

Essay

Using Science Songs to Enhance Learning: An Interdisciplinary Approach

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Music is recognized as an effective mode of teaching young children but is rarely used in university-level science courses. This article reviews the somewhat limited evidence on whether and how content-rich music might affect college students' understanding of science and offers practical suggestions for incorporating music into courses. Aside from aiding memorization, songs may potentially improve learning by helping students feel relaxed and welcome in stressful settings, engaging students through multiple modes (verbal vs. nonverbal) and modalities (auditory vs. visual vs. kinesthetic) simultaneously, challenging students to integrate and "own" the material through the medium of song lyrics, and increasing students' time on task outside of class through enjoyable listening or songwriting assignments. Students may produce content-rich songs of good quality if given sufficient assistance and encouragement by instructors and peers. The challenges ahead include 1) defining the circumstances in which music is most likely to promote learning and 2) developing rubrics for evaluating the quality of songs.

INTRODUCTION

While teaching with music is rare in college classrooms, it has been tried by people such as National Institutes of Health Director Francis Collins, who occasionally sang to students at the University of Michigan "to break up the monotony" (Anonymous, 2011). I myself have used songs for educational purposes since 2002, when I started sharing content-rich songs at strategic points in undergraduate biology classes (cell biology, comparative animal physiology, and biology for engineers; 15–60 students per class). In this essay, I reflect on what I have learned and what remains to be learned about supplementing science curricula with music.

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MECHANISMS BY WHICH MUSIC MIGHT IMPACT LEARNING

The idea that music might enhance learning in advanced science courses, while unproven, is plausible, because there are several overlapping mechanisms through which songs could work, at least in theory.

Enhancement of Recall

Mnemonic devices have been defined as "strateg[ies] for organizing and/or encoding information with the sole purpose of making it more memorable" (Bellezza, 1981). While most songs do not fulfill the "sole purpose" criterion, they often act like mnemonic devices in that they seem to increase memorability. Songs generally can be considered *organizational* mnemonic devices in the sense of structuring information according to meter and rhyme, limiting the possible lyrics that would fit and thus making recall easier (Bower and Bolton, 1969). Some songs may also operate as *encoding* mnemonic devices, in which hard-to-remember words are paired with more easily remembered words, images, or sounds (Bellezza, 1981). A recent review article questions the notion that music offers unique benefits over nonmusical stimuli in facilitating recall of words, yet it concludes, "musical memory is special precisely because musical stimuli (typically) are structured

differently from other kinds of stimuli" (Schulkind, 2009). A related point is that music can evoke strong emotions, which can enhance some aspects of memory (Levine and Edelstein, 2009). Music therefore may help students memorize key lists, formulas, definitions, and relationships.

Reduction of Stress

Given that many students feel out of place in science classes (Osborne *et al.*, 2003), enjoyable music could help these students perceive the science classroom as a friendly environment in which they belong. This idea has some support in physiological and behavioral studies of how music affects students. Certain pieces reliably reduce blood pressure, heart rate, and body temperature in students (Savan, 1999), and these changes may correspond to reductions in anxiety (Russell, 1992). In one survey, 75% of college sociology students reported that lecture-related songs preceding lectures made them feel more comfortable in the classroom (Albers and Bach, 2003).

Multi-Modality Delivery

Some students prefer to learn through distinct sensory modalities; for example, one common taxonomy characterizes people as visual, read-write, auditory, kinesthetic, or mixed-modality learners (Baykan and Nacar, 2007). Songs accompanied by visuals and/or movement (e.g., dancing) therefore have the potential to reach students through multiple modalities simultaneously. The concept of music as a "whole-brain" experience is also underpinned by neurological studies showing that many different regions of the brain can be recruited in processing musical stimuli (Janata, 2009).

Increased Enjoyment

To the extent that music makes homework more fun, it may cause students to devote more time to this homework (Wolters and Rosenthal, 2000). For example, students who are unwilling to read a textbook chapter in preparation for class might nevertheless listen to a related song, perhaps repeatedly. Many students exposed to science songs in class report enjoying them (Pye, 2004; Crowther, 2006; McLachlin, 2009), although this observation is not universal (Winter *et al.*, 2009).

