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Using Heavy Metal Music to Promote Technological and Socio-cultural Understanding

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Abstract

Heavy metal is one of the most misinterpreted musical genres in existence, while also arguably one of the most intelligent, insightful and technologically-rich genres. Heavy metal's history has facilitated multiple engineering developments in its quest for extremity as well as containing a wealth of commentary about global, social, religious and political cultures. A course has been created to help students explore these engineering developments and social commentary in order to promote understanding of the interplay between the technologies and cultural phenomena. This presentation will provide a synopsis of the course and its success over its developmental period.

The course utilizes heavy metal's influences and history to examine where culture and music collide. It then goes further to study the music's relationship with progress in engineering and design. To do this, the course reviews the engineering problem solving process, as well as discipline-specific topics like materials science, electronics, mechanics and manufacturing as they pertain to instrument and equipment design. The course further discusses the impact of software on the creation and distribution of musical media, and the social and legal aspects of the Internet. These topics are then related to the bigger picture of engineering and technology in general society.

Student evaluations of this course suggest that combining these seemingly-disparate topics has struck a chord in students, so to speak. In the first three years of the course, the feedback from the more than 200 enrolled students included such comments as "It inspired unique thought processes that helped explore new topics not touched in other classes" and "intellectually in-depth concepts". For the evaluation question "I rate this course as Excellent", the ratings every year were above 3.45 on a scale of 0-4 ("0" meaning "Strongly Disagree" and "4" meaning "Strongly Agree"). This suggests that combining interesting topics for students with far-reaching and often unusual concept combinations is a winning formula for promoting cross-disciplinary understanding and growth in students' critical thinking skills.

Introduction

Heavy metal (often simply referred to as "metal") is a musical genre consisting of a wide variety of instrumental styles, lyrical themes and cultural phenomena. Generally speaking, all of these topics revolve around the presentation of power and intensity.[1-3] While a complete description of the genre is excessive for this paper, a basic and oversimplified introduction to it is necessary to highlight both the social impact it has had and the technological richness that directly pertains to the audience of the paper. It also provides the framework as to how and why a college course was created to explore these relationships.

Heavy metal's genesis is typically attributed to two hard rock groups: American band Blue Cheer in the 1960s and British band Black Sabbath into the 1970s.[1-4] The former drove the creation of louder amplifiers and guitars distorted to the point of excess, while the latter combined the influences of classical, blues and jazz music with occult- and doom-focused lyrical themes that were atypical of the time period. Together with their peers in bands like Deep Purple, Alice Cooper and The Who, they captured the rebellious spirit of the '60s and embedded it in a powerful package of musicianship and intensity that had not heretofore been experienced. It provided many listeners with an avenue to explore previously-taboo topics as well as to release their teen angst in socially permissible ways. Metal's intensity and power was made possible by significant advances in amplification technology and bands pushing that technology beyond its normal limits.

Throughout the 1970s, lyrical themes changed from protest music about the Vietnam War to escapism and hedonism, and it was still mostly performed by British and American bands. Disco music was one extreme of these themes, and extensively used electronic synthesizers to bolster the dance-worthiness and "out of this world" feel of the music. The other extreme was heavy metal, now in the form of bands like Judas Priest, Kiss, Motörhead and Van Halen. It was still instrument-driven music, which separated it from the likes of disco, and incorporated theatricality, fantasy and virtuosity into the continued musical evolution.[1,4] With LPs and their large format being the media of choice in the '70s, it was a great marketing opportunity to be as fantastic as possible. Fans continued to use metal music as an escape from the stressors in their lives. A major engineering development at this time, and one pioneered by Eddie Van Halen, was the Floyd Rose "tremolo" bridge for the guitar, which enabled both stabilized guitar tuning and greater sonic character to guitar solos.[5]

In the 1980s, metal progressed in multiple musical directions as well as both growing immensely in popularity and burrowing further underground. On the popular side was radio-friendly "hair metal" (e.g. Poison, Bon Jovi, Def Leppard), where both hedonism and hairstyles grew to excess.[1,4,6,7] Until this point, metal's demographic was mostly young, blue-collar, white males.[2,3] With hair metal's more palatable presentation came a significant increase in older, white-collar female fans, though it was still predominantly Caucasian.[1] Records and cassettes were giving way to compact discs (CDs) as the media of choice, and fans were buying them readily.

