Ethics Education as Philosophical History for Engineers

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Abstract

Ethics education in the engineering curriculum is required by ABET. This paper presents an unconventional approach to meeting this requirement as surveyed and tested in the aerospace engineering department of California Polytechnic State University, San Luis Obispo, with the intention of having a lasting impact on engineering graduates throughout their working career. All professions have common codes of competence, integrity, and intended good will towards humanity. Often these codes presume internal regulation and constraint to guard against human nature's self-serving inclinations and proclivities. Here, in addition to relying on student exposure to and knowledge of a particular code of ethics involving case studies of ethical situations, historical vignettes of philosophy and mathematics are presented as part of a senior engineering class in intermittent bursts of weekly storytelling that last approximately fifteen minutes to show the evolution of the moral basis underlying our ethical codes and practices from antiquity to the present day.

The goal of this effort is to complement and enhance exposure to and information about engineering ethics with philosophical history in a way that generates lasting internalized student concern about engineering ethical behavior; that is, in a manner that facilitates the development of what traditionally has been called a *conscience*, an inner feeling or voice viewed as acting as a guide for the rightness or wrongness of one's decisions and actions.

Surveys given before and after the class showed that the engineering students appreciated and benefited from the historical mathematical and philosophical focus on ethics, and that they fully appreciated the significant ethical challenges they will encounter. Their comments labelled this approach as both interesting and unique, and they enjoyed the linkage to many subjects normally confined to the humanities. Their recommendations were noted positively during an ABET visit.

Introduction

The fundamental principles[1] for the Code of Ethics for the National Society of Professional Engineers (NSPE) are shown at Figure 1. The canons conform with and are similar to many long-accepted ethical tenets in all engineering disciplines, and especially in engineering education. To foster discussion based on these ethical tenets in an undergraduate classroom environment is challenging. Since undergraduate students have little experience with serious engineering ethical matters, the case study method is often used. Case studies,

NSPE FUNDAMENTAL CANONS:

Engineers, in the fulfillment of their professional duties, shall
1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents of trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

Figure 1 Engineer Code of Ethics

however, though valuable in providing students with information and knowledge about engineering ethics, remain far removed from the student's actual experience, and therefore do not always foster intense interest and emotional involvement or identification that produce lasting impact. Knowledge of professional ethics in principle thus provides a necessary but often insufficient condition for the end result of ethical behavior in practice. The internal fostering of what was once called *conscience* is also needed. That is the challenging goal of the technique presented here, one that reaches back to the philosophical and mythical roots of ethics to stir the *conscience* of the student by seeking emotional identification with the source of our moral sense.

This reaching back to philosophical roots depends upon a storytelling technique that focuses on presenting philosophical and mathematical topics both familiar and interesting to the engineering student, topics that were instrumental in the evolution of our shared cultural morality. Many topics chosen for presentation arose naturally from the nature of a technical education, but a few were chosen of special interest to female engineering students. These true stories, myths, and interesting cultural situations highlight how prevailing norms of morality emerged episodically in Western culture, including the emergence of the origins of ancient moral codes in the Axial Age and the influence of Greek culture upon them; how they evolved into the ethics of the Enlightenment accompanying the mathematics and philosophies of Galileo, Newton, and Leibniz; and how they were secularized and finally published in a tract by Spinoza. The moral codes that evolved through each historical episode experienced a crisis followed by a reformulation. Today's ethical codes stand as secular moral propositions precariously based on reason alone, whether viewed through the "categorical imperatives" of behavior as described by Immanuel Kant or the "blank slates" of human development as proposed by John Locke.

The selected topics chosen for presentation have two primary characteristics. First, their history exposes a relationship between a particular philosophy commanding a moral code in a given era and the accompanying development of mathematics; for example, the relationship between the philosophy and resulting moral code of Pythagoras and rational numbers in ancient Greek culture. Second, the chosen topic must be a link in the historical evolution of the underlying basis for moral behavior in Western culture following the Enlightenment; for example, the evolving concept of the number *zero* or of mathematical *limits* in parallel with the evolving primacy of scientific reasoning. The topics are limited to Western vignettes, not to ignore or minimize the ethics of other cultures, many of which had strong positive influences on Western ideas, but to constrain presentations to relatively familiar narratives respecting the time limits of a single course and within which both male and female students can experience positive identification.

By necessity of space, the *sampling* here is incomplete, and the reader is referred to Appendix B for more information on the sequence of presentations. The intent of this paper is to illustrate the storytelling process using representative historical highlights with which students can relate to and identify; to show how difficult it has often been in the past to maintain ethical integrity in times of moral crisis that often accompany analogous predicaments in mathematics; to promote and foster an internal emotional sense of *conscience*; and to emphasize the serious ethical challenges that will confront students in the uncertain and precarious future. To avoid a clutter of superscripts, the references are only cited the first time their material is used in the narrative and not every subsequent time. Most of the material is verifiable from a variety of historical sources.

The Axial Age and Greek Culture

Students are often surprised to find that a relatively common set of spiritual beliefs emerged in widely separated cultures during what Karl Jaspers[2] labelled the "Axial Age" (800-200 "Before the Common Era" or B.C.E.), a development of pivotal importance to human thought. Centers of civilization in Asia and the northeastern Mediterranean produced Zoroaster, The Buddha, Confucius, Jeremiah, and Socrates (among other sages) who reflected on the fundamental questions of morality, death, and the afterlife. Out of these reflections the world's great religions were born, simultaneously and independently. In the pre-Axial Age humans had collaborated with divine powers through ritual and sacrifice to keep the world going and to earn divine favors with little thought of a future existence. In these cultures, ritual sacrifices and local taboos maintained social harmony. The evolution of tribal cultures into the urbanized Axial Age cultures of Persia and Greece changed ancient religious practice. This early evolution of spirituality and philosophy is presented through the stories of Zoroaster and Pythagoras.

Zoroaster and the Persians (800-600 B.C.E.)

In times of great societal strife the pre-Axial Age taboos often broke down, and once urbanization took hold conditions were ripe for cultural innovation. Zoroaster [3,4] was a Persian (Iranian) priest who, after receiving miraculous visions when he was 30 years old, reacted to the breakdown of his society by speaking of two deities, one good (*Ahura Mazda*) and one evil (*Ahriman*). These deities, and their respective angels and demons, were locked in mortal combat. Humans must choose between them, and Zoroaster was the first sage to connect human destiny with moral behavior in a cosmic conflict that would culminate on a Day of Judgment called *Frashokereti* at the end of time. A savior figure (*saoshyant*)—an apocalyptic judge—would play a decisive role and result in good triumphing over evil, establishing a paradise on earth. Zoroaster was killed for his beliefs, but the Persian Empire kept his tenets as a state religion from 600 B.C.E. until they were displaced by Islam in 700 C.E. Islam kept many of the ideas and rituals of Zoroaster, including the spiritual practice of praying five times each day.

