Crushing Stereotypes, Making Connections, and Encouraging Creativity: Music and Engineering

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Abstract

Disciplinary boundaries are somewhat artificial, established as a result of organization and out of the convenience of compartmentalization. But creativity has no disciplinary boundaries. *Signals, Systems and Music* is an experimental, multi-campus, cross-disciplinary course designed to attract STEM students as well as students of the arts; to expose them to concepts important to both their own and someone else's discipline of interest; to give them the challenge of working with someone from a different discipline; to help them find ways to communicate with others without having a common language; to aid them in undertaking the act of creation to produce something of value, in this case a musical composition; and, finally, to encourage them to reflect on the connections and commonalities between two distinct disciplines, crushing stereotypes in the process. This paper gives a brief introduction to the course, which we have experimented with through six offerings.

Introduction and Background

Signals, Systems and Music is a course, offered in several variations, at Rowan University, Glassboro, NJ, and Kansas State University, Manhattan, KS, as an experiment, with funding provided by the National Science Foundation (NSF). The basic concept was to bring students from two seemingly disparate disciplines together into an active setting in which they could not just learn about, but actually experience something of, each other's chosen field. In this case, the disciplines are music and engineering.

Specifically, the design and intent were that these students from different backgrounds would work together in teams. Whenever students are placed together in such fashion, they inevitably bring with them preconceptions about how individuals from another discipline approach their work and what they are capable of accomplishing. They typically have stereotypes about the "other person's" dedication to, or the amount of time that will be spent on, a team effort, how she approaches her learning, how he accomplishes his work, how she communicates, etc.—all those things that go into how an individual would collaboratively create a product.

Accompanying K-State's two versions of the course were extensive sets of interviews carried out individually with the students enrolled. The desire was to hear from the students—both the engineering majors and the music majors—some of their pre-existing conceptions, and to see how those perspectives might change as the students began to interact and collaborate.

Objectives

Every subject and endeavor holds foundational concepts that its practitioner must understand at some level. As a very simple example, we might note pitch, loudness, and timbre, three psychoacoustic quantities of interest to a musician. A physicist or an engineer needs to know about basic physical quantities such as frequency, amplitude, and spectral density. There are close, but certainly not identical, relationships between these two sets of quantities.

And every discipline embraces its own creative acts and processes. Composition is a creative act important to music. Design is the central creative act in engineering. The two processes are very similar.

More often than not, when we gain some experience in the concepts and processes in another discipline, we begin to make connections. We not only gain a greater understanding of, and hence, an appreciation for, that discipline, but our understanding of the "stuff" of our chosen discipline increases as well.

This, then, is what we hoped for: a course whose contribution to its students' experience was that of an environment and opportunity that

- Exposed them to concepts important to their own and someone else's discipline of interest.
- Piqued their curiosity after noting the breadth of applicability of those concepts.
- Gave them the challenge of working with someone from a different discipline, finding ways to communicate without having a common language, but undertaking the act of creation to produce something of value.
- Allowed them to reflect on the connections and commonalities between the two disciplines, and as a result, increased their appreciation of both their own discipline and another, as well.

- Aided them, through all the above, in dismantling stereotypes, both of "the other" discipline and its practitioners and of their own chosen discipline.

The Course

The course—entitled *Music, Signals and Systems* at Rowan University, and *Signals, Systems and Music* at Kansas State University—addressed the topics of electronic-signal analysis and generation, systems-oriented approaches to creative acts, and music composition. This effort was a collaboration among the Electrical and Computer Engineering (ECE) Departments and the Music Departments of both Rowan and K-State. The initial target audience at Rowan was first-year electrical and computer engineering majors and undergraduate music majors. The target audience at K-State was broader, including undergraduates and Master's students, both in music and in engineering. At K-State, *Signals, Systems and Music* was offered in two different versions, one during Fall Semester 2012 and the other during Spring Semester 2013. For the ECE students, it was a general-education elective. For the music students, the course was an elective for all but composition majors, for whom each semester was a required course. For the music students, the Fall course was offered under the title *Technology of the Electronic Music Studio,* and in the Spring semester, under *Digital Sound Synthesis*.