On the underground side were faster and more politically- and religiously-charged thrash and death metal bands like Metallica, Slayer and Deicide.[1,3,4,6,8] These bands pushed further the volume and distortion, increased the tempo of the music, and began delivering vocals that ranged from screamed to growled to guttural. In many ways, the resemblance to its origins in rock music (let alone those in classical, blues and jazz) had been effectively eliminated. These extreme bands also increased the technological demands of their instruments, particularly of drum sets, to require sturdiness plus portability for regular touring, and to developments like double-bass drum pedals to enable the required speed.

The 1990s brought globalization and experimentation to heavy metal, and these phenomena are largely related to one another. While nearly all bands up to this point were American, British or German,[1,4] the extremity of metal's offerings in the form of speed and lyric-based rebellion allowed listeners in other (often third-world) countries to experience the same empowerment and angst release felt by the original audiences.[9-12] This audience's exposure to heavy metal usually came through tape trading and worldwide touring by bands like Iron Maiden and Metallica. Bands and fans from Scandinavia, Brazil, Japan and the Middle East were now creating new subgenres of metal and bringing their local influences into the lyrics and music. No longer were the synthesizers of the '70s taboo to metal; indeed, they were often used out of necessity due to the limited financial means and societal freedoms. This created a fantastic melding of electronics and music that was perfect for the dawning of the Internet era.

Until the mid-1990s, cassette tape trading in heavy metal was an industry unto itself, allowing fans and bands to mail dubbed tapes to one another to spread metal like wildfire.[1,4,9,10,11] With the creation of the Internet, file sharing became a beast of a completely different scale, encompassing popular and unpopular music styles and growing to the point where authorities couldn't help but try to manage the practice. The band Metallica was heavily involved in two battles regarding technology usage in their recordings.[1,4] The first pitted them against Napster, an Internet file-sharing service whereby users uploaded songs to a centralized database for free download by anyone with a Napster account. When Metallica won this legal battle, Napster and

centralized file-sharing services like it were all but destroyed. The second battle dealt with the "Loudness Wars", where digitizing sound had enabled the practice of eliminating the "loud" end of the audible range so that the baseline of sonic range could be maximized.[13] This removed subtle highs and lows to make everything "loud", and Metallica was vilified for engaging in this practice on their 2008 release "Death Magnetic" despite releasing a full-range version of this album to a video game company. Thus even the biggest band from this era was not immune to the impact of technology.

Since the turn of the century, heavy metal music has continued to expand in scope and technology.[1,4,11,14] It was quickly delving into greater and greater levels of extremity, from increased musical tempo to variety in vocal styles to unorthodox lyrical themes. New technologies were required to handle it, and thus the popularization of 7- and even 8-string guitars to produce deeper sounds. New electronic pickup designs were generating louder outputs prior to amplification. Guitars were being down-tuned and thus required strings capable of maintaining tension under those conditions. Synthesizers and even drum machines were standard instruments in many newer bands. Oddly and despite all of the technological innovations at hand, one of the most recent developments in metal music involves bands reaching back to the 1970s for their influences and creating "extremity" by being less extreme and more direct than their peers. This includes releasing new music on LPs alongside digital downloads and CDs, proving once again that "what was once old is new again".

Again, this is not an exhaustive history of heavy metal music, but an overview that highlights the technological abundance prevalent in the genre as well as much of the cultural significance of it. Among major genres of music, heavy metal presents a fascinating combination of technological innovation, global development, social commentary and religio-political reaction. There are very few aspects of life around the world that are not somehow addressed through metal music. This makes it an ideal topic around which to discuss with fans and foes of the music alike how these varied aspects intertwine. For the purposes of the audience of this paper, the focus will be on teaching students about engineering, computing and general technology through heavy metal, and the college course created for this purpose in 2009.