The Jews came into contact with the Persians after the Jewish Exile in Babylon (Iraq of today) and developed many parallel beliefs documented in *Ecclesiastes* and in the *Book of Daniel*, and those beliefs eventually entered into Christian writings and thought. The devil is probably of Iranian origin, since he is not mentioned in *Genesis*, but he is clearly an evil spirit in the *New Testament* written approximately 500 years after the Jewish exile. Ironically, the wise men at the manger visiting infant Jesus may have been Zoroastrians searching for their *saoshyant* savior, the one who would eventually annihilate evil in the world. A morality based on the conflict between good and evil thus has its source in the Persian Empire, along with the unavoidable requirement on its inhabitants to choose between them.

Pythagoras and the Greeks (570-495 B.C.E.)

Although the influence of Zoroaster is recognizable in Western spirituality, it was the Greeks who had the most impact on Western thought, for the Greeks, despite the panoply of gods and

goddesses in their mythology, rejected a key tenet from the East that creation emerged from *chaos* or the *abyss*. The Axial Age in Greece produced the unique idea that perfection of both the material and the spiritual worlds was embedded in a rational mathematics. Specifically, this perfection could be demonstrated from mathematical proportion, such as the pleasing tones from ratios of the musical scale, and visual relationships such as those resulting from the Golden Ratio in architecture. The *star-pentagram* (see **Figure 2**) was the visual representation of this perfect ratio for Pythagoras and for the cult which he founded and led. The ratios it displayed were a vision of the *infinite*.[5] The Golden Ratio is geometrically obtained by dividing a line so that the ratio of the small part to the large part is equal to the ratio of the large part to the whole line. Greek architecture implemented this proportion in the Parthenon and other classic buildings.

The Greeks had taken the Egyptian number system and invented geometry with it. Numbers, philosophy, and theology became inseparable. Pythagoras was the spokesman for the Grecian Axial Age, a powerful orator, a renowned scholar, and a radical innovator. His cult and mantra was "*all is number*." It is interesting that the famous theorem accredited to him was known in Greece many generations before his time (possibly originating in India). The passion of Pythagoras was combining mathematics with music, an act reflecting the harmony of the universe. Nature's beauty was a reflection of the perfection of mathematics.

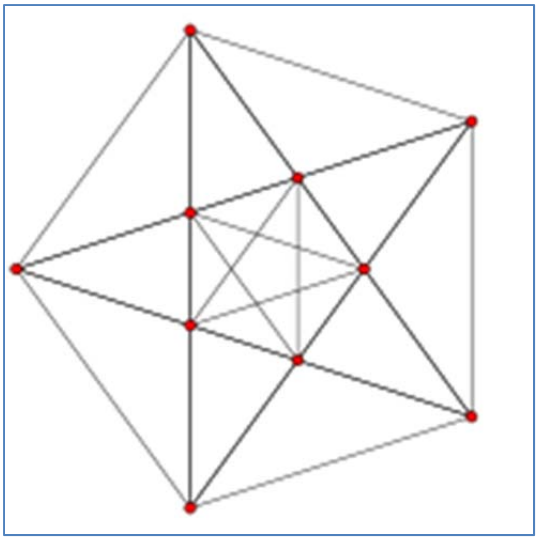

Figure 2 Star-Pentagram Symbol

This notion that ratios controlled the universe took hold in Western culture. They became supernatural links between aesthetics and theology that lasted intact until Shakespeare's time. On this point the Axial Age in Greece differed from mathematics in other civilizations. For example, mathematics to the Egyptians (with a base 10 pictorial number system), and to the Babylonians (with a base 60 system), and to Eastern cultures (with Brahmin and Indian base 10 numbers) was a strictly practical endeavor, not a spiritual one. Second, the concept of *chaos* or the *void* or the *abyss* was allowed in other cultures, but not in the West, not in Greece. In Grecian mathematics, the chaos resulting from any numerical division by *zero* was more than incorrect: it was an inconceivable blasphemy. And so, when a disciple of Pythagoras called Hippasus preached that the Golden Ratio was not a ratio of whole numbers, a religious war resulted between their respective cult followers. Legend has it that Hippasus was drowned, killed by those in the cult of Pythagoras for the blasphemy of proposing irrational numbers, an irreverent label for these numbers that persists to this day. Pythagoras, in retaliation, had his throat cut by those in the cult of Hippasus. Hippasus was correct, of course; the Golden Ratio is indeed the irrational number

$$\frac{1+\sqrt{5}}{2} \qquad (1)$$

The great Aristotle, unfortunately, sided with Pythagoras in his belief in a rational world defined by perfect ratios in nature and by perfect symmetry in the celestial spheres. *Zero* was identified with the *chaos* that would corrupt the natural perfection of the universe. The Western world we inherited from the Greeks was firm: there is no *void* allowed in creation. Integrity at that time demanded belief that morality originated in mathematical perfection and expressed itself in beauty of the human form, in the virtue of heroic athletic and military prowess, in the music of the spheres, and in the symmetric geometries of architectural splendor.

Zeno's Paradox (450 B.C.E.)

It is said that Archimedes, while working on a mathematical technique to compute the area of a parabola using triangles, might have discovered operational calculus if a Roman soldier had not killed him in Syracuse while he worked. Legend has it that he invented the parabolic reflector used at a distance to set fires on Roman ships, Rome being at war with Greece at that time. Archimedes may also have been stymied by one of his own erroneous mathematical conjectures: namely, that "*any number added to itself enough times exceeds any other number*." This conjecture was intuitive but contained no limits; it was mathematically unbound and infinite.

His conjecture had a famous corollary called Zeno's paradox. Zeno, from what is today Elea in southern Italy, was a precursor of Socrates (who died in 399 B.C.E.). Socrates credits Zeno with inventing the dialectic form of rhetoric. Zeno's paradox, building on Archimedes conjecture, disproves the possibility of motion by showing Achilles in a race with a turtle (see **Figure 3**). Every time Achilles covers half the distance, a picture is taken and it is seen that the turtle has moved forward of its former position, remaining ahead of Achilles. Since the number of times this half-distance can be stopped and measured is without end or limit in Greek thought, Achilles will never reach the turtle; hence, motion is impossible.

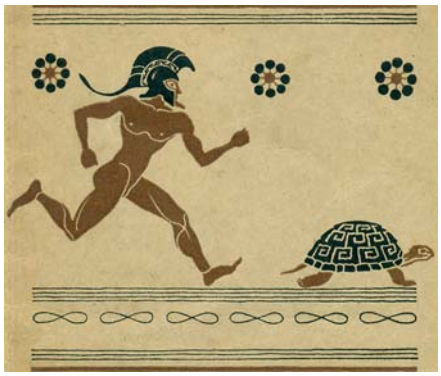

Figure 3. Achilles Races a Turtle (Zeno's Paradox)

The philosophers of Zeno's day, including Socrates and Aristotle, could not refute the paradox. It was obviously proven wrong by daily existence, yet no one could find a mistake. They knew the source of their problem: *infinity*. It would take over a thousand years from Zeno's time before the mathematical tools involving *limits* would answer this paradox successfully. Zeno died (he was tortured by a tyrant name Demylus) thinking his paradox true, and in his Eleatic school of philosophy he taught that everything in the universe was one and changeless; therefore, motion remained impossible for him, a conclusion supported by his paradox that he never abandoned.