The course, in any of its various offerings, had neither mathematics nor music prerequisites, and it treated the topics from a holistic perspective of both systems engineering and music composition. A significant experience was that of creativity. The students were reminded that creativity is important, no matter what disciplinary path they choose. Part of the course was (1) to help them recognize that they are creative beings; (2) to provide experience to develop creativity; and (3) to exemplify that creativity, in its various forms, is founded upon the understanding of fundamental elements within a discipline. Through creative music composition from an engineering-systems point of view, students were exposed to concepts fundamental to both music and engineering, emphasizing the interconnectedness of the disciplines, with a learning goal of (re)awakening the students' creativity. The final semester project consisted of creating and presenting a musical composition. Students worked in teams of two or three, under the requirement that each team include at least one music major and one engineering major.

Figure 1 presents the specific student learning outcomes for both versions of K-State's *Signals, Systems and Music* course, and Fig. 2 provides a brief look at the course content. Johnston's *Measured Tones,*[1] a delightful book understandable by both the STEM student and the music major, provided readings from which in-class discussions and elaboration of concepts could develop. Both versions of the course relied on the book for background. Whereas the Fall version of the course used for music synthesis the classic analog-modular-synth paradigm (largely executed, however, via digital audio workstations), the Spring version was essentially a programming course, in which students learned Csound, a classic, mid-level language written in C and whose purpose was that of sound synthesis. *The Csound Book*[2] was required for the

Spring course, and Dodge and Jerse's text[3] was recommended as additional reading. Additional handouts—excerpts from other textbooks, magazine articles and journal papers, and instructor-generated summaries and supplements—acted as aids.

One example of an instructor-generated handout, written especially with the music major in mind, provided a gentle introduction to, or review of, common logarithms. It included the definition, some useful properties, the bel and the decibel, average power, rms quantities, instantaneous power, the dBV and the dBu, and short example calculations.

Another handout covered a broad set of basic concepts: signals (a definition, some examples, several ways to classify them, etc.), systems (a definition, examples, categories, several ways to classify them, etc.), linearity and linear operators, superposition, time invariance, time-domain and frequency-domain representation of signals, sinusoids as eigenfunctions in linear settings, magnitude and phase spectra, corresponding characteristics of a signal when viewed in the time and frequency domains (e.g., a signal that is continuous in its independent variable in one domain is periodic in the other domain), the all-important sinc function, sampling, aliasing, quantization, and Fourier analysis by pictures.

Upon completion of the course, the student will have the knowledge and skills to:

a. describe the historical relationship of the electronic manipulation of sounds in the creation of music, and the relevance of that relationship for contemporary creativity.
b. demonstrate an understanding of the aspects of the basic physics of sound as it relates to what is perceived as musical sound.
c. understand the electronic generation of musical sounds and how to duplicate/transform "traditional" musical sounds as well as how to create "new" electronic sounds.
d. creatively use a variety of sound-modification devices and techniques in the creation and realization of short musical pieces.
e. exhibit a conceptual understanding of how the elements of music (rhythm, melody, harmony and timbre) relate to elements of engineering (e.g., frequency spectrum, amplitude distribution, energy content, and information) and how they relate to the creative organization that occurs within a musical composition and engineering constructs.
f. organize traditional, manipulated, and created sounds into a musical composition utilizing the electronic musical sounds that clearly integrates the musical and engineering elements in a purposefully creative and aesthetic arrangement.
g. investigate the interplay between their musical and technological imaginations as well as study the fundamental aesthetics of music and signal processing.

Figure 1. Student learning outcomes for K-State's *Signals, Systems and Music* course.

Semester 1

Historical background

Instruments (sounds, timbres)
Creative composers and stylistic variety (immersion experience in earlier compositions, combinations of sounds)
Technological development and their integration (engineering connections)

Analog Modular Components

Wave modification
Creative, musical use (small projects)

Compositional Project

ProTools software interface project
- Filtering
- Duplication, overlap, organizing sounds

Semester 2

Historical Foundations and Current Technology

Hardware-based synthesis
Software-based synthesis
Current Varieties of Synthesis
- Analog, FM, digital, sampling, processing

Digital Synthesis

Learn to use digital-synthesis tool
- What is it, electronically (from both the engineer's and the musician's viewpoints)?