In-Depth Exploration of Content

A doctoral dissertation on the use of science songs in middle school classes (Governor, 2011) suggests that revisiting lecture content in an alternative form (i.e., song lyrics) tests students' understanding in a way that simply rehashing the lecture does not. Students may encounter and address points of confusion when challenged to analyze scientific lyrics. Similar learning opportunities may arise when students create their own science songs and, in doing so, make a number of decisions on how to express their ideas concisely and accurately. This is analogous to the concept of "writing to learn," in which explaining the material in one's own words is considered part of the learning process, rather than a mere reporting of what has been learned previously (Balgopal and Wallace, 2009).

ARE THE THEORETICAL BENEFITS OF MUSIC ACHIEVABLE IN PRACTICE?

A few small-scale studies suggest that some of the hypothetical benefits listed above may be achievable in classroom situations (Table 1). For example, a study of high school food-safety classes found that certain subgroups of students performed significantly better on song-related test questions than students who had not heard the songs (McCurdy *et al.*, 2008). However, the collective evidence summarized in Table 1 is best thought of as preliminary data awaiting more rigorous follow-up studies. The central question, of course, is whether musical interventions can be shown to cause significant gains in student learning. To start to address this question, some stances must be taken on which types of interventions are most likely to yield gains and which types of learning should be measured. Regarding the latter, for instance, proof that songs can improve memorization of scientific words might come relatively easily; a more ambitious study attempting to show that songs improve conceptual understanding beyond verbatim recall would be more interesting to educators but also more likely to fail. Many other projects could also yield interesting data. The "active learning" paradigm, already validated in several contexts (Michael, 2006; Haak *et al.*, 2011), could be explored further via a comparison of passive and active music experiences (e.g., listening to songs vs. writing them). Analyses of the relative importance of the possible mechanisms discussed above would be of interest, as would attempts to correlate music's impact with student traits, such as musical aptitude and preferred learning style. The possibility that songs alter long-term retention well

Table 1. Preliminary tests of music's usefulness in science and/or college-level classes

Summary of study	Reference
Students who learned jingles in a college statistics class scored better on related test items than students who read definitions. Scores correlated with jingle familiarity.	VanVoorhis, 2002
Certain subgroups of high school students (those taught by experienced instructors and those in small classes) scored higher on food-safety knowledge than control groups following exposure to nine food-safety songs.	McCurdy <i>et al.</i> , 2008
In a sociology class taught with and without progressive rock music to illustrate social theory, students scored better on multiple-choice questions after exposure to the music.	Ahlkvist, 2001
In a large biochemistry course, 44% of students found "The Histone Song" (Gilbert, 2006) helpful as a study aid, while only 11% found it unhelpful. In smaller courses on biology for engineers, 86% of students rated songs as at least somewhat enjoyable, and 68% rated them as at least somewhat helpful to learning.	Crowther, 2006; McLachlin, 2009

beyond a given course's final exam is also worth exploring. (I can still recall a 1993 lecture from my own undergraduate days, in which my cognitive psychology professor explained pharmacological desensitization by referencing the Guns N' Roses song "Mr. Brownstone.") In terms of methodology, hypotheses should be tested in multiple courses and semesters taught by different instructors (most studies published thus far are single-instructor, single-course reports); study designs should be adequate (e.g., in terms of randomization of students, statistical power, and assessment techniques) for detecting possible music-related gains in student learning; and musical interventions should be carefully designed (e.g., exposure to a heterogeneous set of songs may not have a clear impact).

PRACTICAL IDEAS ON TEACHING WITH MUSIC

Instructors who choose to integrate music into their courses have several options. From least to most radical, these include posting song links for students to explore on their own time, preceding class with a prerecorded song (or inserting it into a mid-lab break), performing and discussing a song during class, and assigning students the task of writing and performing songs. Prewritten and prerecorded songs appropriate for specific courses can be found with the aid of online tools, such as the SingAboutScience.org database (Crowther, 2012). However, teachers may also find valuable examples in mainstream songs that were not created specifically for educational use (Lesser, 2000; Last, 2009).