The Dark Ages and Hypatia (350-415 C.E.)

Christianity, once a persecuted cult, in the 4th century became a dominant religion throughout the Roman Empire, and its evolving theology turned to Greek thought for its rational basis.

Themes from Zoroastrianism were in the Christian theological background, but various Church councils invariably aligned theological thought with Greek themes of rationality and perfection. After Constantine eliminated religious persecution in the Roman Empire, his Council of Nicaea in 325 C.E. established a creed (the Nicene Creed) that is still said today, with minor variations, in Catholic and Orthodox churches throughout the world.

Nearly a hundred years later, 415 C.E. in Alexandria, a female philosopher, astronomer, and daughter of a highly regarded mathematician took over the Platonist Academy. Her name was Hypatia, and she was 1600 years ahead of her time in proclaiming a moral code primarily based on reason. A religious conflict between the Jews of Alexandria and the monks of Alexandria's bishop, Cyril, led to her death, probably from a Christian mob who thought Hypatia was a pagan mystic who did not know her place in Alexandrian society. She was pulled from her chariot, killed, and her body was sliced into pieces with shards of tiles and burned in the temple. A moral code and political culture based only on reason as practiced by Hypatia[6] became heresy. Fifty years after Hypatia's death, the Roman Empire in the West collapsed. In that era dogmatic religious beliefs, and they alone, defined acceptable moral behavior and fields of scholarly study.

By contrast with western Rome's collapse, in Anatolia (Turkey) the eastern empire[7] thrived for another 1000 years. Its philosophy and mathematics conformed to Greek modes of rationality that were now embedded in Christian ideology, and the geometry of Byzantine architecture reached its zenith with construction of Hagia Sofia and its magnificent dome (see **Figure 4**).

Figure 4. Hagia Sofia (Holy Wisdom) Cathedral/Mosque/Museum

The Calendar and Zero (525 C.E.)

Along with the demise of the Latin Roman Empire, the mathematics of the calendar stumbled along as well. Pope John I in 525 C.E. asked the monk Dionysius Exiguus to *fix* Easter's date for at least 200 years so that it would remain in Springtime, and when Dionysius went backward in time he established Christ's birth at "1" C.E. when it should have been year *zero*, a number banned in the Roman West. To this day our calendar is off one year, and so our celebration of the year two thousand should have been on December 31, 2001 (not 2000). Dionysius also overlooked Herod's death in 3 B.C.E., and so was off by four years in dating Christ's birth. It took until 1583 C.E. for the calendar to get straightened out by scholar Joseph Scaliger, who started the "*Julian*" calendar (named after his father). Today we still start counting on the wrong digit ("1" instead of "0"), and our phones incorrectly show "0" last instead of first on its display. Rocket countdowns, however, are done correctly, ending solidly at blastoff "*zero*."

The Rise of Islam (700-1000 C.E.)

When Islam raced over its conquered lands in the eighth century, it brought back from India to

the Middle East what would become Arabic numerals, including *zero*, a number symbolizing the *void*, a concept that was accepted both in eastern cultures and in Islamic thought. By the ninth century, Caliph al-Mamun established a House of Wisdom at Baghdad whose mathematician, Mohammed ibn-Musa al-Khowarizmi, wrote the first book on algebra, *Al-jabr*, and whose name—due to being mispronounced in the Latin West—is the root of the word *algorithm*. The Arabs called the Indian *zero* the *sifr*; and westerners, when first learning of this banned number, called it *cifra* (root of *cipher*)—in Latin *zephirus*, root of *zero*.

By 1000 C.E. belief in "Great Chain of Being" prevailed.[8] The Latin West had re-emerged and together with the Byzantine East conformed to a classic Greek rationality, but true to tradition professed a mathematics supporting religious dogma that defined established common morality. In contrast, for Islamic lands the Quran dictated its own analogous common morality, but without any ban on the number *zero*. In fact, Aristotelians in a few strict Islamic lands at the time of the first millennium might still find themselves under a death sentence for teaching Greek philosophy. Eternal life that was granted by correct dogma was in play, and so stakes were high.

The Crusades (1054-1204 C.E.)

Everything changed with two events just after the first millennium. In 1054 C.E. the western (Catholic) and eastern (Orthodox) churches clashed dogmatically, each excommunicating the other, ostensibly over changes made to the Nicene Creed. This separation isolated Byzantium within an increasingly powerful Islamic presence. In 1071 C.E. a Byzantine army was soundly defeated by the Seljuk Turks in what is today eastern Turkey near Armenia at the town of Manzikert. Within ten years a significant part of Anatolia was held by the powerful Seljuk Turks, the start of a cultural process that would eventually result, centuries later, in the Ottoman Empire.

Figure 5. Theodosian Walls of Constantinople (Istanbul)

After Manzikert, the hard-pressed Byzantine emperor, Alexios I Komnenos, asked the Latin West for aid, for perhaps 3,000 knights. Pope Urban II, then in a feud with the French King, gave a sermon at Clermont, France, in 1095 C.E. intended to show that he, as Pope, could raise an army as well as a king. Incredibly, up to 40,000 knights answered the call. A People's Crusade followed, numbering up to a hundred thousand. When Byzantine Emperor Alexios saw the scale of what was coming, he closed the gates of the Theodosian walls (see **Figure 5**) to the Crusaders, who then wreaked havoc all the way to Jerusalem, where the total slaughter of inhabitants upon the city's capture is still a black mark on the history of the Latin West. The People's Crusade was also a disaster, not only for those in it, but for Jews who encountered it. Successive Crusades for the next 100 years resulted in little more than catastrophe for both the Crusaders and their Byzantine allies. In an outrageous display of treachery, participants of the Fourth Crusade in 1204 C.E. sacked and

pillaged Constantinople itself, sending its treasures to Venice. The moral base of both the Latin West and of Byzantium, founded on the revealed truths of Christianity and aligned with the rationality of the Greeks, was fast eroding through the violent practices of the defenders of faith.

Zero Enters the West (1202-1500 C.E.)

However, the Crusades proved to be a boon for the merchants and suppliers of military equipment and shipping. The city-states of Italy grew very rich, along with Venice that profited greatly from its sack of Constantinople in 1204 C.E. Banking was started by the Knights Templar. Merchants such as Fibonacci of Pisa learned their math from Muslim teachers, and Fibonacci developed the sequence bearing his name, relating it mathematically to the Golden Mean of the Greeks. Fibonacci, in his book *Liber Abace* (1202 C.E.), introduced the West to *zero* for use in economic calculations, greatly simplifying trades and exchanges. Arabic numerals soon replaced the German *Rechenbank* and wooden "*counting sticks.*" The resulting ban on these innovations by Florence was ignored by merchants and soldiers alike, and by 1400 C.E. *zero* had cracked and broken the old certainties of the West. The new mathematics of accounting displaced the old, traditions were broken, and the moral debaucheries of those in power of both Church and State were documented by Machiavelli[9] in his classic work, *the Prince*.