Receive instruction in cooperative and collaborative processes
- Developing a creative relationship
- Psychological relational models of collaboration
- Small collaborative experiences through learning the technology

Team Projects

Create a musical environment
Create a new musical experience for a traditional musical form (or composition)
Create an educational tool (app) that enables a group of people (socially limited, disabled, culturally deprived populations) to communicate or experience emotion or feeling through music
Create a musical composition with an audience in mind

Figure 2. Abbreviated course content for K-State's versions of the course.

Assessment: Interviews with Students

The Rowan faculty and the K-State faculty took individual approaches to assessment in their respective courses. The information gathered is vast, and its presentation is far beyond the scope and length-constraints of this paper. A very important—and, in the end, perhaps the most exciting and useful—part of the overall exercise, as far as the faculty involved directly with the K-State versions of the course are concerned, was the set of progressive, individual interviews with each student enrolled. The interviews covered students' views on problems encountered; challenging aspects of working with others; perceptions regarding creativity, its place and expression in engineering and in music, and the students' abilities to be creative; stereotypes and preconceived notions; learning to collaborate and communicate effectively; enhanced learning; and the various challenges experienced.

While it is impossible to do justice to the interview process and the variety and depth of responses, it seems useful to include a sampling of responses to various questions to provide some sense of the engineering students' reflections.

> "The most important thing I got out of the course was working with other people that are fundamentally different. I noticed in class that the engineers worked more individually and did not appear to have as much fun with their work. The musicians were talking and laughing all of the time, enjoying all aspects of their work. Getting that wide range of dynamics is a good experience for working with people in the future." (KC:EE)

> "Working as a team is something that is very useful from this course. Working as a team with a set of engineers is good, but working with someone outside of your discipline is very important. I expect that in the future we will be working with a variety of people in corporations. This might be one of the most important aspects of learning from the course." (JW:EE)

> "I really enjoyed talking about the spectra, breaking it down into its sine and cosine components, and then the frequency domain. I am taking a course right now in which we talk quite a bit about that. It's really good to keep it fresh in my mind. Because I had those classes, I got a lot from those discussions. It solidified some things that I wasn't quite sure about. Now I understand the frequency domain . . . ." (KC:EE)

> "I can get straight A's in my classes without using a lot of creativity because that is the way the engineering curriculum is set up. They want to make sure we can follow a process. But in order to be a good engineer, we will have to break from the established lines of thought. Although this is something important to my greater success as an engineer, it has not explicitly been taught or developed in my engineering training. I have had some teachers say that in order to be really good you are going to have to do something more than what you are doing in this class, hinting at the importance of creativity, but it is not something that has been actively cultivated. That would require we

> stop crunching numbers for a few weeks. I have observed the musicians compose beyond rules of an established system. That is a new thought for me. To do something different and possibly end up with something great, I would need to take a risk at maybe doing something terrible. That is where creativity plays into engineering, which is one of the things that attracted me to this course in the first place." (TB:EE)

An extensive report on the interview process, with a comprehensive transcription of responses, organized and placed in context, is in preparation.

Discussion

When we consider what we want from our students as a result of completing a program of study, there is no doubt that we all desire students to go beyond mere attainment of knowledge. Even more than applying what has been learned, we want students to make decisions that can make their part of the world just a little bit better—*to* be willing to step beyond the typical into the realm of *what might be* and *what if.*

The following result was clear from the sets of interviews conducted with the students in K-State's versions of the course: All the students described a clear perception that in their future professions they will need to be able to effectively collaborate and communicate beyond disciplinary boundaries. But they also were keenly aware that their programs of study thus far have led them through a solitary, disciplinary path. They chose the course because they felt a need to fill gaps in their training. They appreciated some of their stereotypes having been shattered. They want to learn how to communicate with those that are not in their circle, and to learn to collaborate.

Students of both disciplines valued the experiences, but most interesting was their discovery of a different paradigm relating to the process of creativity. The engineers discovered the value of stepping beyond a linear process to explore options not clearly evident, and that such can lead toward results beyond expectations. Similarly, the musicians came to recognize the importance of considering perceptions and preferences of others in the creative process.

What we all can learn from the students is that they recognize a need to learn beyond knowledge attainment, and even with the best intentions of instruction, this level of learning is not realized until we as teachers intentionally provide experiences that enable students to be creative, solve problems, consider options, and step beyond traditional disciplinary boundaries.

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