The Creative Process: Risk-taking in an Interdisciplinary Honors Course

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Abstract

This paper describes the integrated content and instructional components of a new college course, HNRS 3900 Math, Music, and Art, housed in Robert Morris University's Honors Program and co-taught by a mathematician and a musician. This seminar emphasized the creativity that drives advances in each discipline. We interwove material from the nineteenth and twentieth centuries through thematic and chronological frames of reference, culminating in the cultural avant-garde and development of the digital computer. Assuming no particular mathematical or musical prerequisites, we used art (broadly defined) and hands-on-learning experiences to bridge the abstract worlds of theoretical mathematics and music theory. To appeal to those students with substantial mathematical and musical background, we presented advanced undergraduate material otherwise absent in our school's curriculum.

Introduction

Honors curriculum is meant to challenge the honors student, to help her understand the creative process of researchers and artists, and to guide her to become a critical thinker and an intellectual risk-taker [11]. With these goals in mind, we set out to design an interdisciplinary course in math, music, and art, focusing on ground-breaking mathematics and music theory from the last 200 years. Through our research, we discovered several examples of self-reflection or self-reference in contemporary art and mathematics which, by definition, leads the scholar, teacher, or student back to the question itself, culminating in the analysis of the creative process [9]. First-hand accounts of the discovery process and risks taken by modern mathematicians and artists complemented the coverage of the math, music, or art content and countered the misconception that these subjects are ancient or elusive.

Not to lose sight of our focus on the creative process while selecting examples from 200 years of material, we took an integrative approach to the curriculum design by identifying four themes common to math, music, and art [9]. We settled on the themes: symmetry, improvisation, infinity, and searching for self and truth. These themes allowed us to demonstrate how mathematics (in particular, symmetry) can be used to understand art or music; how knowledge of improvisation in art or music can shed light on how a mathematician proves a new theorem; and how artists, composers, and mathematicians all grapple with some of the same ambiguities: the transcendent topic of infinity and the fundamental notion of truth.

In the following sections, we connect math, music, and art through the four themes and describe our implementation of the content through interactive lesson plans that model the creative process.

Making Connections and Taking Risks

Throughout our planning process, we incorporated A. Koestler's definition of *creativity* into our course design. He argued that *bisociation*, or the connection of seemingly disparate ideas or contexts, opens the door to new insights and understanding through application of the rules or logic of one idea to the other context [6]. We selected the course themes (symmetry, infinity, searching for self and truth, and improvisation) because they are not only germane to artistic and mathematical breakthroughs in the nineteenth and twentieth centuries, but they also exemplify Koestler's view of creativity.

Symmetry. By demonstrating that math and music are dynamic subjects and not collections of stagnant work found in old textbooks, we encouraged students to take intellectual risks themselves. We began with a new application of math to music explored by D. Tymoczko [12]. After a standard treatment of symmetry, including the definition of a symmetric group, we introduced major and minor triads and the circle of fifths. Together, this comprised enough mathematical and music language to present Tymoczko's work at a basic level. Although this section fit the traditional interdisciplinary approach of using mathematics to describe structure in music, we took a more integrative approach to the three remaining themes.

Infinity. There are probably no more disparate or seemingly incompatible concepts than the infinite and finite. These have obsessed generations of both mathematicians and artists. Tracing the mathematical treatment of infinity from Zeno to the twentieth-century influences of P. Cohen, S. Shelah, and W. H. Woodin, we exposed students to the dilemma of formalizing a concept that conflicts with the Aristotelian principle: the whole is bigger than the part. While mathematicians grappled with this long-standing assumption, musicians were breaking out of the traditional confines of the finite chromatic and diatonic theories through their experimentation in atonal composition as seen in A. Schoenberg's "Emancipation of the Dissonance".

Searching for self and truth. It was through self-reflective works such as G. Stein's *The Autobiography of Alice B. Toklas*, R. Magritte's *Treachery of Images*, P. Glass' *Einstein on the Beach*, and A. Turing's work on universal machines that we provided students with additional insight into the creative process. Arising from self-reference or emerging from the connection of discordant ideas, paradoxes often serve as the catalyst for revolutionary breakthroughs in the arts and mathematics [3].

Improvisation. Finally, to tie together some of the main topics in the course, P. Berliner's formalization of musical improvisation [2] was juxtaposed onto the historical developments of the computer from Euclid to Turing. We presented a culture of "mathematical improvisation" by demonstrating mathematicians practicing their trade, borrowing from each other, importing ideas into new contexts or pieces, repeating their signature arguments, and eventually discovering innovative theorems.

Pedagogy

We faced several pedagogical challenges when organizing the diverse material into a coherent sequence, selecting required reading, creating an interactive classroom, and assessing the students on the creative process. The following are some ways we overcame these challenges.

Structure. We structured the course in a chronological fashion around the four themes. Greek Philosophy and the Trivium/Quadrivium served as an introduction to emphasize the shared foundations of mathematics, music, and art. Following a historical introduction, we spent two to three weeks on each of the themes, and the remaining class time was reserved for students to present their creative projects.

Course materials. As a model for the course, we took an intellectual risk ourselves by choosing a graphic novel to serve as the required text. The graphic novel, *Logicomix: An Epic Search for Truth*, tells a tale related to the development of the computer. The book introduces several key mathematical figures that we encountered in the infinity and searching for truth sections of the course. Since the authors took some artistic liberties in telling their story [4], we supplemented the text with P. Mancosu's "Essay Review of Logicomix" to clarify the historical facts [8]. Other assigned readings included M. Babbitt's "Who Cares if you Listen?" M. Beerbohm's self-referential story "Enoch Soames," and selections from O. Byrne's edition of Euclid's *Elements*. Our syllabus, listing the content, selected readings, and audio examples, is available online [10].