Prelude to the Enlightenment

The serious challenge of *zero* to the Latin West's theology was not recognized at first. In the new universities of the wealthy city-states, many Cardinals played with concepts like *infinity* and *zero* without fear of attack for heresy. But when Filippo Brunelleschi, builder of the great dome on the Cathedral in Florence, created a *vanishing point* in his sketches (see **Figure 6**), a *singularity* that collapsed *infinity* into *zero*, the famous scholar, Cardinal Nicholas of Cusa, saw immediately the implication and— incredibly— deduced that our earth was not located at the center of the universe. His writings led the Polish physician-monk Nicholas Copernicus to advance his radical idea that the earth revolved about the sun. Nicholas of Cusa argued that God *must* have created other places teeming with life. These ideas, however, following Martin Luther's protests against Rome in 1517 C.E., were fast becoming politically dangerous, and in 1600 C.E. the Dominican friar Giordano Bruno was burned at the stake for advancing the concepts and ideas of Nicholas of Cusa.

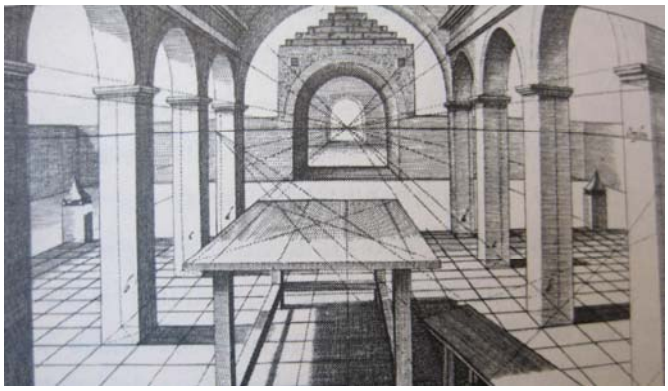

Figure 6. "Vanishing Point" of Filippo Brunelleschi

After Constantinople fell to the Ottoman Turks in 1453 C.E., a series of ongoing civil and religious crises were foreshadowed for the western world. Growing Castilian power[10] in Spain

resulted in the Inquisition, the expulsion of the Jews in 1492 C.E. and in later decades the banishment of Muslims. The subsequent vicious religious wars in the West were exacerbated by Spanish funds from New World gold and silver. The resulting devastation from mortal conflict between the ever-multiplying religious dogmas, each claiming eternal life for the victors, engulfed the entire Holy Roman Empire in tragedy until the Treaty of Westphalia[11] in 1648 C.E. These social and moral catastrophes, like those at the start of the Axial Age, induced deep skepticism into widely held traditional beliefs. In Western cultures, the morality based on competing visions of eternal life for the faithful believer would soon be seriously questioned.

A New Mathematics (1500-1650 C.E.)

When Galileo used his telescope to show the heavens to the chief Vatican astronomer in Rome, the astronomer fainted outright from the shock. There was no heaven "up there." This new and increasing skepticism towards the Aristotelian ideal of earth-centered perfection increased further in the Latin West when Johannes Kepler linked his planetary laws to Newton's concept of gravitation. A new philosophy, free from unproven religious revelations, was needed in the West that still allowed a "perfect" universe. This philosophy would arrive along with a new mathematics called *analytic geometry* that now included the once profane *zero*. In 1619 C.E. Rene Descartes, while recovering from injuries received as a soldier in the Bavarian army, received angelic visions promising a new philosophical unity based on *dualism*, the separation of mind and body. At the center of the coordinate system that today defines *Cartesian geometry*, Descartes constructed a *Cartesian coordinate* cross or grid in which, at the origin, he inserted the infamous "*zero*." He distrusted negative numbers, and he held firm against accepting ultra-radical numbers such as the "*square root of minus one*," to which he assigned the derogatory label "*imaginary*"—a designation that *complex numbers* still carry. Descartes sought a philosophical unification of mathematical certainty and absolute morality that yielded harmony. His *dualism*, however, though promising, was not to survive intense scrutiny. The Dutch *rationalist* philosopher, Baruch Spinoza, and the English *empiricist* John Locke (successor to Sir Francis Bacon, the individual credited with developing the scientific method) rejected the *dualism* of Descartes, but both of them remained committed to Descartes' passion for truth.

The Ethics of Reason: Spinoza (1632-1677 C.E.)

Bento (Portuguese for "*Blessed One"*) Spinoza[12] lived in Amsterdam's Jewish community from 1632 C.E. to 1677 C.E. He was descended from Jews expelled from Portugal, and he took Descartes very seriously, using the command "*strive for truth*" of Descartes to attack both the Bible and the conclusions of Descartes himself. Spinoza's work *Ethics* is his foundation for a rational approach to morality and ethics without dependence on revealed religious dogma. He was expelled from the Jewish community for his views, and his *Apology*, though lost to us, would have called for religious toleration similar to that made by John Locke at a later date in England. Spinoza's rules of living are simple: *get along with others, enjoy those pleasures that safeguard health, and attain enough wealth to maintain a vigorous mind.* He sought a wholeness of his mind with nature and natural processes.

Newton and Leibniz were ten years junior to Spinoza, and Leibniz likely maintained an intermittent relationship of sorts with Spinoza. Leibniz, however, like Descartes, believed in the City of God and in the perfection of creation; Spinoza, on the other hand, believed the creator of the universe had no observable concern for humanity, and that virtue consisted of individuals following their true natures in freedom of action.

Zero Confounds the West: Calculus (1675-1750 C.E.)

One can hardly overstate the importance of Newton to these respective views of Leibniz and Spinoza. Newton showed that mathematical laws like gravitation govern the entire universe at all of its points, the laws being impersonal and absolute in application. Although Leibniz in Germany developed the calculus in parallel with Newton in England, he disagreed with Newton's concept of gravity, for Newton's physics described the awe-inspiring and impersonal universe of Spinoza, a universe without demonstrated concern for humanity and therefore incompatible with Leibniz's *City of God*. Newton's mathematics, however, like that of Leibniz, could not achieve the full power of the calculus without introducing *zero*. Both Newton and Leibniz avoided dividing by *zero* by using invented *fluxions* and *monads*, respectively. It was left to a child abandoned on the church steps of Saint Jean Baptiste le Rond in Paris (1717 C.E.) who named himself D'Alembert, to introduce *zero* into the calculus as a ratio of series that converged to a *limit*. This decisively solved the riddle of Zeno's paradox. The calculus by the middle of the 18th century was in full flower, logically precise and mathematically well defined. This mathematical precision and definition now ironically required that the heretical and chaotic *zero* be embedded within fundamental theorems. A *rationalist* unification of ideas into mathematical laws was progressing that satisfied *empiricist* observations of nature, but ideas as envisioned by Spinoza and not by Descartes; ideas that were separating mathematics from philosophy and theology; ideas based on reason that were introducing the anxieties and uncertainties of *zero*.