Goals of the course

This course was created to discuss engineering and technology concepts through the lens of heavy metal's creation and evolution, and combine that with the expansion and perception of the

genre in America and around the world. In this way, the course represents many of the tenets of liberal education promoted at the university at which it is offered: the arts, humanities, social commentary, global culture, communication through music, science and technological innovation. It is one of only a few courses at its home university that legitimately bridges the gap between STEM fields and the "soft skills" that have become so valued in industry. There is no math used in the course, and as such the audience spans majors from engineering to art to education to business.

The five course outcomes for this course are:

1. Students will describe the engineering and technological developments that have enabled heavy metal music's unique sound.
2. Students will explain how musical instruments that are used in heavy metal music function.
3. Students will explain how each instrument serves a musical need for specific subgenres of heavy metal.
4. Students will identify the worldwide influences and impact of heavy metal music.
5. Students will describe how heavy metal music serves as a vehicle to know about global culture and government function.

Outcomes #1 and #2 are achieved through lectures, discussions and demonstrations of heavy metal music's songs and instruments. For example, a local recording artist guest lectures about guitars to walk students through the transition of an undistorted blues scale to a highly distorted heavy metal riff, and how the amplifier and effects he uses helps him accomplish it. Outcome #3 is met through similar activities that are spread out among multiple class meetings to allow adequate time to build upon prior knowledge. Outcomes #4 and #5 use readings, video content and guests who Skype with the students to develop the requisite breadth of heavy metal's reach around the world. The outcomes are embedded within the topics of every class meeting to ensure that students are regularly and thoroughly exposed to them.

Structure of the course

In order to meet the outcomes stated above, it is necessary to generate interactions with the music, lyrics, history, culture and instruments in a variety of ways. There then must be ways in which to ascertain the accomplishment of the outcomes. This section will describe how the course has structured these elements through experiences and classroom assignments.

One of the unique aspects of content delivery in this course is directly connecting students to professionals in the field of music and heavy metal culture. Not only does it add a "wow" factor to the course, but also it uses technology in ways that mirror the course outcomes regarding the use of technology. In the most recent course offering, six guests (one print media, two radio media, and three professional musicians, one of whom also started an instrument design company) joined the course either via Skype or in person to share their music industry experiences. Three of the guests spoke specifically and in great detail about the relationship between music and technology, and how they drove each other in the realm of heavy metal music. These discussions directly impacted the fulfillment of Outcomes #1, #2 and #3, while also helping break down misperceptions about people in a highly stereotyped genre of music.

It is also necessary to bring demonstrations of music and instruments to the students to drive the fulfillment of Outcomes #1-3. Students heard songs and lyrics from the various subgenres of heavy metal so that we could discuss musical and lyrical qualities of the songs, and consider what technology was required to create them. For example, Blue Cheer played music that was extremely loud with highly distorted guitars. By demonstrating the sonic differences between a small 15W amplifier and a large 100W Marshall stack, and by discussing conceptually how an electronic amplifier signal gets naturally and artificially distorted, the course was able to explore how the musical demands were met by technological advances[15,16]. Exposing students to the actual songs and instruments is critical in their understanding of the course outcomes, and in better understanding the fields of engineering.

The course requires three books plus classroom-response devices, in this case TurningTechnologies clickers or ResponseWare for mobile device. One book provides a history of the heavy metal genre, one provides context to the songwriting process and lyrical themes, and one discusses heavy metal's role in a politically and religiously oppressed part of the world. These books primarily help generate the context and fulfillment of Outcomes #4 and #5. The classroom-response devices allow students direct interaction with topics beyond simple commentary and discussion. As the enrollment in the course has averaged 100 students per offering so far, generating this direct interaction is very important to fully engage every student and help them meet the course outcomes.

Videos are the final way to generate interactions with students beyond demonstrations, lectures and in-class discussion. The class watches the documentary movie "Global Metal", which describes the local heavy metal situations in Brazil, Japan, China, India, Indonesia, Israel and the

United Arab Emirates through interviews with bands, media members and fans. Outcomes #4 and #5 are addressed through this experience. In addition, throughout the semester students watch episodes of "Metal Evolution", an 11-part documentary series that details the growth and progression of heavy metal subgenres. This series incorporates technological developments of amplification and distortion (Outcomes #1 and #3) alongside the geographic and musical evolution of the genre and culture of heavy metal (Outcomes #4 and #5).

