pieces of Bach, and beyond; engineering meanwhile has evolved from the invention of the flute, or at least the wheel, to the information age. Yet the correlation between the

progression of music and the growth of engineering has previously not been clearly defined until now.

Just as mathematics is important to engineering, it can also be found in music. There are necessary ratios in octaves and other musical concepts that are as important to music as multiplication is to mathematics. Therefore, it is not outrageous to suggest that music is integral to mathematics, and likewise, mathematics is integral to music. As mathematics is the foundation of engineering, the relationship between music and engineering is sometimes overlooked. Yet, the music-engineering relationship is much more than the ability to perform better in mathematics. Without music, the field of engineering would not have progressed to its current state; the two fields share a correlation and interrelationship of progression in time.

Music is said to express the feelings and values of the time, but it does more than that. Music shapes the feelings and values of the time, and thus, the creations that arise. Just as yesterday's music has shaped the technology of today, tomorrow's music will further shape the engineering of tomorrow.

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