One may ask whether certain biological topics are especially conducive to a musical approach. My own opinion is that songs can be particularly useful for countering two types of student problems: conceptual misunderstandings and failures to grasp hierarchical layers of information. Prewritten songs may explain concepts in new ways that clash with students' mental models and force revision of those models, or may organize information for improved clarity (e.g., general principles in the chorus, key details in the verses, other details omitted). Songwriting assignments could have similar benefits by forcing students to do the work of concisely restating concepts in their own words and organizing the information in a musical format. As an example of using music to counter misconceptions, I once team-taught a "biology for engineers" course in which my coinstructor complained that many students failed to internalize the difference between genotype and phenotype. I wrote and performed a song to drive home this distinction, the chorus being, "Genotype, ooh. . . It's the genes you possess—nothing more, nothing less! Versus phenotype, ooh. . . Your appearance and health and reproductive success!"

Teaching with Prepared Music

Good advice on teaching with prewritten or prerecorded music has been offered elsewhere (Lesser, 2000; Dickson and Grant, 2003; Pye, 2004; Crowther, 2006); I will summarize it here by noting a few of my instructional objectives that seem to be well supported by prepared music. When my goal is to demonstrate enthusiasm for the course content, few maneuvers do this as vividly as singing about that content. Likewise, when I wish to burn a specific point into students' memories, unexpectedly bursting into song all but guaran-

tees that they will remember that particular moment of class for weeks to come. Another of my general goals is to express support for and solidarity with students; whole-class sing-alongs and/or recruitment of students to provide musical accompaniment may convey a sense that the students and I are working together toward common goals. Finally, to maintain high levels of student attendance and promptness, I have started classes with songs that students will not want to miss.

Student Learning through Song Composition

Tips for facilitating student compositions can be found in sources such as a video by Tom McFadden (McFadden, 2011), known for teaching biology through hip-hop at Stanford. McFadden encourages students to come up with rhymes based on the "freestyle method" (saying whatever comes to mind) and the "alphabet method" (substituting each letter of the alphabet for the first letter or consonant cluster of a target word). Additionally, he notes the value of imperfect rhymes or slant rhymes for expanding students' lyrical options.

An especially interesting aspect of composing science songs is the matching of lyrics to music. While awkward pairings can be humorous, students should be encouraged to reinforce scientific messages with complementary music whenever possible. Some instructive examples of this can be heard in the children's CD *Here Comes Science* by They Might Be Giants (Flansburgh and Linnell, 2009). The old song "The Ballad of Davy Crockett" is used as a template for a new version about an astronaut, implicitly underlining the concept of space as a "wild frontier" (a phrase from the chorus of the original). In the song "Solid Liquid Gas," the tempo changes to convey the relative speed of molecular movements in solids (slow), liquids (faster), and gases (fastest). And in "Bloodmobile," each verse is sung by a different voice representing a function of the cardiovascular system (delivery of oxygen and food, delivery of hormonal messages, counteraction of infections, and disposal of waste), clearly delineating these diverse roles.

While student compositions are not likely to attain the musical virtuosity of They Might Be Giants, they may nonetheless reveal hidden talents and sophisticated understanding. Four of my former cell biology students summarized the work of R. D. Allen and his Dartmouth coworkers on organelle transport in squid axons (Brady *et al.*, 1982) by singing "Your Axon Is a Wonderland," an adaption of the 2002 John Mayer hit "Your Body Is a Wonderland." The students' version began, "They've got the giant axon/ It has no membrane on/ And one thing that's left to do/ Discover that the particles move. . ." The first two lines concisely summarize the experimental preparation (cytoplasm removed from squid axons), and the next two lines indicate the central topic of the study (transport along the axons). Other lines included "I'll use my microscope" (instead of "I'll use my hands"), a reference to Allen *et al.*'s use of video-enhanced contrast-differential interference contrast microscopy. These sorts of encapsulations are, quite literally, "take-home messages": the students can take them home and sing or hum them again.