Engineering and technology addressed in the course

This course addresses a variety of engineering- and software-related facets of technology. It specifically focuses on the application of science to devices and instruments used in heavy metal rather than the science itself, which is addressed in another course at the host university. As such, a broad swath of disciplines is able to be covered in the course through the examples of music creation and distribution. These examples are then expanded upon to generate discussion about how engineering and technology serve society in other ways. The entire discussion begins with understanding the processes of engineering design and problem solving, and then moving to how those processes manifest in the various engineering disciplines. The disciplines described below are not an exhaustive list, but are the most common fields addressed during the course.

Mechanical Engineering

Mechanical design principles are emphasized early and regularly in the course. This is in large part due to the mixed background of majors of the student audience, and mechanics are more tangible for students to comprehend. As guitars and drums are the dominant instruments used in heavy metal, their design aspects are important topics of discussion.[17]

Mechanical considerations for guitars include body shape and the resulting impact on weight distribution and comfort, the attachment of strings and other parts to the guitar body,[17] and the development of the aforementioned Floyd Rose bridge system.[5] This last technology facilitates the introduction of patents to students, as this engineering development takes existing technology and redesigns it for the specific use in the creation of sounds typical in heavy metal music. Original bridge designs are either stationary or have limited string bending capabilities due to the resulting loss of string tuning. The Floyd Rose bridge design allows guitar strings to be locked

in place to create a closed loop, and thus enabling extreme bending of the strings without the loss of tuning. Figure 1 shows a comparison of bridge designs.

Figure 1: A comparison of guitar bridge designs. (from *http://gear-vault.com/electric-guitar-buying-guide/*)[18]

Within the discussion of mechanical design is manufacturing processes, since most music applications are in the Design for Manufacturing context. Early electric guitars were modified hollow acoustic guitars, all of which had a "set neck" that was glued to the body of the instrument (see Figure 2). In 1950, Leo Fender developed a guitar that had both a thinner solid body and a bolt-on neck. Because of the simpler design, the guitar was readily mass-produced and as a result was more affordable. This later led to other companies copying the designs and creating their own versions of Fender's iconic instruments. The situation allows the course to discuss benefits and consequences of mass production, including supply and demand.

Figure 2: A comparison of guitar neck constructions. (from *http://gear-vault.com/electric-guitar-buying-guide/*)[18]

Discussion topics for mechanical design of drums include making drum shells from plied woods, actuators for high-hat cymbals, and kick pedals for bass drums. Of particular importance to this

last item is the double-bass pedal, which allows for high-speed "machine gun"-style drumming common in extreme forms of metal music. Patents are again used in these discussions to exhibit multiple design considerations for the double-bass pedal. The options for double-bass drumming include chain drives, remote pedal placements and multiple batter heads on a single pedal unit. Figure 3 shows some of these designs.

Figure 3: A comparison of bass drum pedals. (from *http://www.theduallist.com/images/n-duallist-pedals.jpg*)[19]

Electrical Engineering

Electrical design principles are also covered early and often in the course. Again, the electric guitar is an ideal starting point for this topic. The generation of an electrical signal from the electronic pickups and magnetic strings is paramount to creating any sort of audible signal from the instrument. This enables the course to discuss how to create a viable electrical system within that instrument's particular size and layout, and what to do with that signal once it has been generated.[17]

The electrical signal from the instrument then needs to be transmitted to a device that allows it to be amplified.[16] The amplifiers typically used in heavy metal use vacuum tubes as opposed to solid-state electronics to amplify the guitar's signal. Both technologies are compared and contrasted in the course, with demonstrations of the pros and cons of them in relation to creating heavy music. It also provides both a historical perspective and a state of the art overview of circuitry, and is readily broadened into a large-scale discussion of signal generation and amplification.