Spinoza's *ethics* appeared compatible with science and the calculus in every emerging detail. Spinoza believed in an impersonal God, and he maintained *"It cannot be said that God loves mankind."* It is for us, he said, to employ reason to find our true self-interest, which in essence is *freedom to act.* The modern secular state in the West, when viewed from a global perspective, resembles much more Spinoza's republic striving for freedom of action than Leibniz's City of God. Spinoza realized, however, that reason and freedom must be energized by virtue.

It is safe to say that Spinoza, should he view a modern engineering Code of Ethics, would approve it providing that one who followed that Code sought freedom to act through virtue. However, Spinoza would advise caution ("*Caution!"* was his motto that was engraved in a signet ring he wore with the image of a thorny rose): *"The virtue of a free man is as great in avoiding dangers as in overcoming them."* If morality is to be based on pure reason, the rationality of Spinoza is an excellent starting point providing virtue is presumed. Unfortunately, the cost of discarding the certainties of dogma was the inevitable introduction of uncertainty into morality.

Today, with Pascal's probability a factor both in mathematics and in Richard Feynman's physics[13] of quantum mechanics, we can expect by analogy a continuing uncertainty embedded

within our individual and collective notions of morality and ethics. Some might ironically call this uncertainty *faith*! Perhaps Richard Feynman says it best: "It is in the admission of ignorance and the *admission of uncertainty* that there is a hope for the continuous motion of human beings in some direction that doesn't get confined, permanently blocked, as it has so many times before in various periods in the history of man."

The Rationalism and Empiricism of the Enlightenment: Locke and Kant (1750-1800 C.E.)

Due to time constraints, Englishman John Locke (1632-1704), a contemporary of Spinoza, and Immanuel Kant (1724-1804), the German philosopher strongly influenced by Locke, are usually the final human subjects for the class presentations on the historical evolution of ethics. Locke's once radical ideas on the *social contract* are reflected in Jefferson's Declaration of Independence and in the Constitution of the United States, and Locke was banished to the Netherlands in 1683 for his political rhetoric, this putting him into contact with the free thinkers mentored by Spinoza (who had died in 1677). Locke was what Immanuel Kant would later label an *empiricist*, a physician; Spinoza, on the other hand, was a *rationalist*, a metaphysician. Yet Locke was deeply impressed by Spinoza's book *Ethics*, and from it came his lasting ideas on the separation of church and state; on religious and political tolerance; on the goodness of human nature; on the separation of powers in the state; and on the state's need for the consent of the governed. Locke is the father of classic liberalism (today's *libertarian*).[14]

Whether *rationalist* or *empiricist*, the philosophical ideas of Spinoza and Locke were radical indeed. Recall that in the Middle Ages of Western Europe there had been general belief in a *"Great Chain of Being"* that held the cosmos together, that defined morality, and that assigned everyone a meaningful place within that cosmos. The utter devastation of Europe's religious wars had put such belief in question. In this skeptical vacuum Spinoza, Locke, and Kant were promoting new, radical ideas based on reason and a belief in human goodness that were to take hold and thrive, at least until the Great World Wars.

Kant maintained that the three greatest *rationalist* philosophers were Descartes, Spinoza, and Leibniz; and that the greatest *empirical* philosophers were Locke, Hume, and Berkeley.[15] Paradoxically, though Spinoza and Locke agreed about the value of tolerance and empathy, they were far apart in notions of divine intervention. Perhaps tolerance and empathy, taken together as key components of virtue, are the common emotional links between Spinoza's *rationalism* and Locke's *empiricism*. If this be so, then the *rational* hypothesis "*other interest is self-interest*" might be *empirically* tested to establish and confirm that common emotional links (like tolerance and empathy) are conducive to harmony in social affairs. Is it possible, then, that the Golden Rule might be shown to be both rational and scientific? This is a most interesting conjecture.

Free Will and Morality (1800-1950 C.E.)

If we look to the towering German philosophers of the 19th century, Schopenhauer comes closest to Spinoza, especially in concepts of oneness and empathy.[16] Both philosophers agreed that the mental processes of the mind (including imagination) and the physical components of the body are aspects of the same substance of which everything consists. Freedom to both men is

freedom of the *will* to act; but ironically, that which drives the *will* from deep within the human psyche is ultimately and totally determined by nature and nurture. Therefore, in their view, *free will* by an autonomous agent such as the *soul* does not exist.

In the *rationalist* branch of philosophy, Kant grounded his ethics solely on one's *motive* or *intent* regardless of consequences. *Good will* rules virtue through focus on duty! Unfortunately, defining what is *good* using *motive* and *intention* alone makes any morality measure subjective, since there is no requirement by Kant for demonstrated external results. According to Kant each individual, regardless of circumstances, had a *categorical imperative* to determine and to follow his duty as demanded by his imagined *intelligible character*, the source of integrity itself. On this point alone, that the individual has an *intelligible character* as an internal moral standard, did Schopenhauer agree with Kant. To Kant the question of free will was ultimately unsolvable by either *rationalism* or *empiricism*.[17]

Eventually the *empiricists*, turning away from Kant's insistence to value only *motive*, produced a practical philosophy of *utilitarianism* (promoted by English philosophers Jeremy Bentham and John Stuart Mill) that emphasized good results. In America, the *empiricist* branch includes the *pragmatism* of William James (the father of psychology), John Dewey's *naturalism*, and Ernst Nagel's *positivism*.[18] The goal is the *good* or the greatest *happiness* for the greatest number. *Utilitarian humanism*, or secular ethics, once promised great solutions for difficult social problems; but over the years, it has often dissipated into a free thinking relativism, driven by statistics and academic social research of questionable value. Author Helen Rittlemeyer, a critic of secularism, has expressed this skepticism by saying: "*In our public culture, the moral has devolved into the empirical*."[19]

The Modern Ethical Dilemma: Loss of Meaning (1900-2015 C.E.)

Secular ethical principles of behavior are now the basis of our engineering codes of conduct, but not without pockets of skepticism. Even when these codes are known and understood, they may not form one's *conscience*. Our ethical presentations in class end with student critiques of ethical predicaments of the modern age in which science and reason, though reigning supreme in theory, have fallen short of their ethical promise in practice through human fallibility.

One explanation for the inability of ethical knowledge alone to form integrity of *conscience* is the alienation of the individual that fails to stop immoral behavior when the fear of being caught is gone. As science now explains phenomena previously in the realm of religious dogma, the "technocrat" has gained prestige in secular culture. The non-scientific individual, however, often sees his position—once relatively well defined within the "Great Chain of Being"—as shrinking into insignificance and potential alienation. Nietzsche, seeing religion's influence waning in European culture, warned of *nihilism*, the disease of modernity. Dostoevsky also recognized this alienation, and in Russia today we have teens[20] "killing themselves en masse, joining suicide clubs with authorities oblivious." Even the most modern and sophisticated democratic nations, such as Sweden and Japan, also have a similar problem of alienation and suicide.