During our preparation for the course, we became acutely aware of a rather large learning curve required of the students to become familiar with the terminology, methodology, and application of theories found in each discipline, especially in the absence of a traditional textbook. To assist with their understanding, we created an extensive Blackboard shell that stored PowerPoint files, mp3s, YouTube clips, assigned readings, and websites. In addition, we established routine vocabulary quizzes compiled by the students themselves, which empowered the students to become responsible for their own comprehension of the material. The students chose any unfamiliar term from the assigned readings and PowerPoint files and created definitions for the quiz in their own words. To further solidify such expansive class material, we created a series of class activities such as games and art projects that demonstrated a particular component of that day's lesson.

Classroom activities. During an introductory lesson, students explored logical relations, axioms, theorems, conjectures, and proofs on their own using the card game *Set*®. For one activity, students played the card game *Set*® and developed their own conjectures for the game. They later proved or provided a counter-example for their conjectures. In another activity aimed at understanding the concepts of *model* and *theory* of propositional logic, the students were provided a list of axioms or *theory* (e.g. no purple card lies next to a red card; if there is a red card, it is an oval; etc.). Then students, using the *Set*® cards, constructed a situation or *model* in which these axioms were all simultaneously true.

During a lesson on symmetry, students took a picture on their smart phone of a symmetrical pattern found on campus. This pattern could be naturally occurring, found in the architecture, or seen on personal objects. We then compared pictures and classified the various symmetries. To apply the algebraic and geometric properties of symmetry to music, we discussed triads, the circle of fifths, serialism, minimalism, maximalism, the twelve-tone matrix, and Neo-Riemannian transformations. To begin such a complex subject, in our classroom activity, twelve students stood in a circle and tossed a ball either up or down to the next person, representing the spatial relationship between a half step and a whole step in a musical scale. For example, progressing from a C to a $C\#$ would involve one student tossing the ball up one spot to her neighbor. In this manner, students could spell out a triad or even demonstrate the circle of fifths with the ball.

Similarly when discussing different sizes of infinity, the students visually expressed their understanding of $\mathbb{N} \times \mathbb{N} \times \mathbb{N}$ by creating a clay model of a subset of it. This hands-on activity provided the students a tangible representation of the equation $\aleph_0 = \aleph_0^3$ as they physically traced out the beginning of a bijection from $\mathbb{N}$ into $\mathbb{N} \times \mathbb{N} \times \mathbb{N}$. Another lecture discussed experimentations, conducted by H. Patch, K. Stockhausen, P. Lansky, and M. Neuhaus, that push the finite boundaries of time and pitch in music. Students experienced potentially infinite sounds such as Shepard tones and other audio illusions. We also secured a performance by touring musician N. Bartlett who performs music on his five-octave acoustic marimba with electronics, a Linux-based custom computer, and an eight-channel cube of loudspeakers. "With the audience positioned in the center of the loudspeaker cube, an elaborate three-dimensional sound environment can be projected into the audience space, totally immersing the listeners in the music" and creating a kinetic audio sculpture in the form of a "three-dimensional soundfield" [1]. Bartlett's performance, along with a class trip to see the M. C. Escher exhibit at the Akron Museum of Art, were two out-of-class experiences during the semester.

Finally, the theme of searching for truth and self called for an examination of fractals, paradoxes (Russell, Liar, Banach-Tarski, Simpson, Smale's, etc.), and the universal Turing machine. Again, we were faced with the daunting task of explaining math to non-math majors, yet our success was in the culmination of classroom activities such as students creating their own paper fractals, posting "This is not my status" on their Facebook pages and constructing their own Escher-style impossible staircases.

Student creative projects. We assigned two creative projects throughout the course to assess student understanding. In the spirit of *bisociation*, one project asked the students to develop a risk-taking presentation that integrated two themes from the course in an interdisciplinary manner. Venturing out of their comfort zone, three actuarial science majors performed their arrangement of J. Pachelbel's *Canon in D* which was based on various mathematical transformations. Other student work included a presentation on M. C. Escher's influence in the movie *Inception*, musical demonstrations on the difference between just temperament and equal temperament, and a Neo-Riemannian analysis of John Williams' music. The student who created the last example, also programmed an animation to visualize her analysis [13]. The other project, serving as the capstone for the class, involved selecting a few first-hand accounts from *The Creative Process* [5]. Incorporating these selections with course content, students described their impressions of the creative process and how it manifests in their own fields of study. One student wrote a four-page poem as part of his final project. He has given us permission to end this paper with the an excerpt describing the creative process and the "trisociation" of this class [7]:

. . . .
Each and every time, it begins with a question
A question of truth and its inherent digestion
Creators often challenge that which is believed
Separating the truth from that which is perceived

Easy it isn't, for the revered names of today
Were chastised for the words that they had to say
In their time of living, in their time of life,
Many dealt with much more, many dealt with such strife

It is through strife that our world exists
Through persevering minds, and sacred trists
Through axioms assumed and redefined
Through parallel structure and teeming minds
. . . .
Know that the impossible stairs in "Inception"
Are just another example of Escher's deception
Know that your beautiful home, the place you know
Is just another Golden Ratio

But most of all, know your past
Know the creators and the concepts that last
Know that all math, all music, all art
Has spawned from a mind, a soul, and a heart

Willing to go where others refused
Willing to give a chance the ideas that others abused
Willing to fail for the sake of success
For failure is part of the creative process
(77–88, 97–108)

References

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