Finally, the electronics of signal modification are addressed in the course through the study of effects processing.[15] Examples of this include distortion (affects signal shape), dynamics (affects signal amplitude), filters (affects signal frequency), modulation (splits and re-combines signals) and time-based effects (signal delay and phase shifting). The most commonly used in heavy metal is signal distortion, originally created through overdriving the vacuum tubes to the point at which the signal becomes "clipped". One form of distortion, termed "fuzz", was actually generated independently by Jackie Brenston & His Delta Cats and The Kinks by physically damaging the speaker cone in their respective amplifiers.[4] This discussion is a great opportunity to use basic sine waves to demonstrate the concepts of the various effects without resorting to the math required to describe it.

Materials Science and Engineering

The most common places where materials are addressed in the course are also guitars and drums. Guitars are made almost entirely of wood, with different types of wood generating different characteristics of sound and other physical properties.[20,21] The structure-properties-processing-performance relationship in woods is used to broadly discuss materials science principles.[22] In addition, the environmental impacts of wood sourcing and sustainable forestry can be addressed through this discussion.

Drum technologies also generate major discussion points on materials science and engineering. Shell materials and the resulting sonic characteristics can be important to metal musicians, who often choose metal over wood shells. Cymbals, and the resulting discussion of alloying, are the greatest benefit to discussing the materials science of drumming. Brass and bronze are the primary metal alloys used for cymbals and they generate different sound characteristics. The alloy composition for each can allow these characteristics to be tuned further for a particular music style or cymbal type. The alloys and compositions will also dictate the manner in which the cymbals can be manufactured, whether cast or rolled. Phase diagrams are presented to discuss these concepts and why a particular composition is favored over another.[22]

Computer Science and Software Engineering

The last major field of study in the course addresses software implications in heavy metal. A large part of this discussion is the impact of the Internet on music creation and distribution

methods. As presented in the Introduction section, cassette tape trading was the lifeblood of early heavy metal and a predecessor to Internet file sharing.[1] Once the Internet boom hit, all of the music industry was affected. Files could be uploaded to and downloaded from first Napster and then via peer-to-peer networks. Music formats shifted from album-based LPs, cassettes and CDs to single-song downloads and streaming. Access to information about bands and their music could be gained initially through news services and more recently via social networking sites. General access to content is very easy to discuss in the larger context, since most of what the students know is that context.

A major benefit to discussing software is introducing the ethics and legalities of the current form of file sharing.[23] This began in 2000 when Metallica sued Napster and its users for the early and unauthorized release of a new song.[1,4] Many of the students in the course were less than 10 years old when this occurred, and thus they have no recollection of the event or its significance. For many students, getting the music for free in one form or another is all they have ever known, and so introducing these topics to them is eye-opening since they have not faced such an ethical dilemma. It is among the most fascinating discussions of the course.

Assessment of the course

To assess the success of the course in delivering the course outcomes to students, it is necessary to rely on direct student feedback from end-of-term course evaluations. For the purposes of this paper, ratings and comments will be presented that deal specifically with how well the course promoted technological and socio-cultural understanding. The rating scale for each question is from 0-4, with '0' meaning "Strongly Disagree" and '4' meaning "Strongly Agree", as well as an option for "Not Applicable (N/A)". Students submitted these evaluations during the final week of the course, and all responses are anonymous.

Before addressing the evaluation scores, it should be noted that between Fall 2010 and Fall 2011 the class size increased to 90 from 24 students and one of the secondary textbooks was changed. Also, between Fall 2011 and Fall 2012 the class size further increased to 117 and the class meeting configuration was changed to thrice per week for 50 minutes from twice per week for 75 minutes. The impacts of these adjustments will be addressed below, if applicable.

Table 1 indicates that students generally agree or strongly agree that the course is excellent. This can be interpreted in a couple of ways. One way is that students were genuinely engaged with the course and its activities, and appreciated the manner in which seemingly disparate topics were connected through valuable experiences. Another way is that students found this course to be somewhat easier than their other courses, and many of the in-class experiences allowed them to avoid more rigorous homework and other assignments. As the author of this paper is also the creator of and instructor for the course, the former interpretation is preferred. Given that the remainder of the rating of the course suggests that students agree with the high effectiveness of assignments, demonstrations and other activities, the first interpretation does indeed seem valid.