Looking back in time, neither the *rationalist* nor the *empiricist* approach to secular ethics anticipated the ethical debacles of our two Great World Wars, including atrocities such as the Holocaust or the actual use of nuclear weapons against populated cities. Some of the most gifted architects and engineers of the Third Reich, at times with the complicity of corporations[21] in the Western world (the punch card records for prisoner documentation provided by IBM, for example) perfected concentration camp processes for industrial scale genocide with little moral resistance or ethical debate from the larger technical community. Profits and technical progress trumped ethics and Spinoza's call for caution. Reason became a tool in the grip of evil.

Here in the United States, President Truman either was unaware or ignored the pleas of O.C. Brewster, a talented engineer, who as a condition for working on the Manhattan Project had received written assurance from Franklin Roosevelt that a demonstration nuclear bomb would be dropped first—as a warning—before actual use against a city. A petition[18] from Leo Szilard, physicist, signed by 70 colleagues, had recommended a hold on atomic weaponry, but this was ignored by Secretary of War Henry Stimson, who said: "*I think the bomb instead constitutes merely a first step in a new control by man over the forces of nature too revolutionary and dangerous to fit into old concepts*."

In fact, dropping the atomic bomb on Japanese cities only aggravated the ethical debate. Mathematics Professor Bridgman of Harvard argued that scientists should "mind their own professional business"; Isidor Isaac Rabi from MIT insisted that the social responsibility of science was to do good science, period; and Oppenheimer himself argued against moral prohibitions against scientific work. The Russians eventually constructed and tested the fifty megaton "Tsar Bomb," a device that could instantaneously destroy an area from Anaheim to Los Angeles. It is apparent that science and reason, whether *rationalist* or *empiricist* in nature, were not always being applied to freedom of action with Spinoza's *caution* or *virtue* in ethical affairs. The recent cheating scandal among nuclear missile officers[22] responsible for deploying nuclear weapons (if the unthinkable ever occurs) has revived this debate with new urgency.

Today, moreover, we have unregulated DNA laboratories[23] in scattered nations practicing *synthetic biology* "on the cheap" and producing highly contagious viruses more deadly than the Spanish flu virus, a virus which killed as many people as the World War I conflict. Some of these viruses—and this belies belief—are being synthetically produced with no known antidote. We have drones authorized to kill an American citizen if that citizen is declared an "enemy of the state"—with such declarations made internally and secretly by the state bureaucracies. We have increasingly intelligent *robotic soldiers and autonomous vehicles* with the capability for deadly force. New rules of *ethical* engagement need definition—rules that may ethically test Isaac Asimov's first rule of robotics "not to injure human beings." Finally, we have the fantastic, futuristic "*singularity*" as popularized by Ray Kurzweil[24], when artificial intelligence, genetic alterations, and nanotechnology will supposedly combine to produce synthetic, living beings far superior to the humans of today—perhaps defining Nietzsche's *superman*. Regardless, s*uperman* or *zombie,* the ethics of creating such self-replicating beings, or of embedding ethics within such beings (a "suicide" gene has been proposed), would provide a huge ethical challenge that is extremely difficult to define much less resolve.[25] (This topic concludes student presentations.)

Student Survey Results

Questions and responses in the student survey of two engineering classes that were given these ethical history presentations are in Appendix A. Questions 1 through 6 were given before the presentations started, and questions 1 through 8 given at the end of the presentations. Results from the survey are summarized in **Figure 7** with eight conclusions**.** The final two conclusions clearly indicate (average 2.9 and 3.0, both Level 1) that the history of ethics presentations helped students to appreciate and understand ethics, with excellent agreement that this approach is highly recommended. Appendix B shows the topics covered in a ten-week course. Appendix C presents all student ratings with two-sigma outlier data shown in red.

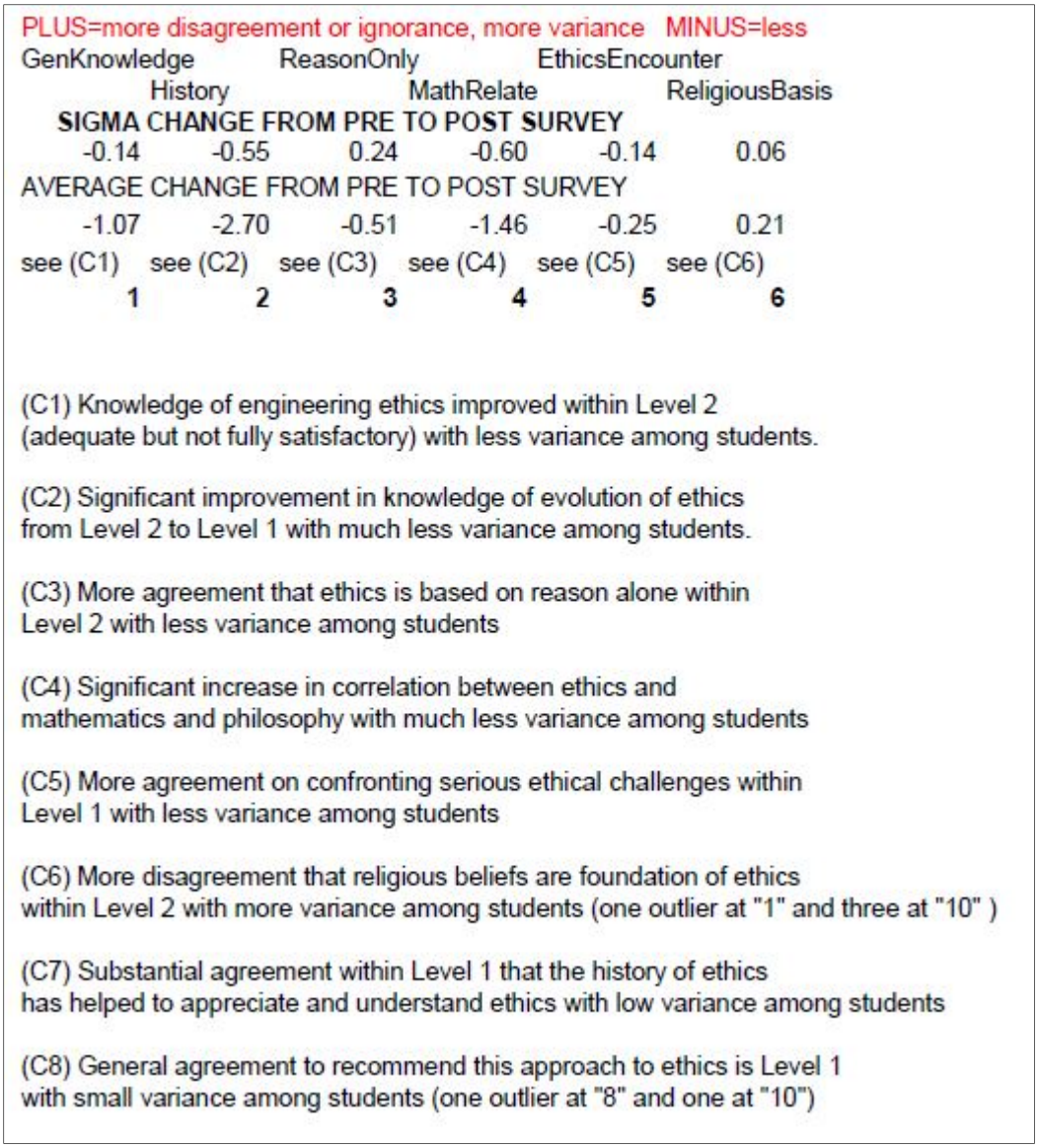

Figure 7 Conclusions from Student Surveys (See Appendix A for Details).