Challenges of Teaching with Music

The example in the preceding paragraph, along with others in the literature (Dickson and Grant, 2003; Pye, 2004; Winter

et al., 2009), illustrates the temptation to use popular tunes as scaffolds upon which to hang new science-based lyrics. The United States Copyright Act of 1976 allows “the fair use of a copyrighted work. . . for purposes such as criticism, comment, news reporting, teaching (including multiple copies for classroom use), scholarship, or research.” The act specifies that judgments as to whether a particular use constitutes fair use depend on four factors: “(1) the purpose and character of the use, including whether such use is of a commercial nature or is for nonprofit educational purposes; (2) the nature of the copyrighted work; (3) the amount and substantiality of the portion used in relation to the copyrighted work as a whole; and (4) the effect of the use upon the potential market for or value of the copyrighted work.” While factors one and four appear favorable to educational versions of songs, it has been argued that “Educators . . . cannot lean only on the idea that what they are doing is for educational purposes; all four factors need to be considered. . . . An egregious violation of just one of the four factors can be enough for a fair use claim to fail” (Leary and Parker, 2011). Likewise, one cannot assume that rewriting song lyrics is a form of parody and therefore is protected free speech, both because parodies are defined as works that *comment upon* the works upon which they are based (which is not generally true of science songs) and because parodies are judged according to the same four factors as other derivative works (Keller and Tushnet, 2004). As a practical guideline, creating new versions of copyrighted songs should generally be acceptable in the context of a class lecture or assignment, but sharing these songs outside of the classroom is not risk-free.

Copyright issues aside, several other concerns consistently arise in discussions of educating with music. The diversity of students’ musical tastes poses practical challenges, for instance. If no individual song about transcriptional regulation will appeal to all students, does one need to offer a hip-hop version, a techno version, a country version, and a hard rock version? Previewing prewritten songs and selecting those in one or more preferred genres is possible via the SingAboutScience.org database (Crowther, 2012). For student songwriting projects, I suggest that each student or group be permitted to create a song in their preferred genre(s), as long as the science is well covered.

Another frequent concern is the feasibility of getting non-musician students to write songs. Several strategies can be applied here. First, tell the students why you created this assignment, so they understand the rationale behind it (Felder, 2007). Second, have the students work in groups, allowing them to specialize according to their abilities and comfort zones; for example, those who do not like to sing might lead the writing of lyrics or creation of visuals to accompany the song. Third, model the behavior expected of the students (Lesser, 2000)—for example, be willing to sing for the students, demonstrating that imperfect pitch is acceptable—and, more generally, create a trusting environment in which creative risk-taking is supported and students can receive advice on their songwriting as well as their science. Enlistment of teaching assistants who can provide this support (and help grade songs) is especially important in larger-sized classes (W. Silk, personal communication). Finally, clearly establish the criteria for grading in advance; students may be relieved to know that they are not being scored on the quality of their singing (unless they are). An example of a simple assignment

Table 2. A sample college-level songwriting assignment and grading rubric^a

Criterion	Point value
Does the song contain accurate information (a minimum of four pieces of useful information about your drug)?	Four accurate pieces? 12 points Sources cited and reliable? 8 points
Are song features well suited for drug topic: Is the melody concordant with the way the drug makes people feel (you would not want a dirge melody for a stimulant) and is the rhythm similarly fitting? Is the information presented logically?	Fitting melody? 4 points Fitting rhythm? 4 points Logical song structure? 4 points
Is the song compelling, interesting to listen to?	8 points

^aThe assignment was as follows: The song will be your opportunity to choose anything from our list of topics that we cover for the other drugs (side effects, metabolism, administration, and others) about your chosen drug that you want to highlight (that has a biological connection). It could be about natural sources of the drug or about how individual experience varies. It need not be a comprehensive analysis of the drug. You do not need to perform your song, nor write out the score (you could just tell me to imagine it is sung to the melody of “The Star-Spangled Banner,” for instance). Your song will be graded according to the standards noted.

and rubric, provided by Linda Martin-Morris of the University of Washington, is shown in Table 2. Other examples of rubrics for grading scientific songs and poems have been published previously (Waters and Straits, 2008; Marcum-Dietrich *et al.*, 2009).

Yet another prevalent worry is that the successful use of songs by a few charismatic, music-savvy teachers may be difficult for others to replicate. This too is a legitimate uncertainty, but, in light of the many ways in which music may be added to curricula, many “normal” instructors may find at least one of these options to be viable. In addition, a multi-case study of middle school teachers found that several were able to integrate songs into classes with few difficulties on their first attempt (Governor, 2011). While music may not become part of every life science teacher’s toolkit anytime soon, its potential applications are intriguing.

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