Table 1: Course evaluation responses, mean value of responses on 0-4 scale.

	Fall 2010	Fall 2011	Fall 2012
The contribution of this course to my education is apparent.	3.55	3.01	2.90
The textbooks were effective learning tools.	3.25	3.13	2.65
Classroom activities were effective tools for learning.	3.76	3.51	3.56
Homework and other assignments were effective instruments for learning.	3.62	3.42	3.42
The lab activities were effective instruments for learning.	3.50	3.62	3.42
The professor explained theories, concepts and applications clearly.	3.86	3.80	3.55
I found this course intellectually challenging.	3.33	2.82	2.75
Overall, I would rate this course as excellent.	3.81	3.49	3.47

The trend of many of these scores is downward, though not detrimentally so. The reasons for this are not easily identifiable because of multiple changes that have occurred between course offerings. That being said, the number of students enrolled in the course is likely one reason. It is simply more difficult to directly and meaningfully engage more students in larger rooms.

In Fall 2010, the 24 students were in a classroom that held a maximum of 30 students; in Fall 2011 and 2012 the approximately 100 students each year were in a lecture hall that held up to 400 students. It is easier to hide (intentionally or not) in such a large room, and more effort by students is required to stay connected. For class size to be the primary reason for the score drops, it would be expected that scores would have decreased more between 2010 and 2011. The

scores that dropped most in this timeframe are “Classroom activities are effective tools for learning”, “Homework and other assignments are effective tools for learning”, “I found this course intellectually challenging”, and “Overall, I would rate this course as excellent”. Classroom activities often work better in smaller venues with smaller enrollments, so it is reasonable to connect this score to classroom size. The other categories are less obviously associated with class size.

Another possibility is that changing to thrice per week with less class meeting time affects the content delivery. This happened between Fall 2011 and Fall 2012, and thus if this were the primary reason for lower evaluative scores then there would be a greater drop during this timeframe. This was the case for “The textbooks were effective learning tools” and “The professor explained theories, concepts and applications clearly”. Since the textbooks did not change, this is not likely the culprit.

However, it is possible that with less time per class meeting to demonstrate, describe and discuss topics, the explanations provided by the instructor were not as thorough as prior years. It is also possible that the connections between textbook readings and in-class explanations were not as well developed after transitioning to less time per class meeting. This is certainly something that the instructor can address prior to the next offering of the course.

Finally, student comments can help with understanding the scores given and the trends observed. This course is taught at a liberal education-focused university and so comments such as “It inspired unique thought processes that helped explore new topics not touched in other classes”, “intellectually in-depth concepts”, and “This course is very different and helped me to become more well-rounded” speak to meeting that focus. Other comments addressed that it made engineering more fun, interesting and useful to real life than their major-specific engineering courses. Student also expressed appreciation of being able to interact with industry professionals, as it provided context and real connection with the subjects and how they used technology. The final prominent type of comment was about how it helped students become more understanding and tolerant of cultures that they had previously stereotyped; these cultures included engineers and scientists, people from other regions of the world and heavy metal musicians and fans.

Students also made a few suggestions for course improvements, giving context to some of the trends observed in the scores above. Some students suggested a smaller room for the course, as

well as possibly a lower maximum enrollment. This correlates with the drop in scores from 2010 to 2011 that was suggested to be enrollment related. Other students offered that longer class meetings would increase their internalization of discussion topics. This suggestion supports the drop in scores from 2011 to 2012 related to clear explanations in class. Other suggestions for improvements were more individualized and did not reach a critical mass to address here.

Summary and Conclusions

A course has been created and offered three times that uses heavy metal music and culture as the vehicle to discuss engineering and technology innovation concepts and socio-political global culture. This course addresses multiple engineering and computing disciplines, and links them to larger-scale technological developments in society. The overall reception of the course by students is highly positive and valuable to them. It appears that this course successfully bridges culture and technology, and facilitates the basic understanding of engineering concepts in the ever-more global society that these students will enter upon graduation.

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