NOTE: (C7 and C8 Are Based on Post-Presentation Responses Only)

Summary of Student Feedback and Resolve

A positive student recommendation was noted[26] by the associate dean of the engineering college in his preparation for a successful ABET visit during the spring 2014 quarter. Students giving positive feedback, I believe, have been motivated towards valuing *conscience* awareness in the long run. Conversely, those students giving negative feedback have probably not been helped by this approach. Outlier students (shown red in Appendix C) with strong opinions either for or against religious influence in the determination of ethics remained outliers from start to finish. If given the opportunity to repeat this experiment, I would prune the topics to retain only those with the highest receptivity from the students' point of view. This remains a challenge.

Final Comments on Ethical Challenges

In our modern, complex world the potential for despotism and resulting loss of ethical control over rapidly evolving technologies demands that we heed the cautionary words of Reinhold Niebuhr: *"Man's capacity for justice makes democracy possible, but man's inclination to injustice makes democracy necessary*."

In the Axial Age, various religions gave people a cosmic meaning for their lives, for their sufferings, and for their losses. The price for this placement at the center of the universe was a set of limitations to individual freedom and a host of rules and/or practices to follow. In the scientific age, Spinoza's freedom of action is a cherished ideal. However, his universe presents itself through nature as indifferent to our personal or collective needs. Although Spinoza put forth the ethics of reason as superior to Axial Age beliefs, promoted tolerance instead of religious war, and recommended empathy instead of domination, the application of this *scientism* of reason, as evidenced by the above examples of ethical dilemmas, has often fallen flat and at times favored efficiency and raw technical progress over ethical concerns.

The ethical challenge appears to be clear: how can we foster and provide meaning and purpose for all individuals, no matter their talent, motivation, or status, given an increasingly materialist worldview and the individual's shrinking importance within it; that is, given an ethical worldview based on reason alone? This is the modern ethical conundrum, the moral challenge that confronts the current and probably the next generation.

If the supremacy of reason—both within science and in the conduct of human affairs—is a *necessary* condition for a moral and ethical society in the modern world, it remains an *insufficient* one. In addition to a code of ethics that puts this *necessary* condition into words, a healthy democratic republic must also allow and promote a diverse array of belief [27] producing individuals who are motivated to strive for excellence in all areas of life; who reject absolutisms or fanaticisms that lead to violence; who both accept and heed their profession's code of ethics in principle and in practice; and, just as importantly, who accept some degree of *uncertainty* as a fact of life and as a reality of their *faith*. This internal acceptance of ethical standards[28] implants within oneself what has traditionally been called the *conscience*, the essence of personal integrity. Many contemporary secular writers are confident that this is achievable.[29]

There remains the danger of overconfidence. Specifically, if one cannot allow a level of ignorance to exist in one's own views, however slight, and thereby *accept the uncertainty* advocated by Richard Feynman as a precondition for progress, one may abandon the difficulty of striving for virtue and either seek what is most appealing materially or succumb to what is most powerful ideologically. The caution urged by G.K. Chesterton[30] during any search for an *ethics* based on reason alone should be taken to heart: "*Wherever the people do not believe in something beyond the world, they will worship the world. But, above all, they will worship the strongest thing in the world*."

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***Appendix A*: Student Engineering Ethics Surveys (Before and After Class Presentations)**

Two Separate Class Sections:
Section 1: 18 students total (2 female). Section 2: 27 students total (3 female).

DEFINITION OF LEVELS: TO HELP ANSWER THE EIGHT QUESTIONS BELOW:

LEVEL I Excellent, Satisfactory, Positive, Agree --- RATING RANGE from 1 to 3 for Level I
LEVEL II Not Satisfactory but Adequate, Partial--- RATING RANGE from 4 to 6 for Level II
LEVEL III Inadequate, Unsatisfactory, Disagree--- RATING RANGE from 7-9 for Level III

RESULTS: Questions 1-6 Were Asked Both Pre-and Post-Presentations:

C1. How would you rate your general knowledge of engineering ethics? (1 to 10 range with markers below)

(LEVEL I. 1-3) My knowledge is excellent; (LEVEL II. 4-6) My knowledge is adequate but not fully satisfactory; (LEVEL III. 7-9) My knowledge is neither adequate nor satisfactory. (LEVEL IV 10): NO CLUE.

RATING BEFORE = 5.1 **RATING AFTER = 4.0**

STD DEV BEFORE = 1.6 **STD DEV AFTER = 1.4**

C2. How familiar are you with the historical evolution of ethics in Western society (case studies and other examples)? (1 to 10 range with markers below)

(LEVEL I. 1-3) My familiarity with this is excellent; (LEVEL II. 4-6) My familiarity with this is adequate but not fully satisfactory; (LEVEL III. 7-9) I am not familiar or knowledgeable with this. (LEVEL IV 10 NO CLUE.

RATING BEFORE = 6.4 **RATING AFTER = 3.7**

STD DEV BEFORE = 2.1 **STD DEV AFTER = 1.5**

C3. How agreeable are you with the hypothesis that the basis for ethics is rationality and reason alone? (1 to 10 range with markers below)

(LEVEL I. 1-3) My agreement is excellent; (LEVEL II. 4-6) My agreement is partial but not fully substantiated; (LEVEL III. 7-9) My disagreement is substantial. LEVEL IV (10): I am completely opposed

RATING BEFORE = 4.9 **RATING AFTER = 4.4**

STD DEV BEFORE = 1.7 **STD DEV AFTER = 1.7**

C4. How confident are you that mathematics and philosophy are related to morality and ethics? (1 to 10 range with markers below)

(LEVEL I. 1-3) My confidence in this relationship is excellent; (LEVEL II. 4-6) My confidence is partial, not fully substantiated; (LEVEL III. 7-9) I have no confidence they are related. LEVEL IV (10): No Clue.

RATING BEFORE = 4.6 **RATING AFTER = 3.1**

STD DEV BEFORE = 2.3 **STD DEV AFTER = 1.9**

C5. How positive are you that you will confront serious ethical situations in your career? (1 to 10 range with markers below)

(LEVEL I. 1-3) With certainty I will meet difficult confrontations posing serious ethical challenges; (LEVEL II. 4-6) Probable confrontations but the situations will not seriously challenge me; (LEVEL III. 7-9) I will seldom be confronted with any serious ethical challenges; LEVEL IV (10): I will never encounter difficult ethical decisions

. **RATING BEFORE = 2.5** **RATING AFTER = 2.3**

STD DEV BEFORE = 2.0 **STD DEV AFTER = 1.9**

C6. I consider that a morality based on revealed religious precepts is the foundation of ethics (1 to 10 range with markers below)

(LEVEL I. 1-3) My agreement with this is excellent; (LEVEL II. 4-6) My agreement is partial but not fully substantiated; (LEVEL III. 7-9) My disagreement is substantial. LEVEL IV (10): I completely disagree.

RATING BEFORE = 5.6 **RATING AFTER = 5.8**

STD DEV BEFORE = 2.0 **STD DEV AFTER = 2.3**

The Following Two Questions Were Asked Post-Presentations Only:

C7. My exposure to ethics as philosophical history for engineers has helped me to understand and to appreciate ethics.

(LEVEL I. 1-3) My agreement with this is excellent; (LEVEL II. 4-6) My agreement is partial but not fully substantiated; (LEVEL III. 7-9) My disagreement is substantial. LEVEL IV (10): I completely disagree.

RATING BEFORE = **	**RATING AFTER = 2.9**
STD DEV BEFORE = **	**STD DEV AFTER = 1.5**

C8. I would recommend this approach or one similar to expose undergraduate engineering students to ethics.

(LEVEL I. 1-3) My agreement with this is excellent; (LEVEL II. 4-6) My agreement is partial but not fully substantiated; (LEVEL III. 7-9) My disagreement is substantial. LEVEL IV (10): I completely disagree.

RATING BEFORE = **	**RATING AFTER = 3.0**
STD DEV BEFORE = **	**STD DEV AFTER = 2.0**

Appendix B: Student Engineering Ethics Storytelling Session Topics [31]

http://www.youtube.com/playlist?list=PLFLUrNkqR8F3FQ2jeQXgJ6W9ujHwJdf_w

WEEK	TITLE	HISTORICAL TIME FRAME	MORAL CODE	REF
1	*The Irrational Rationalism of Pythagoras*	570-495 B.C.E.	Geometric Harmony and Proportion	3,4,5
2	*Zeno's Paradox and Negation of Zero*	450 B.C.E.	Absolute Logic and Perfection	5
3	*Woman Philosopher: HYPATIA*	400 C.E.	Rationalism, Pre-enlightenment	6
4	*Ethics in the Dark Ages: Manzikert toFibonacci*	1050-1100 C.E.	Religious Dogma and Certainty	7.8
5	*Famous Women: Isabella, Joan of Arc, Catherine*	1200-1300 C.E.	Religious Dogma and Revelation	10
6	*The End of Byzantium and Crisis in the West*	1400-1600 C.E.	Religious Dogma and Machiavellianism	7
7	*Cartesian Mathematics and Philosophy*	1600-1650 C.E.	"I think, therefore, I am." Reason rises.	11
8	*The Calculus (Newton, Libniz); Spinoza, Locke, Kant and the German philosophers*	1650-1850 C.E.	Enlightenment Philosophy and Reason meet concepts of uncertainty and limits	12-16
9	*Modern Ethical Dilemmas and Examples*	1850-1950 C.E.	Secular Humanism: Relativist Ethics	18
10	*Ethics in Crisis: Chardon High School Shooting*	Current Day	Post-Enlightenment Crisis: Nihilism and Alienation	19-25

Appendix C: All Student Ratings (two-sigma outliers shown in red)

1=AGREE 10=DISAGREE

GenKnowledge History	ReasonOnly MathRelate	EthicsEncounter RevelationBasis
SIGMA	SIGMA	SIGMA	SIGMA	SIGMA	SIGMA
1.58	2.07	1.72	2.33	2.04	2.20
AVG	AVG	AVG	AVG	AVG	AVG
5.07	6.38	4.89	4.58	2.51	5.80

ETHICS PRE SURVEY DATA (C1-C6)

C1	C2	C3	C4	C5	C6
10	10	10	10	10	10
5	4	5	6	2	6
7	7	5	5	3	7
6	10	3	9	1	2
9	3	10	1	1	1
5	5	6	6	5	6
4	4	7	4	3	9
4	7	4	4	2	5
5	6	6	1	1	6
5	7	5	4	3	10
5	7	4	5	3	6
6	4	7	5	5	3
7	5	4	8	4	5
5	7	7	7	4	9
4	7	4	5	2	8
5	4	6	3	1	8
5	4	3	6	2	3
7	10	6	5	1	8
5	8	5	5	4	5
5	7	2	3	4	8
3	4	3	5	2	2
3	8	8	6	2	5
5	7	3	2	2	5
5	8	3	5	2	7
5	7	4	1	1	6
1	3	2	1	1	4
3	9	5	1	1	6
5	9	6	10	3	6
5	7	4	6	1	4
7	5	4	8	10	9
6	8	3	5	3	5
8	5	3	3	2	5
4	5	5	4	1	9
6	8	7	3	2	2
6	8	6	1	1	6
4	10	4	2	1	5
6	8	4	7	3	5
5	6	6	3	1	1
5	1	3	9	5	3
6	7	3	3	1	7
8	8	5	6	1	8
6	8	6	5	1	6
3	4	4	1	1	5
3	6	7	6	2	6
9	4	6	5	2	5
5	7	7	5	10	5

1=AGREE 10=DISAGREE

GenKnowledge History	ReasonOnly MathRelate	EthicsEncounter RelgiousBasis	HELPED? RECOMMEND?
SIGMA	SIGMA	SIGMA	SIGMA	SIGMA	SIGMA	SIGMA	SIGMA
1.41	1.52	1.98	1.73	1.90	2.28	1.60	1.98
AVG	AVG	AVG	AVG	AVG	AVG	AVG	AVG
4.00	3.68	4.33	3.09	2.27	5.81	2.94	3.03

ETHICS POST SURVEY DATA (C1-C8)

C1	C2	C3	C4	C5	C6	C7	C8
10	10	10	10	10	10	10	10
4	4	3	3	2	8	3	3
7	5	6	1	3	10	3	1
3	4	4	3	1	7	3	3
6	4	5	1	4	3	3	4
4	1	6	1	3	5	3	3
7	8	8	1	2	5	2	1
3	1	4	1	2	7	1	1
4	4	3	2	2	5	5	4
2	2	4	3	3	5	2	2
2	6	4	3	1	10	3	3
3	3	2	2	1	4	1	3
4	4	7	2	1	7	4	4
3	4	4	6	1	6	4	4
4	6	3	2	4	10	5	3
4	3	5	3	2	5	1	2
3	3	2	4	2	1	2	2
3	4	5	4	1	7	3	4
4	2	8	1	3	5	1	1
3	4	1	4	2.5	6	1	1
8	6	8	6	2	7	7	10
4	3	5	5	1	7	4	5
6	4	4	4	1	4	4	4
7	1	3	7	7	4	1	1
4	3	2	4	1	2	3	2
4	4	5	3	2	2	2	2
3	3	7	1	2	9	3	3
4	3	3	3	2	5	3	4
8	4	7	6	10	7	6	8
3	4	2	3	1	8	3	2
3	4	5	5	1	5	4	3
4	4	2	4	1	5	1	1
2	2	3	1	1	5	3	3